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Preface

An exploration of how ergonomics can contribute to the solution of important societal and engineering challenges, Advances in Social and Organizational Factors discusses the optimization of sociotechnical systems, including their organizational structures, policies, and processes. It includes coverage of communication, crew resource management, work design, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work paradigms, organizational culture, virtual organizations, telework, and quality management.

The book provides research on urban infrastructures and how to shape urban spaces, including stadiums and museums. It covers warning systems in cars, voice-based interfaces, and the positive effects on manufacturing processes available from health informatics and management systems. Several chapters examine the role human factors can play in counter-terrorism efforts and in interpreting deceptive behaviors. They provide suggestions on how to improve enterprise resource planning systems and stress the importance of lifelong learning, personalized learning, and work-life balance. The book also highlights issues with special populations, detailing how to design and adapt products and work situations for these groups. In addition to exploring the challenges faced in optimizing sociotechnical systems, the book underlines themes that play a role in all the challenges and how they are linked to each other. It concludes with an exploration of emotional ergonomics and the important positive effects of making people happy and healthy. With chapter authors from around the globe, the book supplies a broad look at current challenges and possible solutions. This book contains a total of eight sections that covers the following topics.

I. Explores how human factors can contribute to a broad range of solutions for issues in sociotechnical systems
II. Discusses the effects of changes at the organizational level and new ways of work
III. Highlights the role of ergonomics in safety and security
IV. Examines the relationship between trust and safety in team performance

The organizers would like to thank all the authors for their contributions. Each of the chapters were either reviewed by the members of the editorial board or germinated by them. For these our sincere thanks and appreciation goes to the members of the board listed below.

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We sure hope this book contributed to increase in knowledge in the field of social and organizational Ergonomics and that you find the papers in this book interesting and helpful to you and your work.

Peter Vink
Delft University of Technology
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Editor

Section 1

Social and Occupational Ergonomics in Interior Design

Environmental Comfort Design Considerations for Future Control Room Interiors

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ABSTRACT

Today, there is a significant amount of research projects focusing on human health and well-being and the connection between the environment and human psychological responses. A holistic approach to integrating control room communications with comfortable interiors is emerging. This paper discusses the socio-cultural aspects of comfort and the sensory communication aspects of environmental comfort design for future control room interiors.

Keywords: Comfort, Future Control Rooms, Socio-Cultural, Environmental Design, Holistic,

INTRODUCTION

Environmental design

The National Academy of Environmental Design (2009), states "Environmental design addresses the impact of the built environment on individuals and the natural world and creates a wide range of interventions informed by human and environmental systems. Environmental design comprises architects, planners, landscape architects, interior designers, preservationists, building technology specialists, and researchers from a wide range of disciplines. Their shared body of knowledge and professional skills affect communities, landscapes, buildings, products, and the individuals who occupy and use them." The term has expanded to apply to ecological and sustainability issues (Szokolay, 2008). Most people relate the term to "green" buildings, global warming and sustainability and focus on the technical and efficiency aspects of environmental design. However, for this paper a human factors psychologist presents the term from a psychosocial viewpoint.

Humans need air, water, food and shelter to survive. Some of the early forms of shelter were caves. Caves are an excellent choice for steady temperature, protection from the elements and intruders. Some environmental designers believe the beginning of environmental design can be traced back to the drawings on cave walls during the early Paleolithic to Neolithic period (35,000 to 4,000 B.C.). Researchers continue to study the true meaning of primitive rock art and cave drawings found in different cave locations around the world (Evans, 2014). According to the

Maude Group (2013), "Contemporary environmental designers have long understood that sensory communication has remained the most meaningful way to connect to an audience since its invention in the Paleolithic period". The drawings may be the beginning of communicating narratives visually (Figure 1.). Communicating narratives visually has profound influences on the viewer. Therefore, most building or room interiors perceived as 'comfortable' would comprise of elements that replicate some aspect of sensory communication.

Figure 1. Bison painting in the Cave of Altamira, near Santander, Spain.

Comfort

The most common definition for comfort found in literature is "a state of physical ease and freedom from pain or constraint", (Google, 2014). A Science direct review of 318 papers, with discomfort in the title, written from 2003 to July 31st, 2013, revealed that 52% of the papers related to patient pain studies. Emotional and psychological issues are not often mentioned in titles, although were sometimes mentioned in the papers. Helander & Zhang, (1997) note that discomfort is related to biomechanics and fatigue factors, and comfort to a sense of well-being and aesthetics. Comfort is a term that is often associated with a physical state or an environmental factor.

According to Looze, Kuijt-Evers & Dieën (2003) generally accepted definitions in comfort literature are; (1) comfort is a construct of a subjectively defined personal nature; (2) comfort is affected by factors of a various nature (physical, physiological, psychological); and (3) comfort is a reaction to the environment. Green & Jordan (2002) discusses how environmental sustainability interrelates between comfort, pleasure and the usability of products. Richards (1980), stresses that comfort involves the sense of subjective well-being. That is, the reaction a person has to an environment or situation. Slater (1985) defines comfort as a pleasant state of physiological, psychological and physical harmony between a human being and the immediate environment.

Chappells & Shove (2005) discuss comfort as a universal physiological construct or a negotiable socio-cultural construct. Kuijer & Jong (2012) argue the universal physiological construct is problematic for reducing energy consumption and negotiable socio-cultural construct offers novel opportunities for sustainable design for exploring practices of thermal comfort. A consequence of negotiable socio-cultural construct is that comfort is seen as an achievement rather than an attribute. Understanding the psychological and emotional connections between human and the environment goes beyond physical comfort (Ong, 2013).

INTERIOR DESIGN CONSIDERATIONS

Control room

The control room originated around fifty years ago and its main purpose was to protect workers and equipment from harsh and often dangerous working conditions. Designs were rudimentary, lacked sound proofing, windows were a rarity and controls were limited to emergency stop buttons and evacuation alarms. After WWII, new technologies emerged and socio-economic changes occurred in industrialized countries (Figure 2.). The type of work and skills required to perform the new work brought about an increased interest in worker and workplace psychology.

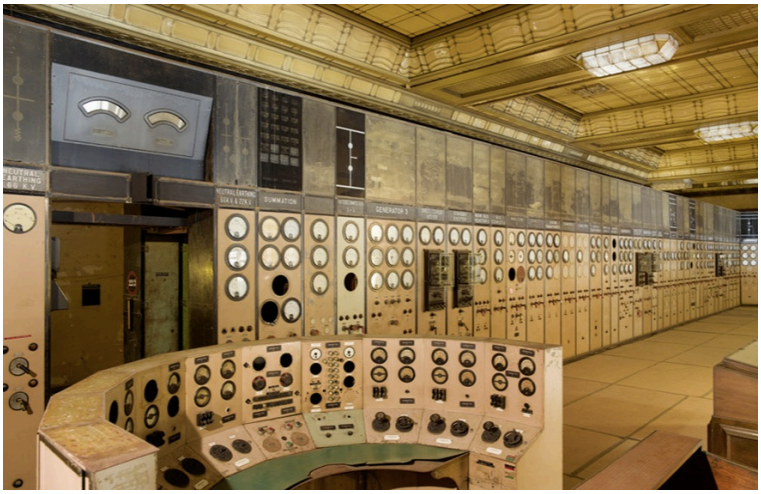

Figure 2. A control room from the 1950's.

The Information age, internet and aging population and emergence of the knowledge worker accelerated the need to develop control rooms based on engineering criteria and scientific frames of reference for the past thirty years.

In the late 90's control rooms were purpose built and industrial and commercial control room standardization emerged. The nuclear renaissance and heightened interest in alternative power, i.e., solar, wind and bio-fuels provided the impetus for new control room design (Ivergard & Hunt, 2010). The purpose of a control room varies from a recording studio, a driver's seat in a car, a plane cockpit or a rapid transit operations center. An important aspect to control room design is to understand the operators and the purpose and guide the operators through effective design to achieve the end purpose. With a renewed interest in thrift and sustainability, designing cost effective, low maintenance, sustainable, comfortable environmental interiors, for present day control rooms is a challenge (Ivergard & Hunt, 2010).

Today the implementation and construction of new, state of the art control room runs a risk of being outdated by the time it is built. New control rooms race against the expediential growth of new technology, world economic downturns, political and social unrest and climate change. The cost of space in a control room is at a premium and some control rooms are designed without the necessary human factor assessments and sacrifice space to offset costs. The resulting control room layouts are challenging and inadequate to provide productive, environmentally comfortable interiors. Retaining highly skilled operators in an environmentally uncomfortable interior is not optimum. Future control rooms may face the same issues with space and cost restraints.

In fifty years will we need control rooms? The need to control processes from a room may not be necessary. Imagine an operator monitoring a power plant from a remote device located off shore on a yacht. Future control rooms and maintenance may be operated and performed by robots or avatars.

There are many factors that affect future control rooms and control room interiors not included in this paper. Economic, political and societal decisions made today shape our co-existence with the environment for the future. This paper discusses the socio-cultural aspects of comfort and the sensory communication aspects of environmental design for future control room interiors.

Control Room Interiors

The control room dimensions are usually determined by the task analysis. A task analysis is a multi-disciplined effort. Various task analysis methods are preferred depending on the functions and systems and purpose of the control room (Brown, 2001). With advent of screen technology Cognitive Work Analysis (CWA) is becoming more widely used. According to Lintern, (2012) resulting screen displays permit operators to deal more effectively with unexpected situations than the traditional display. However, CWA is an arduous process and requires a long lead time.

Maintenance is an area that will grow quickly as future control rooms are designed. Maintenance is often the last item to be addressed; however there are maintenance requirements in the control room. With the focus now on sustainability and risk assessment, maintenance should move to the forefront of sustainable design. More automation means less operators and more maintenance work. General and preventative maintenance, replacements, repairs, redesign installations work tasks are required by humans or machines. Sufficient space for tasks should be assessed for environmental comfort during the design phase.

Traditional control room layouts (Figure 3.) have basic considerations (Salvendy, 2012; Stanton 2005). Going beyond the basics and layout considerations, additional environmental considerations are taken into account, e.g. lighting, and temperature.

Figure 3. Conceptual Layout for control room.

Environmental Comfort

Environmental comfort is a new term, although the topic is taught at in all architecture schools. It is the comfort criteria in the design of the built environment in terms of heat, light and sound. Recently air quality was added and sometimes physical comfort. Environmental comfort is the middle space between the human and the environment beyond (Ong, 2013). Heat or thermal temperature is not considered one of our senses although it is complex and important. If we fail to maintain our body temperature within set limits, we face death. Thermal temperature in building design is fundamental and important. Temperature is the number one compliant by occupants and affects productivity and health (Vink, 2005). People prefer to be in control of their own temperature and will move in and out of varying temperatures not only for comfort but for social interaction. The connection between the two activities leads to overall satisfaction. Studies concluded that people are more adaptable to a wider range of environmental conditions than is acceptable within the current comfort standards (Heschong, 1979; Schiller, 1990). Light in this context is defined in terms of adequate brightness, lack of glare, neutrality of color. A sense of outdoor light or the actual daylight helps with the sense of time. There are lighting comfort standards but no visual comfort standards. Research continues on the health benefits of day lighting and an awareness of the external climatic conditions (Aripin, 2007). The human sensory system welcomes variety, some degree of randomness referred to as contrast pattern recognition, or sensory variability (Heerwagen, 1992). Unchanging environments are boring. Humans experience physiological and emotional daily cycles. We live through our senses and need changing patterns of stimuli to activate them (Humphery 1980; Platt 1961, Cooper 1968; Schooler 1984; Cabanac 2005). Sound is more true to the measurements than heat and light. Air quality is a growing issue in buildings as well as outdoors, especially in large cities. Circulating fresh outside air is best but not always practical depending on the building location to outside noise or pollutants. Ong (2013) states, “Environmental comfort is not a scientific dispute but one that argues for a greater recognition of the diversity of human culture”.

Comfortable Interiors

Comfortable interiors appear to have aspects of the outdoor environment. Throughout history the great wonders of the world are a blend of art, architecture, science and engineering, a form of usable beauty (Figure 4.).

Figure 4. Taj Mahal, India, completed in AD 1648 (2008).

Beyond the visual aspects, the other senses (hearing, taste, smell, touch) are stimulated. Traditional control room interiors tend to be stark, perceived as cold or non-organic, shape edged and devoid of color. An artist's replication of a traditional control room diorama, hand carved from birch and maple wood and formed from steel, encased and frozen in time, void of human presence, making the inherent function obsolete. The viewer of this diorama is to consider their pre-conceived knowledge of the mechanics and functions of a control room, as well as open up to the possibility of how this knowledge can, and will, change through time and context (Figure 5.).

Figure 5. Apparatus, by Roxy Paine, 2014.

New and retrofitted control rooms benefit from on-going innovations in lighting, air and temperature, flooring, acoustics, glass and building materials, screen design, chairs and workstations, and clothing fabric Brooker, Reynolds, & Martin, 2011; Lecher, 2012). All of these innovations provide options to the more traditional control room physical interiors. Additionally, the operator is realized as an integral part of the system and considerations are made to accommodate the operator's physical, psychological, and emotional attributes in the design of future control room interiors.

Future control room interiors

Cinema, games, art, fantasy and science fiction provide us with a plethora of future possibilities for control room. The movies, "Enders Game," "Iron Man", and "Pacific Rim", are visual representations of the futuristic control room interiors and integration of the sensory communication aspects of environmental comfort design and socio-cultural aspects of comfort for control room interiors (Figure 6a. & Figure 6b.)

Figure 6a. The control room in the movie, Ender's Game. 2013.

Figure 6b. The control room with a view, from the movie Ender's Game. 2013.

One of the most famous imaginative control rooms is Dr. Who's TARDIS control room. The TARDIS has gone through updates and upgrades, not unlike real control rooms (Naser, 2005). The TARDIS features relatively open floor plans, in which the control console is vaguely in the middle of the room. Control rooms, interchangeably called console rooms, usually contains walls with roundels, scanners for viewing the TARDIS exterior, and have fairly sparse furnishings. No known TARDIS control room allows for the operation of the console from a seated position. The shape, size and ambience of a control room is highly variable, even within the Doctor's TARDIS, A control room's look can be changed over time. The process by which an operator can transform a control room is fairly simple, like changing a "desktop theme". On some occasions, a TARDIS manages the change itself. Once, the Doctor regenerated with extreme violence, destroying much of his control room; the TARDIS was able to completely redesign its interior and console room without the Doctor's assistance. The console room has gone through at least twelve redesigns, though the TARDIS reveals that she archived 30 versions. Once a control room is reconfigured, the TARDIS archives the old design "for neatness". The TARDIS effectively "curates" a museum of control rooms in the Doctor's personal past *and* future (Figure 7.).

Figure 7. Doctor Who's TARDIS control room, 2012.

Imagination suggests that future control room interiors are a holistic blend of art, science, engineering, and human centric. Future control rooms feel organic, the temperature, lighting, color and shape of the room are optional, chairs and workstations regulate workload and situation awareness for the operators. Operators of the future enjoy customizing their work area for temperature, light, sound and color. Temperature, lighting and color variation and management keep operators alert and clear-headed. Future control room walls, floor and ceilings have individualized light and color schemes for different groups of operators or may change color by sensing mood changes or workload stress or situation awareness cues and direct operators to appropriate tasks. Sounds for alarms are easily recognizable due to accompanied vibrations. All the senses and environmental comfort elements are incorporated into future control room interiors design.

CONCLUSIONS

Since the earliest evolutionary phases of human life, we have had a visceral, survivalist need to be sensitive and responsive to our surroundings" (Bilchik, 2002). Today, there is a significant amount of research projects focusing on human health and well-being and the connection between the environment and human psychological responses. Environmental comfort is a new multidiscipline, and shares the middle ground between the human and the environment and addresses the socio-cultural aspects of comfort and the sensory communication aspects of environmental design (Ong, 2013).

Most of the predictions for future control rooms (Montague, 2012; Wood, 2013; Schwarz, Kehr, Herme & Reitere, 2012; Stedinger & Howard, 2010) envision a human centric design focusing on comfortable, seamless collaborative workspaces. The work is incident or crisis management and keeping up with technology. The workforce is diverse in culture, gender and age. The nature of work in the future itself will be holistic and collaborative rather than hierarchal and compartmentalized. Although, there is mention of new innovative products that serve to provide for physical comfort for temperature, air flow, and lighting, there is little mention of integrating the psychological aspects or all five senses in control room interiors. Therefore, the integration of environmental comfort to include socio-cultural aspects of comfort and the sensory communication aspects of environmental design for future control room interiors should be implemented and further studies are needed.

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The Future Aircraft Interior Design inspired by Crowd Well-Being

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ABSTRACT

The role of the airplane in cross-continental travel is becoming more common today, asking for more attention for in-flight comfort and experience. Now the focus is on technology. However, humans have social needs and they gather and form various social groups in society. In this paper, the airplane is partly assimilated to a microcosm of society with groups of passengers that form a crowd. Through studying the knowledge of crowd well-being in combination with shaping the future context based on research related to technology and its environment an interior design configuration is proposed using a Blended Wing Body (BWB) aircraft. Passengers are suggested to fly with a group of people with similar connections on social media or other future group forming social and technology systems to sustain their physical and psychological well-being, e.g. staying active or having a quiet rest. Based on this vision a design is made including a new seating arrangement with concepts of in-flight entertainment and flight attendant service. This interior design is expected to improve passenger's comfort and experience in long flights by supporting their social and personal needs with advanced technology.

Keywords: aircraft interior, Blended Wing Body, crowd well-being, future design concept, social interaction

INTRODUCTION

In society, individuals who share a culture and other common values gather and form into social groups. Human society is characterized by patterns of social relations between individuals and various social groups (Lenski, 1974). People have physiological needs such as food and breath, safety needs and other higher level needs like friendship, love and respect. People will feel content and positive when their needs are fulfilled (Maslow, 1954). In an airplane, a crowd of passengers travel together, which can be seen as an analogy with society. People expect the same need fulfilment. However, the current airplane interior is arranged in a way that passengers are forced to sit together in rows. They usually feel trapped in limited private space with strangers surrounded. The inflight entertainment is limited and passengers hardly interact with each other, which draw all their attention to the discomfort from seats and the limited legroom especially in a long flight.

To sustain passengers' well-being in the future long haul flights, research related to crowd well-being as well as the future context with regard to technology, transportation and travel patterns were studied with two research questions: 1) what are the requirements for crowd well-being in a future air travel? And 2) What will be the future context in 2050?

In order to answer these questions, a literature study was carried out and eight passengers were interviewed, followed by an interior concept design of a Blended Wing Body (BWB) aircraft inspired by the results of these two studies.

The final design, a Crowd Well-being Blended Wing Body (CW-BWB), is a concept aircraft interior inspired by the 'compact city' metaphor. The city is a nice metaphor as it is an epitome of the society, which consists of different groups of individuals exhibiting versatile lifestyles. The CW-BWB interior follows this city life. For example, the centre of the airplane is an active zone imitating the city centre while the periphery is an inactive zone similar to the suburb, where it is quiet. Passengers are able to select their preferred areas, so that they can interact with people who share similar social connections and interests or stay in quiet peripheral areas. In addition, it provides passengers with various city-like activities on board, e.g. taking a walk, shopping or chatting in the central buffet canteen, and it surrounds them with a simulated green nature. The CW-BWB is expected to improve the flight experience and passenger well-being by stimulating more physical activities and interpersonal interactions..

LITERATURE RESEARCH

The literature research section starts with studying other interior BWB concepts, explaining the relevance of subjective well-being (SWB) and crowd well-being (CWB) for aircraft interior design. Subsequently, studies related to the trends and predictions in social media, communication system, future travel pattern and future transportation (BWB) are explicated for designing the context in 2050.

There are other BWB interiors. For instance, Voet et al. (2012) made an interior and identified that the multibubble cabin was needed to create a pressurized cabin. However, solving the structural problem of BWB is not the focus in this paper. Instead, we give priority to the flight experience of the passenger crowds in a long duration air travel in analogy with the experience in 'a compact city' and the pressurization is solved by linking ceiling and floor with monuments.

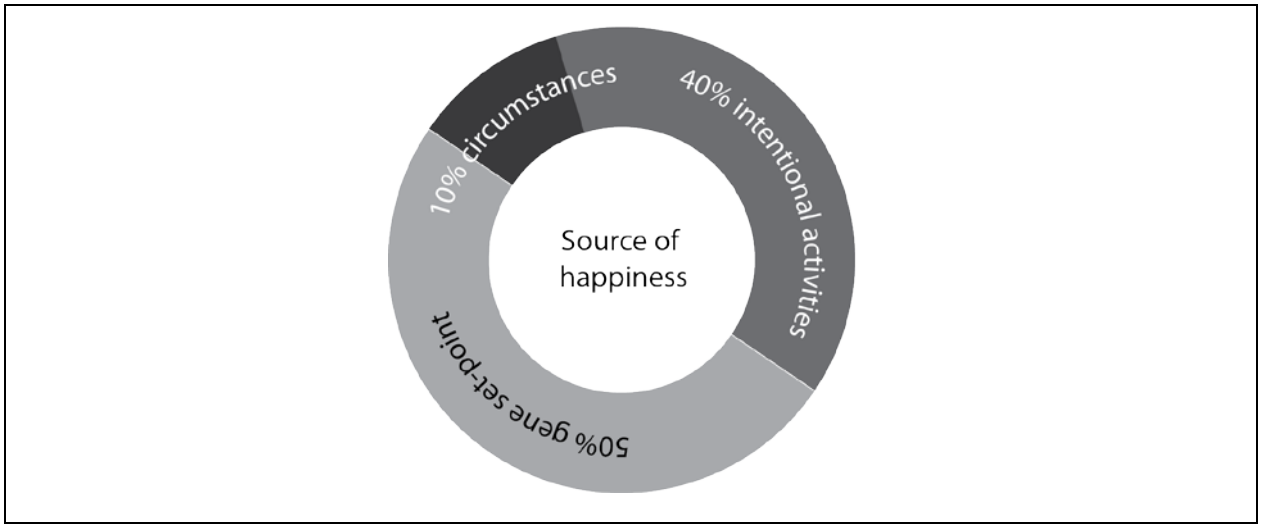

Figure 1. Source of happiness

Well-being in society.

Subjective well-being (SWB) refers to a person's evaluation on the quality of life, including directly emotional reactions to events and cognitive judgement of life satisfaction or need fulfilment (Diener et al., 2009). SWB is influenced by the combination of gene, external circumstances and intentional activities (Lyubomirsky, 2008, see Fig. 1). People with high SWB experience happiness, high life satisfaction and high levels of positive affection (Diener et al., 1999). Li et al. (2013) used the term 'crowd well-being' to define the well-being of individuals influenced by a special social context: a crowd. Figure 2 shows how the society is formed (left figure) and the current arrangement of flight passengers (right figure). In society, individuals are connected and become a network. A network encompasses various social groups which are formulated based on culture, languages, professions and so on. Influences will spread around via the connections in the network (Christakis and Fowler, 2009). However, in the current aircraft interior, passengers are restricted to their own seat, facing the personal seatback screen for hours. The interior is not designed to interact with other passengers. It is even impossible to share a screen and watch a movie together. Since people with different habits and interests are forced to sit together, the interference becomes inevitable with this interior configuration (Fig. 2, right). In the interviews, several participants mentioned that talkative people, crying babies and noisy kids were quite annoying during the sleeping time.

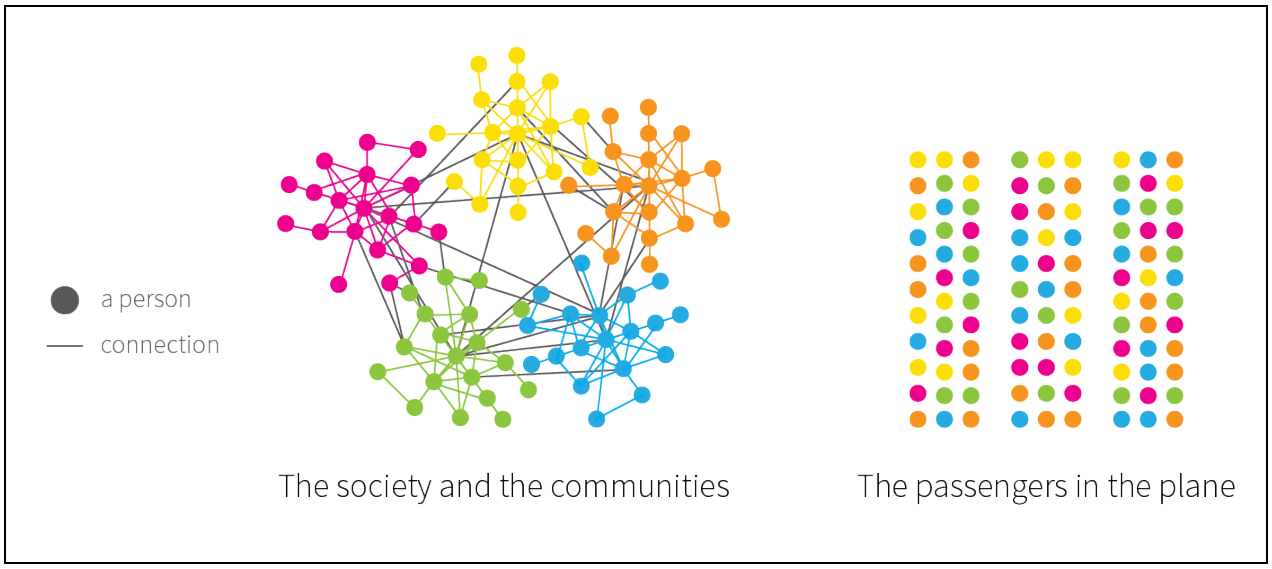

Figure 2.The composition of the society (left figure) and the passengers in the plane (right figure)

Passengers in an airplane can be seen as a crowd, where people tend to influence each other in terms of emotion, attitude and behaviour (Le Bon, 1895; Li et al, 2013). In other words, people are socially connected. The SWB in crowds does not only build upon the fulfilment of the need of a single person, but also on the needs of others around that person. Sheldon et al. (2001) identified the four most important needs for maintaining SWB in events, which are relatedness, autonomy, competency and self-esteem (see Fig. 3). Safety needs are the premise. Once people feel safe, they will search for the higher level needs. This indicates that an aircraft interior should satisfy the higher level needs of the passengers rather than merely guarantee the safety. Passengers should be able to feel independent (autonomy), respected (self-esteem), capable and effective (competence), and a sense of belongingness in the group that they connect with (relatedness).

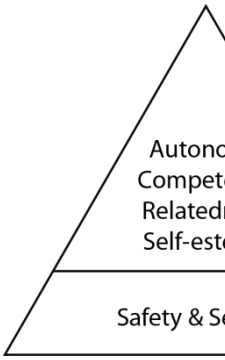

Figure 3. Sheldon's hierarchy of needs for satisfying of needs in events

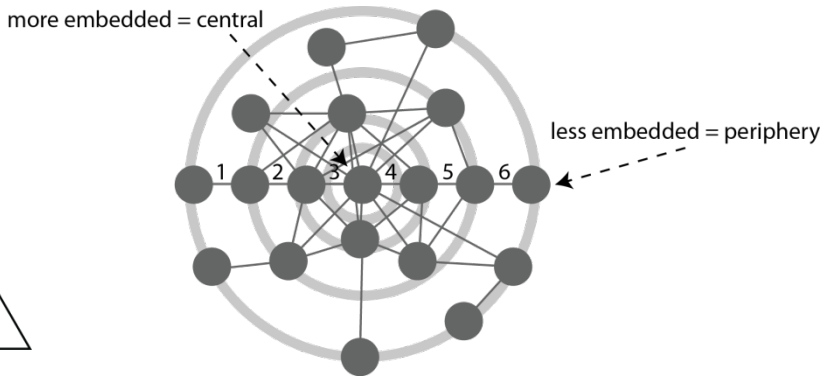

Figure 4. Influences rippling through social network

Figure 4 shows the relations and the connections between individuals when zooming into the structure of the society. Individuals are connected with each other: some situated in the centre of the network, having many connections while others are in the periphery having fewer connections. Both positive and negative influences that start from the centre of the network pass through the connections and fade away gradually. Milgram (1967) indicated that, even in physical world, every two individuals are connected by an average of six degrees but the influences of one person rarely reach another person who is more than three degrees away. In other words, one person is able to influence his friend's friend's friend (Christakis and Fowler, 2009), but the intensity of the influence will decrease after each connection. Thus, in order to spread the positive influence in a social network, the

centre of a network is the most ideal position. Information and service can effectively and efficiently reach more passengers.

Social media and communication tools.

In the physical social network, every individual has different amount of connections. However, in the virtual world, Milgram's (1967) six-degree separation no longer works. Today, everyone can be easily connected via social media, and therefore, the influences can rapidly spread over and affect the whole network. Online social behaviours like creating digital profile, posting comments and sharing state have become prevalent over the past several years (Purcell et al., 2010). Personal information and social networking communities are exposed online. People increase the frequency and duration of staying in the virtual world and the perception of privacy and risk on the Internet has also changed (Rogers, 1997). As the result, the online unencrypted data, such as the personal profiles and comments, will become reliable resources and references for the use of business. In 2050, when the Internet is truly ubiquitous and people are born with the virtual world surrounded, social media or future forms of connectedness will definitely a realistic necessity in daily life, and influence the society dramatically.

On the other hand, the evolution of the communication tools has kept accelerating in the past years. Recently, the debut of wearable-tech products, such as Google Glass and Samsung Galaxy Gear smartwatch, have raised intensive discussions and predictions about their future application in terms of communication. When social media shift from 'portable' (mobile technology) to 'wearable,' the connections between individuals and the influences will become more ubiquitous, which will also change human behaviour as well as the concept of the social network. For instance, Kortuem et al. (2003) investigated the social potential of wearable technology with the concept "wearable community" (Kortuem et al., 2003), which facilitates the "face-to-face encounters" instead of human-screen interaction. By synchronizing with social media, wearable-tech product is able to bring the interaction from the virtual world to the physical world. With the assistance of the social media, flight passengers can be categorized into various groups. For instance, active passenger groups sit in the centre of the airplane while inactive passenger groups have a quiet rest in the sleeping cabin located in the periphery. Conflicts and interference can be prevented when people in the same group share similar intention or expectation. Besides, wearable-tech products can be the most effective tools for passengers to receive personal guidance and helpful information during the flight.

Travel pattern in 2050.

People will be connected extensively in the virtual world in 2050. However, the connections and interactions in the physical world are still encouraged. Today, people travel between megacities, seeking for business opportunities, international experiences and versatile lifestyles. Global cooperation and interaction are motivated because of improved communication technology and ubiquitous accessing to the Internet. The increasing income and the population also lead to the global passenger mobility (Schäfer, 2007). As various transportations facilitate efficient mobility within and between the urban areas, people from megacities desire to travel further without increasing the travel time (Schäfer, 2007). As the result, in 2050, transporting a great amount of people and cargos will become an important issue. Demands for high-efficiency vehicles will increase in the future (Schäfer, 2007).

To improve the efficiency of vehicles, requirements related to seating capacity, fuel efficiency and the potentials of manufacturing were taken into considerations in many studies. Blended Wing body was the most applicable among other future aircraft concepts (Schilperoord, 2006). The research by Liebeck (1998) regarding to Blended Wing Body provided 800 seating capacity. Voet (2012) provided 300 seating capacity with a smaller type of aircraft. However, both of them still use the traditional configuration as shown in Fig. 2, which leads to unsatisfied experience with in-seat service

DESIGN METAPHORE

The insights and findings obtained from literature research were concluded with a 'compact city' metaphor. A city provides versatile functions with people from various backgrounds and having different lifestyles. The five primitive elements of a city are (1) public space situated in the city centre, (2) buildings located in periphery for dwelling, (3) streets for connecting between centre and periphery, (4) transportations make the mobility efficient, and (5) landscape for fulfilling the needs in touching green nature (UrbanDesign.org, 2013).

A city also satisfied people with different needs. First, the city centre is an energetic and busy area where people socialize and do various activities. It is a place for young adults or business people. Dwelling buildings in city centre offer people personal space and enable them to have a rest. Second, people in different ages choose their preferable

activities and space. Young people tend to stay in the city centre for diverse activities and spend most expense on events. The Elders mostly possess of more property than the young so they are able to afford spacious living environment in the rural area. The city metaphor inspired the final design: the CW-BWB interior is divided into active and inactive zones like city centre and suburb, which is consistent with the result from literature research (see subsection 'Well-being in society'). The translation from the metaphor to the final design will be described in the next section.

THE DESIGN OF THE CW-BWB

Crowd Well Being Blended Wing Body (CW-BWB) is an interior design concept based on social interaction in 2050 (Fig. 5), supporting various groups of passengers' well-being in flight. The virtual connections in 2050 allow passengers to be seated among persons closely connected to them on the social media. Before the flight, the passengers form into twelve groups based on similar connections, professional fields, interests or language etc., which is suggested by the booking system synchronized with the social media. Groups can travel together, but it is also possible to fly alone. Several parties will achieve benefits with this design concept.

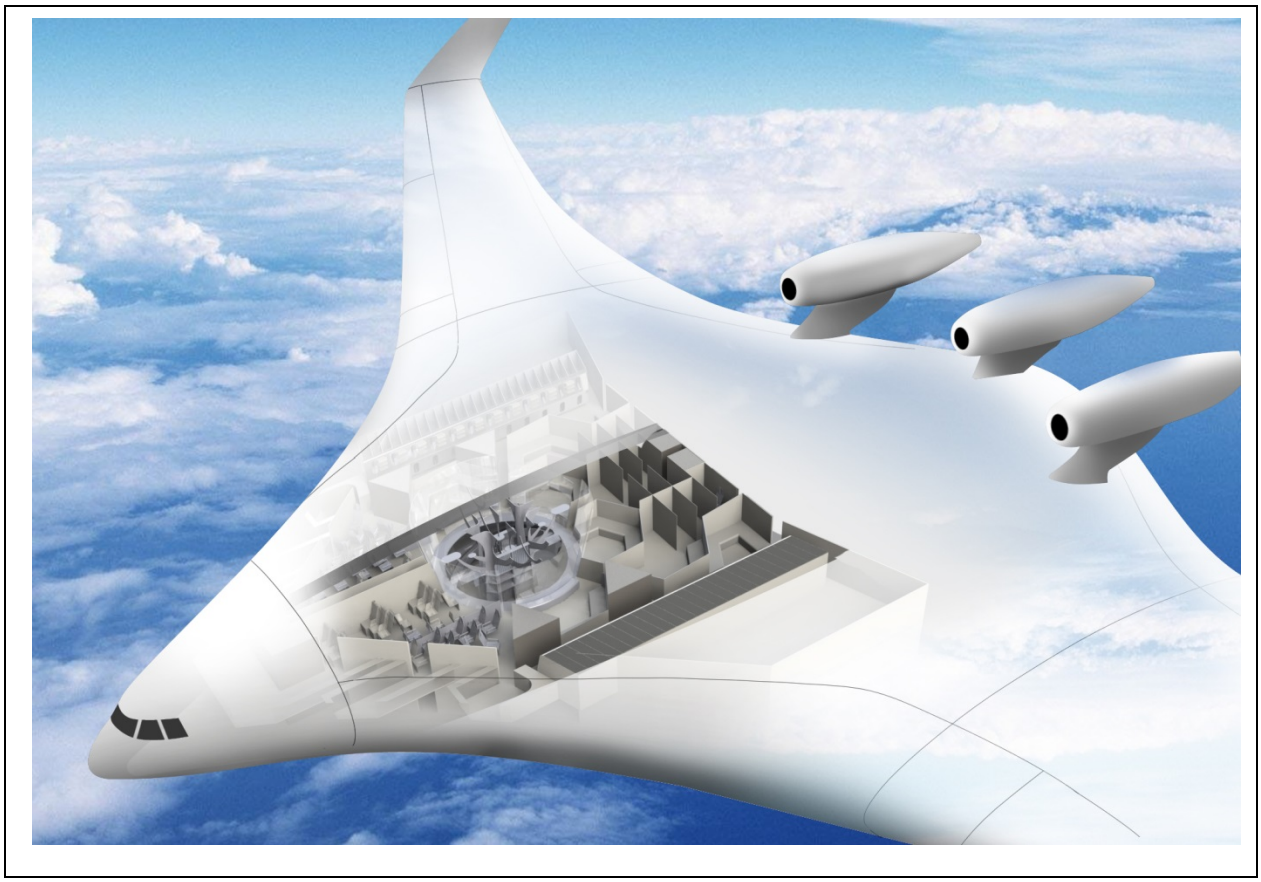

Figure 5. The Crowd Well Being Blended Wing Body (CW-BWB)

Passenger benefits.

• Efficient boarding. Groups are formed before boarding suggested by booking system with optional connecting to social media. Efficient boarding is achieved through multiple entry points (boarding gates) and cross aisles. The cross aisles also contribute to the safety by connecting with the emergency exits at the rear of the aircraft, which enable passengers to evacuate in a short time (Fig. 6).

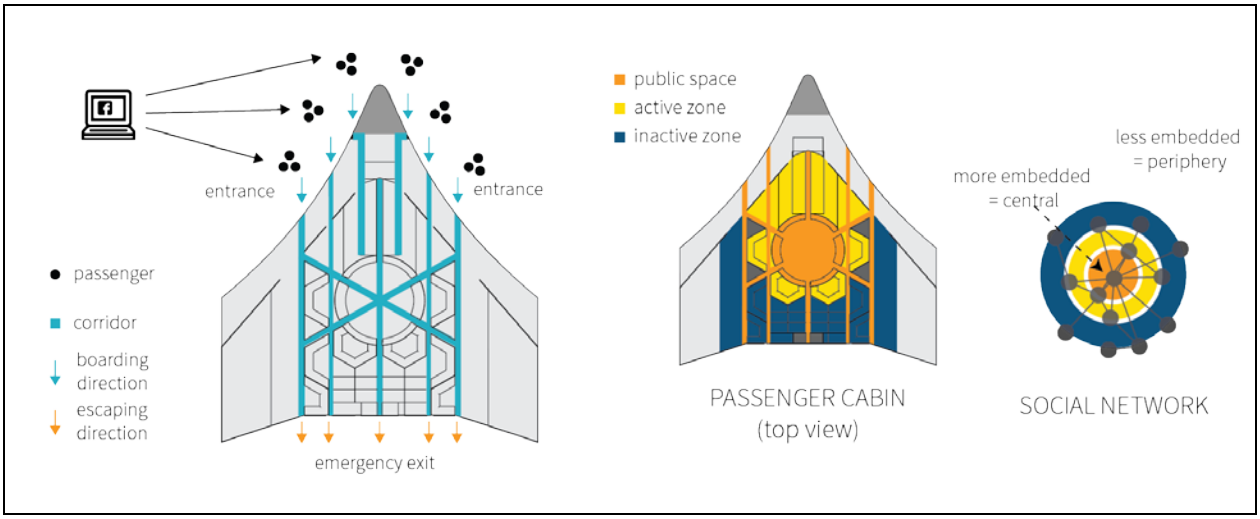

Figure 6. Cross aisles and group formation before boarding Figure 7. Divided sections for various functions

• Freedom of personalization. People can choose to book a single seat, a sleeping cabin or a group seat. Buffet in the centre of the airplane provides freedom of the timing and portion of the meals.

• Fly quietly or actively. Noise insulation is achieved by providing section divisions. The peripheral seating sections are for passengers who want a quiet travel. The centre seating sections are for people who seek companies and networking. The ripple pattern effectively centralizes the active passengers, allowing the noise to fade away before reaching the periphery area.

Figure 8. Various activities are provided with the configuration of CW-BWB

• Various activities for sustaining passenger well-being. Activities for increasing the physical and psychological well-being are available in the spacious cabin. For example, the passenger could enjoy the scenery (watching OLED), exercising, shopping, enjoying buffet, networking and walking around in the plane surrounded by simulated nature scene, green tree-hub, blue sky (see Fig. 8).

• Cost-effectiveness. Passengers acquire better rest and achieve more goals by taking the flight. A flight ticket means more than transportation. he manifestation of driver fatigue is a process influenced by several factors.

The distinction of different factors contributing to driver fatigue is important in order to evaluate measures for fatigue detection and countering (May and Baldwin, 2009). Thus, this knowledge is important for car manufacturers as the starting point of the development of fatigue countermeasures.

Operator & economic benefits.

Efficient boarding leads to low turn around time. CW-BWB needs fewer flight attendants because of all the personalized services, such as the central buffet. The divided sections and various in-flight activities will attract different passengers. The passenger groups are no longer divided by first, business and economy class. More people can afford this comfort in-flight experience with reasonable price, so the range of target group is expected to expand. Besides, profits obtained from in-flight activities, shopping and food services are possible. Flexibility in passenger and cargo ratio can also be adjusted according to airlines' decision. For instance, airlines can replace some sleeping cabins by cargo storages if those cabins are not fully booked.

DISCUSSION AND CONCLUSIONS

The CW-BWB interior design conveys a new possibility for civil aviation in 2050. Wearable technology, ubiquitous computing and the Internet provide a proper context for Blended Wing Body to transport multiple passengers and cargo without decreasing positive experience. Additionally, CW-BWB does not sacrifice its passenger capacity for these diverse in-flight entertainments, which meet the intensive traveling needs among megacities.

The eight participants from interview session were asked to evaluate the final design according to the visualizations. Seating with people who have similar personal profiles was highly appreciated since it fulfils the need for relatedness. Activities including moving around in the airplane, networking and having buffet were highly graded as well because it respects passengers' autonomy. Noise insulation and the efficiency in boarding were mentioned frequently as the advantages of this design concept. Nevertheless, they pointed out some negative aspects. The various choices of seats might cause confusion on booking. They also doubted about the capacity of the active central bar if many passengers swarm into it. The seats, compartments, lavatories and galley still need more detailed design. Besides, form aesthetics, ergonomics, colour scheme and materials need to be taken into consideration in the future design as well.

Although CW-BWB still has a lot of space for improvement, it gives a direction and an inspiration for aircraft interior design in 2050. CW-BWB uses social media and new communication systems like wearable products that enable group travelers to easily access to the information about seating, buffet etc. The in-flight activity is not limited to having meals and drinks provided by attendants and taking the all-in-one entertainment provided on the seatback screens. CW-BWB sustains passengers' well-being by offering diverse personalized activities and supporting the interpersonal relatedness in a cost-effective way. CW-BWB proposes a promising future for air travel. It changes the meaning of taking a flight: it is not only a way to transport passengers from one place to another, but also a place for enjoying diverse activities, networking and refreshing. We are interested in further investigations on examining the interactions in the CW-BWB interior.

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The Vitalizing Office Workstation: Biomechanical, Physiological, Subjective and Performance Effects

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ABSTRACT

The problem of physical inactivity, caused by both lifestyle and work-related factors, is affecting an ever greater number of the office-based workforce. In addition to this, physical inactivity has been associated with an increased risk for various chronic diseases as well as various musculoskeletal disorders. As the majority of an individual's time is spent at work, a means of introducing more activity into the workplace environment would appear to provide potentially the most effective solution. One of these potential solutions is that of dynamic workstations. In a controlled laboratory setting, the biomechanical, physiological, subjective and performance effects of two dynamic workstations were contrasted against two more conventional workstations. Measures assessed included physical activity and percent of heart rate reserve. The performance of basic computer and office tasks was assessed using a standardized battery of tasks included a typing task, a reading task, a telephone task, a task examining mouse dexterity and a set of cognitive tasks. The set of cognitive tasks included two reaction tasks, a memory test and an Erikson flanker test. To determine the acceptability of these workstations, subjective experiences of the participants were recorded using a questionnaire.

Keywords: VDU workplaces, physical activity, postural analysis, task performance, subjective experience

INTRODUCTION

In Europe more than 40% of all employees predominantly work at computer or visual display unit (VDU) workstations (Parent-Thirion et al., 2007), with many of these office workers sitting for extended periods of time statically without effective breaks and without sufficient movements. Office work, which as a result of static and prolonged sitting postures at VDU workstations, can therefore result in negligible circulatory demands and low muscular activity (Klucharev et al., 2000; Hjortskov et al., 2004). This physical inactivity at work is further exacerbated by various lifestyle factors and is becoming a growing problem that affects an increasing percentage of the workforce as a result of increasing industrialization (Haskell et al., 2007; Straker and Matthiassen, 2009). The implications associated with permanent low levels of physical activity include both short-term health effects, such as a loss in physical capacity (US Surgeon, 1996), and long-term health effects (Straker and Matthiassen, 2009) such as an increased risk of developing chronic diseases such as cardiovascular disorders (Thorp et al., 2010), type II diabetes (USDHHS, 2008) and musculoskeletal disorders (Sjøgaard and Jensen, 2006).

In addition to negating the harmful effects of inactivity, physical activity has also been associated with health improvements such as increasing metabolism, muscle activation, (Straker and Matthiassen, 2009), lowering blood pressure, and decreasing the risk of developing numerous chronic diseases such as coronary heart disease (USDHHS, 2008). But these negative effects of inactivity as a result of office work are difficult to compensate sufficiently by only increasing activity during non-working hours (Ekblom-Bak et al., 2010). It is necessary to find suitable means of introducing more physical activity into the workplace environment that goes beyond the minimum activity demands at the workplace such as taking the stairs (Levine and Miller, 2007).

Various studies have investigated different seating concepts aimed at introducing more dynamic components into sitting and therefore negate the negative effects of static postures and physical inactivity (Ellegast et al., 2012a; Stranden, 2000; Robertson et al., 2013; Pronk et al., 2012; Starker et al., 2013), but to date these seating concepts have not yielded significant results in a change in muscle activation (O'Sullivan et al., 2013, Wittig, 2000; van Dieen et al, 2001; Ellegast et al., 2012a) or physical activity (Ellegast et al., 2012a) in comparison to their more static counterparts. An alternative concept that has been developed to promote more activity during working hours is that of dynamic workstations. These stations combine a computer workstation with physical activity for example in the form of walking or cycling (e.g. Carr et al., 2011; Levine and Miller, 2007). This concept has recently gained increased interest with more models of dynamic workstations becoming available on the commercial market. Recent research has shown that dynamic workstations have benefits such as increasing energy expenditure (Levine and Miller, 2007), improving musculoskeletal health (Straker and Mathiassen, 2009) and reducing stress (Thompson et al., 2008). The full extent of the associated health benefits, the effect on task performance and the subjective reaction to these workstations have still not been comprehensively investigated, all of which are necessary to allow for a smooth implementation into the work environment. This paper aimed at addressing elements of the quantity of physical activity these dynamic workstations may cause, their effect on task performance and the subjective experience of the users.

METHODS

Participants and experimental design

Twelve healthy participants, 6 males and 6 females, all who predominantly perform computer-based tasks as the main component of their work, volunteered. The participant group had a mean age of 38.7 years (±11.4 years), a mean height of 171.3 cm (±8.8 cm) and a mean weight of 75.0 kg (±15.4 kg). Participants with any health problems were excluded.

A randomized repeated measures design was selected to assess the effect of six different workstation conditions on task performance, physiological and biomechanical and subjective experience. For the six different work conditions, two conventional workstations, namely a standing and a seated workstation, and two different dynamic workstations each at two different intensities were selected. After an adaptation phase, each participant was required to complete a set of standardized tasks, described in detail below, for each workstation condition. The order of the workstation conditions and tasks was randomized for each participant.

Workstations

The two dynamic workstations assessed included a treadmill desk that formed the walkstation condition and a recumbent elliptic trainer. The two more conventional workstations selected were a seated and standing station, which due to similarities in elicited posture, provided a conventional counterpart for each dynamic workstation. The walkstation comprised of the Treadmill Desk TR1200-DT5 by LifeSpan and was assessed at a speed of 0.6 km/h and 2.5 km/h. The recumbent elliptic trainer station comprised of the LifeBalance Station by RightAngle and was assessed at an intensity level of 4 (9 Watts) and 12 (17 Watts), both at 40 RPM. The two dynamic workstations are depicted in figure 1 in addition to the laboratory set-up with a participant wearing the CUELA (Ellegast et al., 2012b) and an EMG system.

Figure 1. The Treadmill Desk (left) and the LifeBalance Station (right) in the laboratory set-up with a participant wearing the data capturing equipment

Assessment of Physical Activity and Heart Rate

Precise posture analysis and quantification of the physical activity was assessed and determined with the expert measurement system CUELA (Ellegast et al., 2012b). This person-centered measuring system consists of thirteen inertial motion sensors (3D accelerometers and gyroscopes) as well as a miniature data storage unit attached to the participant. The sensors were positioned on the head, at the thoracic spine (Th3), lumbar spine (L5/S1), the wrists, the upper arm, the thighs and lower legs. From the measured signals (sampling rate: 50 Hz) joint angles and physical activity intensities (PAI) are calculated. The PAI were determined using the kinematic data from the sensors by calculating a sliding standard deviation of the high-passed filtered vector magnitude of the 3D acceleration signals with a time window of 1 second (Weber et al., 2009). A whole body PAI (PAI_{total}) was calculated by combining the measured segment activities according to the segment mass distribution assumed in biomechanical models such as by Winter (1990). The physical activity values obtained have been presented as a percentage of the gravitational force (%g=100*g) in the form of percentiles (50th and 95th percentile) to show the degree of acceleration.

Heart rate was selected as the indicator to determine the strain elicited by the different workstations and was recorded throughout testing using the Polar WearLink sensor and monitor model RS400. The sampling frequency was set to 1 Hz. To normalize the heart rate data, all results presented were calculated as per cent of heart rate reserve (%HRR) (ACSM's guidelines, 2010). A resting heart value was recorded over a period of 5 minutes in a prone position prior to the start of testing and the maximum heart rate was calculated using the age-predicted heart rate maximum as proposed by Gellish et al. (2007).

Assessment of Task Performance

The set of tasks selected was aimed at simulating basic office tasks and included five different tasks with various subtasks. Each task aimed at testing a different skill usually required by most VDU workstations and the battery of tasks included a typing task, a reading task, a telephone task, a mouse dexterity task and a set of computer-based cognitive tasks. The content selected for the typing, reading and telephone tasks were set so that the difficulty level was approximately standardized and no content was repeated between the workstations for one participant. Each of these tasks had a set duration of five minutes. The reading task had on average every 100 words a character rotation, and the performance criteria assessed included the number of correctly identified errors and number of characters read. For the typing task, the participants were required to copy a text from a window in the top half of the computer screen to a word document situated in the bottom half of the screen and was assessed for both speed and accuracy. The telephone task was aimed at assessing the effect that the dynamic workstations would have on speech quality and was assessed by the number of words spoken and the number of errors made in the repetition of the spoken text. The subjective quality of the spoken text was rated using the MOS scale (Gu et al., 2005). The mouse dexterity test, based on Fitts Law (Fitts, 1954), consisted of two different tasks, namely one with a randomized stimulus ("Random Circles") and the second one with a predefined response pattern ("Multi-direction"). The battery of cognitive tasks consisted of a Go/No go association task (Nosek and Banaji, 2001), a subitizing task (Simon et al., 1993), an Eriksen

Flanker Test (Eriksen and Eriksen, 1974), and a memory task. For the mouse dexterity task and each of the cognitive tasks, accuracy scores and reaction times were recorded.

Assessment of Subjective Experience

Subjective experience was assessed using several questionnaires, applied prior to the start of the testing session and then again before and after the direct use of each workstation, as well as at the end of the entire testing session. The questionnaire at the start of the testing session was used to collect basic anthropometric data, physical activity habits, as well as work-related factors such as working hours, main work tasks and VDU use. In addition to this expectations regarding the dynamic workstations were documented. The questionnaire applied before and after direct use of the dynamic workstations assessed bodily discomfort using the Local Perceived Discomfort scale and subjective opinion regarding the effect of the workstation on posture and on performance of the conducted tasks using Likert scales. In addition to this, questions pertaining to usability, acceptance and additional aspects regarding dynamic workstation implementation were included. At the end of the testing session a questionnaire with open-ended questions with regards to preferences of the tested workstations and questions pertaining to suitability and implementation factors of the workstations were asked. The results of the comfort, discomfort and productivity scores obtained from the questionnaire by combining and averaging the scores for the content-related questions will be included in this paper.

Data Processing and Statistical Analysis

ANOVAs for repeated measures (General Linear Model, GLM) were performed in order to determine the significance ($p < 0.05$) of the effect of the workstation condition (6 conditions) on the physical activity parameters, the task performance parameters and the questionnaire scores using the conventional sitting condition as the reference condition. Where required, post-hoc multiple comparisons were performed and to counteract the problem resulting from multiple comparisons, a Bonferroni correction was applied. Additionally for the parameters pertaining to physical activity (PAI_{total} and %HRR) the interaction effect of condition and task (condition x task) was also assessed and due to similarities in posture, the conventional standing condition was additionally tested for significances compared to the low and high intensity conditions on the walkstation. SPSS Statistics (Version 20) was used for the statistical analysis.

RESULTS

Physical Activity and Heart Rate

Significant effects (p-value <0.001) on the resulting whole body physical activity (PAI_{total}) both for the 50th and 95th percentile were determined for all the dynamic workstations. The inferential statistical results of the PAI_{total} scores are presented in table 1 and the descriptive results are presented in table 2. In comparison to the sitting workstation condition, all workstations tested except the conventional standing workstation resulted in an increase in physical activity. Similarly for the two walkstation conditions in comparison to the conventional standing workstation, obtained significantly higher PAI_{total} values. The factor task showed a significant effect on both the 50th and 95th percentile of the PAI_{total} values and the interaction factor was significant for the 50th percentile.

Table 1: Statistical results of condition, task and the interaction effects with the post hoc comparisons for physical activity intensities (PAI_{total}) values for the 12 participants for all tested conditions. *Significant effects (p<= 0.05)

PAI total [%g]	Condition (p)	Sitting vs.					Standing vs.		Task (p)	Condition x Task (p)
		Standing	Recumbent Elliptic Trainer		Walkstation		Walkstation			
			Low Intensity	High Intensity	Low Intensity	High Intensity	Low Intensity	High Intensity		
50%ile	**<0.001**		*	*	*	*	*	*	0.003	0.002
95%ile	**<0.001**		*	*	*	*	*	*	0.002	0.056

The highest amount of physical activity was achieved at the walkstation at the high intensity condition, with the 50th percentile of the PAI_{total} value at 14.9 %g (±2.8 %g). This was followed by the recumbent elliptic trainer at the high intensity condition, with the 50th percentile of the PAI_{total} value at 4.5 %g (±0.8 %g). When compared to the

conventional sitting workstation theses dynamic workstations yielded a 16.6 and 4.4 fold increase respectively in the mean 50th percentile values.

Table 2: Mean values and standard deviation (SD) of the 50th and 95th percentiles for the PAI_{total} values for the 12 participants for all tested conditions.

PAI total [%g]	Conventional		Recumbent Elliptic Trainer		Walkstation	
	Sitting	Standing	Low Intensity	High Intensity	Low Intensity	High Intensity
50%ile	0.9	0.8	4.0	4.5	3.7	14.9
(SD)	(0.6)	(0.3)	(1.2)	(0.8)	(1.3)	(2.8)
95%ile	1.6	2.0	5.2	5.4	5.3	17.1
(SD)	(1.2)	(1.4)	(2.0)	(1.0)	(1.8)	(2.9)

The mean %HRR was significantly affected by the condition (p-value <0.001) and the statistical results of condition, task and interaction effects with post hoc comparisons are presented in table 3. Post-hoc comparisons revealed that the recumbent elliptic trainer at the high intensity condition and both of the intensity conditions at the walkstation conditions yielded a significant increase, when compared to the conventional sitting condition. In comparison to the conventional standing condition, neither of the two walkstation conditions yielded a significant change in %HRR. The effect of task on mean %HRR and the interaction factor were not significant.

Table 3: Statistical results of condition, task and the interaction effects with post hoc comparisons for mean percentage of heart rate reserve (%HRR) for the 12 participants for all tested conditions. *Significant effects (p<= 0.05)

	Condition (p)	Sitting vs.					Standing vs.		Task (p)	Condition x Task (p)
		Standing	Recumbent Elliptic Trainer		Walkstation		Walkstation			
			Low Intensity	High Intensity	Low Intensity	High Intensity	Low Intensity	High Intensity		
Mean HRR [%]	**<0.001**			*	*	*			0.086	0.055

The lowest mean %HRR was measured at the conventional sitting condition at 9.4% (±5.5), and the highest mean %HRR were measured at the recumbent elliptic trainer for the high intensity condition at 27.5% (±7.7). When compared to the conventional sitting workstation, the recumbent elliptic trainer resulted in an increase of 2.1 and 2.9 fold at the low and high intensity conditions respectively and the walkstation yielded a 1.5 and 2.5 fold increase for the low and high intensity conditions respectively. The mean %HRR results are featured in table 4.

Table 4: Mean absolute heart rate (standard deviation) and mean percentage of heart rate reserve (%HRR) for the 12 participants for all tested conditions.

	Conventional		Recumbent Elliptic Trainer		Walkstation	
	Sitting	Stand	Low Intensity	High Intensity	Low Intensity	High Intensity
Mean %HRR [%]	9.4	14.2	20.0	27.5	14.3	23.6
(SD)	(5.5)	(5.7)	(10.0)	(7.7)	(5.6)	(8.3)

Task Performance

Task performance was evaluated for the conventional standing workstation and the four dynamic workstation conditions against the conventional sitting condition. This comparison with the conventional sitting condition was used then to determine statistical differences using a general linear model. Of the five tasks selected, only one type of task yielded significant effects with regards to task performance. Additionally both subtasks of this task, namely the mouse dexterity task, yielded significant effects in task performance. The statistical results are featured in table 5.

Table 5: Statistical results with post hoc comparisons for the task performance criteria that were significantly affected when compared to the performance obtained at the sitting workstation. *Significant effects (p<= 0.05)

Task	Subtask	Performance Criteria	Significance (p)	Sitting vs.				
				Standing	Recumbent Elliptic Trainer		Walkstation	
					Low Intensity	High Intensity	Low Intensity	High Intensity
Mouse Dexterity Tasks	"Random Circles"	Score	0.001	0.955	1.000	0.144	0.349	0.005*
	"Multi-direction"	Score	<0.001	1.000	1.000	0.431	1.000	0.010*

The descriptive results for the reaction time and score obtained for the two mouse dexterity subtasks for each workstation condition are depicted in table 6. For both of the mouse dexterity tasks, the fastest mean reaction time was for the seated workstation, with 610.5ms (±101.9) and 696.0ms (±114.9) for the task "Random Circles" and "Multi-direction" respectively. Descriptively, the slowest mean reaction time was recorded for the walkstation at the high intensity condition, with 804.7ms (±113.9) and 697.8ms (±114.4) for the task "Multi-direction" and "Random Circles" respectively. None of the dynamic workstations in comparison to the sitting workstation had a statistical effect on reaction time of this task. With regards to the score obtained for the "Random Circles" subtask, similarly to the reaction time, the highest score obtained was for the seated workstation, with a score of 1162.9 (±67.6). For the task "Multi-direction" the highest score obtained was for the standing workstation, with a score of 1243.8 (±75.0). The lowest score mean reaction time was recorded for the walkstation at the high intensity condition, with a score of 1074.7ms (±70.9) and 1034.3ms (±88.9) for the task "Random Circles" and "Multi-direction" respectively. The deterioration of score for both mouse dexterity subtasks at the walkstation for the high intensity condition was the only significant effect on task performance.

Table 6: Mean reaction time (ms) and score for the two mouse dexterity tasks for each of the workstation conditions (Standard deviation). *Significant effects (p<= 0.05) in comparison to the sitting workstation.

Mouse Dexterity Task	Performance Criteria	Conventional		Recumbent Elliptic Trainer		Walkstation	
		Seated	Standing	Low Intensity	High Intensity	Low Intensity	High Intensity
Random Circles	Reaction time (SD)	610.5 (101.9)	643.6 (112.4)	652.2 (110.8)	655.4 (103.6)	662.0 (105.2)	697.8 (114.4)
	Score (SD)	1162.9 (67.6)	1147.3 (76.3)	1140.3 (87.3)	1119.4 (64.3)	1109.0 (79.4)	1074.7* (70.9)
Multi-direction	Reaction time (SD)	696.0 (114.9)	706.1 (114.4)	715.9 (139.9)	726.7 (116.9)	748.8 (125.7)	804.7 (113.9)
	Score (SD)	1240.6 (158.3)	1243.8 (75.0)	1181.5 (72.8)	1175.5 (98.4)	1165.4 (94.6)	1034.3* (88.9)

Despite no further significant findings in the performance of the remaining tasks, the results will be described briefly to allow for a more comprehensive discussion of the potential implications with regards to task performance at dynamic workstations. For the task "Reading", speed (the number of characters read) and accuracy (the number of

correctly identified characters) was assessed. As figure 2 depicts minimal differences in reading speed and accuracy were noted between the different workstations. The number characters read ranged from 6556 characters (±3303.7) to 7070 characters (±3612.4). The number of correctly identified errors ranged from 70.5% (±22.5) to 84.4% (±17.1).

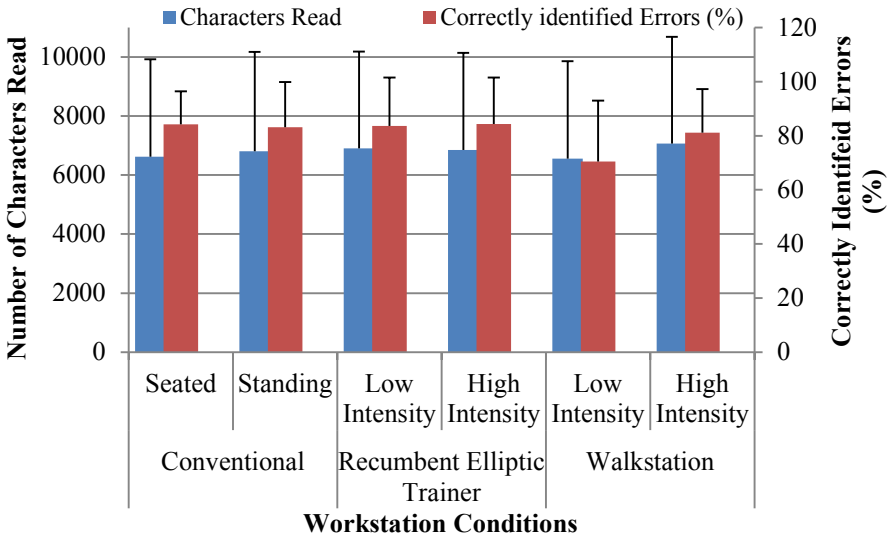

Figure 2. The mean number of characters read and the percent of errors correctly identified for the reading task for each of the workstation conditions (Standard Deviation).

Similarly the performance results, in the form of characters typed, differed minimally between the workstations and ranged from 815.8 characters (±205.2) to 908.2 characters (±289.9). With regards to accuracy, the number errors typed ranged from 10.8 errors (±8.4) to 18.8 errors (±19.9).

For the telephone task, the descriptive results differed minimally between the different workstations. The number of words spoken ranged from 450.0 words (±47.3) to 461.7 (±38.1) and the percent of spoken errors ranged from 6.0% (±3.4) to 6.8% (±5.4). The results from the subjective evaluation of the speech quality using the MOS scale yielded scores for all the workstations between 4 and 5. At a rating of 4 the speech quality is defined as good with the level of distortion being perceptible but not annoying. A rating of 5 defines the speech quality as excellent and the level of distortion as imperceptible.

The descriptive mean results for reaction time and accuracy for each of the cognitive tasks for each workstation condition are depicted in table 7. The mean reaction time for the Go/No-go task for each of the workstations was between 383.3ms (±79.1) and 419.0ms (±57.3). With regards to accuracy, the score ranged between 94.6% (±5.4) and 98.5% (±2.9%). For the subitizing task, the mean reaction time ranged between 929.8ms (±96.1) and 997.6ms (±83.5), and the accuracy score 80.0% (±11.5) and 84.6% (±8.7). For the Erikson Flanker test, for all workstations the mean congruent reaction time was less than the mean incongruent reaction time. The range of the reaction time was 470.9ms (±80.0) to 497.0ms (±96.5) for the congruent task and 514.5ms (±63.1) to 555.3ms (±136.8) for the incongruent task. The accuracy of the Eriksen Flanker task ranged between 97.9% (±2.5) and 99.2% (±1.9). The accuracy for this task also had the smallest standard deviations for the workstations compared to the standard deviations for the accuracy of the other tasks. The mean reaction time for the memory test was between 681.3ms (±109.8) and 721.3ms (±102.2). The percent of correct responses was between 74.9% (±8.1) and 84.8% (±9.4).

Table 7: Mean reaction time (ms) and accuracy score (%) for all the cognitive tasks for each of the workstation conditions. (Standard deviation)

Task	Performance Criteria	Conventional		Recumbent Elliptic Trainer		Walkstation	
		Sitting	Standing	Low Intensity	High Intensity	Low Intensity	High Intensity
Go/No-Go	Reaction time (SD)	394.3 (55.1)	383.3 (79.1)	405.2 (46.3)	399.8 (56.0)	419.0 (57.3)	404.7 (40.0)
	Acuracy (%) (SD)	94.6 (5.4)	95.1 (5.6)	98.5 (2.9)	94.8 (3.1)	96.1 (4.7)	96.9 (3.0)
Subitizing Task	Reaction time (SD)	997.6 (83.5)	978.2 (124.5)	959.8 (132.6)	929.8 (96.1)	983.2 (84.2)	939.0 (100.7)
	Accuracy (%) (SD)	80.5 (8.2)	80.0 (11.5)	82.1 (9.8)	82.5 (8.7)	80.3 (11.7)	84.6 (8.7)
Eriksen Flanker	Reaction time: Congruent (SD)	494.6 (78.1)	470.9 (80.0)	497.0 (96.5)	472.3 (71.4)	487.4 (64.8)	474.6 (78.8)
	Reaction time: Incongruent (SD)	545.4 (86.8)	516.0 (84.1)	555.3 (136.8)	514.5 (63.1)	520.7 (58.5)	523.4 (92.8)
	Accuracy (%) (SD)	99.2 (1.9)	97.9 (2.5)	98.3 (2.4)	98.3 (2.4)	98.8 (2.2)	98.3 (2.4)
Working Memory	Reaction time (SD)	688.7 (107.5)	682.0 (131.0)	721.3 (102.2)	681.3 (109.8)	709.7 (108.5)	695.0 (130.5)
	Accuracy (%) (SD)	76.7 (11.2)	79.8 (16.5)	74.9 (8.1)	83.1 (9.5)	84.8 (9.4)	76.6 (11.1)

Subjective Experience

Subjective experience was assessed using combined scores obtained for the categories comfort, discomfort, and productivity. The scores ranged from 1 to 7, with 1 being no discomfort and 7 being extreme discomfort for the discomfort questionnaire component, and for the comfort and productivity questionnaire components, a score of 1 was regarded as being the most negative score and 7 the most positive score. These scores were statistically compared between the different workstation and of the four categories, only the productivity score was significantly different (p-value: 0.006). Based on the post-hoc multiple comparisons, the productivity score was only significantly different for the walkstation at the high intensity condition compared to the conventional standing workstation (p-value: 0.027) and for the walkstation at the high intensity condition compared to the recumbent elliptic trainer at the low intensity condition (p-value: 0.016). The walkstation at the high intensity condition received lower productivity scores (3.32 ±0.43) when compared to the conventional standing workstation (3.95 ±0.31) and recumbent elliptic trainer at the low intensity condition (3.83 ±0.32). The statistical results and the mean scores calculated for each questionnaire component are featured in table 8. Based on the results in the table, all the workstations were classified as having low discomfort scores. Pertaining to the comfort questionnaire component, all workstations had a fairly neutral score that lay between 2.79 (±1.40) and 3.73 (±0.86) for the comfort score.

Table 8: Mean values and standard deviation (SD) of the Questionnaire scores pertaining to discomfort, comfort and productivity for the 12 participants for all tested conditions including the statistical results of the comparison of the scores obtained for the sitting workstation. *Significant effects (p<= 0.05)

Questionnaire Component	Significance (p)	Conventional		Recumbent Elliptic Trainer		Walkstation	
		Sitting	Standing	Low Intensity	High Intensity	Low Intensity	High Intensity
Discomfort	0.396	1.46 (0.88)	1.67 (1.01)	1.73 (1.17)	1.83 (1.01)	1.92 (1.30)	1.67 (1.03)
Comfort	0.123	3.73 (0.86)	3.58 (0.88)	3.08 (0.68)	3.04 (1.09)	3.12 (1.09)	2.79 (1.40)
Productivity	0.006*	3.96 (0.36)	3.95*[1] (0.31)	3.83*[2] (0.32)	3.66 (0.39)	3.62 (0.56)	3.32*[1,*2] (0.43)

DISCUSSION

This research aimed at investigating and comparing the biomechanical, physiological effects, task performance and subjective experience of dynamic workstations contrasted against more conventional workstations. Based on the results, significant alterations in physical activity and heart rate were found, while negative effects on task performance and subjective experience were more limited.

The physical activity intensities and percent of heart rate reserve significantly increased as a result of these workstations. Additionally the heart rate data showed that the dynamic workstations elicit a significantly higher heart rate in comparison to the conventional sitting workstation, with the tested conditions being rated as very light intensity exercise as the elicited %HRR was below 30% (US Surgeon, 1996). A higher exercise intensity using these workstations could not be reached as they have been specifically designed to allow for light intensity exercise, and have speed and resistance limitations deliberately set. Based on these results and these design specifications, using these dynamic workstations it would not be possible to obtain the ASCM guideline of a minimum of 30 minutes of moderate activity five days a week (ASCM, 2010). But as even all of the dynamic conditions assessed elicited significant increases in physical activity and three of the four dynamic conditions elicited significant increases in %HRR, this suggests that these workstations may have positive health implications as evidence suggests that any amount of physical activity and movement can lead to health benefits (USDHHS, 2008; Thompson et al., 2008; Levine and Miller, 2007). The benefits from activity are not only dependent on the intensity but also on the individual, and therefore some individuals may profit in terms of positive health effects more from these workstations in comparison to others. An example of this would be that deconditioned individuals through low intensity exercise might become more active (Haskel et al., 2007; USDHHS, 2008).

For these workstations to be a viable option in the work environment, their effect on task performance is an important consideration. Available literature provides contradicting information regarding the effect of moderate and acute exercise on basic cognitive processes (Straker et al., 2009; Tomporowski, 2003). This study focused on a group of basic tasks which contribute in some form to daily office work. Significant alterations in task performance were found for only one task of the five assessed, namely the mouse dexterity task, when compared to the task performance for the conventional sitting workstation. Deterioration in the score obtained while using the walkstation at the high intensity condition can be potentially attributed to biomechanical factors. During walking, specifically at the higher speed condition, the individual was less stable as a result of the small movements of the upper trunk produced during walking (Winter, 1995), and despite supporting the upper limbs on the treadmill desk, the upper limb fine motor movements were affected and consequently the accuracy was impaired. As none of the other task performance criteria for the other tasks was significantly affected, one can conclude with caution that it may be possible to perform basic office tasks while using these dynamic workstations. However, further research is warranted to determine the effect of these workstations on more complex tasks in a field-based setting.

A final crucial aspect to whether dynamic workstations really are an option for the work environment in the future is the subjective opinion specifically regarding discomfort, comfort and productivity. Subjective experience assessed in this study found only very limited significant differences and this was pertaining to the productivity of the walkstation for the high intensity condition. This negative assessment of one's own productivity at this station was minimally reflected in the decrease in the performance results of the mouse dexterity task at this station. The subjective experience results specifically pertaining to productivity are limited to this specific test situation as it would be expected that as the tasks increase in complexity, the subjective opinion of one's own productive as effected by dynamic workstations would also be altered. No significant differences were determined for the comfort and discomfort scores when compared to a conventional sitting workstation, and this may have positive implications for introducing these workstations in the work environment. However the limitation of the duration of the testing session needs to be considered and additional studies pertaining to the long-term use of these workstations is required.

CONCLUSIONS

To conclude, the dynamic workstations tested showed significant increases in physical activity in comparison to sitting and in some cases the standing workstations. Additionally only limited tasks were significantly negatively affected by the workstations and only limited negative subjective experiences were determined. These results tend to

suggest that dynamic workstations really may be a viable option to increasing physical activity in the workplace to an extent that may yield health benefits. Numerous studies have shown that physical activity not only promotes physical health but may also be associated with long term positive effects on cognitive ability. This further highlights the need to incorporate physical activity more in everyday life, specifically working life. Additionally regarding long-term aspects the employer may also benefit from these workstations by having a healthier workforce. Further studies are required to determine the exact extent of the health benefits and the suitability in the work environment in addition to determining which tasks and occupations are best suited for these workstations. Furthermore a trade-off may need to be accepted between the potential benefits of these workstations and the "adaptation phase" regarding task performance and therefore research regarding the duration of adaptation required for performance and social acceptance is necessary.

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Comfortable Rear Seat Postures Preferred by Car Passengers

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ABSTRACT

The joint angles of three most common postures of passengers sitting in the rear seats (sleeping, standard, upright) were recorded to develop an ideal posture model for rear seat passengers within a car. The passengers were positioned in a realistic mock-up of a whole car interior with a fully adjustable back seat and postures recorded. The results showed that the upright and standard postures have similarities to the postures of the driver's seat in the literature. The relaxed posture showed a higher angle between trunk and thigh compared with the driving position and the variation in leg postures was much larger, which can be explained by the fact that the legs have more freedom in the rear seat than in the driving position.

Keywords: rear seat, posture, RAMSIS, comfort.

INTRODUCTION

Today's traffic situations show a diversified use of cars differentiating in two typical ones: commuting and vacation. The number of passengers can vary massively regarding to the various situations with compacts, station wagons and sedans as the most frequently seen car concepts (see Fig.1). Even if the number of SUVs would increase and new car concepts emerge like rear passenger focused ones, in commuting and vacation those three car types remain the most frequent ones for a while. Interestingly, a traffic observation showed that those car concepts also proved to be the ones that are most flexible as they can be used for both use scenarios (see Fig. 1).

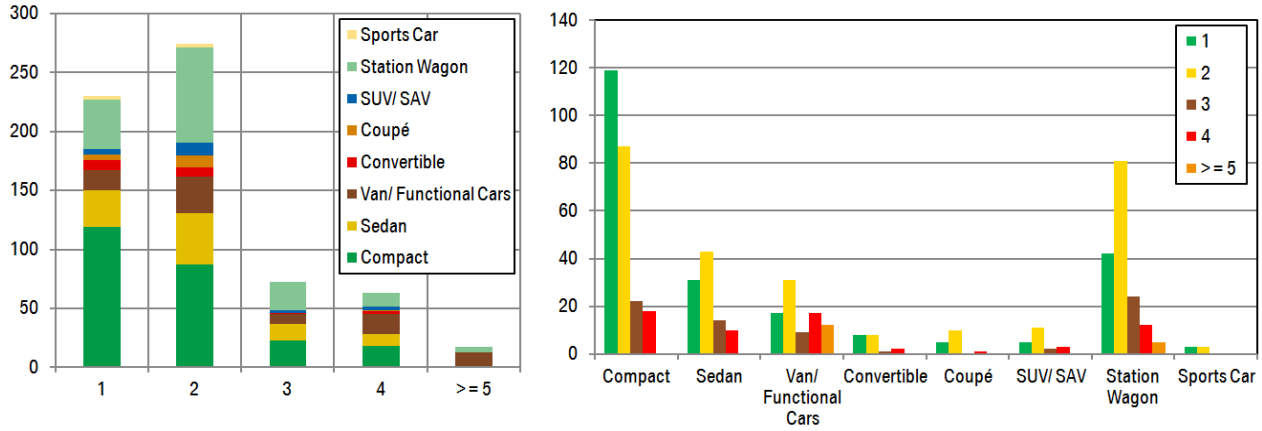


Figure 1. Traffic analysis (trip from Munich to Delft on a Sunday: 850 km/530 miles on a highway). In the left picture the frequency distribution of passenger numbers in different car types is shown, the right picture illustrates the car types with the related passenger numbers.

Especially for long travels comfort plays an important role. However there are not many rear seat comfort models. Whereas a lot of research exists about the comfort of the driving seat e.g. by seating pressure distribution (Mergl, 2006; Zenk, 2008), comfort angles (Looze et al., 2003) and seating design (Franz, 2010), only little knowledge exists about the rear seat. In spite of the forced posture of the driver resulting from the maneuvering of the car (reaching the pedals, steering wheel, changing gears, view up forwards and backwards), the back seat passenger lacks a concrete task. Therefore an indefinite number of possible postures unfolds only restricted by the cabin and design of the back seats.

From a prior train passenger observation and analysis (Kamp et al., 2011) three typical sitting postures were seen most often. These positions are chosen for further study in the rear seats. It is important to select these three positions as the number of postures is indefinite. The examination of comfort angles in relation to those sitting postures is of importance in designing back seats as it can be assumed that the often chosen postures in trains, where there is also much freedom of posture choice could be transferred to the rear seats.

Thus for an insight in passenger habits and postures in passive driving situations the train study on 580 travelers was used (Kamp et al., 2011). The train movement was evaluated to be more comparable to a car's movement, because of the similar impact on passengers regarding longitudinal and lateral acceleration, as well as decelerating. Therefore the activities can be transferred to those rear seat passengers would conduct in various travel situations (commuting, vacation, etc.).

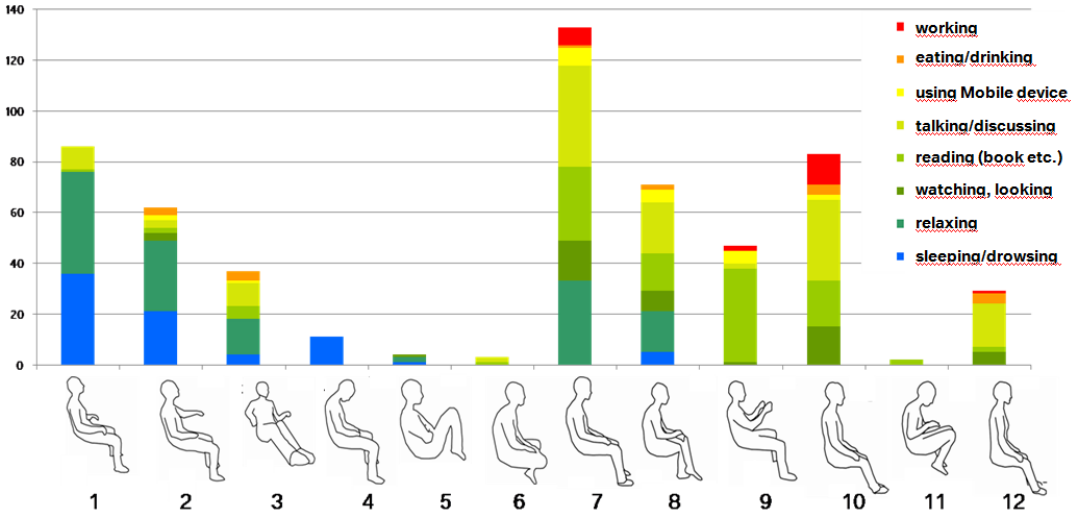


Figure 2. Research of typical activities of train passengers and the resulting postures.

In Fig.2 on the left, postures for relaxing and sleeping activities are shown and in the middle the tasks are reading,

watching and talking. These activities show a more upright posture. On the right side, postures seen for activities like working, eating, drinking and using mobile gadgets are illustrated. Based on these 12 postures, which were observed during travelling, a selection was made for the rear seat of a car. Most of these postures are not applicable for the rear seating of a car, because of safety requirements and physical constraints due to the car's package. For instance, there is a shaft tunnel in the middle between the seats which limits space for your feet and lower legs. However three positions out of the 12 observed postures are possible and most observed (Kamp et al., 2011). Fig. 3 represents those possible three postures a back seat passenger could choose.

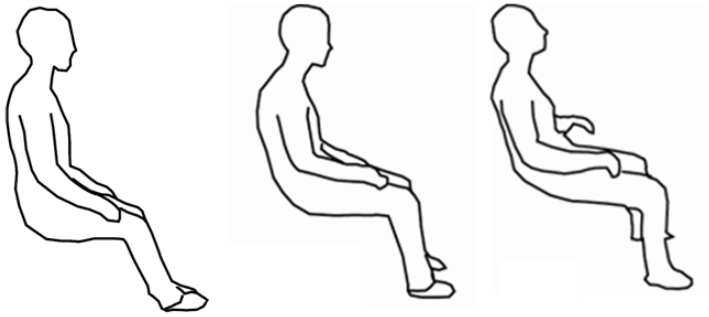


Figure 3. Resulting 3 possible postures applicable for back seat passengers after a selection from the 12 observed postures.

The left posture represents an upright position for short term travelling, watching the surrounding, using your mobile phone, talking to other front seat car passengers and eating. Additionally, Kamp et al. (2011) illustrated that this posture could be the most frequent one for diverse activities with high, medium and low activity levels in trains which is a comparable travel situation to the rear seats. In the middle the posture would need more space for a slightly relaxed seating, still awake and typically performing activities like listening to music. The right one is a special position for bigger cars and long term travelling with relaxing, maybe sleeping and drowsiness as major characteristics. This position maybe even more important for long term travelling (Khan & Sundström, 2007). For car manufacturers it is also important to consider these three postures, because in smaller cars only the upright position is possible and larger cars allow the relaxed position to be possible. Also, for software (like RAMSIS) it is important to further specify the posture for the different body parts. Therefore, it is interesting to have a closer look on these postures and analyse these more deeply.

The research question for this study is:
What are the angles in space with respect to a reference position of the different human body parts while sitting in the three described positions in a sedan?

METHOD

To answer the research question first the previously defined three typical postures derived from the study of Kamp et al. (2011) were more precisely analyzed. For this purpose 20 subjects were positioned in these three postures in a mock-up of a car interior which had the same size as a real car: a luxury limousine with adjustable back seats (see Fig. 4). Posture and comfort were recorded for all subjects sitting in this mockup. The measurement of the posture was done by using PC-Man, which is a software for measuring anthropometry based on stereophotography.

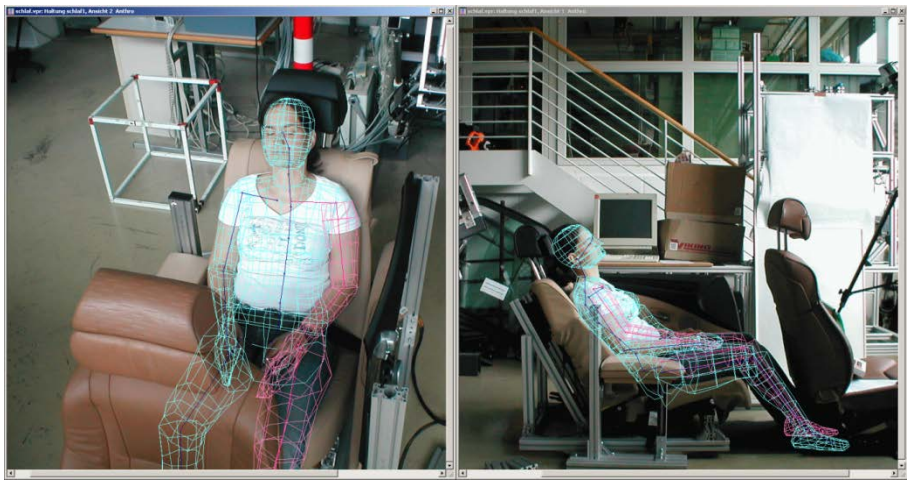


Figure 4. The typical PC-man net of a subject sitting in a sleeping position in the mock-up.

The experiment started with collecting anthropometric data of each subject like age, body height, sitting height, leg length. A total of 20 subjects took part in the experiment (11 male and 9 female). The subjects were between 21-36 years old and with body height from 1.58-1.97 meters. According to Seidl (1994) the comfort angles do not necessarily depend on the body height which means that we can hypothesize that the same comfort angles will be obtained for everyone.

The comfort was checked by using a questionnaire and the posture was recorded by taking pictures for the stereophotography right after the position (see Fig. 4). The stereo photogrammetry delivered data on complete body segments and for comparing the joint angles to the literature. The joint angles in the sagittal plane were calculated with the support of RAMSIS.

The backseat itself was fully adjustable, including angle of seat pan, backrest and upper lumbar rest (see fig. 5). Also the height of armrest (left hand side and right hand side) and headrest were variable which is important to enable a good position in order to achieve a high comfort situation (= posture).

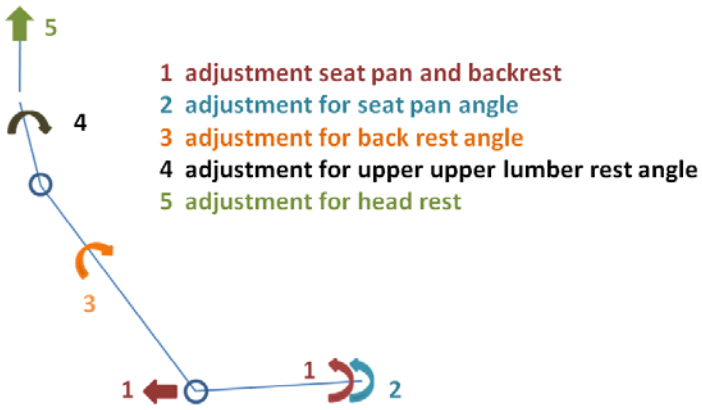


Figure 5. Fully adjustable mock-up seat. Overview of the adjustment possibilities.

Protocol

The experiment started by putting a subject in the initial situation. In this initial situation: the seat was adjusted in a very uncomfortable position in order to ensure that subject has to adjust the entire seat according to the own preferences and not just take over the predefined settings of previous subjects. For each subject the following sequence was defined:

1. Fasten the seat belt (a lap belt for more realistic rear seat posture, important for pelvis position in relation to the seat pan)

2. Adjust seat for standard posture.

3. Adjust seat for a relaxed posture.

4. Adjust seat for the upright posture.

All three postures were recorded via stereophotography, after the subject reported that the position is taken and after each posture a questionnaire was completed. The intention of using this sequence was to avoid that the subject uses same posture for upright and standard position. The upright position was also seen as the ideal one for the last sequence for answering the questionnaire using a blotting pad.

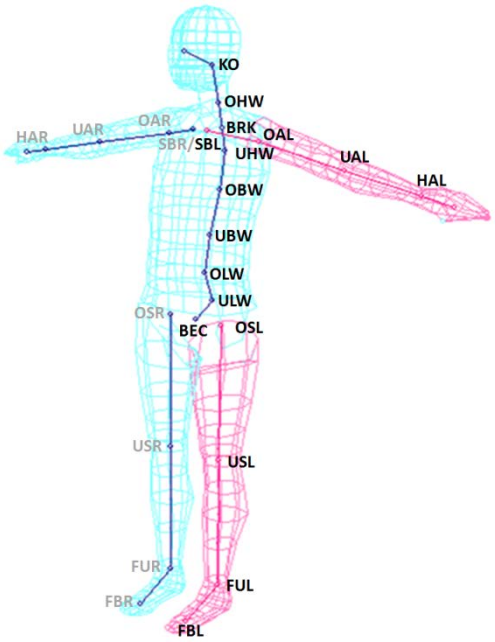
RESULTS

All of the subjects declared that they feel like sitting in the backseat of a real car. For this reason the mockup was considered as suitable for the test series. As planned the subjects did indeed adjust their seat to another position in all three situations. In Table 1 the measured joint angles for the three passenger postures are compared with the RAMSIS driver posture. The thigh angles are comparable between driving posture, the upright and standard posture. Only the relaxed posture differs as the subjects show a larger angle of the trunk, because the subjects were stretching their legs: z = 61.1° instead of 82.1° of the driving posture.

Noticeably, in the upright position the thighs are closer with y = 5.5° than 11.1° which can be explained by using the thighs as support for notebooks, books, etc. The foot opening angle of the driving posture (z = 72.0°) is bigger than the one of the passenger model (z = 59.0°), because of the missing pedals. Therefore the foot can be kept relaxed.

The whole chain of arm, elbow and shoulder of the relaxed passengers' position differs intensively from the driving posture as the arms lack a concrete task and consequently can rest in a relaxed but manifold position.

Table 1: Average of measured joint angles for 20 subjects in three different postures with standard deviation (SD).

RAMSIS		RAMSIS driver posture angels [°]		
	RAMSIS Joint	x	y	z
	BEC	0	0	-26.9
	ULW	0	0	-14.7
	OLW	0	0	16.6
	UBW	0	0	7.9
	OBW	0	0	9.6
	UHW	0	0	12.5
	OHW	0	0	-5.7
	KO	0	0	-1.4
	OSL	-12.4	11.1	82.1
	USL	0	63.1	0
	FUL	0	0	72.0
	SBL	0	-7.8	5.7
	OAL	-66.9	-33.0	75.6
	UAL	4.6	-54.0	0
	HAL	0	6.6	8.5

RAMSIS Joint	passenger upright posture [°] (SD)			passenger standard posture [°] (SD)			passenger relaxed posture [°] (SD)		
	x	y	z	x	y	z	x	y	z
BEC	0	0	-17.2 (9.3)	0	0	-16.7(9.5)	0	0	-31.4 (8.2)
ULW	0	0	-5.0 (7.9)	0	0	-5.9 (7.0)	0	0	0.9 (4.9)
OLW	0	0	6.9 (4.4)	0	0	5.9 (5.0)	0	0	5.5 (3.3)
UBW	0	0	2.8 (3.4)	0	0	3.2 (4.0)	0	0	2.3 (2.9)
OBW	0	0	13.5 (7.6)	0	0	10.2 (4.7)	0	0	6.9 (3.9)
UHW	0	0	9.9 (5.6)	0	0	7.5 (4.4)	0	0	6.8 (5.4)
OHW	0	0	9.5 (6.3)	0	0	-0.9 (6.9)	0	0	0.2 (8.6)
KO	0	0	4.8 (4.7)	0	0	-1.0 (3.8)	0	0	0.1 (4.2)
OSL	-5.7 (8.2)	5.5(5.4)	76.2 (9.5)	-7.4 (7.5)	9.0 (7.3)	79.1 (9.4)	-9.1 (9.7)	10.7 (7.5)	61.6 (12.6)
USL	0	76.8 (11.6)	0	0	80.8 (7.6)	0	0	76.3 (10.1)	0
FUL	0	0	61.4 (5.3)	0	0	62.5 (4.4)	0	0	59.0 (5.6)
SBL	0.1 (0.8)	1.7 (6.1)	-0.9 (5.6)	0.1 (0.8)	-0.6 (6.8)	0.4 (6.6)	0.2 (0.8)	3.1 (7.7)	-3.7 (5.5)
OAL	-14.3 (21.6)	-52.6 (14.8)	46.9 (11.7)	-12.4 (17.3)	-53.6 (12.4)	45.3 (19.7)	2.3 (16.5)	-57.2 (11.5)	42.1 (13.0)
UAL	3.9 (13.4)	-84.5(12.0)	0	4.8 (17.2)	-62.5 (13.8)	0	6.9 (17.7)	-56.6 (13.1)	0
HAL	0	-2.1 (5.4)	0.8 (3.8)	0	-4.2 (11.3)	0.0 (0.0)	0	-2.1 (14.9)	-0.3 (1.3)

The visualization of the three different postures in RAMSIS can be seen in Figure 8 with presenting the mean values for each joint angle.

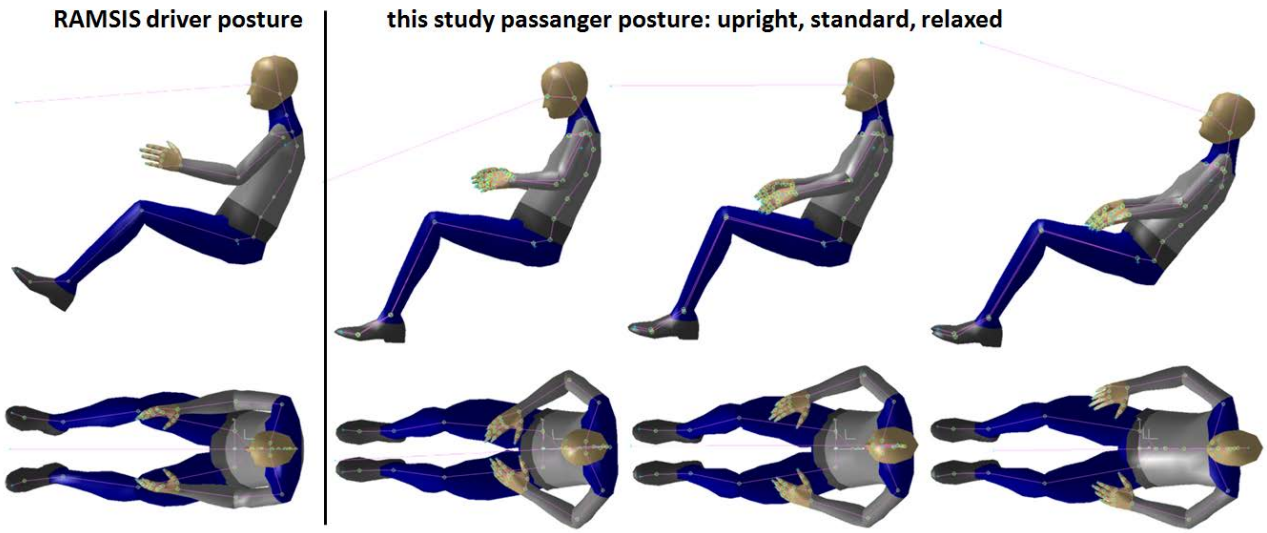


Figure 6. Visualization of the results in RAMSIS: upright posture (left), standard posture (middle), relaxed posture (right)

In order to highlight the differences and to compare the findings of the study to the established values of the literature, the 3D angles were projected on a 2D surface:

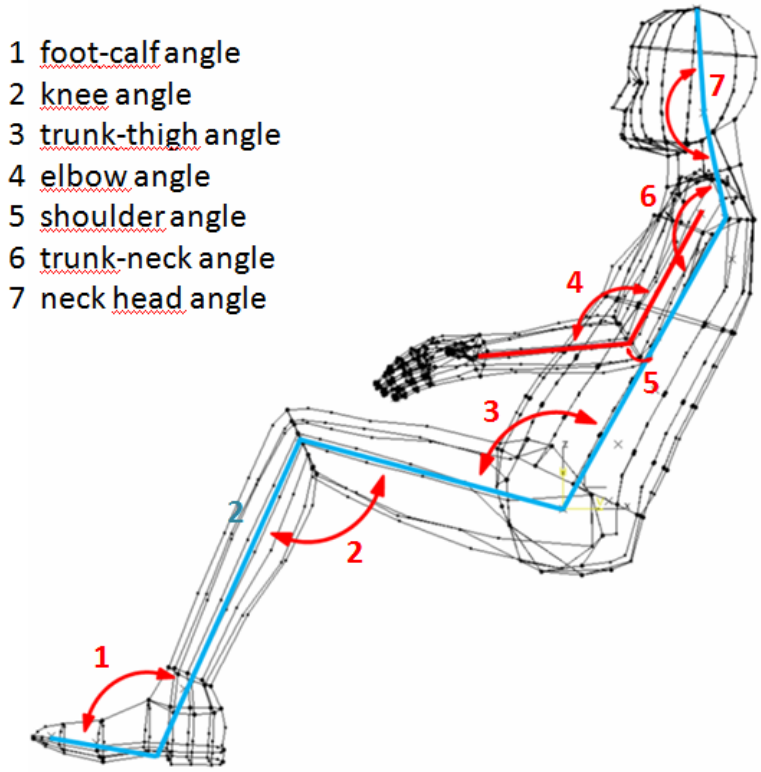


Figure 7. Projection of RAMSIS manikin in 2D-plane showing the measured joint angles.

A comparison of the three different passenger positions is shown in Table 2.. The average angles with the standard deviation (SD) the subjects took in the comfortable position are shown in Table 2. The difference between the upright and standard position was not that large. The only significant difference can be seen in the shoulder angle which has an average value of 32.4° for the upright position and 0.6° for the standard posture. This is obvious because subjects were using their hands for doing tasks like filling out the questionnaire (representing tasks like using a mobile device, eating, reading in a magazine etc.). The difference in the sagittal plane was largest between relaxed and the other two (see table 1), while the trunk-thigh angle is 104.2° for the standard posture the relaxed position showed here 118.9° because subjects sit more relaxed. Accordingly, the elbow angle in the relaxed position is 139.9° compared with 128.5° for standard position. Also foot-calf angle and trunk-neck angle show a slighty more open angle. The questionnaires showed that the majority of the subjects could take their ideal position.

Table 2: Average of measured joint angles for 20 subjects projected on the sagital plane:

Classification	Passenger Sitting posture		
	Upright (SD)	Standard (SD)	Relaxed (SD)
Trunk-thigh angle	105.5 (5.5)	104.2 (7.6)	118.9 (10.5)
Knee angle	103.4 (12.5)	99.5 (9.9)	104.9 (11.9)
Elbow angle	113.1 (11.7)	128.5 (14.1)	139.9 (11.8)
Foot-calf angle	104.9 (5.8)	104.7 (4.6)	107.9 (8.2)
Shoulder angle	32.4 (13.3)	0.6 (12.6)	1.0 (11.8)
trunk-neck angle	130.3 (3.5)	139.5 (0.7)	142.7 (2.1)
Neck-head angle	177.5 (4.6)	187.2 (3.9)	185.3 (4.3)

DISCUSSION AND CONCLUSION

Regarding the research question this study shows that it was possible to detect differences in postures. The three positions found in the study of Kamp et al. (2011) did show different angles in space in a sedan mock-up. Analogous to Kamp's study, the armrests were excluded, as even in passenger trains the support was seldom used.

The differences were largest between the relaxed and both other positions (upright and standard). In Table 3 a comparison with the literature is shown. Most values are comparable with the literature and fall within the range that is described in the literature. Differences are especially found in the relaxed position. The trunk-thigh angle in the relaxed position is close to the highest recorded in the literature. In the literature sometimes this trunk angle is also compared to the horizontal and the upper leg is usually not equal to the horizontal, enforcing the difference to the literature. This difference is easy to explain as in the literature the driving position is taken. Probably the head position in our study is also more backwards than in the driving position.

So for the rear seat it is important to use somewhat different guidelines than often used for the driver's seat, as there are also advantages of a reclined and slumped posture (Fujikmaki & Mitsuya, 2002). Important differences are the lacking driving tasks and therefore the increase probability of posture variation. The standard deviation was also high in some recordings like for the lower leg and upper leg which can also be explained by the fact that the driving task is missing. Because of this variation it is perhaps wise to further investigate the findings with more subjects or even in different cultures in order to identify the influence of cultural differences.

In the market there is a growing popularity of SUVs and new vehicles possible due to the electric cars. Therefore in a new study the advice is also to pay attention to the posture in a SUV. And for instance, pressure mat data are missing. As Mergl (2006) and Zenk (2008) identified the ideal pressure distributions for the position in the driver's seat. Further research is needed also to identify long term effects of comfortable postures in the rear seats. So this study should integrate pressure distribution data in order to be able to design the ideal rear seat.

Table 3: Comparison of measured joint angles of this study with the angles measured in the literature

Classification	**Rebiffe** (1969)	**Grandjean** (1980)	**Porter and Gyi** (1998)	**Park et al.** (2000) mean (SD) Range	**This study** mean (SD)		
					upright	standard	relaxed
Trunk-thigh angle	95-120	100-120	90-115	117.4 (7.71) 103-131	105.5 (5.5)	104.2 (7.6)	118.9 (10.5)
Knee angle	95-135	110-130	99-138	133.7 (8.53)	103.4 (12.5)	99.5 (9.9)	104.9 (11.9)
Elbow angle	80-120	-	86-164	113.0(14.01) 86-144	113.1 (11.7)	128.5 (14.1)	139.9 (11.8)
Foot-calf angle	90-110	90-110	80-113	100.8 (8.61) 82-124	104.9 (5.8)	104.7 (4.6)	107.9 (8.2)
Shoulder angle	-	-	-	19.5 (6.38) 7-37	32.4 (13.3)	0.6 (12.6)	1.0 (11.8)

trunk-neck angle	-	-	-	-	130.3 (3.5)	139.5 (0.7)	142.7 (2.1)
Neck-head angle	-	-	-	-	177.5 (4.6)	187.2 (3.9)	185.3 (4.3)

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Adaptive Customization –Value Creation by Adaptive Lighting in the Car Interior

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ABSTRACT

In this paper adaptive customization by color changing LEDs is investigated. Two forms of customization are studied: one system reacts on the color of subjects' clothes and one system was influenced by a color blending App. Both are built up in a real car. The emotional responses were recorded before and after the test with 70 subjects. Emotions as attraction, hope and joy were found as reactions and 58.6% preferred this approach of steering the interior lighting. Half of the sample preferred the color mixing and half the automatic color detection system showing that there are two clear interaction preferences. The expectations recorded prior to the test influenced the level of experience massively and also interfered with the subjects' emotions.

Keywords: crowd sourcing, customization, HMI, emotional value added.

INTRODUCTION

In the BMW museum it is shown that high class customization of luxurious cars in the 60s and 90s was offered for only one person e.g. the BMW 507 and the BMW Z8 (see Fig.1). The initial buyer could choose among a lot of interior features, colors and materials and therefore the car was customized to the buyer's needs. However, this is only an advantage for the 1st owner of a car and can seldom be applied to the retail market or car sharing. In the past, customization was only available for make-to-order products. Nowadays, customization is realized by colors and materials aside of technical features in form of packaging or sub-brands in order to satisfy an increasing demand for individualization (Futschik, 2011). Another possibility for customization is to change the appearance of the interior continuously.

Figure 1. The interior of the Z8, which is made custom specific and the color repeats itself in different parts of the interior.

In the last years the application of LEDs increased in our homes, decorations and in cars itself either as safety features like head and tail lamps (Lachmayer, 2011) as well as interior design elements (So & Chan, 2009) e.g. as programmable and application steered LED lightstrips (Donath, 2013) or photonic textiles (Klaß, 2005). For the second owner and car sharing users, which could be a change in the mobility behavior of customers especially in bigger cities, customizable lighting elements in the interior can be an interesting approach. Therefore, in this project RGB LEDs are used that can be adapted continuously during the lifetime of the car.
To test whether this is possible and appreciated by customers this project is initiated. Several design stages (ideation, user innovation contest, benchmark on customization with smart phones, integration into the car) were applied for generating a prototype followed by a qualitative and quantitative study. The overall research question is: 'can adaptable customizable functions create a value for customers?' and more specific: 'is color connected to the user being influenced on experienced emotions?'.

THE IDEATION STAGE

The first design stage consisted of a student workshop identifying a relationship between excitement or positive experiences and customization (n=18 subjects). The purpose was to lead to the core question of customization to be a buying motivation in a time in which mobility solutions tend to change massively e.g. flexible ownership models of cars, individualization and decreasing significance of owning a car as status symbol (Winterhoff et al., 2009; Horx, 2010). The students of various backgrounds doing their internship at BMW were subdivided in teams of 3 to 4 in order to play different games in randomized order. The excitement of games in which the participants needed to be on their own were rated low whereas the individualizing of an easy brick game like Make 'n Break by setting own rules proved to be as intense as group experiences like performing a stand-up play with puppets. It seems that customization of the game where users can make their own rules increased excitement. This was a motivation to continue and the question is what can be customized by users themselves within the car.

USER INNOVATION BY CROWD SOURCING

As a next step crowd sourcing applied in the form of a web-based contest (cf. Terwiesch & Ulrich, 2009) was used to generate an user-oriented pool of ideas for customization of the automotive interior (Fueller et al., 2005; Fueller & Hieberth, 2004; Barl et al., 2003; Shawney et al, 2005, Ernst & Gulati, 2003; McAlexander et al., 2002; Fueller et al., 2008; Wiegandt, 2009). Via platforms, posters, advertising and social media (e.g. Facebook) participants were invited to submit functions or designs allowing an enhanced degree of customization compared to current cars. With the incentives of prizes (first prize was a visit to BMW, combining extrinsic with intrinsic motivation (Walter & Back, 2011)) the competition resulted in a broad variety of 740 ideas for customization of the automotive interior. The contest members were 1075 participants who evaluated the ideas by choosing "I like this idea" or "I would use this idea" (illustrated by thumbs up/down). Simultaneously, an evaluation group of experts within BMW selected ideas (Riedl et al., 2010). The best ideas out of both pre-selections were sent to a jury of external and BMW experts. They evaluated the ideas and selected the winners. The winning idea "color matching camera and lighting" was intended to sense the color of the clothing of the driver and adapt the interior color of lighted panels to the clothing color. This idea was taken as an inspiration for the mock-up and transferred to a design of adaptable lighting elements.

BENCHMARK ON CUSTOMIZATION WITH SMART PHONES

To check if this idea has a change of acceptance, the need for customization was also investigated among other products like the iPhone. Qualitative interviews with seven iPhone users on applying different mobile covers or sleeves in bright colors, materials and equipped with different functions were studied. Two main characteristics of customization could be identified in how the product is affected in order to adapt it to a person: aesthetic customization and functional customization. Aesthetic customization is represented by material (silk bag, leather sleeve and silicone cover), texture (croc, form of a chocolate bar, a cassette player) and color (gold, green, brown etc.), functional customization by added functions like charging, protection cover and antenna amplification. The consumers were willing to pay for this aesthetic customization from 8-20 Euros and 16-80 Euros for the functional customization. This means customization related to color is already used among other products supporting the vision that the new idea of adaptive interior lighting has potential.

INTEGRATION IN THE CAR: BUILDING THE MOCK-UP

The experience of the adaptive interior lighting was created by mounting a camera in the car in the inside mirror serving as the color sensor. The camera was programmed to detect the colors of the clothing in the area of the right shoulder. According to this data input the color of the LEDs were manipulated. Openings (dot shape) were made in the dashboard and door trims. Behind these openings RGB LEDS were mounted able to change color (see Fig.2a). Additionally, the LEDs could receive the signal from an APP via WLAN to change or blend colors by the usage of an iPad (see Fig. 2b).

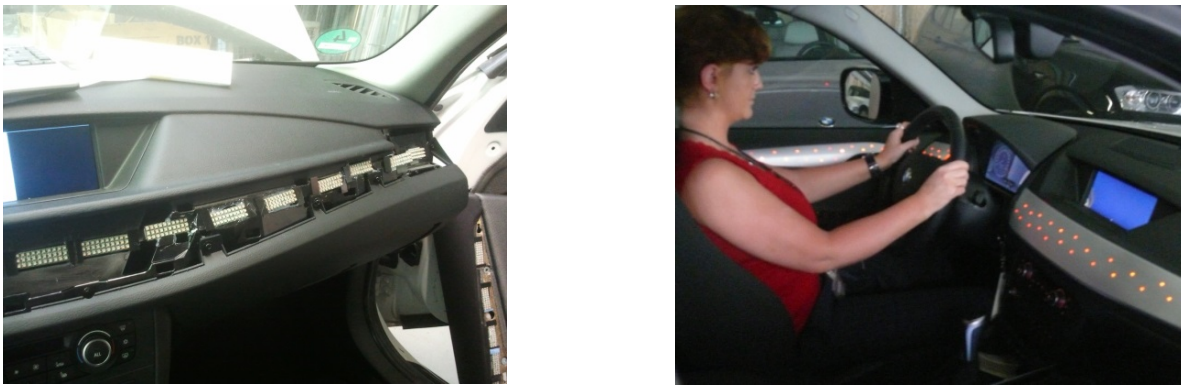

Figure 2a. Adaptive interior lighting mounted in the dashboard (left picture), red lighting of dashboard and door trims adapted to red shirt of driver detected by camera.

It is interesting to position this interaction of the driver with the adaptive interior lighting into a broader scientific perspective to add to the understanding of human preferences. This is done by using Human-Machine- Interaction models (cf. Schlick et al., 2010; Bubb, 2008). Lessons could be learned on the adaption of subsystems to the driver's skills, psychological and physical restrictions of information processes e.g. through Cognitive Engineering (Rasmussen et al., 1994). As both models consist of valuable information, but neither one serves as the right approach for this study, a combination might be useful. Schlick's model represents the inner information processing of humans in relation to the respective stimulus, whereas Bubb's model describes the effect of environmental impact on human, machine and the information flow between. Both aspects were used and transferred into an adequate model for studying customization systems for the automotive interior (cf. Figure 3) analoguous to Bubb's model in a closed loop with a special focus on the consumer trend "simplify" i.e. the customer's expectation of an simple and intuitive access to a technological system (Winterhoff et al., 2009; Lemmer, 2011). The model in Fig.3 has a machine and a human side. In case of using the App, the system information is taken (information output on the App) and there is a reception in the human, then the human detects and decodes and an action follows.

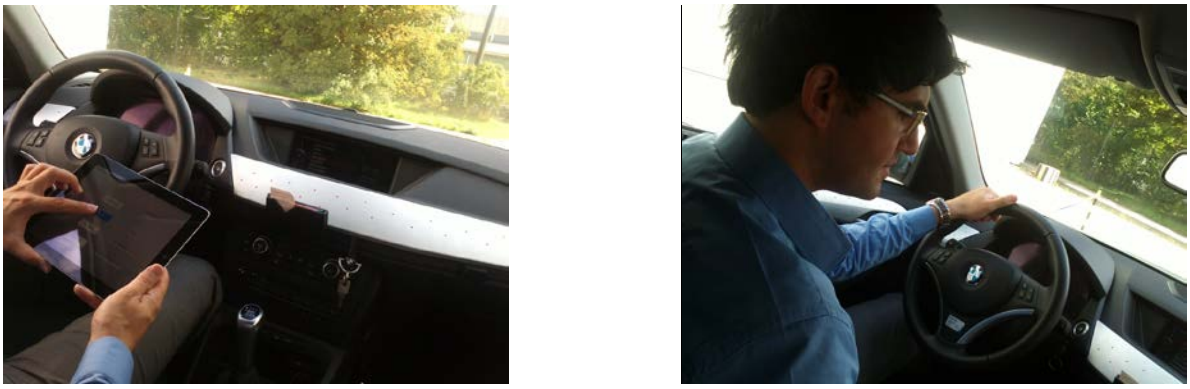

Figure 2b. The color choice by APPsteering.

For the design of an adaptable interior lighting the resulting research questions regarding their character of customization are:

Do users prefer an automatic adjustment or a conscious choice by an App? What effect can be identified of the subject's expectations on their emotional arousal before and after the test?

METHOD

A study with 70 subjects was performed to answer the research questions whether the conscious color choice or the automatic color adaption were preferred and to identify differences between those two interaction processes between human and machine (cf. Figure 3). Regarding the inner processes happening within a human, the camera-based adaption is representing an interaction with no detection or decision. So the system automatically detects the color of the subject's clothes and decides which color should be displayed by the LEDs. The App allows the subjects to decide on the interior lighting color.

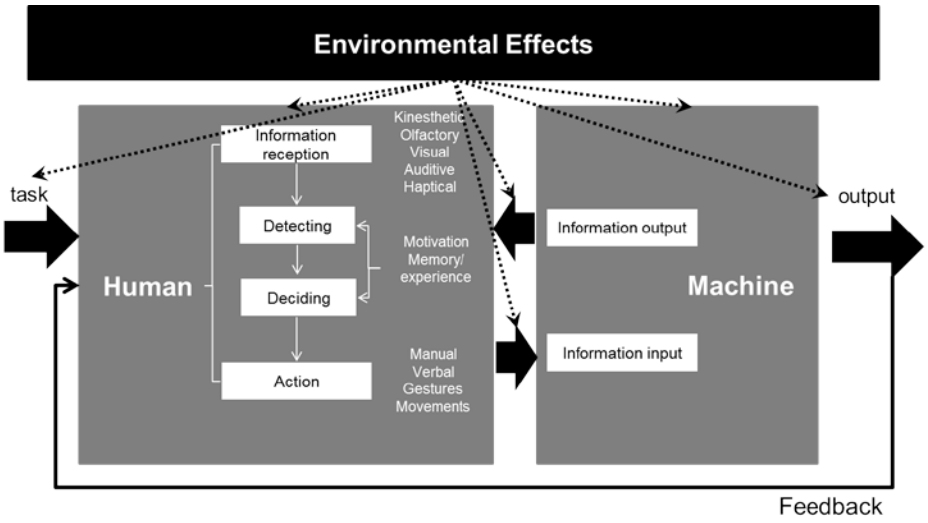

Figure 3. Conceptual Model of Human-Machine-Interaction based on the model of Schlick et al. (2010) and the lecture notes of Prof. Bubb.

According to the Human-Machine model (cf. Fig. 3), the lighting adaptation can be subdivided in an information input part and an information output part. To identify the expectations of the subjects and the resulting interference the researcher questioned these aspects prior to the presentation.

First a pretest was conducted with 11 participants (5 females, 6 males) receiving a product presentation and who afterwards filled out a questionnaire with a special focus on the emotional added value of customization. The pretest showed it was difficult to catch the subjects' emotions, also that a lab situation would be more convenient, as lighting conditions outside could vary massively. So the mock-up was positioned inside with constant lighting conditions. Before and after experiencing the interiors a guided interview was held with 70 participants. The mean age of the study population varied between 20 and 59 years with a majority of middle aged subjects, 27 females and 43 male most of them working at BMW (R&D 71.4%, Production 12.9%, Marketing 5.7%). In order to identify the emotional responses of subjects the emocards (Desmet et al., 2001) were used along with a bipolar 7-point Likert scale of 2 opposite emotions: aversion-attraction, fear-hope and boredom-joy. The subjects had to rate those 3 emotions before and after the test. All pre-tests indicated that a verbal description of the emotion is necessary in order to prevent misinterpretations. Other items like satisfaction were excluded as subjects lacked understanding of the reason why an interior feature should lead to dissatisfaction, this will be more important associated with comfort ratings or usability than emotional responses. Even in the pretest the subjects prove to have an above average level of consumer innovativeness as well as a high automobile involvement. However, they showed only an average level of a need for customization. This issue was also found in the 70 subjects involved in the complete test (>50% high scores in innovativeness, >70% high scores in automobile involvement, > 20% mediocre to moderate high scores in automotive customization). Established marketing scales were combined with an automotive customization scale which was developed by the researcher through prior experiments to this study. T-tests of the questionnaire items prove to be significant, serving as a profound tool for the study. The marketing scales along with a typical catalogue of buying criteria for a car were tested in a 5-point Likert scale with 1 as lowest score and 5 has highest. For instance, overall quality, reliability and quality of the interior were valued as most important by the sample, whereas variability of the interior, brand image, reputation of the manufacturer, customization and storage capacity were regarded as not important. The first interview part was questioned before the subjects experienced the feature. It was done to identify their expectations of the word "adaptive lighting", the frequency of color switching of interior lighting (never 14.3%; once 10%; more than once 22.9%), the most favorite colors and most favorite clothes colors. As the majority of subjects mentioned that they would only change the lighting color of the interior seldom to never, a new approach to operate this color change is a plausible way to lead users to a new customizable and adaptive experience. A comparison of the new steering possibilities with current ones e.g. a switch to change a pre-defined set of colors has to be drawn and rated by the subjects as well as qualitative interview parts regarding the reason for their choice (automatic adaption by camera-input or blending colors with an iPad App). Other questions were focused on whether this steering option should go further in form of a brainstorming technique. This particular interview part was conducted sitting in the driver's seat, as the researcher aimed for continuation and similarities in

the setting combined with the anticipation of being an actual driver in the car. This scenery should lead to a deeper insight in the authentic user-product interaction.

Pre- and post-ratings of emotions were tested with t-tests for paired comparisons ($p<.05$). The positive scores of the preferences were also tested against the negative scores using Wilcoxon ($p<.05$) along with a cross-tab analysis to discover relationships with subjects preferring the camera based adaption of the lighting color and with subjects preferring the App on a CE device e.g. iPad. The impact of expectations was tested with cross-tabs and ANOVA. Additionally, the validity of the Likert scales was checked with correlations and ANOVA with the established emocards.

RESULTS

The pretest showed that the subjects preferred an adaption of the lighting's color according to their mood. Even if the most favorite color in general and regarding clothes' color is blue, the majority preferred the conscious color choice via interfaces like an App on a CE device to the camera-based one. This trend was investigated further in a guided study with 70 subjects. Again the color blue proved to be the most favorite color (33.3%) followed by green (14.4%), red (12.6%), black (8.1%) and no preference at all (9.9%); other colors like white, orange, yellow, magenta, purple, cyan and grey were chosen as well, but played only a minor role in the sample. However, the most favorite clothes colors are decisively different with blue (21.4%), black (18.8%), no preference (17.0%), red (13.4%) and white (7.1%) compared to the pretest sample. Here the downwards order of preference changed, as colors like grey and brown are preferred as clothes colors, opposite to their general favorability, followed by orange, green, cyan, magenta and purple.

The test with emocards (Desmet et al., 2001) alongside Likert scales showed significant correlations for the scales of aversion-attraction (before=-.514, after =-.440), fear-hope (before=-.565, after =-.438) and boredom-joy (before=-.453, after =-.497) both before and after the test. As the scales are inverse, the correlations are negative. Attraction and hope show significant correlations to almost all emotional responses except for the mood asked before the test by emocard, this might be a result of the forward orientation of the item. The level of joy before the test also correlates intensively with other emotions, after the test joy is not only correlating with the emocard, but also strongly with the level of attraction (.813) and hope (.807).

Table 1. The frequency distribution of the EMOCARDs before (a) and after (b) experiencing the feature.

	excited neutral	excited pleasant	average pleasant	calm pleasant	calm neutral	calm unpleasant	average unpleasant	excited unpleasant
Before	5.7	11.4	57.1	10	10	0	5.7	0
After	14.3	22.9	45.7	10	1.4	1.4	1.4	2.9

Table 1 shows the results of the emocards before and after experiencing the adaptive lighting system, revealing a general feeling of average pleasantness. According to the Wilcoxon test the 2 samples of emotional responses before and after differ significantly from each other ($p = .023 < .05$). So the change in emotional feedback especially the rise of percentages of the "excited neutral" state and "excited pleasant" state, along with a decrease in negative responses from before the test to after, is significant.

Table 2. The frequency distribution of the different emotions elicited before (a) and after (b) experiencing the feature.

	negative emotional response	-3	-2	-1	0	1	2	3	positive emotional response
Before	aversion	2.9	0	2.9	7.1	17.1	38.8	31.4	attraction
After	aversion	5.7	5.7	4.3	11.4	35.7	15.7	21.4	attraction
Before	fear	2.9	1.4	1.4	14.3	34.3	24.3	21.4	hope
After	fear	5.7	2.9	5.7	12.9	25.7	27.1	20	hope
Before	boredom	2.9	0	2.9	14.3	30	35.7	14.3	joy
After	boredom	5.7	2.9	5.7	12.9	25.7	27.1	20	joy

The positive emotions of attraction, hope and joy have the highest scores. Whereas the level of attraction in the before-after analysis shows a small decrease, the level of hope indicates a small increase. Simultaneously, the rating of joy remained unchanged. The item attraction could be affected by the subjects' expectations being higher than the actual experience itself. As the Wilcoxon test proved a rather strong significance of p = .001 with the emotion aversion and its counterpart attraction, this change in opinion seems to be an important observation. Consequently the effects of expectations and the resulting implications upon the subjects' emotions should be investigated further.

Regarding the preferred steering possibility offered by the lighting, the preference was equally divided, 50% preferred the camera and 50% preferred the color blending by an iPad App. Figure 4 shows the results regarding the question if the chosen operation by camera or App would be worse or better than the common one i.e. a switch for lighting color changes. Figure 4 shows the frequency distribution of the sample along a 7 point Likert-scale, indicating a preference for the new approaches of operations of the interior lighting. As main reasons for this evaluation the individual choice and independence through an App was mentioned by 35.1% representing the half of the sample preferring the App. The other half favoring the cam-based system indicated the adaptive reaction without the intervention of the driver (17%) or the direct changing with automatic adjustment (16%) as cause for the choice.

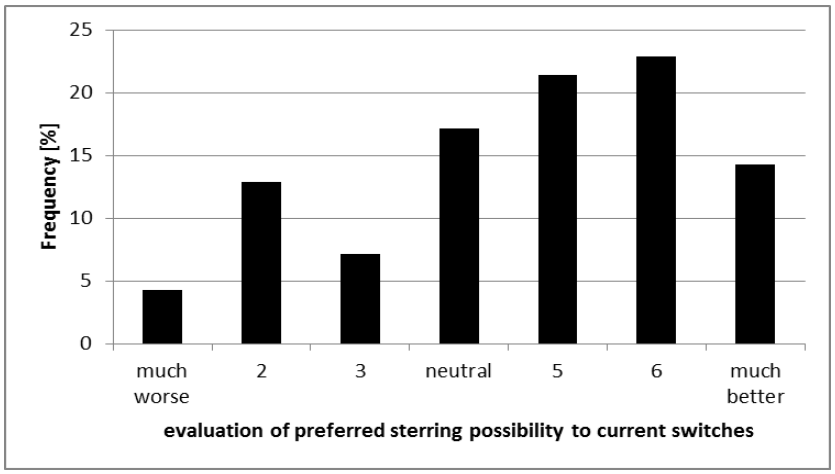

Figure 4. Comparing the new control of light with the current one. The question was is the new one worse or better on a 7-point Likert scale.

On the question whether the steering of the color should be changed further than App or CAM, the majority of subjects wished a combination of various steering possibilities of the lighting color within the automotive interior, e.g. integration of App in the car as hardware (18.6%), combination of cam and switch (13.3%), combination of cam and App (8.8%), combination of cam and iDrive (4.4%) , combination of cam/switch/music (0.9%) and combination of App and voice control (0.9%). But also new ideas like biometric recognition (15%), camera-based hues changing according to the driving mode (5.3%) and identification of the driver by the key (1.8%) were considered. Interestingly, the CE device applications also influence some subjects to come up with ideas like shooting a picture of today's clothes and sending it to the car (2.7%). Thus, most subjects are inclined to have functionalities beyond the camera-based system or App.

Given the fact that the sample can be equally divided in subjects preferring the camera-based lighting color adaption and those preferring a conscious choice and color blending with an App interface, the differences between those two clusters would be interesting. Therefore, a cross-tab analysis lead to the results summed up by Table 3.

Table 3. Comparison of characteristics between subjects preferring a camera-based adaption of the lighting or a CE-device App.

CAM

significances	Chi-Square	Cramer's V	ANOVA	Conclusion
App	.000	.887		those subjects choosing CAM inclined no preference for APP steering and vice versa
influence steering	.000	.605	.000	no preferences (meaning APP): manual influence of systems appreciated by subjects preference (CAM): automatic influence of systems appreciated by subjects
Additional steering posssibilities	.000	.789	.002	no preferences (meaning APP): combination of APP and switch, data input from external/ weather conditions, cominbation of APP and voice control, ID via key preference (CAM): combination of camera & switch, harmonic color choice controled and stored preferences within iDrive, combination of camera, switch and music choice, foto of clothes @ home + send to car--> welcome scenario, combinatio of cam & iDrive (for fine-tuning, memory)
Reason for steering choice	.000	.871	.000	no preferences (meaning APP): combination of cam & App, App with seldom change in color, individual choice & independent from other systems via App preference (CAM): adaption/adaptive reaction without intervening of driver, influence and individual choice via clothes color corresponding to s.o.'s mood

APP

significances	Chi-Spuare	Cramer's V	ANOVA	Conclusion
CAM	.000	.887		those subjects choosing CAM inclined no preference for APP steering and vice versa
Additional steering posssibilities	.000	.802	.009	no preferences (meaning CAM): CAM-based, combination of CAM and switch, harmonic color choice controled and stored preferences within iDrive, combination of camera, switch and music choice, foto of clothes @ home + send to car--> welcome scenario, combinatio of cam & iDrive (for fine-tuning, memory) preference (APP): APP, combination of APP & switch, data input from external/ weather conditions, cominbation of APP and voice control, ID via key
Reason for steering choice	.000	.837	.000	no preferences (meaning CAM): adaption/adaptive reaction without intervening of driver, funny gimmick with surprise effect, direct changing/ automatic adjustment preference (APP): combination of cam & App, App with seldom change in color, individual choice & independent from other systems via App

The camera favoring cluster discloses a strong relationship to the item questioning the level of influence of a human upon a machine or mechanism responsible for the color change (p = .000, Cramer's V = .605). The increase in automation is appreciated by this particular cluster as various combinations of camera-based lighting and additional functionalities e.g. combination of camera, switch and music choice etc. (p = .000, Cramer's V =.789). Consequently, also the reasons for favoring the camera as source for the color reflect the automation idea with no intervention of the driver or the inference to clothes representing the mood of its wearer. In contrast, the App cluster favors all App related combinations with additional steering possibilities (p = .000, Cramer's V = .802) and constitutes the conscious choice and independence from other systems as major reasons (p = .000, Cramer's V = .837).

The influence of expectations on the emotional arousal of the subjects was analyzed by clustering the answers of subjects regarding expected information input forms for the color adaption and potential data output forms. In Figure 5 the data input can be subdivided in environmental causes, human causes and automotive causes with a major emphasis on the first two (cf. Table 4), whereas the most subjects expect a change in the lighting in form of color and intensity or have no expectations at all.

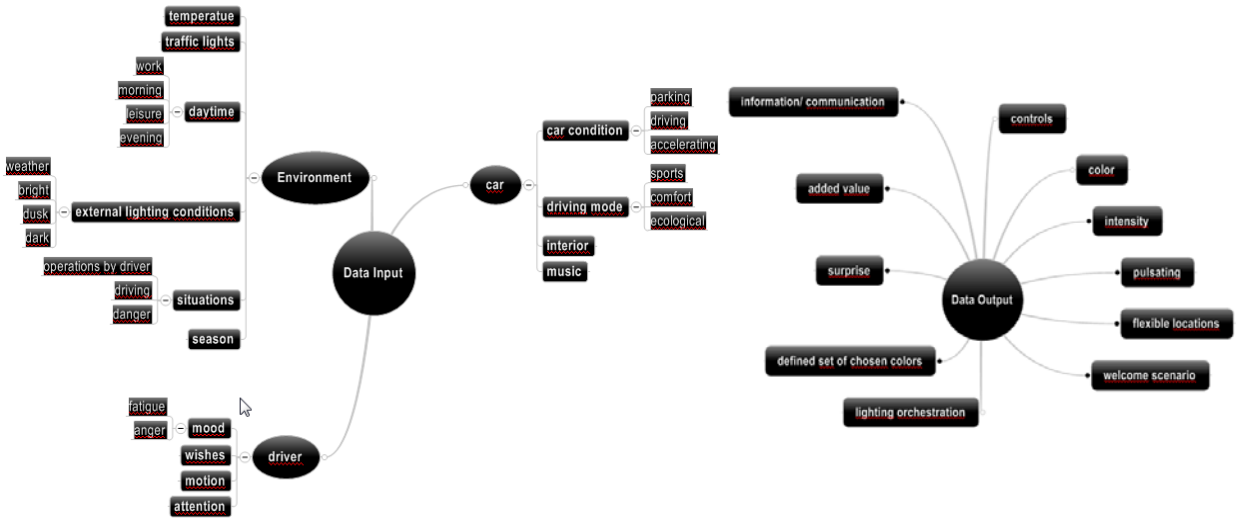

Figure 5. Clusters of expectations of adaptive lighting regarding various forms of information input and information output.

Table 4. Frequency distribution of expectations of data input and data output (downwards order).

data input	external lighting conditions (i.e. weather, bright, dusk, dark)	22.2%	data output	intensity	22.1%
	driver's mood e.g. anger	18.8%		color	21.1%
	driver's wishes	11.1%		no expectation	20.0%
	no expectation	7.7%		flexible locations	8.4%
	situation (i.e. driver operates, focuses on driving, dangerous situations)	6.8%		added value (wellbeing)	7.4%
	driving style/ car condition (i.e. acceleration, driving)	6.8%		defined set of chosen colors	6.3%
	driving mode (sports, comfort, eco)	5.1%		no need	5.3%
	music	3.4%		controls	3.2%
	driver's attention e.g. fatigue	3.4%		welcome-scenario	2.1%
	no need	3.4%		lighting orchestration	1.1%
	interior	2.6%		surprise	1.1%
	motion	2.6%		information/ communication	1.1%
	daytime (i.e. worktime, morning, leisure, evening)	2.6%		pulsating	1.1%
	season	1.7%			
	temperature	1.7%			

A cross-tab analysis showed a rather strong significant relationship between the expectations and the item "joy" ($p = .000$, Cramer's $V = .606$). Boredom representing the negative counterpart of enjoyment in this study was the emotion that the subjects felt regarding motion, situation, temperature and the driver's attention as data input. On the other hand, subjects with no expectation at all or expecting an adaptation following the daytime, external lighting conditions, the interior, season, the driver's wishes, music or the driving mode showed enjoyment of such an adaptive lighting concept. The emotional arousal of attraction and hope, questioned after the test, also proved to be significant in relation to various forms of data input (attraction: $p = .002$, Cramer's $V = .517$, hope: $p = .001$, Cramer's $V = .527$). The negative counterpart of attraction i.e. aversion tends to be felt by subjects expecting no need for such an adaptive lighting or the driving mode, external lighting conditions, seasonal changes or the daytime as optional data input sources. Subjects with a neutral emotional state have possible expectations as external lighting conditions or motion. Interestingly a change of the lighting according to the season evokes both aversion and attraction by the subjects. The driver's wishes, daytime and season are also not distinctive in relation to the subjects' emotions from fear to hope. Fear is implied by subjects expecting no need for having this system and having no expectation at all. Hopeful subjects tend to expect an adjustment according to the driver's attention, situation, temperature, interior, music, driving style or season. If the lighting adapts according to the driving mode, the driver's attention, the mood or the daytime, the same subjects valued the exterior design as an important car buying criterion ($p = .003$, Cramer's $V = .533$). Also the purchase argument of having a comfortable car ($p = .003$, Cramer's $V = .531$) is very important, especially when there are no prior expectations. Analogously, the data output indicating average strong significant relationships with the buying criteria roominess ($p = .000$, Cramer's $V = .595$) and interior design ($p = .004$, Cramer's $V = .508$) rated very important, again having no expectations is interfering with the subjects' evaluation of ideas of potential ways the lighting should change.

DISCUSSION AND CONCLUSION

Regarding the research question 'Do users prefer an automatic adjustment or a conscious choice by an App? What effect can be identified of the subject's expectations on their emotional arousal before and after the test?' it is clear that half of the study population prefers the App and half prefers the automatic adjustment. If color is connected to

the user experiencing emotional arousal, the study could verify a general feeling of average pleasantness as well as an increase in positive and decrease in negative emotional responses (emocards) compared with the pretest. The Likert scales offered a deeper insight in this general emotional feedback. Whereas the level of joy remained unchanged, there was a little increase in the level of hope and a little decrease in attraction after the feature presentation indicating that expectations could have a biasing effect on the emotional experience of the subjects.

This effect was investigated further by an analysis and clustering of the answers to the qualitative question concerning expectations of the word "adaptive lighting" prior to the feature presentation. According to the HMI model (cf. Fig. 3) the information input for the color adaption could be subdivided in environmental, human and automotive causes, whereas the information output is concentrated upon the function itself; in this case the general characteristics of RGB LEDs like changing color or intensity, but also flexible locations and even an added value like wellbeing were expected. The subjects expecting no need for any adaptive lighting, tended to show aversion and fear of the feature. Surprisingly, having no prior expectations of the systems proved to be a crucial reason for enjoyment as emotional response along with other expectations (adaption to daytime or external lighting conditions, adaption to the interior, season, the driver's wishes or music). But convenient input forms as motion, temperature, attention or the situation known from other features or systems were regarded as boring. The appreciation of either a steering of the lighting color by an App or a camera of 58.6% compared to 24.4% preferring the common steering by a switch, proved a general trend to new ways of interaction. The main difference is the location of decision making which is internalized in the user by the conscious color choice by an App and externalized by the camera.

In this study 50% preferred the App and 50% preferred the camera-based solution. Even if both steering possibilities offer advantages as the conscious choice and control over the color (App) to the automation of color changing without the intervention of the driver (camera), functionalities beyond these were pursued. As a result, users are searching for new and surprising interactions with a machine especially in terms of emotional features like lighting.

The general pursue of added value, expected by 7.4% of the subjects, is proven by relationships between characteristic App and camera reasons, as well as a strong tendency for color changes happening once (28.6%) or more frequent (57.2%). For those subjects expecting an added value at the same time valued roominess and interior design as very important. Even in the iPhone study the aesthetic (material, texture, color) and functional customization (charging, protection and antenna amplification) provided additional value.

Although the mock-up of the color changing system reached a high level of integration, the brand attribution was hindering associations to other brands and therefore limited the openness of the brainstorming part of the survey. The homogeneity of the sample (mostly engineers, male, aged 20 to 59) would need to be compared to actual buyers with an extraordinary need for customization to draw conclusions, especially a focus group of customers regarding the car as an expression of themselves and as an extension of office and living room, so-called Sensation Seeker (Winterhoff, 2009). Other direct measurement techniques for emotional feedback would be important to consider as well in future research like, Facereader (Benţa, K.-I. et al., 2009; Melder et al., 2007; van Kuilenburg 2005), EEG (Oude Bos, 2006) and heart rate by ECG measures (Appelhans & Luecken, 2006) in order to get data which is not filtered through perception, cognitive processes and interpretation of emotional illustrations and scales. To conclude neither automobile involvement nor consumer innovativeness were low in this study, the need for customization however was only average, indicating that the marketing scales show no relations to customization per se.

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Ergonomic Aspects of an Intelligent Building

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ABSTRACT

The issue of intelligent building is one of the most important design challenges in today's world. The main factors that influence the development of an intelligent building are cultural, civilization, technical and economical conditioning. The development of information technology and control engineering has allowed the construction of a building that responds to the needs of people in an automatic and flexible way. Full integration of electronic systems allows a building to be categorised as smart objects and attest to its quality. Human factors are considered in the context of intelligent building design that is to adapt to the requirements of users in order to improve the quality of life. The purpose of this article is to show the ergonomic aspects of an intelligent building taking into account factors affecting the peace of mind and well-being of people in two environments: work environment and housing environment (work environment and housing environment are the primary spaces where people spend a major part of their life). These are not only technical factors, but also elements associated with the arrangement of space. The article discusses factors which also determine the quality of an intelligent building. It examines the ergonomic aspects within the interdisciplinary context taking into account, above all, convenience, comfort and safety of users.

Keywords: Intelligent building, ergonomic aspects, housing environment, working environment

INTRODUCTION

Widespread access to consumer goods in the fifties and the sixties created demand for higher quality of life in affluent societies. On the other hand, the development of IT and automation has allowed to construct a building that responds to human needs in an automatic way at any given time. Since the beginning the idea behind developing an intelligent building has been to increase the comfort of use while reducing maintenance costs. Ergonomics, which explores the relationship between man and the elements of the environment, is developing in line with the direction set by technological progress and our civilization. This is of particular importance in an intelligent building. Human factors are considered in the context of intelligent building design that is to adapt to the requirements of users in order to improve the quality of life.

In this paper, ergonomic aspects of an intelligent building are explored against the backdrop of factors that affect mental comfort and well-being of people in two environments: work environment and housing environment. The aim of creating intelligent buildings is to create high-quality working environment but also in other aspect to create high-quality housing environment. It is worth pointing out that over the last twenty years intelligent buildings in most cases have developed into office buildings. In recent decades, with the development and popularization of information and communication technology, traditional ways of using space began to evolve. Nowadays, due to the ease of communication between people over the Internet, it is possible to work at home in many professions.

An intelligent building is equipped with control systems that control almost everything. Thus, the building becomes more comfortable and better equipped with modern appliances. Such building, by offering a higher quality of both

the physical environment and space, offers better conditions and better organization than conventional buildings, which in turn makes everyday life much easier. It is worth noting that all elements of a building that are controlled remotely offer great help for people with disabilities. What is more, intelligent building provides an opportunity to reduce maintenance costs while increasing user comfort.

THE DEFINITION OF INTELLIGENT BUILDING

There is no single universal definition of an intelligent building. According to the definitions adopted internationally an intelligent building is a building that adapts to the changing conditions of its environment (Krainer, 1996), and is equipped with systems that provide comfortable living conditions. An intelligent building is a building that knows what is happening inside it and outside it and can decide the most effective way to create the right environment for users on time (Atkin, 1988). At the beginning the name intelligent building was assigned to objects that provided control over primary installations. Over time, more complex element of intelligent buildings appeared, namely the control and monitoring centre that had control over the entire building (Winnicka-Jasłowska, 2005). An intelligent building, which has an artificial intelligence and thus is able to understand the surrounding situation and find appropriate and targeted response, can adjust to users' needs better than ordinary buildings and has the ability to adapt.

However, the overall concept of comfort and the idea of adaptation to the changing environmental conditions may not be sufficient. It is well known that people also differ as far as individual perception of comfort conditions is concerned, which is influenced by the cultural element. Therefore, in order to ensure comfort in a building based on artificial intelligence one has to make it more flexible and adapt it to the needs of individual users. A building must be able to easily adapt to anticipated needs.

Indeed, most of the existing definitions of IBs in the world state that an intelligent building is an apartment building or an office building where you can live safely, comfortably and efficiently (So and Chan, 1999). An intelligent building offers us above average safety. It constantly monitors the environment through electronic sensors and reacts in an intelligent way to any irregularities; it warns us of impending danger and triggers adequate procedures to minimize potential losses (Niezabitowska, 2005). This basically means that it automatically activates the alarm, notifies a fire department, unlocks the doors on escape routes, activates smoke venting, etc.

A very important issue in intelligent buildings technology is related to energy saving policies. Optimization procedures regarding energy consumption are not only justified in terms of reducing operating costs, but also because of the environmental benefits. In order to accomplish optimization procedures, an expert system containing rules that perform energy saving strategies is set up in the central computer (Sierra et al., 2004). However, it is necessary to verify if the rules defined in the energy saving expert system may eventually alter the comfort conditions established by the control strategy expert system.

A definition of an intelligent environment is presented in a book by Cook and Das (2007): an intelligent environment is ‘one that is able to acquire and apply knowledge about the environment admits inhabitants in order to improve their experience in that environment’. Cook et al. (2009) have also clarified an intelligent environment as ‘an electronic butler, which senses features of the users and their environment, then reasons about the accumulated data, and finally selects actions to take that will benefit the users in the environment’.

Buildings are technology, they accommodate technology, and they use technology. Buildings as objects become intelligent in the moment of gaining computer ability (Sherbini and Krawczyk, 2004).

Therefore criteria by which the building needs to have to be considered as intelligent are:

- Input system that receives information by means of information receiver.
- Processing and information analysis.
- Output system that reacts to the input in form of a response.
- Time consideration that makes the response happen within the needed time.
- Learning ability.

The definition of intelligent architecture should therefore include all of these criteria and systems. Moreover, an intelligent building is therefore a building that has the ability to respond (output) on time according to processed information that is measured and received from exterior and interior environments by multi-input information detectors and sources to achieve users’ needs and with the ability to learn (Sherbini and Krawczyk, 2004).

It is worth pointing out that intelligent architecture is a way of functional integration and developing sustainable combination of supporting material that assists in reducing environmental impact. The next step is an eco friendly or sustainable building together with its derivatives - green building, climatic-building or eco-building - which use alternative technical solutions (i.e. the use of geothermal energy, water basins, energy produced by solar panels or

windmills) in order to decrease or stop energy consumption. Hybrid systems - that utilize traditional heating systems that are backed up by alternative sources - are also frequently used.

FACTORS AFFECTING USER COMFORT

Elements that determine user comfort in intelligent buildings are multi-faceted. They consist of both the technical equipment as well as the interior design, interior equipment, quality of appliances and functional arrangement.

Building equipment systems

The diverse requirements in an intelligent building can be met by using modern building maintenance systems. These are:

- HVAC (heating, ventilation, air condition), that is heating and cooling as well as mechanical ventilation of the rooms,
- Lighting the rooms with daylighting systems, also by refracting sunbeams and artificial adaptation to the conditions of residence,
- Modifying the intensity of light in rooms through the use of automatically controlled shutters,
- Installations (e.g. water) with consumption adjustment.

Automatic systems are controlled by artificial intelligence techniques.
There are integrated systems that operate in a facility, such as computer network, telephone network, power grid.

Safety is provided by technical and electronic systems:

- Fire detection system - fire protection
- Intruder alarm
- Access control system
- Cable and satellite television system
- Intercom system
- Sound and notification system
- Video surveillance system
- Emergency lighting system
- BMS - Building management system

Efficient operation of all these systems is not possible without providing the building with electricity and without equipping it with automatic control systems. This system allows for continuous monitoring of environmental parameters and helps keep them at a set level. What is more, these systems allow the exclusion of certain installations in the building when they are not needed. The systems can turn off the lights when there is nobody in the room (savings up to 50%), turn off the heating when there is nobody in the room (savings up to 30%) or when the room is too hot (Niezabitowska, 2005). Automatic monitoring devices and computer programs allow for the analysis of operation of these devices in search for more economical solutions.
Automatic control system determines the quality of an intelligent building. The priority, however, is full system integration. An intelligent system has the ability to learn from the environment.
An intelligent system makes a contribution as far as optimization of buildings is concerned by transforming them into dynamic space with a high standard of comfort and user satisfaction. So the ergonomic aspect of intelligent buildings is of key importance in this respect.

It is worth pointing out that an intelligent installation is very universal; it is possible at any time to reprogram and adapt it to the individual needs of users. With the option of remote control it is possible to monitor the status of the alarm system, but also to manage other systems from outside.

The benefits of integrated systems are as follows:

- increasing comfort of the facility
- increasing safety of people and property
- facilitating management of the building (visualization)
- lowering operating costs
- lowering upgrading and expansion costs
- flexibility when changing the purpose of the building

Factors in housing environment

Buildings provide framework for human life. But people do not want to stay in a building only to feel safe. They have numerous needs and expectations regarding everyday life. This refers to, inter alia, activities such as sleeping, resting, eating and maintaining personal hygiene. These basic bodily functions require functional adaptation of spaces, specialized equipment and arrangement. It is here that the need for affiliation, recognition, self-realization - described by Maslow (2013) - is met. Intelligent technologies also affect the appearance of a place. It should be noted that with the advent of Internet technology, data can be sent to authorized users all over the world. They can perform the same monitoring and control functions at home and when they are thousands of miles from home.
All appliances can be controlled from a single panel thanks to the integration of all system components. Smart houses can also be controlled remotely: using a telephone, the Internet or even an iPad. We also expect intelligent buildings to make decisions regarding relevant changes of physical parameters, adapting them to our needs.
An intelligent system, based on readings from appropriate sensors that monitor in real time the conditions inside and outside the house, adjusts the temperature and humidity to a predetermined level. Turning on air quality control makes the windows open automatically as soon as the system detects contamination or smoke, caused for example by cooking. When the windows are opened, heating or air conditioning is of course shut off. This environmentally friendly feature minimizes energy consumption. Below we can analyze various rooms in a building as well as the equipment and arrangement that make life easier.

The kitchen is one of the most important rooms of an apartment or a house. Technological advances associated with the development of computerization in all areas of life created a new model of smart kitchen in an intelligent home. There are many factors that affect user comfort. The design of every kitchen should provide optimum comfort conditions for food preparation, and so the kitchen should be equipped with a set of technological appliances. The kitchen is for many people a kind of a laboratory where one creates recipes and then tests and improves them. Therefore, it is a place that combines many processes from different branches of science such as chemistry, biology, and sometimes even physics. The kitchen is a place where you can hold a conversation not only between family members at the table, but also using devices connected to a smartphone, for example. Systems used to connect home appliances to the Internet, allow to control and manage individual devices and program them, to remember settings, optimum parameters of microclimate etc. (Charytonowicz, 2012). Tactile steering panels are used to control the refrigerator from the distance, cookers etc, however some devices can be controlled by mobile phone (Dubrawski, 2009). Kitchen devices are able to inform the user about breakdown, need for supplies replenishment.
The tendency to equip the kitchen in an intelligent building in an environmentally friendly manner is very important. This applies to equipping the kitchen with appliances that can save energy and water. Dishwashers are connected with fast water heating systems and can use half of the load, whereas washing machines consume less energy and reduce water consumption by half. Advanced filtration systems ensure access to safe drinking water, and new methods of cooling in refrigerators allow storing products at the appropriate temperatures. In turn, water taps are able to control the flow of water. Modern appliances are smarter, faster, more elegant and more ecological. They are definitely more suited to the requirements of users and are often multipurpose. The entire kitchen technology can make everyday life easier. An intelligent kitchen - in addition to offering technical and ecological (and economic) improvements - must meet safety requirements. It is here that one has to deal with heat, hot dishes, gas and sharp knives. Safe kitchen is one in which users can easily use kitchen appliances without any dangerous situations that may cause an accident.
Modern kitchen is open and is usually connected to the living room. It may form a common multipurpose area or be partially combined with the living room through a hole in the wall. The openness of the kitchen makes the introduction of interesting, modern and well-designed solutions and appliances more exposed. On top of that the hosts will have visual contact with other people sitting in the living room area.

Another important room in the house is the bathroom. An ergonomic bathroom is a comfortable interior designed in an optimal way, providing easy access to sanitation. When designing this room one must provide security through

the use of appropriate materials. This applies mainly to the floor, which can form a slippery surface when it is wet. These guidelines apply to every bathroom in every house but the ease of use ought to be improved in an intelligent building. Intelligent fittings for kitchens and bathrooms are becoming more and more popular. Modern taps are equipped with the following features: automatic on and off switch, coloured light-signalling device, level of water consumption and filling the tub for bathing.
In our homes and apartments there are more and more appliances and devices that make it easier to perform daily duties. Intelligent systems can now also be used in the bathroom, which is why one can not only increase the functionality and usability of the space, but also save water and electricity. The bathroom is a place where you spend a lot of time and therefore it should be above all functional and comfortable, and preferably also economical. More and more innovative solutions that one can use apply to both the technical and the aesthetic area. The surface of tiling and sanitary fixtures is covered by special coatings that help keep them clean. While most of us are accustomed to white tubs and sinks, today we have wider range of colours and a wide variety of materials - stone (e.g. marble, granite), wood, steel, and even glass. More and more often they are also equipped with features such as massage, but also speakers and screens that we can connect to our smartphones or tablets, and by doing so listen to music in the shower, answer the phone or check email.
Faucets are ecological and aimed at reducing the amount of water consumed. We can choose from a contactless, electronically controlled taps that sense movement and automatically shut off water supply as soon as one withdraws his/her hand from the stream. There are also thermostatic taps that not only eliminate the risk of burning one's skin, but also reduce the amount of water going down during temperature regulation. Also, faucet aerators become more and more popular. Aerators create a non-splashing stream by delivering a mixture of water and air and reduce water consumption by up to 60 percent. One of eco novelties is a technology that allows to connect a water basin to a lavatory - so that the water that we use for washing is reused for flushing. Bathroom interior design is largely dependent on the size of the room. The interior can be equipped with basic accessories, but can also act as big bathing zones with relaxation areas.
The living room and the bedroom are one of the most important parts of a house. The equipment and arrangement of those rooms have a direct impact on the quality of our sleep or rest. The living room, however, can fulfil an additional function, as required by a modern way of life. If a house does not have a separate study or a work area, the living room can combine work-leisure function.
Nowadays, due to the ease of communication between people over the Internet, it is possible to work at home in many professions. The combination of these two aspects of life (private and professional) means that the boundaries between work and leisure area tend to fade away in apartment buildings, and public and private zones slowly lose their meaning. Users often seek "multifunctional zones". Within the concept of intelligent buildings their adaptability of functioning plays more important role.

Each building should meet the needs of people. It is well known that the most important human needs are met in housing environment. The quality of a house depends on many factors, namely a good functional layout, the possibility of creating an interesting arrangement, originality of solution, ecology and finishing. In addition, in each building the well-being of people is affected by, amongst others, appropriate air temperature, air quality, acoustic quality, optical quality, appropriate intensity of natural and artificial light. Studies show that people are not indifferent to the above issues. It is a process of interaction in the environment-human relationship, although one should remember that man also affects the environment.
All functional zones in a residential building must meet individual needs of users - provide the right temperature in the rooms, good lighting, the right kind of artificial lighting, and the right interior colours and make it easy to change the solutions.

Factors in work environment

The modern working environment is gradually developing towards a more 'intelligent' one, which means remarkable technological, architectural, psychosocial and medical innovations. Important parameters of the intelligent office building design have been sought out from among a large number of parameters of the intelligent building concepts (Himanem, 2003).
Ergonomics in the work place and the requirements concerning the quality of the work place result from the need to ensure good organization but also from an employee's performance. A person who spends long hours at work and puts a lot of intellectual effort into their work should be provided with the best possible conditions. Research has

shown that an employee's engagement is closely related to working conditions. In relation to office environment - apart from the requirements connected with the need of technical and functional quality - organizational needs play a key role as well.
The possibility of designing and building an 'intelligent' work environment using current technology is far more than just a glimpse of the future. Widespread research work has been put into making this enticing vision a reality. As a result, a wide variety of technological devices, solutions and scenarios for an intelligent work environment currently exist (Röcker, 2010). At present, however, merely parts of a complete, working, intelligent environment have been developed: for example, a smart LED-lighting solution has been developed that adapts to user contexts and preferences (Bhardwaj et al., 2010).
Intelligent work environment have to be ergonomic, ecologic, user friendly or adaptive to users' needs. Many workplaces offer comfortable office rooms that have useful devices to help increase work productivity. Designing a functional intelligent work environment requires a multi professional approach – not only architectural knowledge but also technical, medical and psychosocial insight. Users' needs must be taken into account when designing intelligent buildings (Clements-Croome, 2004).
An employee needs an individual, comfortable work environment that is well designed, well equipped with working tools and - depending on the type of work - completely or partially isolated from other areas. The place of work, for example an office building, should have a proper organizational quality that on the one hand facilitates communication, but also presents the possibility to concentrate. In a word, it should have functional qualities that will affect the creativity and productivity of an employee. An important element associated with an intelligent building is the peace of mind of a user. While the adjustment of space in an apartment building depends on the user herself or himself, it is more complex in the workplace. There is a need to create the right conditions for a number of people in different positions that require individual arrangements. It was stated that offices with various spatial arrangements affect the quality of work environment.

The sophisticated spatial solutions and the new ways of using space can influence the productivity of the workers and their spatial experience (comfort or discomfort) (Himanen, 2003). Functional connections with other rooms and areas of the building are very important in this respect. As in the domestic environment, it is important to set the right temperature, create the right microclimate, provide good lighting and use proper interior colours. One of the challenges is creating a comfortable computer terminal that is adjusted for a specific person, where the computer screen is positioned at a comfortable distance and at the proper height and glare is minimized. This is important especially for those who spend long hours in a constrained posture. Free zone in office spaces is also important for employees who - while crossing the zone - can not only change their position but also create new ideas.
Functional solutions in office spaces in intelligent buildings are very important. Office space can be divided into enclosed areas and open areas - the former include offices, conference rooms or archives, and the latter include spaces with no defined boundaries. The layout depends on the type of work and has a direct impact on the comfort of work. Each type has its advantages and disadvantages, nonetheless, each type is equally important in every office.
When designing an office one should bear in mind the essential role of team work which is important as far as the proper functioning and growth of any organization. Meetings and conferences are often organized in every office. In this context, the appropriate design becomes a necessity. This is where contemporary furniture systems that can be combined in any way come into play. What matters are flexible solutions allowing you to make quick changes. In modern offices many different functional areas are combined: work area, meeting room and lounge area. If there is enough space one might want to create an area with comfortable sofas where you can discuss interesting ideas. This system is an answer to the need of organizing short meetings or individual workplaces in a dedicated space. Thus, the concept of an intelligent building should take into account and combine the possibility to model space in a flexible and multi-functional way.
Large automated and well-furnished office spaces are to provide better physical comfort (quality of air conditioning equipment, lighting) to employees. The level of quality of the environment in an office depends primarily on the perceived air quality. A feature that makes it difficult to shape a proper comfort zone in an office is an individual, diversified reaction to air quality. This in turn calls for individualized control of environmental parameters in the workplace.
What matters most in office buildings is the quality of both the organizational and the physical environment. A building can further work processes or impede them causing a decrease in productivity. An intelligent building offers higher quality and better conditions than a traditional building. It must not be forgotten that one of the most important elements of the quality of a building is microclimate, which has a direct impact on our mood and health.

CATEGORIES OF QUALITY IN AN INTELLIGENT BUILDING

There are two general categories of quality in an intelligent building: the quality of the physical environment and the quality of space (Niezabitowski, 2005). Each of these categories contains elements of technical quality, functional quality, behavioural quality, organizational quality and economic quality. Building technology creates the quality of the physical environment in which an individual resides. The physical environment is shaped by the following elements: microclimate, lighting as well as the efficiency of IT and telecommunication network, automatic systems and other media. The quality of the physical environment is responsible for the physical comfort which to a large extent also translates into our peace of mind, whereas the quality of space mainly affects our psychological comfort.

The overall assessment of the quality of an intelligent building can be determined using methods and quality assessment tools for buildings. Buildings can then be classified into three groups A, B and C. One can also determine how the building fulfils user needs.

CONCLUSIONS

Ergonomic aspects of an intelligent building are multi-faceted solutions that facilitate the use of a given facility. These are elements that are used to equip a building with adequate facilities, fittings and interior design features and the right functional solutions. They not only influence the quality of an intelligent building but also user comfort. In both the housing and office environment they depend on users' individual needs. A modern intelligent building must be ecological, and therefore environmentally friendly and sustainable. There is a close relationship between man and his environment, which has a direct impact on his psyche, emotions, mood and health. As a result, human needs result from personality traits and physiology. The desire to stay at a certain place depends on our mood.
The aim of an intelligent building is to create a friendly, comfortable housing/work environment while striving to achieve considerable cost savings.
A key issue in the case of both the residential and office buildings is the flexibility of solutions and, therefore, adaptability and the ability to adapt to changing environmental conditions.

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Can Design Teachers Evaluate Students' Products from an End-User Point-of-View?

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ABSTRACT

The purpose of design education is to teach future designers to create products that fulfil the needs, wishes and expectations of the targeted users. Therefore, it seems reasonable that teachers in design education should have knowledge on how users experience products and apply this in the evaluation of design assignments. The question is whether 'teachers are able to estimate the user experience?'. To answer this question the correlation between the assessment of products done by users and by teachers is analysed, by assessing 76 products designed by students. The teachers assessment correlated strongly to the assessment done by a jury of end users, ($\rho = 0.743$, $\alpha < 0.000$), if the products designed for general target groups (i.e. adults between 18 and 65 years of age without special disabilities or very specific problems and needs). However, no correlation was found between the assessment of teachers and a jury of end users of products designed for people with disabilities or very specific problems and needs (such as bed bound hospitalized children).

Keywords: Design Assessment, User Experience, User Involvement, Design Education

INTRODUCTION

In design education design students are trained to create products that fulfil the needs, wishes and expectations of the targeted end-users. During the education program students are coached and assessed mainly by teachers[1], sometimes assisted by designers and specialists from companies who are cooperating in the student design projects. It is important that the persons who train designer students have a clear understanding of the needs, wishes and expectations of the target groups and of methods to discover those in order to be able to teach students how to focus

[1] In Belgium, where this study was conducted, the Art Academies are no Universities yet (but will be integrated into the universities in 2015), so the teachers are not (yet) professors.

on end-users in their design work. A part of such education concerns the evaluation of products and services, designed by students, with the end-user in mind. In order to do so teachers in design education should be able to understand users and to estimate how users experience products. Evaluation in education is widely studied, resulting in handbooks (e.g. Eger, 2010; Daams 2011; Dirken, 2006) and guidelines on the topic (for example Tuning EU, 2013). However, little is known about whether teachers evaluate products and services the same way as end-user do. A lot of research about evaluation in art and design is done, but it is mainly of a general nature. It describes whether evaluations are summative or formative, (Danvers, 2012) or it indicates that assessment should focus on the student, process and product (Harpe et al., 2009). Design assessment is even described as an artful practice that might be linked to a form of connoisseurship (Orr, 2010).

The goal of this study was to explore the relationship between assessments of design students' products carried out by teachers on the one hand and by end-users on the other hand. The hypothesis in this research was: 'teachers are capable of understanding the end-users, resulting in a positive correlation between the assessments of teachers and the assessments of end-users'. The purpose of design education is to educate designers who can design products which fulfil the needs, wishes and expectations of users. It can be assumed that user experience of a product is important to design education, and as a consequence user experience is supposed to be important in the assessment of products designed by students. Which means teachers should be able to understand users and to estimate how users experience products.

In this study the assessment of 76 student products executed by teachers and a jury of users was analyzed. The 76 products are divided into a group of products designed for general target groups (i.e. adults between 18 and 65 years of age without special disabilities or very specific problems and needs) and a group of products designed for people with disabilities or very specific problems and needs.

Although the hypothesis of this research is 'teachers are capable of understanding the end-users', it can also be assumed that designers and users do not share the same vision on products, especially when it comes to innovation. The long time between the introduction of innovative products and the acceptation of this product by the main potential users suggests that designers see products different than common people do. The time between introduction and acceptation can vary between several years to several decades, or even centuries (Rogers, 1995). For that reason, in addition to the research described above, a cognitive mapping was done with design teachers about the way users and designers look at products and assess them. The mapping can also reveal the design teachers view of users.

METHODS

Data Set

In this research 76 products designed by students are studied. The products were designed by 54 students of the 'Product Design Education' program of the Media Art & Design-faculty (of the Limburg Catholic University College in Genk, Belgium). Some students made more than one product (see Table 1). The products were designed by students who were in either the second or third bachelor year (age of the students at the time of study is typically 18- 23 years) or in one of the master years (age at the time of study is typically 21- 26 years). Most products were made by bachelor students (90%) as shown in Table 2.

Table 1: Number of cases per designer

	Number	% products
Students who designed one product	36	47
Students who designed two products	15	20
Students who designed three products	2	3
Students who designed four products	1	1

Table 2: Case specifications: gender, study level, number of cases per designer

Students' gender	
Male	51 (67%)
Female	25 (33%)
Students' Level of education	
1st bachelor year	0
2nd bachelor year	39 (51%)
3rd bachelor year	30 (39%)
1st master year	2 (3%)
2nd master year	5 (7%)

Depending on the assignment, each of the students had to create a working prototype of a product or a concept in form of a mock-up or non-working prototype. In addition, the students had to show how their product worked by a presentation (either in PowerPoint or Prezi). In Figure 1 an example of a concept and a working prototype is shown. Most of the products (56/76) are designed for a more general target group, for adults between 18 and 65 years of age without specific disabilities or very specific problems and needs and for a specific activity (for example photography). Twenty products in this study are products designed for people with specific disabilities or very specific problems and needs (for example a washbasin for hairdressers working with elderly) (see Table 3).

Table 3: type of assignment assignments, subgroup and expected end result

Type of assignment	end result	number of cases
Products designed for general target group without specific disabilities or very specific problems and needs		
Bachelor assignment		
Bicycle aid for teaching children to ride a bike	working prototype	17
Camera support for making pictures at 2.5 m height	concept model	10
Sitting element	concept model	3
Hand tool re-design	working prototype	4
The ultimate mobile means of communication for blind people	concept model	1
Free assignment bachelor graduation	working prototype	16
Interface redesign	concept model	5
Products designed for general target group without specific disabilities or very specific problems and needs		
Bachelor assignment		
Product for daily life for disabled people	concept model	2
mobile toy cabinet for bed bound hospitalized children	concept model	5
Washbasin for nursing home hairdressers	working prototype	6
Master assignments		
Free assignment; master graduation	working prototype	5
Designers Against aids	working prototype	2

Figure 1: left: an example of a concept of a new Hairdryer; right: an example of a prototype of a dog support for people in wheelchairs

Study Design

Product assessment

Both design teachers and a jury of end-users, who were part of the target groups the students designed their products for, assessed the products. This assessment was done after the presentation of the product by the student. In order to ensure that the teachers and the users assessed the same characteristics of the designed products, both groups were asked to pay special attention to: 1) the functionality (i.e. ease of use, adjustability to the user, fulfillment of the users' needs and wishes), 2) the design, (shape color, texture), and 3) the perceived maintenance of the products. A jury of teachers (3-5 teachers) and a jury of end users (3-10 members) anonymously and individually rated the products by giving a score between 1 and 20 (1=low; 20=high). The jury of users who performed the assessments were not involved in the design process. The teachers were specifically asked only to assess the product, not the design process.

Statistical Analyses

The data were analyzed statistically, by means of Bivariate Correlations ($\alpha < 0.05$). First the whole group was analyzed and afterwards the two subgroups separately.

Cognitive mapping

In order to further understand the similarities and differences between the assessments of teachers and users and to understand the possible differences in the vision on products of designers and users, a cognitive mapping (Martin, 2012) was performed in a workshop at the 18th International Design Educational Meeting (IDEM), 2012. Ten design teachers, from different countries in Europe, South America and the Middle East, participated in this workshop. Two questions were addressed in the mapping: 'Do designers assess products in the same way as users? Why or why not?' The results of the cognitive mapping were summarized in the workshop and approved by the participants.

RESULTS

Comparison of the assessments of design teachers and end-users

The scores for the students' products given by teachers varied between 5 and 17 (scale 1-20), the average score was 11.96 (SD = 2.705). The scores given by the jury of end-users varied between 5 and 18, with an average score of 13.28 (SD = 2.789). Figure 2 shows the individual scores for each designed product.

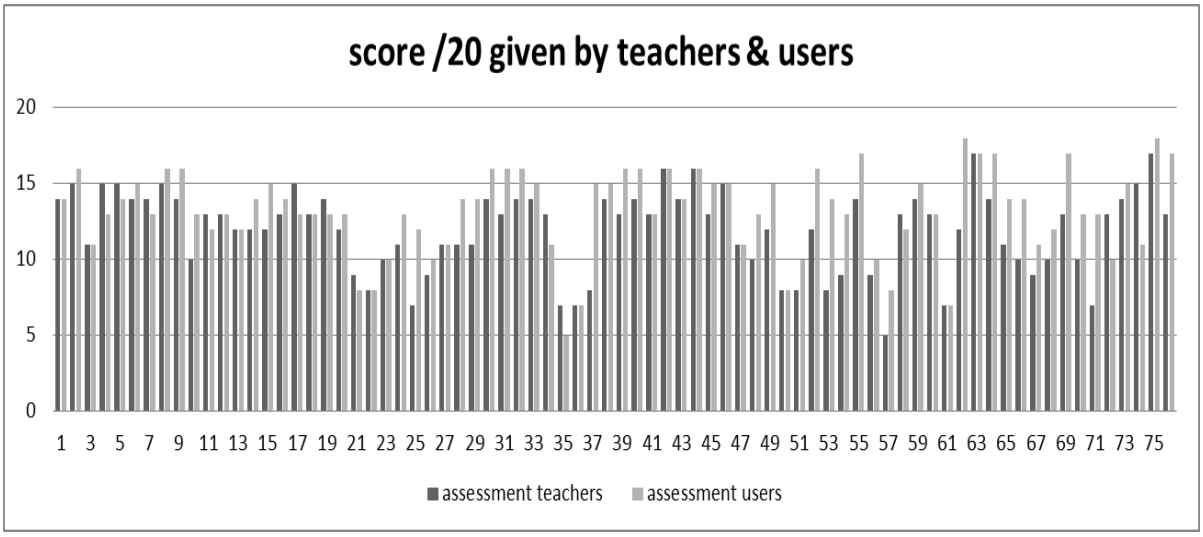

Figure 2: assessment of the products by design teachers and users

The results of the analysis of the scores for all students' products together showed a strong positive correlation between the assessments of design teachers and of end-users ($\rho = 0.694$, $\alpha < 0.000$; see Table 4). Analyses that were performed separately for each of the two subgroups of end-users (i.e. healthy adults and people with disabilities or very specific problems and needs) show different results. No correlation between teachers' scores and users' scores was found for products that were designed for people with disabilities or very specific problems and needs ($\rho = 0.470$, $\alpha = 0.066$). For products that were designed for adults without a disabilities or very specific problems and needs, a strong correlation was again found ($\rho = 0.743$, $\alpha < 0.000$).

Table 4: correlations between the assessment of users and teachers

	number of cases	α	ρ
All Cases	76	< 0.000	0.694
Design for people with a disability	20	0.066	0.470
Design for people without specific disability	56	< 0.000	0.743

Designer teachers' vision

The results of the cognitive mapping were summarized in the cognitive mapping session workshop and approved by the participants. The main point of view of the designers teachers was: that the difference between designers and users is that users want products that are functional, user friendly, beautiful and familiar to them. New products need to have a relationship to products they already know. All these things are also important to designers, but designers see innovation important as well, much more then (most) users do. Designers (and design teachers) value form, function as well as innovation, while users value mainly form and function, innovation is less important to them. They (users) don't want things that differ much from the products they are used to. Most people don't want modern design or the latest new technologies. They prefer familiar products and products that resemble what they already know. Another conclusion of this workshop was: designing is also about communication. Users don't speak the designers' language, or rather designers don't speak the users' language. Designers don't understand the users (completely). Because of their different approach towards products, designers find different aspects of the product important than the users do. It is difficult to estimate the user experience, especially for young beginning designers. It is only by experience and a lot of user involvement that designers are able to understand the user experience. Young designers often neglect this importance. Design education has the responsibility to increase the awareness of the design students and of the importance of user involvement in design.

DISCUSSION

The goal of this study was to explore the relationships between the assessment of products by teachers and by end-users. The hypothesis this research was: there is a significant positive correlation between the assessments of teachers and of end-users.

Correlations between teacher assessment and user assessment of products

Although strong correlations, between the assessment done by teachers and the jury of end-users, were found in the analysis of total group of the students' products, it is premature to conclude that teachers are always able to estimate the users experience. When products designed for the more general target group (healthy adults between 18 and 65 years of age, without special disabilities or very specific problems and needs) and products designed for people with disabilities or very specific problems and needs analyzed separately, different results were found. For products designed for the more general target group a positive correlation between the assessments by users and by teachers the strong correlation still stands. Apparently, for this subgroup teachers were able to estimate how users would experience the product. This was to be expected since user experience is an important focus of the education and the faculty and teachers pay a lot of attention to user experience, as mentioned in the introduction. This becomes clear in the many user-oriented courses in the curriculum of Product Design (such as ergonomics, psychology, emotional

design, experience design, etc…, MAD-faculty, 2013). Moreover, user assessment of products designed by students are organized regularly during the curriculum (in several projects each academy year), enabling the teachers to keep their user knowledge up-to-date.

For products that were designed for people with a disability however, no correlations were found between the assessment of teachers and the jury of end users. A possible explanation for this is that it is simply impossible for a teacher to have in-depth knowledge of the needs of the large variety of specific users their students design for. The lack of correlation between the product assessments of the teachers and of the users emphasizes the importance of involving users in the assessment of products in design education. The goal of design education, as mentioned in the introduction, is to train designers that can create products that fulfil the needs, wishes and expectations of the targeted end-users. Because teachers are unable to fully understand all users it is necessary for student to be confronted with the users assessment of their products. It will make the designer students aware of the designers' limited insight into users and the importance of user involvement in the design process. This is in line with the conclusion of the cognitive mapping with the design teachers were they emphasized the limited understanding of users of young designers and the importance for young designers to be aware of the importance and value of user involvement.

Differences in vision on products of designers teachers users

The cognitive mapping showed that one of the difficulties in designing is communication (in broader sense). Designers don't speak the users language (Kok et al, 2014). Daams (2012) and Dirken (2006) also stated that one of the problems in design is the mismatch between the product image of designers' and users (the product image communicate different to designers than to users). The difference in the designers and users "language" results in products that may be logic and intuitive from the designers' point of view, but not for users. Other researches also showed that designers and users interpret products differently. Van Kuijk (2009) concluded in his research about pre-use and post-use evaluations of electronic consumer products that there is a gap between expected and experienced usability, apparently users don't interpret products the way designers do. Den Ouden (2006) concluded the same in her research: customers have certain expectations of the usability of products they buy. However, once customers use those products, many are not as user friendly as they appear. Products sometimes are so hard to use that consumers need assistance to use them, or even return or abandon the product.

Limits of this research

This study was conducted in a design academy, the products that were assessed here concerned prototypes and concepts and as such often did not focus on secondary use like placing a buggy in the trunk of a car or replacing a battery. Therefore generalization of the findings in this paper should be done with care. It would be interesting to do a similar study on products that are already on the market, to see whether these correlations are still valid. This study was conducted in only one academy, to generalize the correlation between teacher an user assessment more research in other design schools and academies should be conducted, but this study does show the correlation for this specific situation, which is an indication that teacher and user assessment have similarities. Also, in the cognitive mapping in another gremium the relationship was affirmed.

The research itself has also some limitations. The assessments are done individually and anonymously on paper, but it is still possible that the users and teachers are influenced by each other because the products are presented to the users and the teachers at the same time in the same room and they were allowed to ask questions. The juries of end-users were rather small (3-10), especially for the group of products for people with disabilities or very specific problems and needs, nevertheless it gives an indication about how users would assess these products. To draw more general conclusions complementary research with al larger group of end-users should be conducted.

Although the cognitive mapping was done in an international group of designer teachers. Generalizing the designer teachers' vision, about the differences of assessing products between users and designers (teachers), the formulated in the mapping should be done carefully, because the mapping was done in a small group of ten designer teachers. A cognitive mapping with a larger group of designers would be interesting to see whether this vision on the differences in the way people and designers look at products still lasts.

CONCLUSIONS

The results show that teachers seem to understand how users (adults between 18 and 65 years of age, without special disabilities or very specific problems and needs) evaluate products. Significant correlations were found between users' evaluations and teachers' evaluations. In the assessment of products for people with disabilities or very specific problems and needs no significant correlation was found between the assessments of users and the assessments of teachers. This may be caused by the fact that it is more difficult for teachers to estimate the user experience for such specific target groups. From this study, we conclude that user involvement in product assessment during design education is important, especially in the assessment of product for people with disabilities or very specific problems and needs.

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Cerebellar Diseases and Occupation

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ABSTRACT

Cerebellar degenerative disorders are neurological diseases that may result in functional difficulties affecting autonomy and employability. Besides being a personal problem, cerebellar diseases are also a social issue in terms of costs incurred by the national health system and in the employment sphere. The aims of our study were to characterize and analyze the most important individual and organizational variables in a sample of working and non-working subjects affected by cerebellar ataxia. For the purposes of our research, we prepared two sets of tests, one for workers and one for non-workers. Both versions contain a socio-demographic, organizational and clinical diagnostic section and the Resilience Scale for Adults. The version for workers is composed of the Work Ability Index and the Health Service Executive Management Standards Indicator Tool. The version for non-workers consists instead of the Search for Work Self-Efficacy Scale. We have enrolled 45 patients (spinocerebellar ataxia, Friedreich's ataxia and sporadic adult-onset cerebellar ataxia). Ataxic subjects display moderate levels of work ability. Workplace accessibility remains a critical issue that must addressed through targeted rehabilitation as well as ergonomic and training interventions. Such interventions are likely to be effective because ataxic workers positively perceive their abilities, strengths, planning and control capacity.

Keywords: Cerebellar ataxia, workers, musculoskeletal disorders, job placement

INTRODUCTION

As neurological disorders become increasingly widespread at the beginning of the third millennium, the burden of such disorders on public health is likely to become a growing problem. WHO has predicted that the contribution of global Disability Adjusted Life Years made by neurological disorders will increase from 92 million in 2005 to 103 million in 2030.

Cerebellar degenerative disorders are neurological diseases that may result in functional difficulties involving upper and lower limb movements (Serrao, 2012, Schöls 2004, Wilson 2007, Fogel 2007) and affecting autonomy and employability (Serrao, 2012). Furthermore, the diagnosis of cerebellar ataxia is likely to represent a stressful experience, known as a crisis (Roberts 2005), which may greatly perturb psycho-physical homeostasis. This crisis is an acute disruption of psychological homeostasis in which one's usual coping mechanisms fail, leading to distress and functional impairment. The subjective reaction to a stressful life experience compromises the individual's

stability and ability to cope. Moreover, receiving a diagnosis of cerebellar ataxia forces individuals to confront their own vulnerability, to face physically and psychologically demanding treatments, undergo social disruption and, often, interrupt their habitual routines and long-term plans.
Besides being a personal problem, cerebellar diseases are also a social issue, given their high incidence, in terms of costs incurred by the national health system and in the employment sphere. This is also due to the fact that cerebellar dysfunction affects people of working age. Moreover, the individual's social context also gradually changes as the symptoms of the disease worsen. Indeed, other people's attitude and behavior towards the disabled person changes significantly, particularly in the workplace where there are often three forms of prejudice (Scarpat, 1983): i) discrimination due to ignorance resulting from insufficient information on the real costs of employing a disabled person; ii) statistical discrimination due to the conviction that the disabled are less productive; iii) discrimination by prejudice. The presence of these prejudices prevents work from playing a major role in the life of ataxic subjects.

The aims of our study were to characterize and analyze the most important individual and organizational variables in a sample of working and non-working subjects affected by cerebellar ataxia in order to identify those areas that are perceived as most critical and the strategies required to enhance patients' job placement, autonomy and wellness.

METHODS

Instruments

For the purposes of our research, we prepared two sets of tests, one for workers and one for non-workers. Both versions contain a socio-demographic, organizational and clinical diagnostic section and the Resilience Scale for Adults (RSA) questionnaire (Friborg et al, 2003).

The RSA consists of 33 items and was developed to measure intrapersonal and interpersonal protective resources that may facilitate adaptation and tolerance to stress and adverse negative life events (Friborg, et al., 2006). It comprises six factors: personal strength, which is subdivided in positive perception of self and positive perception of the future; social competence; structured style; family cohesion; social resources. This tool, which was translated into Italian, was used in a recent study conducted on amyotrophic lateral sclerosis patients (Pagnini, et al., 2011) (score: 33-77 high resilience, 78-121 moderate resilience, 22–165 low resilience). These scores are obtained by summing the scores attributed to the six factors, each of which has specific ranges. As the Italian version of this tool refers to healthy subjects, the results should be interpreted with caution.

The version for workers is composed of the Work Ability Index (WAI) (Tuomi et al, 1998) and the Health Service Executive (HSE) Management Standards Indicator Tool (Cousins, et al., 2004). The WAI was validated in Italy (Costa, 2003; Costa, Goedhard, Ilmarinen, 2005) and consists of seven dimensions: current work ability as opposed to lifetime best; work ability in relation to the demands of the job; number of current diseases diagnosed by a physician; estimated work impairment due to disease; sick leave during the past year (12 months); own prognosis of work ability two years from now; mental resources (score: 7-27 poor, 28-36 moderate, 37-43 good, 44-49 excellent). In this study, we adopted the short version of the questionnaire (Nübling et al., 2004), which was previously used in the Nurses Early Exit Study (NEXT) (Camerino, et al., 2006). This version differs from the original one insofar as item number three contains 14 medical conditions instead of 51. The shorter version is more readily completed and appears to have a better "face validity" (Nübling et al., 2004; Radkiewicz, et al., 2005). The Italian version of the HSE Management Standards Indicator Tool (Rondinone et al., 2012) consists of 35 items and two alternative response formats: a frequency format (1=never, 5=always) and an agree format (1=strongly disagree, 5=strongly agree). The seven risk factors are: demands referring to issues such as workload and work patterns, control, managerial support, peer support, relationships, role and change (Cousins et al., 2004; Rondinone et al.,2012; Marinaccio et al., 2013). As part of the stress risk assessment performed in Italy, the questionnaire results are compared with the percentile of a reference population of more than 6,000 subjects. The percentile score allows the groups to be placed in categories based on their own mean scores. The percentiles correspond to classes of risk perceptions for the 7 factors: "high" (the score is below the 20th percentile); "average high" (the score is below the 50th percentile but at or above the 20th); "average low" (the score is above the 50th percentile but below the 80th); "low" (the score is at or above the 80th). This tool, designed for the assessment of work-related stress risk within the organization in a sample of healthy subjects, was selected for this study as a tool for the evaluation of the subjective perception of ataxic workers within their work environment. Consequently, as our observations do not obviously yield an objective image of the organization, the results should be interpreted with caution (Cousins, 2004).

The version for non-workers consists instead of the Search for Work Self-Efficacy Scale (SWSES). This tool, which is composed of 12 items, assesses people's perceptions of their own ability to select job offers, to build strategies for the attainment of a goal, to respect other people's competences, and to work with new members, to manage time restrictions and stressful situations that are typical of job searches, and to consider a failure a challenge rather than a problem. It is based on four dimensions: frustration coping, enterprising exploration, proactive career planning and relational integration (Pepe, et al., 2010).

Participants

To date, we have enrolled 45 patients from two centers for the study of cerebellar ataxia in central-southern Italy, comprising 22 workers and 23 non-workers, aged between 18 and 60 years of age (mean (m) 42.3, standard deviation (SD) 11.1).

Men account for 59.5% of the patients (age m 43.5 years, SD 10.5; 38.6% with an age range between 41 and 50 years; 29.5% with an age range between 51 and 60 years) and women for 40.1% (age m 44 years, SD 11.6, 37.5% with an age range between 41 and 50 years, and 37.5% with an age range between 51 and 60 years).
The patients interviewed were predominantly married or cohabiting (48.9%) and all had a high school diploma (47.7%).

20 patients were diagnosed with autosomal dominant ataxia (spinocerebellar ataxia, SCA1 or 2), 15 patients with recessive ataxia (Friedreich's ataxia, FRDA) and 10 with sporadic adult-onset cerebellar ataxia (SAOA). As patients with both SCA, FRDA and SAOA may present an impairment of other systems than the cerebellar one, we included only patients with a clinically "pure" form of ataxia. Thus, we excluded patients with major involvement of neurological systems other than the cerebellar one (extrapyramidal, pyramidal, peripheral nerve or muscle). The severity of ataxia was rated using the International Cooperative Ataxia Rating Scale (ICARS) (Trouillas, et al., 1997). All subjects gave informed consent prior to taking part in the study, which complied with the Helsinki Declaration and had local ethics committee approval.

RESULTS

About 40% of the respondents had received a diagnosis of ataxia by 2000, 55% between 2001 and 2011, and the remaining 5% over the past two years; 55.6% of the subjects have no other medical conditions, while 18% have at least one other disorder not related to neurological diseases.

The number of workers with a permanent job is 51.2%. 21% have worked for between 1 and 5 years, 31.6% for between 6 and 15 years, 23.7% for between 16 and 25 years and the remaining 23.7 % for more than 25 years. The most frequent areas of employment are public administration (18.8%) and the services (18.8%) and industry (12.5%) sectors, with white-collar workers prevailing (50%) over blue-collar workers (31.3%).

Injuries were sustained by 15.8% of the workers or non-workers (who had worked previously) in the course of their professional careers. The most commonly reported traumas were due to falls (66.7%) and sprains (16.7%).
As regards the ergonomic aspects, the majority of the subjects claimed that no adjustments had been made after the onset of symptoms to either their work tasks (63.3%) or to their workstations (66.7%).

The majority of subjects who did not report any invalidating symptoms when they were interviewed had no difficulty in accessing their workstations (73.9%) or work environment (63.2%).

By contrast, workers with disabling symptoms complained of the absence of elevators (15.8%) and of toilets for people with disabilities (5.3%), of an excessive distance from the workstation (13%), of an unstable floor (4.3%) and of shelves that were difficult to reach (5.3%).

Consent was given by 72.7% of the workers for the INAIL research group to contact their work organization so as to be able to re-design their workstations.

RSA

The RSA results revealed a high, moderate and low level of resilience in 40%, 57.8% and 20.2% of the subjects, respectively.

The overall mean score was 57.8 (SD 15.7), whereas the scores for workers and non-workers were 75.1 (SD 14.5) and 81.8 (SD 16.39), respectively.
The *Personal strength* factor showed that the level of resilience in *Positive perception of self* in the overall sample is moderate, though workers were found to have higher self-esteem (m 13.9, SD 3.6) than non-workers (m 15.5, SD 3.7).

The overall mean score in *Positive perception of the future* was 12 (SD 3.8), which indicates a moderate level of resilience.

The *Social competence* factor revealed high levels of resilience among the subjects (m 12.3, SD 5.0).

In the *Structured style* factor, subjects were found to have a moderate level of resilience (m 10, SD 3.07) (m 9.2, SD 2.3 for workers and m 10.7, SD 3.5 for non-workers).

Findings also indicated a high level of resilience for *Family cohesion* (m 16.64, SD 3.5) (m 16.5, SD 3.8 for workers and m 16.7, SD 3.4 for non-workers).

Lastly, the *Social resources* factor revealed an overall high level of resilience (m 12.7, SD 5.6), (m 12.3, SD 6.1 for workers and m 13.1, SD 6.1 for non-workers).

WAI

In ataxic workers, the score was "excellent" in 18.2% of the subjects, good in 54.5%, moderate in 18.2% and poor in the remaining 9.1%. The overall mean WAI was 38.4 (SD 5.4), with a range of between 27 and 45. Work was reported to be challenging from a psychological point of view by 41.2% of the workers. The perception of the ability to work in relation to the physical demands of the job for subjects between 31 and 40 years of age was good for 23.5% and moderate for 23.5%. The health status was found to allow 52.9% of the workers to carry out their work despite the symptoms. This finding is supported by the fact that only 58.8% of the respondents had taken between 10 and 24 days of sick leave in the previous 12 months.

HSE Management Standards Indicator Tool

The results yielded a score of m 3.85 for workload, m 4.05 for control, m 3.78 for managerial support, m 4.22 for peer support, m 3.81 for relationships, m 4.66 for role and m 3.71 for change. The fact that all the mean values are above 2.5 (mean of the 5-point scale) indicates that the perception of risk is low. When the data were transformed into percentiles, all the dimensions were placed in the average low risk range with the exception of the relationships dimension, which was placed in the average high risk.

SWSES

We are waiting for implementing the sample size of non-worker subjects because only the 40% of them under fifty years is searching for a job.

CONCLUSIONS

A high percentage of ataxic subjects display, despite reporting difficulties related to the symptoms of their disorder, moderate levels of work ability. However, workplace accessibility remains a critical issue that must addressed through targeted rehabilitation of ataxic subjects as well as ergonomic and training interventions. Such interventions are likely to be effective because ataxic workers positively perceive their current abilities, strengths, planning and

control capacity, and ability to achieve their goals in the future. Moreover, they would allow ataxic workers to perceive any tension in relationships within their organizations to a lesser extent. The aim of the Italian Worker's Compensation Authority is to promote campaigns aimed : i) at improving the quality of work activity of neurological patients, particularly of ataxic workers, and ii) at helping non-workers find employment and go back to work. These aims will also be achieved by creating a dedicated job accommodation network designed to provide neurological subjects and employers with the best suggestions for interventions on the basis of the characteristics of their pathologies.

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Comparative Study of Noise and Thermal Load Levels by General and Individual Sampling

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ABSTRACT

This paper is a comparative study of the levels of two environmental parameters in a job, heat and noise, analyzed from two different perspectives, the general and the particular. The study was conducted in a university dining for analysis considering two individuals that work in the field of cooking. The objective of the study is to evaluate the two environmental factors in this sector, noise and thermal load, and determine the variations between the levels of both aggressors measured in the general work environment, and levels that are perceived directly by the operator. To carry out the experience the instrumentation used for measurement of general environmental conditions were hygrometer, anemometer and sound level meter; and the instrumentation for measuring individual parameters were noise dosimeter, heart rate monitor and calorimeter consumption. Recorded data were analyzed and the values obtained from sampling equipment of the general environment and the personal sampling devices were compared. The comparison of the results obtained revealed that in a work environment as the analyzed, where operators have a continuous movement between different jobs, the use of individual measuring instruments are more accurate than measuring equipment of the general environment to set the exposure to dangerous levels of heat load and noise.

Keywords: Noise, Thermal Load, University Dining, Measuring Instruments

INTRODUCTION

All job in which develop productive tasks, must have working conditions that safeguard the psychophysical health of workers and the task to perform without undue fatigue. The operator that is in a pleasant atmosphere, under hygienic conditions, without experiencing heat or cold and with the least possible noise, considerably reduces fatigue, concentrate on his work, is done better and avoid accidents. The poor working conditions are among the

The University dining in the Faculty of Engineering, is a work environment in which there are different physical aggressors that can interfere with the activity being performed, as well as the health of the people working in it. Given the characteristics of the processes that take place inside, the main physical attackers present in this environment are the noise and the heat load.

Inadequate thermal environment causes reduction in physical and mental performance, and therefore the productivity, causes irritability, increased aggression, distractions, mistakes, discomfort from sweating, increased heart rate, which affects negatively on health, and even in extreme situations can cause death. An environment affected by heat load causes the elevation of body temperature, produces tension or stress to which the body responds with physiological mechanisms of thermoregulation, governed by the thermal control center located in the

hypothalamus. Since the main physiological defense mechanism of the human body is sweating, conditions should lead to allow the removal of sweat from the skin surface to remove heat (Velázquez, 1995). To facilitate the removal of heat is important to wear clothing of lightweight material that does not hinder the evaporation of sweat.

Noise is another important factor that must be eliminated or reduced as far as possible to increase worker efficiency. It is common cause of fatigue, irritation and production falls, further if is intermittent or constant tends to emotionally excite workers, altering his mood and increasing the risk of accidents (Mondelo, and others, 1995). If the noise exceeds certain levels, not only causes discomfort, but can also affect hearing health of people, with the passing of the years causing occupational diseases such as deafness.

Manage exposure to these bullies in the workplace is not a complex activity, however required a high level of knowledge of the physical parameters that comprise, the particularities of the tools necessary to carry out the measurements and criteria for interpretation and evaluation the values obtained to determine with certainty the level of exposure to physical aggressors analyzed.

To measure these environmental factors different instruments are used, which allow a general monitoring of the work environment, or a personal analysis for each operator. General measurement equipment, allows knowing the existing levels in a determined aggressor in an environment, while an individual or personal equipment considers the particularities of each individual to determine what levels are actually perceiving the person. The use of one or other equipment is determined by different factors such as time, cost, business interruption, discomfort to the operator, etc. However is useful to know if the values measured by the two instruments are comparable and allow checking the existence of harmful levels for the operator.

The objective of the study is evaluate two environmental parameters in a work environment, noise and thermal load, and determine the variations between the levels of both aggressors measured with equipment of general sampling of the environment, and levels that are perceived directly by the operator by an equipment of individual or personal sampling.

The experiment is conducted in a university dining, considering for the analysis the kitchens area. This area is characterized by the existence of numerous sources of heat, such as ovens and stoves used for cooking food, as well as continuous noise sources such as fans and kitchen exhaust, random noise sources such as handling dishes, pots, cookware and the voices of people working in the sector.

METHODOLOGY

The evaluation of environmental parameters of noise and thermal load, was performed following the procedures and standards established in the Argentina Hygiene and Safety regulations. Different days were taken for analysis, but environmental conditions were similar.

The kitchen area under analysis has three distinct but interconnected areas that are: the stores sector, where provisions to the daily menu are saved, the food preparation sector, where the food is washed, cut, processed and preparing and the cooking sector where the food is cooked. The sectors considered for the analysis are the cooking and food preparation, which are characterized by a greater and constant presence of people working and therefore with a greater risk of exposure to workplace bullies. In these two sectors were installed measuring equipment of general environment. For personal sampling equipment, two workers were selected that develop their activities continuously in both sectors.

Thermal Load Evaluation

The evaluation of Thermal Load of the general environment, is performed following the method of WBGT (Wet Bulb Globe Temperature). To measure this index is used an instrument that allow to obtain both the values of the different environmental parameters, as well as the index value of a direct way. Whereas the environment is a kitchen located in a closed setting, the expression used is for indoor environments.

$$WBGT = 0,7Tg + 0,2Tbh + 0,1Tbs$$

Where Tg = Globe Temperature

Tbh = Wet Bulb Temperature

Tbs = Dry Bulb Temperature

Once the index it knows, is necessary to establish the level of demand of the task and determining the ability of acclimation of the operators. As workers in this sector have spent several years in his post, are natives of the province, so they are used to the task and the job itself does not require too much effort, considering that both workers are acclimated. To know precisely the level of demand of the task was used the method measurement and analysis of the heart rate. This method allows the assessment of energy expenditure in situ, without interfering with the task that develops, facilitating the acceptance of the method by the individual subject to study, and allowing reproducibility. The procedure is based on the existence of a lineal relationship between heart rate and energy consumption that produce during a particular activity (Sole Gomez, 2008). To record this value to each operator has placed a heart rate monitor. Through this instrument the metabolic consumption was determined during the measurement time and was able to establish the level of demand of the task.

With respect to the particular analysis of the thermal load, the method of thermal balance or energy balance is kept. This method sets the amount of heat that must be dissipated by evaporation (E_{req}) for the body to remain in thermal equilibrium. The probability of this equilibrium is determined by the ralation between E_{req} and the maximum capacity of evaporation (E_{max}) calculated on the assumption that all the skin is damp with sweat.

$$E_{req} = M \pm C \pm R$$

Where M is produced by the heart rate monitor, the heat radiation R and convection C are given by:

$$R = 11x ((Tg + 14{,}4 \text{ x } V^{0,5} \text{ x } (Tg – Tbs))) \text{ Kcal/h}$$

$$C = 6 \text{ x } V^{0,6} \text{ x } (Tbs – 35) \text{ Kcal/h}$$

Tg and Tbs are terms of temperature obtained with the thermal load meter and V is the velocity of the circulating air, measured with a vane anemometer.

The evaporation capacity of the environment, is a function of airspeed and the partial pressure of steam (Pa),

$$E_{max} = 12 \text{ x } V^{0,6} \text{ x } (42 – Pa) \text{ Kcal/h}$$

To compensate the effect of light clothing is tentatively, it has been recommended temporarily reduce by a third the value of each one of the estimated coefficients. This correction factor has been calculated on the basis of empirical consideration (WHO, 1969).

Noise Evaluation

The noise evaluation is also done from two different perspectives, the general work environment and individually perceived by the operator. The noise of the overall work environment is assessed by measuring the levels of this aggressor by a type II sound level meter, which determines the L_{Aeq} (equivalent continuous sound level) value compared to the maximum allowed by national law. The noise perceived by the operator during the development of their activities is recorded by a noise dosimeter, laptop equipment carried by the operator while performing their activities. This instrument determines the noise dose (D) to which the operator is exposed. In order to compare values recorded by both instruments and contrast with the maximum permitted by law, the values of L_{Aeq} and Dose (D) are related by the following expression (Giménez de Paz, 2013):

$$L_{Aeq} = L_{max} + 10 \text{ x } \lg (D)$$

Where L_{max} is obtained from the regulations.

RESULTS

Thermal Load Evaluation

The values obtained by the heart rate monitor and the heat load shown in Table 1.

Table 1: Measurements Results thermal load

	DAY 1	DAY 2	DAY 3
Operator	Marcelo	Omar	Marcelo
Study Duration	3:24:40	3:26:25	4:04:45
Personal Sampling Equipment			
Energy Expenditure (Kcal/h)	286	183	383
Minimum heart rate (bpm)	72	73	74
Average heart rate (bpm)	95	81	103
Maximum heart rate (bpm)	117	88	132
Average pace (min/km)	3:46	4:28	3:10
Distance (km)	4,8	3,6	4,8
General Sampling Equipment			
Wet Bulb Temperature (°C)	22,8	23,5	26,32
Dry Bulb Temperature (°C)	28,39	30,44	29,66
Globe Temperature (°C)	29,54	31,21	30,43
WBGT Average (°C)	24,82	25,81	27,55
Average Humidity (%)	50,52	49,89	71,08
Air Velocity (m/min)	20	20	20

Whereas operators are acclimated and according to the energy consumption the requirement of the task is moderate, by Table 2 analyzed if is heat load and on this basis the corresponding period of work. As the WBGT index average weighted over time is less than tabulated value (Table 2), there is little risk of exposure to heat stress (Law 19587, 1979), in all cases analyzed.

Table 2: Board work / rest (Law 19587, Regulatory Decree 351/79)

Work requirements	Acclimated				Unacclimated			
	Mild	Moderate	Heavy	Very Heavy	Mild	Moderate	Heavy	Very Heavy
100 % work	29,5	27,5	26		27,5	25	22,5	
75 % work 25% rest	30,5	28,5	27,5		29	26,5	24,5	
50 % work 50% rest	31,5	29,5	28,5	27,5	30	28	26,5	25
25 % work 75% rest	32,5	31	30	29,5	31	29	28	26,5

In this case, as there is no heat load, periods of normal rest for the activity are contemplated. Pauses during the development of the task allow the recovery of the organism through the gradual elimination of fatigue for muscle load. Usually, the response is exponential and recovery effect is greater at the start than the end of the task. It is

better to make many short pauses, than only one long (Melo, 2009).

Applying the method of energy balance is determined the amount of energy that the body needs yield (E_{req}) and the atmosphere can be removed (E_{max}). Considering the heat storage capacity that has the body, can calculate the acceptable working time to avoid exposure to thermal stress due to the elevation of the internal body temperature.

Table 3: Allowable Working Time. Method of energy balance

	DAY 1	DAY 2	DAY 3
Ereq (Kcal/h)	237	140	340
Emax (Kcal/h)	203	210	165
Allowable working time (min)	113	-	22

While on day 2 removal capacity of the environment allows body heat to evaporate, in the other days occurs a buildup of heat could lead to heat stress.

The difference observed in the results obtained with the two methods, a general analysis shows that is not enough for this type of work, in order to define the presence of thermal stress. While the WBGT method determines a low risk of exposure to heat stress, energy balance shows the possibility thereof if certain work periods are not respected.

Table 1 shows the characteristic of this task, because while the workspace is small, 50m^2, operators have a constant displacement that exceeds the 5km in the workday.

Noise Evaluation

In an environment of this kind, in which there are no permanent jobs, because operators are walking much of the time as evidenced by recording distances (Table 1), the location of the sound level meter is key to values obtained adequately represent the levels to which operators are exposed. In this respect two locations for the sound level meter were selected, one at the sector of preparation of food and other cooking sector, considered to be representative for recording noise levels, and both do not interfere with normal operation of the activities.

The values measured with the sound level meter, as well as with the dosimeter indicates, for each sector, in Figures 1 and 2.

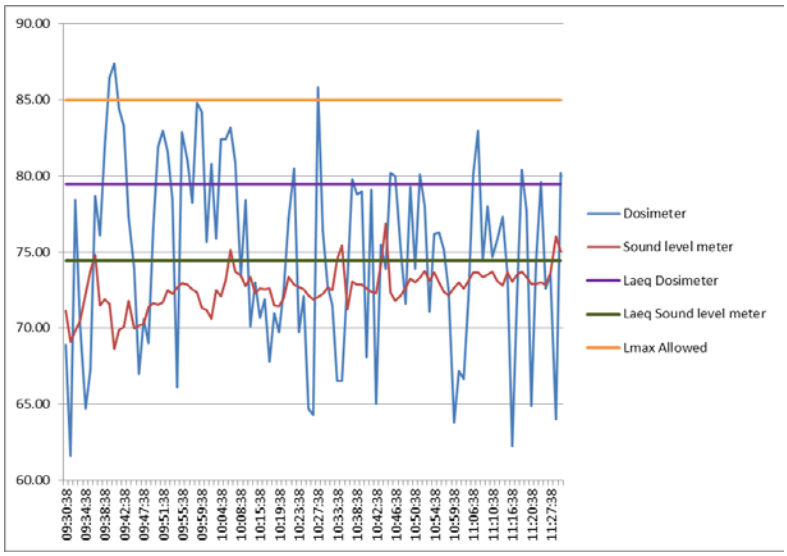

Figure 1. Record sound level meter and dosimeter first measurement

Figure 1 shows the noise levels recorded at each instant by both equipment during the first day of measurements, as well as the specific levels of L_{Aeq}. In this case the meter was installed in the sector of cooking, and the dosimeter

was worn by one of the operators active in the two sectors of the kitchen. As noted, the L_{Aeq} measured by the dosimeter is 79.5 dBA, while the L_{Aeq} sound level meter is 74.4 dBA.

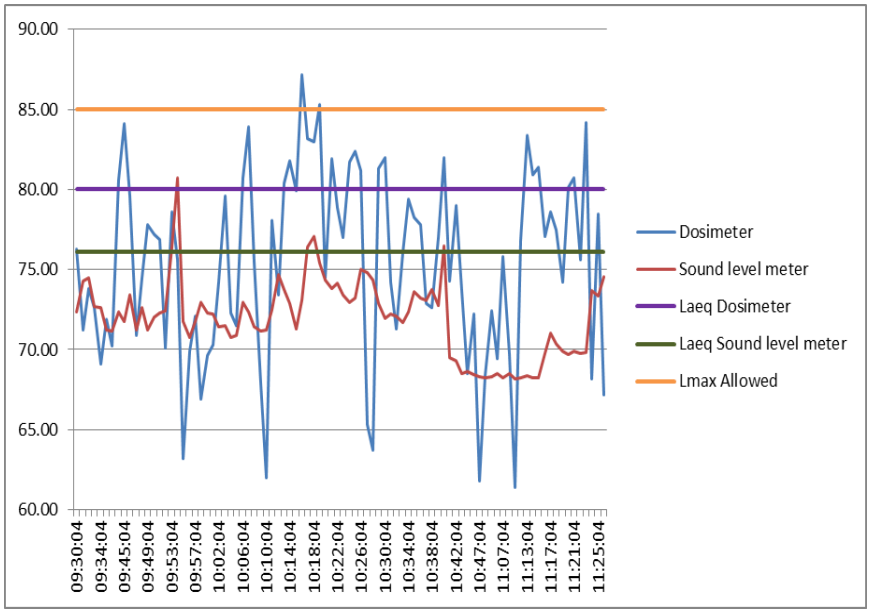

Figure 2. Record sound level meter and dosimeter second measurement

Figure 2, corresponding to the second measurement, show the levels recorded by the meter installed in the area of food preparation, while the dosimeter was placed at another operator which operates in both sectors. The L_{Aeq} measured by the dosimeter is 80.04 dBA, while the L_{Aeq} sound level meter is 76.08 dBA.

According to the results, recorded values by the dosimeter in different days and with different operators, are very similar. Similarly, the levels recorded by the meter located in the two sectors, differ in less than 2 dBA. However, if we compare the L_{Aeq} of the dosimeter and the sound level meter, the latter is significantly lower than the first. This shows that for a work environment of this kind, in which operators have a constant movement between different sectors, the values of the general measurements in each sector, are not representative of what the operator really sees.

Even though reported levels are not harmful to the work period, reaches limits that may be considered annoying. If the measured values are greater, so that the exposure is conditional for a period of time, the level recorded by the dosimeter indicate a shorter time than it would be to consider the values given by the sound level meter for each sector exposure.

CONCLUSIONS

Measurements of thermal load and noise in the workplace allow to know the levels to which workers are exposed in their jobs. For this, pitch measuring instruments so that it do not interfere with the normal course of activity, but which values obtained result representative of the levels to which workers are exposed.

In the analysis of the thermal load, by implementing the method as universally known as WBGT, a low probability of thermal stress was determined. By using the energy balance method, significantly higher value was obtained, probably closer to reality since it depends on the characteristics of each individual, such as heart rate and the associated metabolic consumption. This method provides a higher probability of heat stress, if the normal periods of work and rest for this activity are not respected.

Measuring noise in a working environment with a sound level meter, to assess existing levels and confirm that the limits set by the rules is not exceeded, although it is one of the methods commonly used, does not ensure that the measured values are those actually perceives the operator, at least in environments of this type where a continuous movement thereof. In this case in order to obtain values that are representative of what is perceived by the operator;

it is convenient to use a tool such as the dosimeter. Comparing the equivalent values measured by the two instruments, we can see that for the dosimeter is 5dBA above those obtained by the sound level meter. In this case it is below the allowed limit values, but in a different situation, with higher levels of noise, probably hearing health of the workers can compromise when considering the values measured with a sound level meter.

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Section 2

Improving Manufacturing

Vessel Information - Rich Meta-file to Increase the Life Cycle of Small Craft Passenger Boats

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ABSTRACT

The aim of this paper is to present a methodology that will focus on the increase of the life cycle of small craft passenger boats made of composite materials (Glass Reinforced Plastic, GRP). Passenger boats (small craft, with length overall up to 30m), are sea-going vessels which carry passengers for recreational purposes, such as small charter cruises, for the purposes of scheduled routes or transportation of professional personnel or ship crews. The goal is to develop a user-friendly, dynamic information-rich vessel's technical metafile will include all aspects of the vessel from initial customer specifications and required regulations, to shipyard designs, final sea-trial data to post-delivery surveys and inspections. Using the meta-file as the main knowledgebase, a number of applications will be developed to allow the collaborative building of the vessel with synchronous update of the current rules and regulations, allowing this way all the interested parties to be up-to-date and fully aware.

Keywords: Product life cycle management, Boat building, Frequent upgrades

INTRODUCTION

Passenger boats (small craft, with length overall up to 30m, Figure 1), are sea-going vessels which carry passengers for recreational purposes, such as small charter cruises, for the purposes of scheduled routes or transportation of professional personnel or ship crews. Typical distance between starting port and final shore for small passenger vessels is up to thirty (30) nautical miles, carrying on average a hundred (100) passengers, extending the limits also to (80) nautical miles and 300 passengers. Operating small-craft passenger vessels counts for approximately five hundred (500) units across Greek sea- waters.

Figure 1: Daily Cruiser Boat

Our application will decrease the cost of designing, building, maintaining and modifying vessels, and consequently increasing the product's life span by t. A user-friendly, dynamic information-rich vessel's technical metafile will be designed and developed which will include all aspects of the vessel; from initial customer specifications and required regulations, to shipyard designs, final sea-trial data to post-delivery surveys and inspections. This dynamic data-set will be integrated into visual depictions of the vessel (i.e. three-dimensional drawings). Visual representations will effectively connect design aesthetics and design elements (e.g. number of passengers and scale of comfort) with installed parts, equipment, and their properties (supply vendors, cost of purchasing/servicing, technical characteristics etc.). Furthermore, all aspects of this technical file would be dynamically connected with customer requirements, regulations and required specifications by the Classification Society (ex. Structural properties, safety regulations, required equipment etc).

As a result, any decision made in any stage of the product's life-cycle, from initial design to post- delivery modifications, would be based on updated information provided by all parties involved. The boatyard could forecast costs regarding different decisions, and offer different solutions (different equipment, environmentally friendly or more durable materials, layouts, etc), and Classification Society would be well informed about the effectiveness of such changes, ensuring that they would be according to its Rules and Guides or setting new applicable rules/regulations/recommendations and surveys to be carried out. Moreover, the customer could visualise different solutions based on the Boatyard's and Classification Society's recommendations and intervene in the entire business process, while keeping a better and more information rich access to the boat lifecycle details.

Any interested party and authorities, will have access to the dynamic technical metafile, easily reviewing construction, operating and surveying data, information regarding updates on on-board equipment, systems and regulations applying on the vessel. The vessel's technical file follows its life- cycle and is less dependent on ownership. New owners will be provided with information on the history of the vessel from initial design to the latest survey.

CURRENT SITUATION

Life-cycle model of the vessel

Local transportation needs and tourism set business demand for building passenger vessels. Usual requirements include operating speed, capacity and maintenance cost. Small passenger boats are usually made of composite materials, built by boatyards (boat manufacturing yards). There are three (3) major parties involved in the process of boat manufacturing: the customer, the boatyard and the Certification Body. Customers can be either companies, individuals or boat owners unions.

Customers are typically represented by one or more technical consultants during the building period and many time can act on behalf of large naval firms in purchasing or modifying boat transactions.

The Boatyard is usually a company with all the necessary means of production (facilities, specialized personnel, etc) but subcontractors are also employed for various parts installed on vessels. The Boatyard incorporates as business partners, industry vendors (manufacturers or importers) for materials, and equipment (ex. Propulsion engines, generators, navigation systems, etc).

The Certification Body, is either a public (Administration Surveying Body) or private organization

(Classification Societies) with the responsibility of setting the applicable rules/regulations/ recommendations for the construction of boats/ships. Moreover, surveys are carried out in the construction and post-delivery stages of boat's life-cycle in order for the boat/ship to be certified as sea-worthy according to Society's standards.

The process of building, delivering and operating a passenger boat consists of different stages, which can be summarized as follows:

- Configuring customer requirements based on business demands
- Setting boatyard's specifications and forming an initial design proposal based on customer requirements and yard's production standards, accompanied by economic offer
- Approving a final design by all parties: customer, technical consultant, Classification Society and boatyard followed by shipbuilding contract
- Boat manufacturing and equipment installation according to specifications and national regulations. Frequent surveys conducted by the Classification society
- Performing final survey, sea trials and delivery of boat. The vessel is operated by the final user.
- Conducting annual boat surveys by the Classification Society to ensure that the vessel is operated and maintained in accordance to Society's guides and National regulations. As a result, a maintenance schedule is followed which is implemented by the boatyard (maintenance regarding the boat structure), industry vendors (for example annual engines service) or other business units specialized in boat maintenance.

Besides the annual commonly scheduled maintenance, the final user (customer) communicates frequently with the boatyard for various technical issues regarding usage and maintenance (parts replacement, servicing procedures and guides). In addition, due to the fact that customer requirements may change in accordance to service demand (business environment) or alterations to regulations may take place, there are frequent inquiries for modifications to the initial design, in order to meet newly formed business demands. Implementing those modifications will increase product life and economic return of investment. These changes on initial design can vary in terms of cost, depending on the scale of modifications. Economic gain can be met either by reducing operating cost (e.g. less fuel consumption or reducing maintenance cost of propulsion engines), by meeting new business demand requirements (e.g. adding passenger seats) or by improving services and being more competitive (e.g. adding services on-board, reducing arrival time, etc).

From the aforementioned it is obvious that the entire life-cycle of the vessel is following a rather linear value chain with sparse or insufficient interlinks. Our plan, is using UIW approach to transform the entire business process into a recursive loop with one common point of reference, the vessel meta-file.

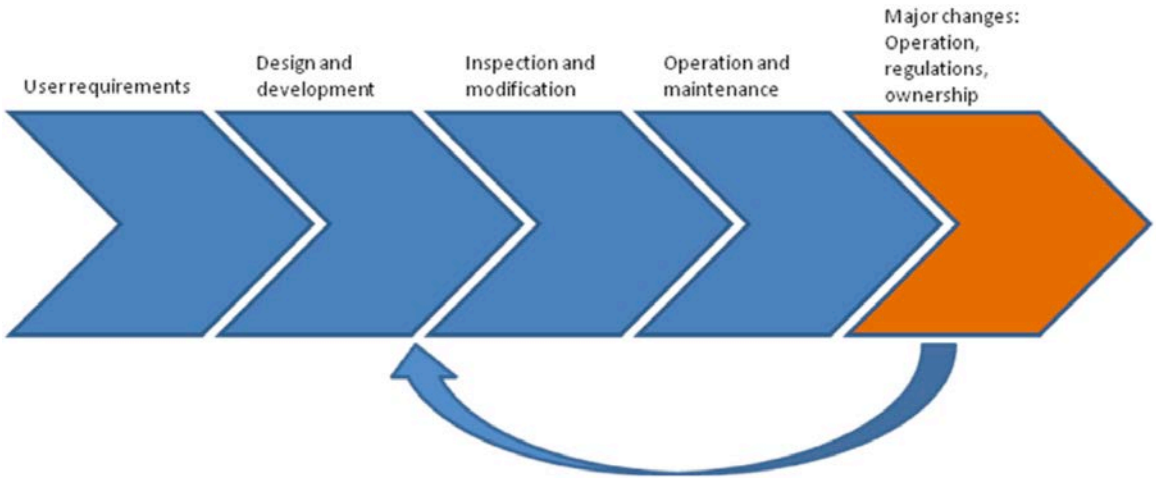

Figure 2: Current value chain in ship design and operation

VISION FOR THE FUTURE

Our cluster concentrates in the development of an application, which aims in aiding the increase of the life cycle of small craft passenger boats made of composite materials (Glass Reinforced Plastic or GRP). Passenger boats (small craft, with length overall up to 30m), are sea-going vessels which carry passengers for recreational purposes, such as small charter cruises, for the purposes of scheduled routes or transportation of professional personnel or ship crews. Typical distance between starting port and final shore for small passenger vessels is up to thirty (30) nautical miles, carrying on average a hundred (100) passengers, extending the limits also to (80) nautical miles and 300 passengers. Operating small-craft passenger vessels count for approximately five hundred (500) units across Greek sea-waters.

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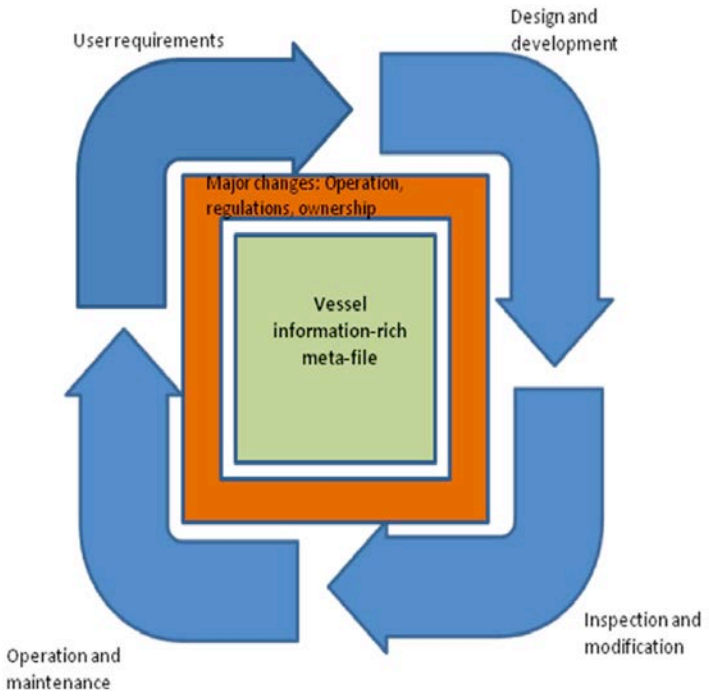

Figure 3: Value Chain process concept

As a result the system will enable the owner:

- to effectively organise the maintenance of the vessel by accessing all relevant information and reducing overall time and costs by 30% due to the availability of the vessel technical information;
- to be informed on equipment and systems updates thus following market dynamics while expanding the life-cycle of the vessel;
- to be early informed about costs involved in necessary modifications to meet new business demands, decreasing lead time in product modifications by at least 20%;
- to forecast total costs and prepare an elaborate financial plan about the vessel's use, putting the emphasis also on environment-friendly materials that could expand the life cycle of the product while decreasing the overall environmental footprint;
- to transform the vessel into a Meta-Product that is accompanied by an information-rich environment.

Moreover, the system will enable the Boatyard:

- to provide customers with a complete dynamic system of recorded vessel's technical information, used for initial design, construction, operation and future modification thus decreasing the overall process implementation time by at least 30%;
- visualize various technical solutions based on all aspects of building (financial and regulative) and enabling the use of advanced and environmentally friendly materials throughout the process;
- use enhanced visualizations as a communication and promotion strategy
- effectively communicate required specifications with vendors and the Classification Society decreasing the communication overhead while maintaining effectivecommunication;
- reduce costs of design and implement modifications by at least 20%.

In Addition, the system will enable the Classification Society to:

- effectively communicate required specifications to both the Boatyard and the Customer facilitating the entire process;
- reduce surveying costs by at least 20%, regarding the continuously monitoring of the vessel which will be visible to the end-user
- provide information to any interested party (ex. Future owners) with no previous involvement, details and current status of the vessel;
- effectively evaluate the purchasing price of the vessel and make decisions regarding modifications;
- plan the required inspection for renewal of vessel's Class and statutory certificates;
- associate all information to the vessel transforming it to a Meta product whose information is accessible by all stakeholders involved

CONCLUSIONS

As a conclusion, the flow of information on the system between all involved parties will reduce the cost of maintenance and modifications, and will effectively reduce time of on decisions regarding design of those modifications and consequently will promote the expansion of the vessel's life cycle.

AKNOWLEDGEMENTS

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Industrial Ergonomics: The Impact of a Macroergonomics Program with a Well-Defined Performance Goal in Reducing Work-Related Musculoskeletal Disorders

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ABSTRACT

This study describes a corporate macroergonomics program designed to identify jobs with work-related musculoskeletal disorder (WMSDs) risk exposure, reduce that exposure, and evaluate the subsequent effect upon WMSD cases. The adoption of a company-wide ergonomics program comprised of: a plan to address WMSDs (ergonomics plan), risk identification and reduction process, clearly defined responsibilities, and employee training is reviewed. Various technical initiatives facilitating program implementation including standardized job risk assessment tools, training and certification process for individuals performing risk analyses, central database to record assessment results, and management system to track progress are described. Between 2004 and 2008, 2020 jobs from 116 locations were analyzed, risks identified, interventions completed, and results documented. A statistical analysis of the results from 33 US locations showed a significant relationship between number of at-risk jobs addressed and a subsequent reduction in WMSD Incidence Rates (IRs) and lost-time IRs. The percent reduction of risks at each facility was also found to significantly reduce lost and restricted workdays. The reduction in WMSDs supports the effectiveness of the key program elements of management commitment, identification and improvement of problem jobs, and knowledgeable location-based resources and underscores the importance of well-defined performance-based metric for effective WMSD reduction.

Keywords: Ergonomics Programs, Industrial Ergonomics, Macroergonomics, Participatory Ergonomics, Work-related Musculoskeletal Disorders

INTRODUCTION

Much has been written about what is required to have a successful industrial ergonomics program; these recommendations vary but essentially describe a core set of program elements. The US Government Account Office (GAO) report, *Private Sector Ergonomics Programs Yield Positive Results* (1997), identified these components of successful company programs: management commitment, employee involvement, identification of problem jobs, analysis

and development of controls for problem jobs, training and education, and medical management. The Occupational Safety and Health Administration's (OSHA) *Ergonomics Program Management Guidelines for Meatpacking Plants* (1993) focused on management commitment and employee involvement, but also included worksite analysis, hazard prevention and control, medical management, training and education. Figure 1 summarizes the National Institute of Occupational Safety and Health (NIOSH) in Elements of Ergonomics Programs, which includes more specific actions but also has similar categories of program requirements (1997).

Looking for signs of WMSDs	Setting the stage for action	Building in-house expertise-training	Gathering and examining evidence of WMSDs	Developing Controls	Establishing health care management	Creating a proactive ergonomics program
Cues and tip-offs to problems	Management commitment and employee roles	General and specialized training needs and access to resources	Health and risk factor data collection and assessment	Options for reducing risks and evaluating effectiveness	Duties of health care providers and others	Accent of prevention

Figure 1: Pathway to controlling work-related musculoskeletal disorders (WMSDs)(NIOSH, 1997)

Many studies have proposed similar program elements as theoretical constructs (Vink, Imada, Zink, 2008; Haines et al., 2002). Additionally, there are applied studies that show the importance of elements such as widespread employee participation and clearly defined goals (e.g., De Jong & Vink, 2002).

In applied settings, a company's ergonomics program is influenced by where the program is positioned organizationally (Vink, 2005), and its design must support the specific business-related objectives (Haines et al., 2002). It is important to distinguish ergonomics programs and WMSD programs as separate entities with separate strategies and objectives, although they commonly overlap. For example, an ergonomics program aligned with safety or health operations or risk management within a company will likely focus primarily on WMSD reduction (Molen et al., 2005). A program aligned with engineering or product development may focus more on operational efficiency or quality or customer requirements (Vink, 2005). Industrial ergonomics programs are frequently focused on WMSD reduction, using a variety of processes and strategies. In practice each company needs unique strategies and implementation tactics to implement their ergonomics efficiently and effectively, whether the objective is reduction of WMSD, operational efficiencies, or customer experience. Macroergonomic concepts can provide guidance to designing and implementing an ergonomics program that supports a company's business objectives (Hendrick, 1996).

Hendrick (1996) and Koningsveld et al. (2005), among others, propose a combination of applying macroergonomics principles to create a comprehensive program structure and to document company-wide benefits. Vink et al. (2008) and Noro & Imada (1991), have promoted participatory ergonomics strategies, which give explicit attention to the involvement of employees with their concomitant variety of expertise, knowledge, and skills and local autonomy as a critical factor for achieving success. In an industrial corporation, both macroergonomics and participatory ergonomics work synergistically, leading to an ergonomics program that is both efficient and effective and demonstrates value across organizational structures.

Macroergonomics (Robertson, 2001) considers what is needed to obtain management support in the context of factors, such as culture, mission, vision, business objectives, development of a comprehensive plan (including strategies, tools, and resources), and what business results to measure (WMSD reduction, production, cost reduction, customer satisfaction) to demonstrate value to the company. Macroergonomics provides guidance for practitioners to create and implement an ergonomics program that supports business objectives.

Participatory ergonomics (Noro & Imada, 1991) considers how to achieve the business objectives in the most efficient and effective manner through integration and collaboration with partners, including business units, health and safety, engineering, employees' expertise, and others. It is also seen when employees are involved in the process of identifying problem jobs and providing the framework to make sure the right knowledge and skills are included at each key phase of an ergonomics intervention. In a complex organization with multiple locations, a prime challenge is balancing between the efficiencies realized through centralized programs and each location's unique business requirements.

This paper describes how a company's ergonomics program applied both macroergonomics and participatory ergonomics in combination with a well-defined metric and reduced the number and severity of WMSDs. It describes the

macroergonomic strategies of the organizational structure and ergonomics program, but focuses on management support, program strategies and tactics and the resources (participatory ergonomics) that executed the ergonomic WMSD risk reduction projects.

Management Commitment

The company's commitment to ergonomics has a long history (Larson 2006, 2008, 2012). Ergonomics has been a component of the company's health and safety program for over 30 years. The company formal policy (3M website 2013) states the company "recognizes the importance of safety and health to business success and strives to continuously improve performance and be a leader in safety and health…and is committed to the safety and health of all its employees and will provide a safe and healthy workplace worldwide."

A companywide Safety and Health (S&H) Policy and safety and health management system was adopted over 20 years ago and is comprised of over 30 technical elements. It defines the required safety and health performance requirements for all operations worldwide. Integrating the ergonomics (WMSD) program into the broader health and safety program provided many advantages, not the least of which was a common platform for communicating technical information and assessing compliance, making it easier for the various operations to assess progress towards achievement of their objectives. As one element of the company's health and safety program, ergonomics performance was reviewed annually, and continuous improvement opportunities were listed in each location's annual S&H objectives. In the safety and health management system, every location's ergonomics program requirements were defined and listed: a written program, performance of WMSD risk exposure assessments and intervention methods, identification of responsible individuals with appropriate knowledge and skills, and ergonomics training for all employees. Integration of ergonomics requirements into the S&H annual planning process ensures ergonomics was consistently part of each location's operational management.

For more than two decades OSHA's WMSD recordable incidents comprised the single largest category of work-related recordable and associated injury/illness costs in the US. As shown in Figure 2, the company had a similar experience with WMSD data in its US operations, WMSD cases accounted for at least 50 percent of all reportable cases. This was true for all OSHA reportable categories: number of cases, the number of lost-time cases, the number of restricted time cases, and the total lost and restricted days.

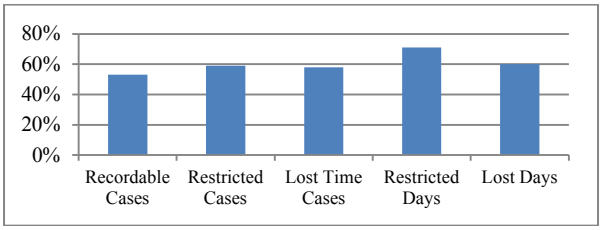

Figure 2: 2002 percent WMSD recordable vs. all recordable cases summary (US locations only)

Additionally, WMSDs were also the largest category of Workers Compensation dollars. Therefore, the ergonomics program focused on reducing the prevalence and cost of these work-related illnesses throughout the company.

In 2000, as part of the company's transition to a stronger centralized Safety & Health management system, the ergonomics program was redesigned. This redesign included developing training programs, adopting standard job analysis tools, and adopting an internal ergonomics certification process. These changes set the stage for a transition to a robust macroergonomics approach, resulting in the company's current comprehensive ergonomics program (Larson, 2008, 2012).

In 2002, the company's management directed that three company-wide safety and health goals were to be developed, one of which focused on WMSD reduction and ergonomics. A five-year ergonomics goal to implement the company's Ergonomic Risk Reduction Process (ERRP) and reduce unacceptable WMSD risk exposures in specifically targeted jobs by 75% by year's end of 2008 was sanctioned by upper management and implemented globally in 2004.

The purpose of this study is to describe both the ergonomics program development actions and the implementation actions completed between 2004 and 2008. It provides a description of the company-wide ergonomics risk reduction process (ERRP), followed by a summary of the ergonomics training and certification process. Then, it provides an

in-depth analysis of the impact upon WMSD incident rates at 33 US manufacturing locations chosen for the study.

Ergonomics Risk Reduction Process (ERRP)

The Ergonomics Risk Reduction Process (ERRP) is a global, comprehensive process. The strategy supports the application of ergonomics in all company locations. However, local regulations or cultural differences can impact the availability of WMSD case data .

The ERRP process follows a traditional before-and-after research strategy, utilizing risk reduction data. Actual job assessment follows a Define, Measure, Analyze, Improve, Control (DMAIC) job assessment strategy, as shown in Figure 3, and is comprised of baseline analysis, identification of issues and solutions, implementation of solutions, and verification of results.

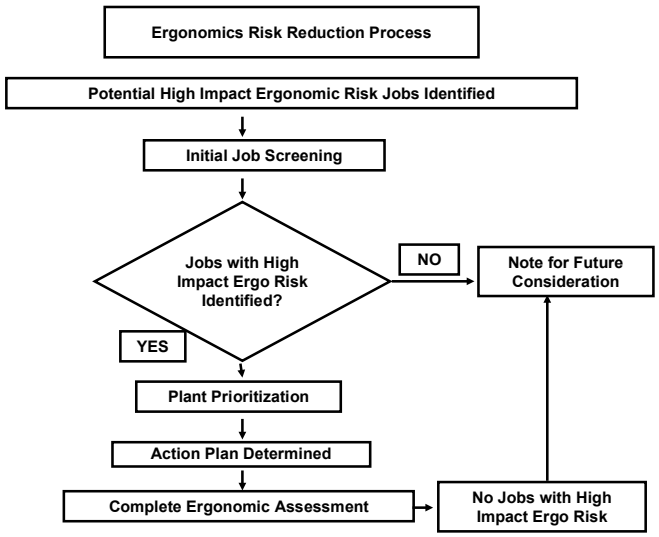

Figure 3 Flowchart of risk reduction process

Job Assessment Tools

A WMSD or ergonomics job assessment tool must be credible – sufficiently rigorous to accurately analyze the job activity and identify undesirable actions, yet not overly sensitive resulting in false positives that consume resources (Punnett & Wegmann, 2004). The results of the analysis must provide information helpful in identifying solutions, not just list data. It must be usable by the target user population, which may be professional ergonomists, health and safety professionals, or others. It must provide information that can be communicated to obtain management support and gain employee involvement.

The company's ergonomic risk assessment tools needs to be applicable to a wide variety of manufacturing, converting, processing, and packaging operations. It needs to be usable by health and safety staff that do not have advanced ergonomics education. The Ergo Job Analyzer (EJA) (Auburn Engineers, 2001) is used when conducting job analysis on existing equipment and processes. An additional tool, the Ergonomics Design Criteria Tool (EDC), was developed and adopted for engineers' use during the design and specification of new equipment and processes so that ergonomic issues are designed out as much as possible. Both tools use a similar risk identification strategy and are based upon common WMSD risk exposure criteria.

This standard ergonomics assessment and improvement process (ERRP and the two analysis tools) facilitated the identification, remediation, and management of WMSDs, supported consistent and effective communication with management and employees, provided operational efficiency, and finally, protected the assets of the corporation, including employee safety and health, product-quality and productivity, and the company's reputation.

Establishing Target Jobs

A job prioritization strategy was adopted and implemented, and potential high-risk jobs were identified and placed in a location's Potential High Risk Job Pool (PHRJP). Criteria for inclusion in the PHRJP included jobs with a history of WMSD related injuries, employee complaints, high job demands, or considered by health safety personnel to have ergonomic concerns. Once identified, these jobs became the target jobs for the five-year improvement goal. In this way each applicable manufacturing, distribution, and laboratory location identified a specific number of Potential Target Jobs (PTJs) to be considered for ergonomic improvement. The targeted jobs in this study were primarily from manufacturing locations but also included distribution operations and mining operations.

Personnel Resources

Resource individuals with technical knowledge of ergonomics are necessary to achieve successful ergonomics interventions. Because the majority of manufacturing locations in the company consist of fewer than 400 employees, hiring professional ergonomists at each location was not an option. However, each location had a professional safety, industrial hygiene, and/or occupational health resource person. The corporate ergonomics program relies on these location resources to lead and implement the ergonomics program and interventions at each location. Almost all the resources had a formal educational background in a health and safety area or engineering and were familiar with ergonomics in general, but few had more than a basic working understanding of the field. The company's internal ergonomics training and certification process, created in 2003 focused on developing a common core of ergonomic job analysis and assessment skills. This training effort standardized and significantly increased the ergonomic expertise throughout the company and allowed for each location to have an ergonomics resource.

Training and Education

In addition to the training created for the ergonomics certification process, numerous additional training modules were created: general employee ergonomic awareness, which includes WMSD information and guidance on manual material handling and workstation layout. Specific training was developed and made available online for plant engineers, maintenance departments, process and manufacturing engineers, and supervisors. Additional modules provided guidance on project management, cost benefit strategies and measurement techniques, and creation and preparation and presentation of project proposals to management.

Medical Management

Not all musculoskeletal disorders (MSD) are work-related and may result from non-occupational factors. Due to the complex nature of MSDs and variability of employee physical capability and limitations, and the sometime difficulty of distinguishing between WMSDs and MSDs, it is unrealistic to expect to eliminate all MSDs from workplaces. Medical case management has a significant impact upon WMSD severity.

Consequently, it is essential to educate employees about early signs and symptoms of MSDs and inform them about actions to take, including how to obtain assistance from a health care provider. Specific medical management protocols are useful but will vary based upon state and country regulations. During the study period, occupational medicine staff acted as a point of contact with employees experiencing symptoms of WMSD. As a result, they had unique information to help identify targeted jobs within a location, and often participated on project teams. Specific information about WMSD case management within the company is outside the scope of this paper. Its impact is unmeasured but known to influence severity results.

OBJECTIVE

The objective of this paper is to answer this question: In a complex, global company, what impact does a comprehensive ergonomics program with a focused goal to reduce WMSDs risk exposures have on the reduction of WMSDs?

METHOD

Program Performance Data

Each year every location provides an update of their ergonomics program implementation via a questionnaire which is part of the health and safety management system. By answering a series of questions specific to implementation of the four key program elements (plan, risk reduction, responsibilities, and training) each location's compliance can be determined as a percent of compliance. 100% indicates all program elements are in place. In this case study, the answers from each year from 2005 - 2008 were averaged by region. Unfortunately, due to a change in the data software, the 2004 data was not available for analysis. The responses were averaged by region: Canada, Asia Pacific, Europe/Middle East, Central and South America, and US. Additionally, standard deviations were calculated.

Job Identification

The locations varied from less than 20 employees with one type of manufacturing operation to those with more than 2,000 employees and dozens of assorted manufacturing operations and equipment, each with unique ergonomic-related challenges. Each location established a list of target jobs using the following process.

The first action was for each location to identify jobs with potential ergonomic issues and list them in a spreadsheet as shown in figure 4 as being a potential high risk job (PHRJ). Jobs were listed if there were recorded WMSD injuries or employees had reported MSD signs or symptoms, if there were employee complaints or high turnover rates, or if the jobs required physical conditioning time or were restricted to a specific job population. Additionally jobs typically considered to be "hard jobs" were included in the spreadsheet. The jobs listed on the spreadsheet became the pool of jobs for each location's 5-year goal objective. In this way the number of jobs for each location was independently determined by each location and was based upon their operations and potential WMSD risk.

	EJA Risk Factor #1			EJA Risk Factor #2	EJA Risk Factor #3	
Job & Department	WMSD Loss Information First Aid Cases, Recordable Cases , Lost Time or Restricted Case			Employee Indicators of Excessive Job Demands Job Complaints, High Turnover..	Miscellaneous Indicators of Excessive Job Demands (Formal Selection, Work Conditioning or Stretching Programs)	Supplemental Data Location Health and Safety Expert Opinion of Job
Lam Operator – pulp	X		X			
Lam Utility Operator Tall boy	X		X	X		X
WBO Packing – 1133690	X					
Chem Opr	X			X		
Viscose Shredder – Hoe Out	X				X	X
Converting – Utility	X	X				X
Wrapping Operator A	X		X	X		
Wrapping Operator B	X		X	X		

Figure 4: Potential high risk job pool worksheet example

Knowledgeable and Skilled Personnel Resources

Individuals from each manufacturing and distribution location completed a rigorous series of computer-based training modules in biomechanics, physiology, anthropometry, and workstation design solution identification. Business justification and project management strategies were also required training for the ergonomic resource person at each location. Also, each resource individual participated in a 3-day, hands-on workshop conducted in a manufacturing location and submitted three completed interventions, which were reviewed and critiqued by the corporate board certified (CPE) ergonomists (Larson and Wick, 2012; Larson, 2012). At the workshop, participants learned about

and then practiced applying the standard job assessment tools to analyze manufacturing jobs for unacceptable WMSD risk exposures. They also practiced using measurement tools, such as force meters, goniometers, and pinch gauges, and learned how to video document the tasks to conduct more detailed posture analysis. By conducting the workshop at manufacturing locations, participants were provided hands-on practice analyzing actual jobs *in situ*. This formal training and EJA certification process were used to document that a core ergonomic knowledge base had been attained and that a verified ability to perform ergonomics job assessments had been developed. The number of participants trained and certificates earned were enumerated for the period between 2004-2008.

Program Data

Due to multiple causes, only descriptive data are available globally. Many locations did not fully participate in all five years of the project due to changes (e.g., acquired during the course of the project, closures, etc.). Similarly, during this time, the health and safety incident reporting system changed, which affected the consistency of the non-US WMSD data. However, it was possible to perform a more rigorous evaluation of the data from 33 plants located in the United States.

With regard to the program, 2004 was used as the baseline year for all data globally. During 2004, program actions were primarily preparation, completion of the initial training, and identification of the target jobs. The ergonomic interventions were primarily completed between 2005 and 2008. The following analyses were conducted to study the effect of the ergonomics program.

First, each location's responses to the ergonomics program implementation questions were compiled and reviewed. Next, the number of participants attending ergonomics workshops and participating in the EJA Certification process was determined. Finally, the number of targeted jobs remediated and the percent of risk factors reduced in those targeted jobs were calculated and summarized for global company locations by region.

WMSD Data from US Plants

In addition, four different measures of WMSD were collected at 33 different US locations between 2004 and 2008. These were: the incidence rate of WMSD cases (WMSD IR), the incidence rate of WMSD cases resulting in days off work (WMSD LT IR), the incidence rate of WMSD resulting in days off or restricted work (WMSD SR IR), and the incidence rate of days off or restricted work resulting from WMSD (WMSD SR Days IR). The four reporting categories are defined by OSHA.

RESULTS

Program Implementation

Program implementation was evaluated by reviewing the location answers to the ergonomics program implementation questions for each year between 2005 and 2008. Very high implementation results of over 80% were reported for the US, Canada, and Europe. Asia and Central America locations reported implementation score between 60% and 80%. The impact of business acquisitions appears to significantly confound the results and increase the variability both within regions and among regions. Due to data limitations it was not possible to evaluate the specific impact of acquisitions upon program implementation.

Resources

During the five years, over 200 company health and safety staff from over 20 countries completed the required courses and attended the 3-day workshop. There were 25 workshops conducted at company manufacturing locations around the world. Fifty-one individuals completed the entire certification process within the 5 years, and 130 were still pursuing the certification after 2008. During these five years, there was approximately a 10% dropout rate primarily due to changes in job responsibility of work location.

Job Analysis

Locations applied the ERRP (conducted ergonomic job assessments, implemented ergonomic interventions, and

conducted post job assessments) for target jobs listed in their potential high risk job pool (PHJRP). The target job distribution ranged from a low of 1 to a high of over 80 as showed in Figure 5.

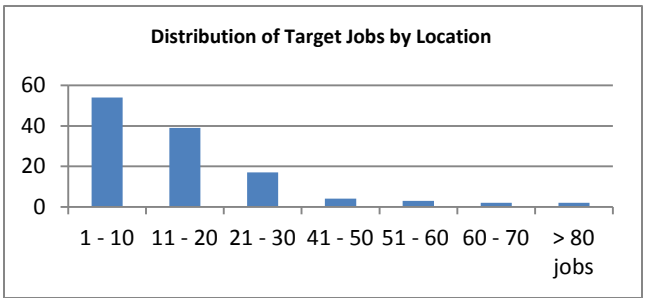

Figure 5: Distribution of target jobs (n=116)

Risk reduction was determined by completing before-and-after job analysis. The number of times a WMSD risk exposure exceeded the unacceptable level for any of the EJA 36 exposure elements was totaled and used as the baseline risk number. Subsequently, the same process was used to determine the number of risks present after remediation. The percent reduction of risk elements was based on the post risk number divided by the baseline risk number.

Globally, 116 locations participated in the Ergonomics Goal: 57 US, 16 Asian, 5 Canadian, 30 European, and 8 Latin and South American. Initially, the number of jobs identified for ergonomics analysis was 1909; however, a total of 2020 jobs were completed during the five years as some locations exceeded their initial target number. The number of jobs targeted in US locations (48%) versus non-US locations (52%) is generally proportional to the company's overall operation distribution.

Table 1 summarizes by region the number of target jobs addressed and the percent of identified unacceptable WMSD risk exposure reduced.

Table 1: Summary of target jobs by region

Initial # of Target Jobs	Number of Target Jobs Completed	% of Target Jobs Completed	Region	Percent of Risk Reduced in Target Jobs
914	939	103%	United States	78%
186	222	119%	Latin / South America	56%
425	466	110%	Europe	60%
100	105	105%	Canada	88%
284	288	101%	Asia Pacific	68%
1909	**2020**	**106%**	**Average:**	**73%**

WMSD Case Incidence Rates

Incidence rate data regarding WMSD cases were available from US based facilities. Incident rates are based on the following standard formulas, and represent the incidence of an event per 100 workers per year worked.

The number of WMSD cases per 100 workers per year worked is defined as (WMSD IR) = (WMSD cases * 200,000) / number of work hours. The number of WMSD cases resulting in days off work (WMSD LT IR) = (lost-time WMSD cases * 200,000) / number of work hours. The incidence rate of WMSD cases resulting in days off work or days restricted work (WMSD SR IR) = (lost-time WMSD cases + restricted time WMSD cases) * 200,000/number of work hours. The WMSD days severity incidence rate (WMSD SR Days IR) = (lost-time WMSD days + WMSD restricted time days) * 200,000/number of work hours.

As shown in Figure 6, for US locations there was a 28% reduction in all WMSD recordable cases, a 29% reduction in restricted time WMSD recordable cases, and a 59% reduction in lost time WMSD cases between 2004 and 2008.

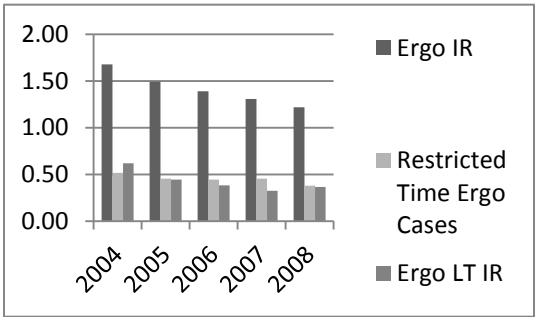

Figure 6: US ergonomic recordable incident rates: 2004 - 2008

Regression Analysis

The WMSD incidence rates described above were analyzed using forward stepwise regression to evaluate the impact of the program implementation and risk exposure reduction upon WMSD incidence rates at the beginning and end of the five year program for 33 US locations (2 mining operations, 2 distribution centers, 29 manufacturing operations) for whom data was available for all 5 years.

The effect of the number of target jobs completed and the percent of risk factors reduced (PRR) on the WMSD incidence rates was evaluated using forward stepwise regression. Both reduction of the number of target jobs and the percent reduction of risk factors were found to have significant effects in reducing WMSD incidence rates.

For this analysis, the number of target jobs was normalized to establish a job assessment completion rate for target jobs per 100 employees using this formula: Job assessment rate (JAR) = (Number of target jobs completed * 200000)/ number of work hours

There were four significant results of the regression analysis, which are presented in Table 2.

Table 2. Regression results

Forward Stepwise Regression Results, 2004 compared to 2008			
Independent Variable	Dependent Variable	P level	Adjusted R^2
JAR	WMSD IR	< 0.001 *	0.328
JAR	WMSD LT IR	0.049 *	0.085
PRR	WMSD SR Days IR	0.032 *	0.105

The results demonstrate a significant effect between JAR and subsequent reduction of WMSD cases and WMSD LT cases. Specifically, the greater the number of jobs targeted per 100 employees (more employees impacted by interventions), the greater reduction of both WMSD cases and WMSD LT cases. There is also a correlation between the overall percent of unacceptable risk (PRR) elements reduced and the WMSD Severity incidence rate: the greater the percent reduction in unacceptable risk elements the fewer lost and restricted workdays.

A suggestive, but insignificant relationship exists between WMSD Lost Days IR as a function of JAR with a p-value of 0.069. It is interesting that there was no significant relationship between WMSD Severity (lost and restricted) cases as a function of JAR. Why? Maybe quicker return to work?

DISCUSSION

The research question this paper seeks to answer is: In a complex global company, what impact may the implementation of a comprehensive ergonomics program in combination with a focused 5-year goal to reduce WMSD risk exposures have upon subsequent WMSD rates?

It is difficult to report scientifically whether this is successful as there is no research golden standard applied and no reference or control group. However, statistically significant reductions were reported in this paper and the effects

are clear. The initial company intention was to reduce the number of unacceptable risk exposures in 1909 target jobs by 75%. The result was 73% of unacceptable risk exposure in 2020 jobs was accomplished. Other studies on this program clearly show financial benefits in operational efficiency as well as WMSD risk reduction (Larson et al., 2014). The estimated operational efficiency financial benefits of 18 internal award winning case studies from 2010 and 2011 was over $3,500,000. Caroly et al. (2010) also described that there are both hard, quantified, financial benefits and soft, non-financial benefits of these types of ergonomic interventions.

The program elements in this case study are based upon research identifying what a successful ergonomics program should include (GAO, 1997; NIOSH, 1997; OSHA. 1993). The strength of this case study is that these elements are as much as possible applied within one global company with a common perspective and support of health and safety. The in-depth analysis of the 33 US locations that participated throughout the 5 years of the study was also valuable as the remediation of target jobs and MSD risk factors was shown to reduce both the incidences of WMSDs and the lost or restricted work days associated with WMSDs.

However, real world data has gaps and variability; this is especially true in a global company's data. In this review for example, the impact of acquisitions upon the program implementation results was not able to be researched. Also, the non-US and Canadian locations reported more variability in program implementation, which would have been interesting to understand, especially to research the program implementation and WMSD impact differences of various countries. The impact of program implementation is difficult to study given the real-world data limitations. Also, differences in country specific regulations led to inconsistent reporting of WMSDs. Due to these confounding influences, the global data analysis was limited to descriptive summary information of risk exposure reduction and percent program implementation by region. No formal analysis was possible regarding impact of program elements upon WMSDs. This is an area that needs further research in order to better understand the impact of each program element upon WMSD reduction.

Another issue in applied research is that there is no control group, and approaches of the trained and untrained experts could be different, thereby having an effect on the outcome of the study. However, if too much is standardized in research and microergonomic solutions are prescribed like in the study of Driessen et al. (2011), the primary needs of employees are not tackled and effects could be small. This study is quite the opposite: large effects, but not much is standardized in the research design as it is a field study from many locations with independence to decide for the intervention process and solutions. In previous overviews of field projects with few implementation restrictions, large effects are shown as well (e.g. Koningsveld et al., 2005). And, when we researched various microergonomic improvements after a comprehensive workplace improvement in an office organization, we found no significant additional effects upon WMSDs (Larson, 1996).

To increase the knowledge, there is a need for collaboration between research and practice, which is recognized within the ergonomics profession (Chung, 2011; Neumann, 2010; Buckle, 2011). The application of an ergonomics program is the world of practitioner. In the introduction it is shown that elements of the program are based on research, which could probably play a role in the success. But knowledge needs to be more specific and there is a need to find out which elements are crucial and which are less important. It seems that considering core ergonomics training and job assessment training of persons on the work floor can impact WMSDs in industrial operations (Haydee, 2011; Herrera, 2011; Stanton, 2003; St. Vincent, 1997; Vink, 2005), but also the macroergonomic, management commitment, and participatory ergonomics combinations seem useful for setting the stage for macroergonomics to be applied (Hendricks, 1996).

CONCLUSION

This study shows that a real world application of ergonomics to reduce WMSDs within a complex global company can be successful. The results prove that an ergonomics program consisting of elements of management commitment, identification and improvement of problem jobs, and knowledgeable location-based resources to reduce WMSD rates and severity is useful.

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3M Poland Manufacturing: An Ergonomics Success Story

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ABSTRACT

As a member of the European Union (EU), 3M Poland must comply with both Polish and EU law. The primary Polish Health and Safety law and EU norm (EN 614-1:2006+A1:2009 - Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles) describe the proper ergonomic design of machines and workstations. This paper describes two successful ergonomics case studies from two 3M manufacturing locations in Poland. It describes the job assessment process, details job assessment results, describes solutions implemented, and provides information about cost and benefits realized. In this session, two case study projects, one from Janinów and the other from the Rabka site, will be presented. One of these projects (Janinów) won 3M's internal Applied Ergonomics Innovation Awards (AEIA) in 2012, and the second from Rabka will be nominated for this same prize in 2013. The projects describe the application of the Ergonomics Risk Reduction Program, which improved workers' quality of life, productivity, and product quality, as well.

INTRODUCTION

The intent of the 3M Ergonomics Program is to use ergonomics expertise consistently throughout the company in order to improve employee health and safety through development and use of standardized program elements, job analysis tools, and training programs. Ergonomics program requirements are defined in one element of an internal Global Health and Safety Plan. One aspect of the program, 3M's Ergonomics Risk Reduction Process (ERRP), is a systematic process of identifying, prioritizing, assessing, and reducing unacceptable ergonomics risk in jobs throughout 3M's manufacturing and distribution operations. The ergonomics assessment tool provides a consistent, objective methodology to identify and quantify ergonomics risk exposure in all 3M manufacturing and distribution operations (Larson 2012). 3M recognizes ergonomics improvement through an Annual Ergonomics Innovation Award (AEIA). Over the past 11 years, over 600 ergonomic improvements from around the globe have been submitted to an internal database that all internal ergonomics resources can access.

The experience in Poland demonstrates that the ERRP and ergonomics job assessment tool also help the company comply with the Polish and European law (norm EN 614-1:2006+A1:2009 - Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles).

Two case studies, one from Janinow and the other from Rabka, will be presented. Job assessment results, solutions implemented, and information about costs and benefits realized will be detailed.

METHODOLOGY

The Ergo Job Analyzer (EJA) tool was used to evaluate jobs and identify unacceptable work-related musculoskeletal

disorder (WMSD) risk exposures (Auburn Engineers, 2003). The EJA tool is 3M's standard ergonomics risk assessment tool, which is applied at all manufacturing operations globally. A separate project team was established for each project. Team members observed, videotaped and photographed the activities of the workers, conducted a detailed assessment to measure forces and awkward postures, wrote descriptions of the main tasks, and interviewed the workers about their activities. After evaluating the job, the team, led by the location's ergonomics resources, identified and implemented appropriate controls. A follow-up assessment was conducted to verify all changes were successful in reducing WMSD risk.

CASE STUDY 1: JANINOW FEMA LINE – AUTOMATIC TURNOVER OF SCOURERS

Results from the ERRP review and listening to employee complaints suggested the FEMA line as having potentially unacceptable WMSD risk. The specific FEMA line required employees to manually turn over 40,000 scourers in order to properly orient the scourers for packaging. The primary employee complaints were related to extreme wrist postures, performing highly repetitive movements during the scourers production, and contact stress to the forearms. The location's ergonomics resource applied the EJA, and the assessment results supported the employee's complaints. Specifically, wrist postures – between 45 and 70 degrees – were repeated over 3,600 times per hand each workday (see Figure 1). Additionally, neck flexion, contact stress to arms, and hand turned palm down were also identified as concerns (see Figure 2).

A multidisciplinary team, including a production engineer, project engineer, MU supervisor, and external company designers, worked to improve the equipment and eliminate the identified unacceptable WMSD risk exposures. It was decided that, due to the potential for wrist strain injury in the execution of this task, it was a priority to eliminate the manual process and design an automatic station to turn over the scourers.

Figure 1: Repetitively turning over the scourers

Figure 2: Wrist posture and contact stress

Figure 3: New, Automated Machine

To verify the automation changes were effective at eliminating the unacceptable WMDS risk exposure, a new EJA assessment was completed. The assessment results indicated that the unacceptable risks for the operator from this line were eliminated by 80% (wrist flexion, repetition, mechanical stress to arms, hand palm down and neck flexion) and productivity was increased by 70%. Now the speed of the automatic conveyor is the same as the maximum speed of the whole line.

CASE STUDY 2: RABKA – MIXING AREA

As with the first case study, this project also was identified and prioritized using the ERRP: a workstation at the manufacturing area had employee complaints about the difficult work. The EJA resource applied the EJA to identify the unacceptable risk exposures, which corroborated the employees' complaints about lifting and carrying. Before the improvements, all the lifting and carrying tasks in the mixing were manual. There were three tasks in the mixing area that, when combined, resulted in an employee lifting and carrying over 9,000 kg each shift. The first task was transporting the resin in bags, which was delivered from a warehouse into the production area to the mixer; the second task was loading chemicals into the mixer; and the third task was transporting the material to the storage compound. Reducing or eliminating the lifting and carrying of the very heavy buckets weighing over 38 kg was the most important and critical issue for the Ergonomics Team (see Figure 4).

Figure 4: Weighing and transporting resin into mixer – 38kg per bucket

A multidisciplinary team worked to improve the equipment and eliminate the primary issues of lifting and carrying the materials. Additionally, the job assessment also identified bending and contact stress to arms as actions of concern. The objective of the project team in Rabka was to eliminate all ergonomically unacceptable risk in the Mixing Area. There were several improvements made to this process.

The first improvement was to use an electric truck with an embedded scale to eliminate the manual lifting of buckets to weigh the material. This change also made it easier to transport the resin from the mixing area to the press and facilitated the dumping of resin into the mixer. The new process is performed in one step by electric truck and eliminated three manual operations previously performed by an employee using buckets. Additional benefits were increased capacity and more accurate direct weighing of resin to the container as seen in Figure 5, thereby increasing process consistency and improving product quality.

Figure 5: Weighing and transporting resin into mixer using electrical forklift truck with scale

The second improvement was eliminating lifting of bags weighing 25 kg from the pallet (see Figure 6) and installing mini-silos or supersacks, which empty the resin directly into the container located on the new forklift. This improvement eliminated the manual lifting of two big bags in the Mixing Area. An additional benefit was a reduction in manufacturing floor space needed for this operation, allowing for the possibility of better managing the workspace.

Figure 6: Wooden pallet with 25 kg bags

The third improvement focused on eliminating the existing storage system and installing a new, fully automated storage system, as shown in Figure 7. The new system eliminated lifting of containers from the floor and reduced the floor space needed for the operation.

Figure 7: Silos and automatic storage compound system

After implementing the improvements, a new EJA assessment was conducted and employees were asked to provide feedback: the unacceptable risk exposures were totally eliminated and employees were satisfied with the improvements.

RESULTS

The FEMA line won a 3M AEIA award in 2012 and the Mixing Area improvements will be submitted for award consideration in 2013. The projects describe the application of 3M Poland's Ergonomics Risk Reduction Program. The results improved workers' quality of life and increased productivity and product quality. Before modification, there were some quality problems with the proper proportion of raw materials that were added manually by operators into mixer. After automating the process of mixing components, there are no more problems with quality.

CONCLUSION

These two case studies describe the application of 3M's Ergonomics Risk Reduction Process and the ergonomics improvements made in two manufacturing operations. In both projects, unacceptable WMSD risk exposure was eliminated. The results achieved improved the workers' quality of life, reduced overhead (reduced floor space for the operations), increased productivity, and increased product quality.

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Blending Corporate Ergonomics with European and French Regulations

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ABSTRACT

For global corporations with operations in France, a challenge has been to merge the European Union (EU) and French ergonomics regulations with the company health and safety requirements in order to achieve efficient and effective results without unnecessary work. In this case study the company's corporate ergonomics program focuses on reducing work-related musculoskeletal disorders (WMSD) and is more detailed and prescriptive than EU or French regulations. This paper details the way a global company with manufacturing operations in France meet both company and governmental regulations related to WMSDs. In 2008 a comparison of the company and EU requirements was completed. This paper describes the process, from the initial audit to the ongoing implementation of the ergonomics program as part of the health and safety management system throughout France. Using the company's risk reduction process and job assessment tools resulted in compliance with EU and French regulations and standards. It took only a year to see the first jobs evaluated and the reduction of unacceptable WMSDs risk exposures due to ergonomic intervention.

Keywords: Ergonomics Programs, Industrial Ergonomics, Macroergonomics, Participatory Ergonomics, Work-related Musculoskeletal Disorders, European Ergonomics, French Ergonomics

INTRODUCTION

EU safety and health legislation is based on a 1989 framework directive that specifies the principles of health and safety prevention and risk assessment. This directive details the guiding principles and defines the minimum requirements that must be implemented in order to promote continuous improvement in workers' health and safety. This directive has two goals: 1) place all European companies on an equal footing; and 2) ensure a high level of protection of workers to avoid pain and suffering while minimizing loss of company income due to risks related to work. Additionally, the company in this case study requires a high level of employee protection and improvement of health and safety and focuses on both regulatory compliance and proactive health and safety approaches. The company's ergonomics program is one of these approaches.

If risk prevention is not coordinated within a company, each site could, theoretically, meet local and company requirements with a job or specific program. But what use is it to accumulate tools for risk analysis related to work activity if they are not coordinated to serve a company's health and safety prevention strategy? What must be done faced with this potential situation?

This case study details the work carried out by France operations to implement the company's ergonomics program to reduce work-related musculoskeletal disorders (WMSDs), understand and respond to all the requirements of European directives, and integrate the program into the company-wide ergonomics prevention approach in the company.

Prevention Requirements of EU and French Regulations

There are minimum requirements of the European Directive 89/391 - OSH "Framework Directive" on the European Agency for Safety and Health at Work 1989 that an employer has to implement to promote continuous improvement of health and safety (EU Directive 1989). From a global point of view, a directive is a tool to harmonize national legislation. EU directives are legally binding and have to be transposed into national laws by the Member States. The directive establishes what the results must be, but each State can manage how to achieve the result. These minimum requirements are detailed in the French regulation with the same structure as the European Directive (EU Directive 1989):

- Keep a list of occupational accidents and illnesses.
- Evaluate all safety and health risks of workers.
- Designate worker(s) to carry out activities related to the protection and prevention of occupational risks.
- Implement measures which assure an improvement in the level of protection afforded to workers and are integrated into all the activities of the undertaking and/or establishment at all hierarchical levels
- Ensure that each worker receives adequate safety and health training.
- Consult workers on introduction of new technologies.
- Inform and consult workers and allow them to take part in discussions on questions relating to safety and health at work.
- Consider worker's capabilities as regards to health and safety when assigning tasks to workers.

The obligation addresses the implementation of a global process of prevention in the company. The Directive's approach is based on risk assessment in the company, followed by implementing a program of actions and training to improve health and safety among workers. For continuous improvement, the process needs to be actualized by consulting all the staff every year.

To evaluate this approach, an initial review was conducted at all company sites in France. All other company requirements were integrated through the company's health and safety management system. The aim of this review is to identify the health and safety processes already in place at each site, and then to interview all employees to understand their knowledge of and attitudes toward these risk management processes.

Initial Review

The initial review was conducted between October 2008 and June 2009 at all France operational sites. Interviews were conducted at all levels of the company, that is to say, from the site manager to operational staff.

The review identified these positive points:

- In the company, occupational accidents and illnesses are monitored in a common system.
- The company requires each site to implement a health and safety program with identified actions to eliminate risk, conduct training, and monitor compliance through :
    - Regularly scheduled audits to verify plan addresses risk prevention
    - Quarterly progress reviews
    - Risk assessment teams include health and safety committee members
- An organization was established with appropriate resources, i.e., central and local knowledgeable and skilled resources are in place to implement the system.
- Change management processes were in place at the main factories to address new products, new working areas, etc.

The review also identified these areas for improvement:

- **Programs**:
    - Risk assessments from various locations were not always comparable which made prioritization across all France facilities challenging.
    - Actions were often initiated as reactions to incidents instead of proactively addressing issues identified

in the risk assessments.
    - Additional ergonomics risks (handlings, repetitions, and awkward postures) were identified during the visits.

- **Resources**:

    - Health and safety resources on site needed additional training to more efficiently and effectively address ergonomics risks identified during the visits in the locations;
    - A process to assure communication of assessment results to operational staff was missing

- **Change Management:**

    - Updating risk assessments is conducted at least annually but also needs to be incorporated as part of a management of changes process.
    - Opportunities to incorporate health and safety improvements beyond ergonomics were not always taken.

ACTION PLAN: IMPROVE PREVENTION IN FRANCE OPERATIONS

A team composed of several operational areas worked to provide a concrete action plan to improve the process of prevention that was audited. Based on the findings, the proposed actions were structured on two axes: what needs to be improved and what does not need to be improved. The needed improvements included:

- Optimize the risk assessment tool by using the company model.
- Systematically initiate an action and training program based on risk assessment priorities.
- Update risk assessments to incorporate changes, modifications, and anticipated risks associated with new projects.
- Integrate operational teams when assessing risks.
- Implement the company's ergonomics program to reduce the potential WMSD issues that were identified during site visits, i.e., handlings, repetitions and awkward postures.

This action plan was presented to France site managers for review and validation. The stated goal was to optimize risk prevention because existing programs in order to more effectively meet the overall objectives of the EU Directive, the French regulation, and the company policy, specifically assure the protection of employees at work. The numbers of accidents and illnesses were trending upward.

Keep a List of Occupational Accidents and Illnesses

The human (accident and illnesses) and financial (direct cost of accidents and occupational illnesses) consequences were detailed during this meeting, providing strong arguments to support the plan.

To present this information, it was imperative to have a good list of occupational accidents, incidents and illnesses. This part of the European regulation is highly specified in the French regulation and is closely monitored by French authorities. In fact, each company must have a register of occupational near misses and incidents. But each accident or illness that needs medical treatment or more needs to be reported to French authorities, whatever the gravity of the injury. Each event is listed and then tracked by the authorities in terms of severity and costs.

We used these lists of accidents, illnesses, and diseases to graph the trend in WMSDs at the company operations in France. In 2009 ergonomics issues became the primary source of incidents related to occupational activity (see Figure 1).

This information confirmed the proposal to prioritize the company's ergonomics program.

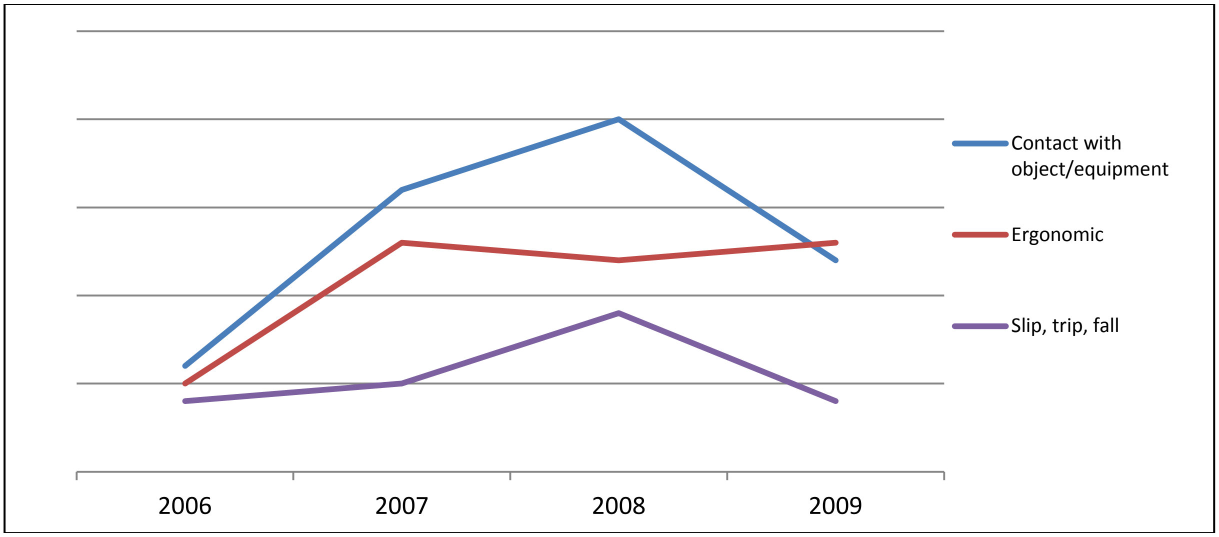

Figure 1: Trend of Accidents in France Operations

In addition, a financial analysis of the costs of these WMSDs was very influential in supporting the proposal to implement the program. It was based on direct costs related to WMSDs at company operations in France. As this information is confidential, the explanation will deal only with general data available in France.

The French National Agency for the Improvement of Working Conditions (ANACT) estimates a WMSDs cost between €100 to €500 per year per employee for all employees, even if many of them do not have a WMSD (ANACT). This represents for company operations in France a significant cost each year. If we consider that the indirect costs of these accidents and diseases are between 3-7 times the direct costs, productivity of some of our sites could be improved by working initially on improving health conditions and safety of workers.

At the end of this presentation, the action plan was validated. The France manufacturing management wanted to act quickly by engaging projects to improve working conditions. So, the first step was to optimize the risk assessment tool by using the company's model to determine if job analysis risk assessments would confirm the trends of occupational accidents and diseases.

Evaluate All Safety and Health Risks of Workers

From the EU point of view, there are no precise rules explaining how to assess risks. The French regulation provided these details in 2001:

- Identify hazards and risks in each work unit of the company for all occupational activities.
- Transcribe the results of risk assessments into a single document, accessible to all employees.
- At least once per year, update the assessments for any significant change or new information that may alter the initial assessment.

Who is exposed to a risk? What kind of risk? When? How? All these questions must be addressed in the risk assessment. However, even as initial assessments complied with regulatory requirements, it is a challenge for country-wide or global programs to be more proactive and implement programs and adjust resources in constantly changing manufacturing operations.

The implementation of the company’s risk assessment model allowed us to retain regulatory elements that were available in the previous assessments and to give more consideration to the risk assessments. Indeed this model defines a consistent level of exposure where preventive action can more proactively be addressed.

Following this initial step, which consisted of transferring the previous assessments into the new model, jobs were assessed. In the end, two categories were extracted: jobs that required preventive actions or programs or those jobs where levels of protection and prevention were limited to maintenance and/or monitoring.

In 2009, the company's operation in France was composed of seven sites, and more than 9000 job evaluations were done. Forty percent of the identified health and safety incidents were related to ergonomics. The recommendation of the audit was to act on preventing WMSDs. Thus manufacturing managers supported WMSD prevention by implementing the company's ergonomics program.

With these assessments, all sites were able to identify a list of jobs for which improvement projects were needed. It was necessary for each location to have a knowledgeable ergonomics resource.

The first part of the ergonomics program needed to be implemented while ensuring that the minimum requirements of the Framework European Directive were addressed:

- Implement measures which assure an improvement in the level of protection afforded to workers and are integrated into all the activities of the undertaking and/or establishment at all hierarchical levels.
- Ensure that each worker receives adequate safety and health training.
- Consult workers on introduction of new technologies.
- Designate worker(s) to carry out activities related to the protection and prevention of occupational risks.
- Inform and consult workers and allow them to take part in discussions on all questions relating to safety and health at work.

Involving Workers in the Program

The company's ergonomics program is based on the implementation of an internal organization at each site and the achievement of specific objectives. A key objective for each site is to have an internally "certified" ergonomic resource, which also meets the regulatory requirement to designate workers to carry out activities related to the protection and prevention of occupational hazards (Larson, 2012).

To be certified, a worker must develop and implement a minimum of projects after taking ergonomics training. An ergonomist approved by the company's corporate ergonomics ensures that the resource has correctly identified ergonomic risks using the company's tools and that the project has improved work conditions and prevented risks (Larson, 2012). In France there is no specific regulation on the kind of certification or degree a professional ergonomist must have to work in a company. The company's ergonomics program is much more prescriptive about this. In 2009, 10 people were trained and 4 were fully certified in France locations.

A certified ergonomics resource at each plant is also an indicator that management looks at each quarter. Each indicator, when it is below the level required, is systematically questioned. This shows both the support of the management but also the desire to improve working conditions. This focus on risk prevention promotes the development of skills in ergonomics globally.

Implementing Measures to Ensure Improvement

We have seen that risk prevention makes sense when an organization implements a program to improve the health and safety of workers (Larson, 2012, Vink, Imada, Zink, 2008). The risk assessment results identify the jobs that may need to be improved, but this is just the first evaluation that needs to be completed. The number of work areas to improve varied from only a few to several. These are projects the ergonomists have to further evaluate and implement interventions.. The company's ergonomics program provided guidance about how to prioritize projects.

A company tool is used to list and evaluate risks and provide management and ergonomic resources with the information to prioritize projects (Larson, 2014). Beyond WMSD information, accidental events, surveys of operators, opinions of occupational medicine professionals, and prevention organizations can also be considered. Each project selected is included in an annual health and safety program goal at each location.

The goal of the company's ergonomics was to achieve improvement of these identified jobs as part of a well defined goal (Larson, 2014). From 2010 to 2013, more than 130 unacceptable risks were reduced or eliminated and nearly 60 workplace improvement projects were carried out across 9 sites. At the end of 2013, the percent of ergonomic incidents was reduced to 30% when compared to other health and safety incidents.

However, during these years of improvements, many new projects were implemented in each site and there were

multiple modifications of existing work areas. Many of these changes were made without taking into account ergonomic studies or the opinions of certified resources or experts and are part of the ongoing effort to increase the proactive efforts to reduce WMSD risk exposure.

Ensure that Each Worker Receives Adequate Safety and Health Training

Another requirement of the company's ergonomics program is to train everyone at a site about their responsibilities and roles toward ergonomics. As detailed in the program, training must be adapted for all operational categories. This is more than what is required in European and French regulations. These requirements only focus on workers being trained "to handle loads correctly and the risks they might be open to particularly if these tasks are not performed correctly" (Council Directive 1990). However, this does not include addressing what are WMSDs, what are the steps to avoid risks, and what are the operator's responsibilities. This training goes beyond simple recommendations provided to an operator about work technique. At the conclusion of the training, each trainee must understand what goals need to be reached and how they can participate to achieve reduction in WMSD risk.

The employee training was conducted at the work area of the workers which helped to change opinions or behaviors regarding ergonomics at their own work location.. At the conclusion of this training, everyone agrees to two or three commitments as decided by the team. Instead of only providing advice to a worker, this training focused on shared commitments toward a specific goal such as avoiding awkward postures during activities.

It is necessary to train everyone at a facility, from supervisors, engineers, team leaders, staff representatives, and health and safety workers to operators so that everyone can identify what role he or she plays in ergonomics. The internally certified ergonomics resource on staff is the technical leader .but participation by all from management to operators is needed to facilitate the transition from reactive to preventive mode.

Some operators requested to take the full training to become ergonomics certified resources. Six operators were certified at two sites in the past two years. They successfully developed and implemented effective improvement projects at their facilities. They also trained their colleagues on specific workstations, participated in LEAN projects to improve work conditions as well as productivity, and they have been brought in to consult with employee representatives.

This extensive training has contributed to involving and engaging a greater number of employees in the prevention of safety and health and to facilitate:

- Identification of problems and their causes
- Participation in the development of practical solutions
- Formalization of advice, suggestions, and ideas for improvement
- Consultation of workers in new projects

This participatory approach led by location ergonomics resource allows more projects to include ergonomic consideration, even those which do not seem to relate to ergonomics (Vink, 2008).

Consult Workers on Introduction of New Technologies

The France regulations specify that each project that modifies health and safety conditions must be discussed with representative personnel (most of the time a union representative). A complementary approach involving representatives of workers to the direct participation of workers is also required when designing workplace modifications (Council Directive, 1990). Many ergonomics achievements have demonstrated that this approach is the simplest one. It corresponds to the desire of management for ergonomics to be integrated into several levels of the organization quickly and well.

But additional opportunities continue to emerge. As in many other corporations, management has introduced the LEAN manufacturing model as a basic tool for improvement (Bourgeois, Gonon, 2010). The specific opportunity is to integrate ergonomics into the LEAN process improvement projects during the design or modification study of a workplace to reduce WMSD risk exposure and improve working conditions as part of lean projects (Bourgeois, 2012).

Take into Consideration the Worker's Capabilities

To comply with this EU requirement, all operational people that can make changes or modifications to a work area were trained, including:

- Engineering team
- LEAN engineers and technicians
- Supervisors
- Process engineers
- Team leaders
- Maintenance workers

The goal was to train operators to integrate ergonomics during the creation or modification of a work area. At the end of the project, another analysis would be done to control if any additional risks were identified.

The training is based on the company's ergonomics design criteria (EDC). This tool ensures that changes or creation of a workplace will be made in accordance with the capacity of workers by setting thresholds for many criteria, such as manual handling, repetition, forces, postures, and environment (e.g., light and noise).

CONCLUSION

After all these steps, we have seen a reduction of the incidents related to ergonomics in France operations. This is quite positive because the number of sites has increased from 7 to 13 from 2009 to 2013. In 2012 this was particularly true because four new plants were integrated into France manufacturing. However, the maturity of the implementation of the company's ergonomics program in nine other plants likely contributes to the good results in 2013. This improvement also has an impact on WMSDs direct costs. But there is still room for improvement.

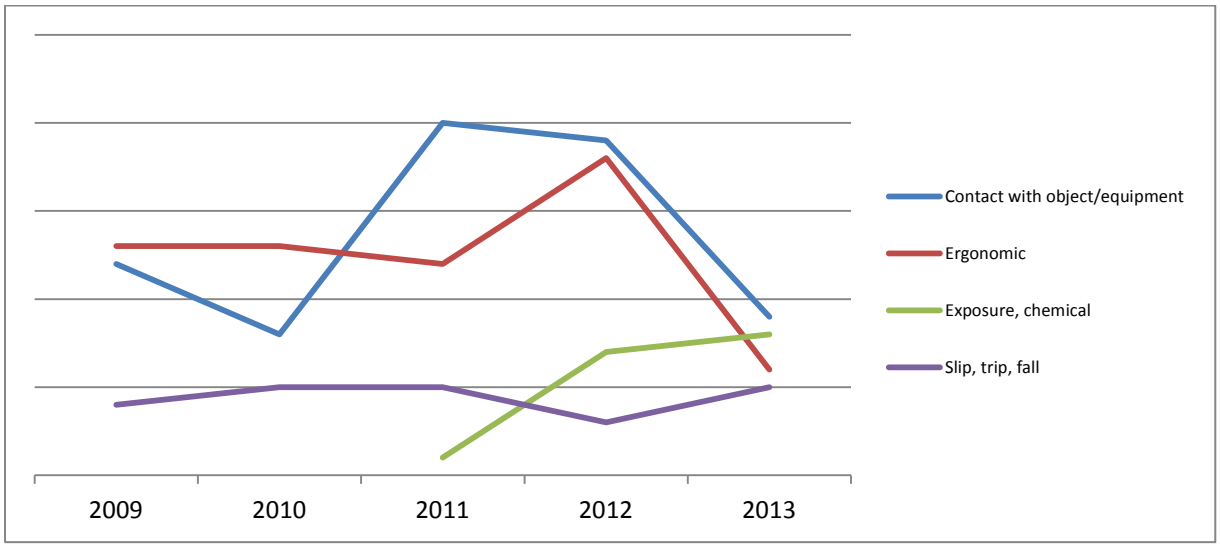

Figure 2: Company France EHS Incidents 2007-2013

WMSDs remain localized at four recently acquired sites as well as at an existing site. If the 1989 framework directive promotes continuous improvement of health and safety of workers, the implementation of simple requirements is not so simple. The company's ergonomics program Ergonomics Program facilitates this expansion by providing the practical tools and an easy-to-follow structure. From 2006 to 2009 the numbers of incidents was growing, and at the beginning of the implementation of the company's ergonomics program this trend was stabilized. The successful results suggest that the program should be fully implemented at each site.

The participation of operational staff, health and safety committees, and management commitment are essential to the improvement of working conditions within a company (Vink, 2008, Larson, 2012). Everyone must act toward prevention and continuous improvement of health and safety.

Also, this company program meets all the minimum requirements of the European Directive transposed in a local

regulation. Even if this program is prescriptive, it is more detailed than what the regulation addresses. The program allows facilities to meet regulations and provide powerful tools to go beyond. But it is necessary to blend them together. The example of how the ergonomics program was used to answer both regulatory and global corporate goals provides very good feedback to the company. The France manufacturing management has decided to structure all the others health and safety programs in the same way.

Opportunities to incorporate health and safety improvements beyond ergonomics can always be improved.. Action was often addressed through independent initiatives and collaboration tools. Also, prevention of WMSDs was not fully integrated into the business strategy. The biggest opportunity is to broaden the perceive value of ergonomics risk assessment from being a regulatory obligation to a real starting point of health and safety risk prevention. Risk prevention is not only a sum of numerous requirements to address, it is also a comprehensive and global approach to implementation.

Other aspects must be implemented within companies to prevent any drop in health and safety. Training and responsibilities of designers, packaging services, and teams of business need to be engaged. There is also a need to implement organizational measures (for example, flexibility) and training in ergonomics for human resources.

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WRMSD Survey. A Comparison Between Assembly and Manufacturing Tasks

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ABSTRACT

A survey about the presence of WRMSD was conducted at an industrial concern where automotive parts are produced, in the central region of Mexico. Two samples were involved. One of them consisted of 114 workers who perform assembly tasks using CNC hydraulic presses. The other contained 153 CNC lathe operators, who manufacture the parts to be later assembled. All subjects were male. Both groups operate Advanced Manufacturing Technology (AMT) machinery, facing both physical and cognitive demands. The subjects completed a questionnaire on the presence of musculoskeletal complaints, rating its severity on a 0-10 scale. Ninety percent of the assembly workers pointed to at least one body region with complaint; 85% of the manufacturers did the same. Most of the ratings fell in the 4-5 markings. Upper and lower back, neck and both wrists were the body regions most affected for the whole sample. Our findings are very much in line with the current trends, and clearly point to the need for ergonomic intervention in regards of workspace layout and tasks procedures, in order to diminish the risk of musculoskeletal damage for both groups.

Keywords: Musculoskeletal, Manufacturing, Assembly

INTRODUCTION

Appearance of musculoskeletal complaints, which may start as a minor hindrance and later develop into severe chronic damage, has long been cited in ergonomics literature as a frequent work-related occurrence. This has brought about the term Work-related Musculoskeletal Disorders (WRMSD). Recently a tendency has appeared to analyse the soundness of such proposed relationship. A number of papers have been published where this issue is tackled. A conclusion is common to the majority of these reviews: Although there still remains to be proven beyond doubt the link between work circumstances and musculoskeletal damage, the evidence points firmly to the role certain factors seem to play in either giving rise to the unwanted outcome, or in worsening a pre-existing, non-work related pathological condition. Thus, Punnett, and Wegman (2004) mention a series of work-related factors repeatedly identified as influential for the development of apparent WRMSD. These include "rapid work pace and repetitive motion, forceful exertions, non-neutral body postures, and vibration."

In their review paper, da Costa and Ramos Vieira (2009) make a very important discrimination between risk factors of a biomechanical nature, and those of a different nature. Among the first, they cite "excessive repetition, awkward postures, and heavy lifting". Among the second group of factors, the authors mention heavy physical work,

smoking, high body mass index, high psychosocial work demands, and the presence of co-morbidities. There is a noticeable coincidence between the factors listed by Punnet and Wegman (2004), and those named by da Costa and Ramos Vieira (2009). Albeit with slight differences in denomination, this is particularly true for the biomechanical features present in a work situation. The inclusion of psychosocial factors by the latter authors is a clear enrichment in the approach to this ever so relevant issue.

The present study was developed at two sites pertaining to an international concern devoted to the production of automotive parts, concretely, constant velocity joints (CVJ). The sites are located at Guanajuato, in the central region of Mexico. There is an ongoing relationship between our research group and this firm since 2011; the assessment of occupational ergonomics matters being an important part of it. The presence of musculoskeletal complaints among the work force has been a major concern for the medical officers at the sites, and the managers share this preoccupation.

The making of CVJ involves three main productive operations: forging, machining and assembly. All three production areas include the operation of advanced manufacturing technology (AMT) machinery, where the operator faces both physical and cognitive demands. Since this is more prevalent in the machining and assembly sections, the study here reported contemplates only those two productive areas. In the machining operations the AMT machinery is present in the form of CNC lathes; in the assembly process it takes the form of CNC hydraulic presses. Figure 1 shows these two types of machinery, illustrating as well the prevalent working conditions.

Machining process using a CNC lathe

Assembly process using an hydraulic press

Figure 1. Machines used in machining and assembly process

Because of their bearing on the results of the study, it is worth mentioning some important differences between the two productive realms. First one is the nature of the production operation itself: the manufacturing of three main pieces in machining, named “bell”, “semi-axis” and “tulip”. Two kinds of product generate the assembly operation performed on those parts: short CVJ, and long CVJ. A second difference comes from the shape of the parts being manipulated: the machining operation generates separate components with a maximum length of 70 cm which are rather easy to hold one-handedly; assembly creates a set with a length that ranges from 80 cm to 110 cm which in its final shape requires the use of both superior extremities.

A third and logical difference comes in the weight of loads being handled. Whilst in the machining process the pieces weigh an average of 4.5 kg., in the assembly process the average weight is 7 kg. A fourth difference, quite important from the ergonomics perspective, is the nature of postures linked to each productive operation, albeit both involve the same basic tasks and movements, namely, 1) the loading-unloading of pieces in the machine, 2) operations on the machine’s control panel, and 3) the inspection of the pieces once the process is completed.

Another factor is worth mentioning. Due to increased demand from the market, starting precisely on 2011 the firm’s managers put in place an extended 12-hour shift throughout four week days, with a two-days’ break. This scheme involves two work shifts, and once completed a six-day cycle, the worker returns to a different shift. From the initial approach to the field operators, they have expressed the existence of "excessive tiredness or fatigue" at the end of their working day, as well as experiencing an increase in musculoskeletal discomfort generated by their work.

When the early findings were presented to the firm's managers and medical officers, they requested the performance of the study here reported. Its main goals were:

- To determine the presence of WRMSD among workers of machining and assembly operations.
- To determine the intensity level of WRMSD.
- To compare the findings for both productive operations.

METHODOLOGY

Study design

The study design is non-experimental, descriptive, and cross-sectional. Permission was obtained from the company´s managers beforehand. The survey was applied to workers classified as CNC lathe machine operators and homokinetic joints assembly operators, who were previously advised of its application.

Sample

A sample of 114 CNC lathe machine operators and 153 homokinetic joints assembly operators was obtained from the company's records using proportional simple random method. Once selected, workers were individually screened for the following criteria inclusion: at least six previous month experience as a CNC machine operator, no history of musculoskeletal injuries in the past six months, and no history of cardiovascular disease. After being screened and upon acceptance to participate, workers signed a consent form which also informed them on the purpose, information to be collected, procedures, risks and benefits, and measures to ensure confidentiality.

Materials

A three-part survey instrument was devised for the study. The first part incorporated Corlett-Bishop (1976) map (figure 2); the subjects were asked to point on the figure those sites where they had experienced some form of discomfort (however light this might be) over the prior 15-days period, *and which they judged to be linked to their work for the company*. In part two, they were asked to signal the intensity of the perceived sensation, using Borg's 10 point scale of perceived physical discomfort (Borg, 1996) (shown as table 1). The third part of the instrument gathered information on a number of demographical features relevant to the purposes of the study.

Procedure

The survey was applied during off-duty periods. After selection and screening of the subjects, trained research assistants administered the questionnaire. Selected participants were summoned to a meeting room where they received an oral explanation on the project and instructions on how to complete the questionnaire. The research associate was present at hand to answer any questions or doubts which arose from the questionnaire. Once they completed the questionnaire, every participant received a small present.

Data analysis

Descriptive and proportion analyses were performed on all variables. In order to determine if differences of WMRSD between the two samples were significant, a two-proportion hypothesis test was applied. Level of significance was set at $\alpha = 0.05$. The SPSS V17.0 software was used for data analysis.

Code	Body region
1	Left elbow
2	Left arm
3	Left shoulder
4	Neck
5	Right shoulder
6	Right arm
7	Right elbow
8	Left leg
9	Right leg
10	Left ankle
11	Right ankle
12	High back
13	Middle back
14	Low back
15	Buttocks
16	Left hand
17	Right hand
18	Left wrist
19	Right wrist
20	Palm of the left hand
21	Palm of the right hand

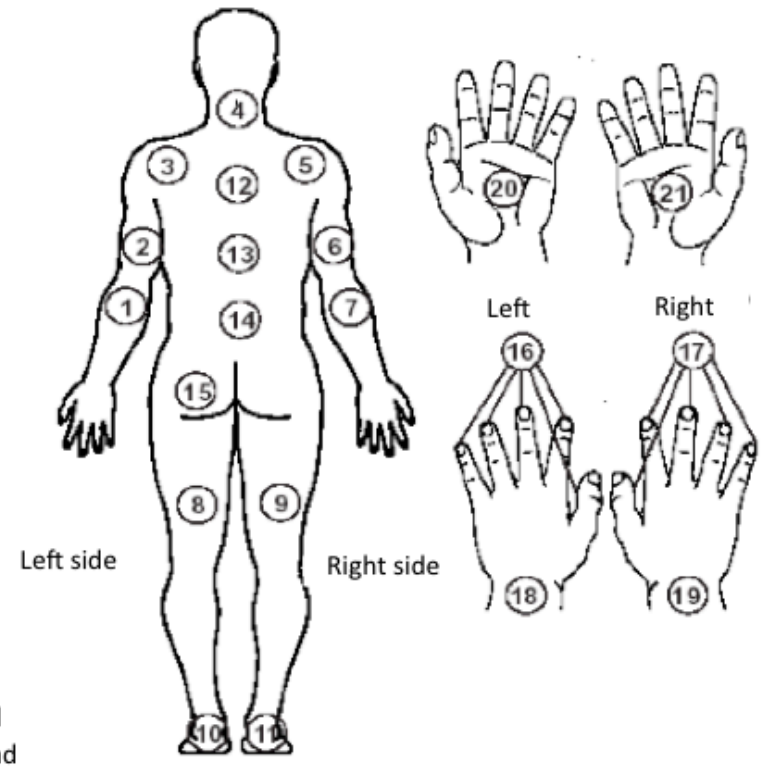

Figure 2. Corlett-Bishop map

Table 1. Borg's 10 point scale of perceived physical discomfort

Point	Description	Point	Description
10	Very, very severe	4	Somewhat severe
9		3	Moderate
8		2	Slight
7	Very severe	1	Very slight
6		.5	Very, very slight
5	Severe/heavy	0	Nothing at all

RESULTS

A total of 267 workers participated in the research. One-hundred and fifty-three of them operated a CNC lathe to manufacture some of the parts that later will form CVJ; the remaining 114 worked in a facility where CVJ are assembled through the operation of CNC hydraulic presses. All the subjects were male. Table 2 shows demographic data for machining operators; data for assembly workers appear in table 3.

Table 2. Demographic data of machining process operators

Variable			Variable			Variable		
Age (years)	**N**	**%**	**Body stature (cm)**	**N**	**%**	**Body weight (kg)**	**N**	**%**
<20	5	3.3	<150	8	5.2	<60	2	1.3
21-30	94	61.4	151-160	79	51.6	61-70	18	11.8
31-40	38	24.8	161-170	55	35.9	71-80	36	23.5
41-50	12	7.8	171-180	8	5.2	81-90	42	27.5
>51	4	2.6	>181	3	2	>90	52	34
No answer			No answer			No answer	3	2
Total length of sleep during a day (hours)	**N**	**%**	**Length of stay in the firm (years)**	**N**	**%**	**Seniority in current job (years)**	**N**	**%**
<5	5	3.3	<1	37	24.2	<1	52	34
5-6	50	32.7	1-3	51	33.3	1-3	44	28.8
6-7	56	36.6	3-6	28	18.3	3-6	29	19
7-8	26	17	6-9	19	12.4	6-9	12	7.8
8-9	6	3.9	>9	17	11.1	>9	6	3.9
>9	1	.7	No answer	1	.7	No answer	10	7
Number of dependent persons	**N**	**%**	**Marital status**	**N**	**%**	**Educational status**	**N**	**%**
0	7	4.6	Single	27	17.6	Middle School	9	5.9
1-2	76	49.7	Married	124	81	High school	64	41.8
3-4	65	42.5	Divorced	0	0	Technic degree	79	51.6
>5	3	2	Common law marriage	2	1.3	No answer	1	.7
No answer	2	1.2	No answer					

Table 3. Demographic data of assembly process operators

Variable			Variable			Variable		
Age (years)	**N**	**%**	**Body stature (cm)**	**N**	**%**	**Body weight (kg)**	**N**	**%**
<20	3	2.6	<150	1	.9	<60	18	15.8
21-30	59	51.8	151-160	28	24.6	61-70	28	24.6
31-40	46	40.4	161-170	52	45.6	71-80	47	41.2
41-50	6	5.3	171-180	31	27.2	81-90	15	13.3
>51	0	0	>181	2	1.8	>90	6	5.3
Total length of sleep during a day (hours)	**N**	**%**	**Length of stay in the firm (years)**	**N**	**%**	**Seniority in current job (years)**	**N**	**%**
<5	6	5.3	<1	35	30.7	<1	38	33.3
5-6	52	45.6	1-3	27	23.7	1-3	30	26.3
6-7	32	28.1	3-6	25	21.9	3-6	24	21.1
7-8	17	14.9	6-9	27	23.7	6-9	21	18.4
8-9	7	6.1	>9	0	0	>9	0	0
>9	0	0				No answer	1	.9
Number of dependent persons	**N**	**%**	**Marital status**	**N**	**%**	**Educational status**	**N**	**%**
0	5	4.4	Single	29	25.4	Elementary school	1	.9
1-2	52	45.6	Married	85	74.6	Middle School	80	70.2
3-4	49	43	Divorced	0		High school	24	21.1
>5	4	3.5	Common law marriage	0		Technic degree	9	7.9
No answer	4	3.5	No answer			No answer		

Work-Related Musculoskeletal Disorders

Figure 4 shows the absolute frequency of WRMSD on all 22 body segments depicted in Corlett-Bishop map. For both samples the highest frequency of WRMSD was observed on low back, high back, neck, right ankle and right wrist, precisely in that order.

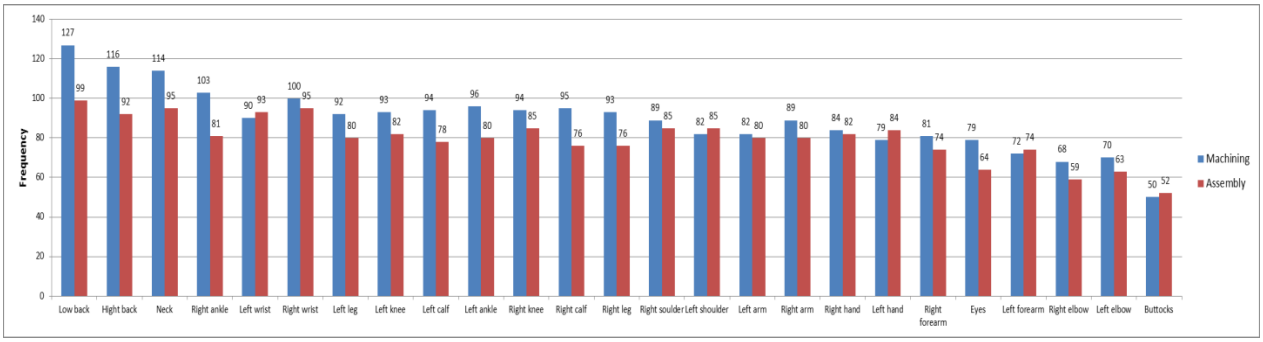

Figure 4. Absolute frequency of WRMSD in both samples

Because absolute frequency values might be misleading, the data was converted into sample proportions. The result is shown inf figure 5.

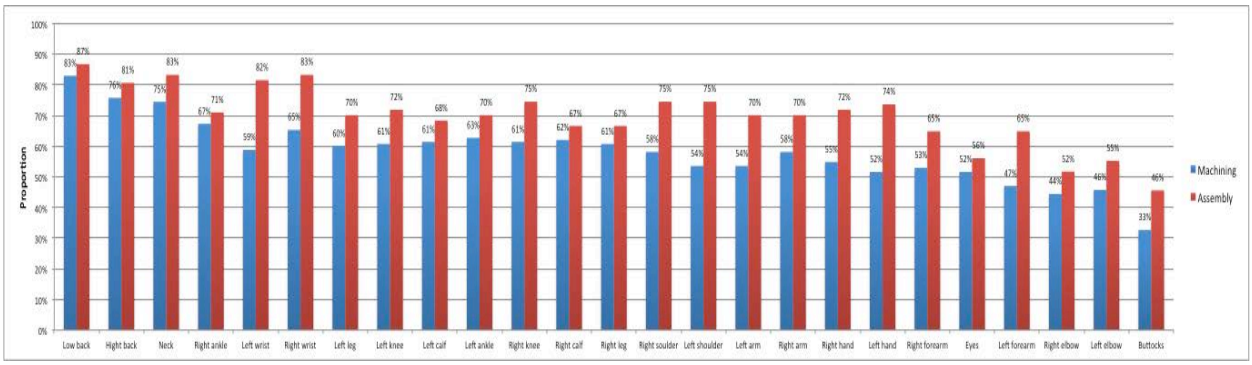

Figure 5. Proportion of WRMSD in both samples

Modal values for the intensity level of WRMSD as reported were identified. This is shown in figure 6.

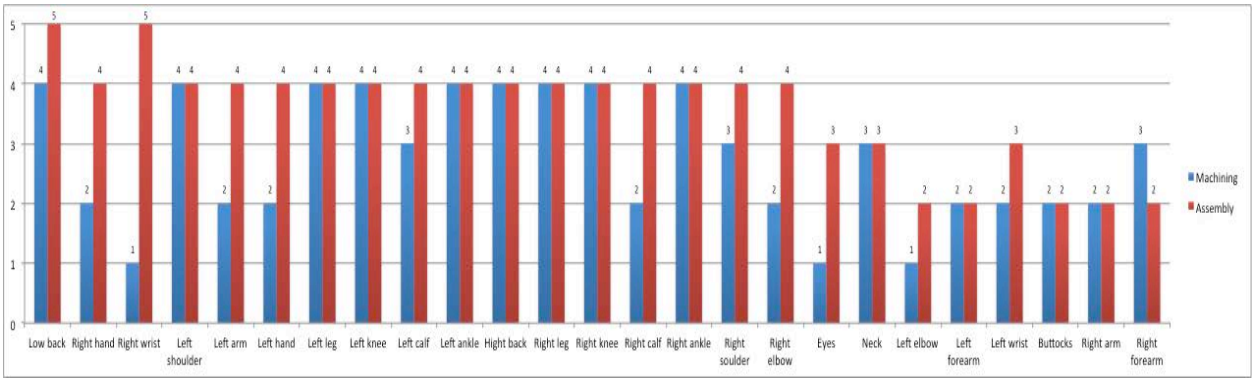

Figure 6. Intensity level of WRMSD. Modal values.

A two-proportion hypothesis test was applied probing for significant differences between the two groups of workers. The main results of this procedure showed that proportion of discomfort in assembly workers was significantly larger on *left wrist, left shoulder, buttocks, and left forearm*. On the other hand, proportion of discomfort was significant higher among machining operators on *right wrist, right knee, right shoulder, left arm, right arm, right hand, left hand, and right forearm*. No significant differences were found on the rest of body segments considered.

A summary of these findings, as well as the relevant descriptive measures is shown in table 4.

Table 4. Descriptive measures and statistical analysis results

Body zone	Frequency assembly	Frequency machining	Proportion assembly	Proportion machining	Proportion Difference	P value	Significant Difference?
Left wrist	93	90	82%	59%	0.228	0.001	Yes
Left shoulder	85	82	75%	54%	0.210	0.001	Yes
Buttocks	52	50	46%	33%	0.129	0.031	Yes
Left forearm	74	72	65%	47%	0.179	0.004	Yes
Right wrist	95	100	83%	65%	0.180	0.001	Yes
Right knee	85	94	75%	61%	0.131	0.024	Yes
Right shoulder	85	89	75%	58%	0.164	0.005	Yes
Left arm	80	82	70%	54%	0.166	0.006	Yes
Right arm	80	89	70%	58%	0.120	0.044	Yes
Right hand	82	84	72%	55%	0.170	0.005	Yes
Left hand	84	79	74%	52%	0.221	0.001	Yes
Right forearm	74	81	65%	53%	0.120	0.049	Yes
High back	92	116	81%	76%	0.049	0.341	No
Low back	99	127	87%	83%	0.038	0.39	No
Neck	95	114	83%	75%	0.088	0.084	No
Right ankle	81	103	71%	67%	0.037	0.515	No
Left leg	80	92	70%	60%	0.100	0.09	No
Left knee	82	93	72%	61%	0.111	0.058	No
Left calf	78	94	68%	61%	0.070	0.238	No
Left ankle	80	96	70%	63%	0.074	0.205	No
Right calf	76	95	67%	62%	0.046	0.441	No
Right leg	76	93	67%	61%	0.059	0.324	No
Eyes	64	79	56%	52%	0.045	0.465	No
Right elbow	59	68	52%	44%	0.073	0.237	No
Left elbow	63	70	55%	46%	0.095	0.124	No

Level of significance $\alpha = 0.05$

DISCUSSION

Body parts most affected by musculoskeletal complaints were strikingly similar for the two groups of workers who took part in the study. Both lower and upper back, neck, left wrist and right wrist were signaled as sites of complaint by over 80% of the assembly workers. Among the machining operators such rate was reached only for the low back, albeit high back and neck were quite close to it.

Another feature worth noticing in the results is that complaint rates were consistently higher for the assembly operators. Nonetheless, regarding the top 5 sites of complaint, statistical tests found equality of rates for lower back (87% assembly, 83% machining), upper back (81%, 76%) and neck (83%, 75%). In a stark contrast, significant differences were found for the rates of complaint for both left wrist (82% assembly, 59% machining) and right wrist (83%, 65%).

The affected body segments in both groups are very much in line with the findings of the review papers already cited. The biomechanical factors there mentioned are clearly present in their work circumstances, particularly forceful exertion, heavy lifting, awkward or non-neutral body postures and repetitive motion.

On a different approach, modal values for the intensity levels assigned on Borg's scale offer a very interesting insight to the complaint patterns in the two groups. They are rather close for the low back, where the machining operators reported the highest intensity with a value of 5; here the assembly workers assigned a 4. A rather unexpected contrast comes with the values for the right wrist, for whilst the proportion of assembly workers who complained was significantly higher, the situation is markedly reversed in regards of the intensity level, with a mode of 5 for the machining operators and 1 for the assembly workers. This no doubt relates to repetitiveness and awkward postures, which are worse for machining operators. Other than that, most of the equalities shown for the proportion of complaint rates are replicated for the intensity levels.

CONCLUSIONS

The findings herein reported make a clear case for an urgent intervention seeking to enhance the ergonomics of the productive operations subjected to analysis. Rates of complaint over 80% are absolutely unacceptable. Fortunately the firm's management fully agreed with this appreciation and has started an ergonomics program in both facilities involved.

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Design, Maintenance and Refurbishment of Turbines in a Collaborative Environment

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ABSTRACT

In this paper, a conceptual prototype of a collaborative tool for supporting decision making in the context of power plants maintenance is presented. The context of this industrial problem together with an analysis of the need for such a tool is also described. Then, a use case analysis is performed, as a conceptual specification of this tool. This conceptual prototype was evaluated using the cognitive walkthrough technique and the results of that evaluation process are also presented here.

Keywords: Collaborative work, 3D visualization, Cognitive walkthrough, Turbine maintenance.

INTRODUCTION

Inspection of turbines in Fossil and Nuclear Power Plants presents some challenging issues in balancing different needs for representation and the extent to which business concerns permit common representations can be shared. On the one hand, the results of these inspections have to be communicated in the most accurate way, especially if defects have been detected, to the power plant, to the engineers who have to evaluate the results and the company that has to carry out the repair. On the other hand, this information could also be shared with the companies in the supply chain that designed, supervised and manufactured the turbine so that they can analyse the problem, propose a definitive solution and even modify the design to avoid these kinds of problems in future designs.

The Use-it-Wisely (UiW) project funded by the European Union within the 7th Framework Program, is tackling these issues by investigating a new business model that implements continuous product-service adaptation. An adaptation platform will be developed, including a multi-disciplinary actor-product-service system model, an adaptation mechanism based on the knowledge and skills of all actors involved in the system and an interactive collaborative distributed environment. One of the industrial cases where these ideas will be demonstrated is focused on the decision-making process after the inspection of a turbine in a power plant.

Tecnatom is a Spanish company that carries out routine turbine inspections in FPPs (Fossil Power Plants) and NPPs (Nuclear Power Plants across more than fifty gas and steam turbines from different technologies and manufacturers. The results of these inspections have to be transmitted in the most efficient way, especially if defects have been detected, to the power plant, to engineering to evaluate the results (sometimes Tecnatom, other times the turbine designer). They are sent to the company that has to carry out the repair. This information also has to be shared with the companies that designed, supervised and manufactured the turbine so that they analyse the problem, propose a definitive solution and also modify the design to avoid similar problems in future designs.

Apart from the inspections, these turbines could have some kind of design modification due to different plant requirements: increase of the electric power generated by the plant, avoid specific degradation mechanisms, such as magnetite deposition, etc. Depending on the reason for the modification, including the percentage of power increase compared to the original one, the whole turbine or merely a subset of it may have to be replaced. These improvements may delay or even avoid whole-turbine replacement, and consequently reduce overall costs in terms of time, materials and lost production.

In these cases, Tecnatom's interest is centred in reviewing the design before it has been applied in order to guarantee that the new or improved parts could be inspected as well as the requirements of such inspection. Moreover, Tecnatom sometimes provides advice about the feasibility of the change from the point of view of maintainability. In all those cases the communication between the different actors: power plant or final user, the turbine designer, the manufacturer, the companies that carry out the maintenance, the engineering firm that evaluates the results of the inspection, the engineering company in charge of the repair/modification, and so on, are both very important and somewhat challenging.

During the last 15 years, Tecnatom has internally developed software tools to manage the inspection and testing plan as well as the subsequent results of such inspections. These tools are successfully implemented in several Spanish FPPs, coal fired and combined cycle plants. Recently, our end users (mainly plant owners) have identified a requirement for a more reliable tool which provides value-added services in collaborative environments for supporting the decision making process along the life cycle, from designers to engineers.

Therefore, the specific objectives in the updating of these tools to generate an innovative and smarter one, can be broken down into the following requirements:

- The provision of interactive 3D drawings in which the results of the inspections, the modifications/repairs carried out could be introduced. The application should be compatible with the most popular formats of spreadsheet, photography and CAD systems: .xls, .jpg, .dwg, .igs, .stp;

- The availability of 3D part library (e.g., screws, blades of different designs) in order to check the results of the design modifications, selecting the best proposal, before it is put into practice. In this aspect, designers don't usually take into account accessibility issues to maintenance and inspection;

- The availability of inverse engineering tools to recalculate stress, strains, etc. The application should be able to easily export data to FEM (Finite Element Modeling) tools such as ANSYS (compatible formats: IGES or STEP).

- Connection with simulation tools (such as those associated with Computational Fluid Dynamics) in order to know how the operation affects existing defects in the turbine.

In this case, all actors have different knowledge and different goals. The different stakeholders may have difficulties understanding the situation in the same way and may find it difficult to communicate their own view. Actors may make different proposals that the plant has to evaluate. It is very hard to make comparisons with previous inspection data and while decisions get made it is not clear that all outcomes have been equally or fairly evaluated. As a result, it has been noted that when a problem is detected in a turbine, the decision making process for solving it, takes a long time, since many actors are involved and the available information is based on paper reports and 2D drawings.

We envisage UiW aiding in the following example scenario: Tecnatom, as the inspection company, has detected a problem in a turbine's blade (e.g. a crack in the foot). All the results of the inspection are entered in the tool (including pictures) through pre-defined templates and are added to the common model where all the information is stored and managed. There are four possible decisions to be taken:

1. Leave the blade as it is and reschedule subsequent inspections for shorter periods (e.g. every 2 years, instead of 8);

2. Repair the blade and reschedule inspections, increasing the inspection scope (e.g. in 4 years, instead of 8; the inspection time is increasing up to 3 days.);

3. Substitute the blade for a new one and reschedule inspection (e.g. in 4 years, instead of 8);

4. Redesign the blades considering the information collected from past inspections, taking advantage of this change to improve design for vibration reduction or turbine efficiency increase.

In order to take the optimum decision, several actors have to discuss the situation: the owner of the turbine (Power plant), the designer, the manufacturer (involved in case of redesign), the inspection company and the engineering firm. All these actors have access to the common model which includes 3D models, annotations, documents, etc. (maybe it could require different user interfaces depending on the user profile). All actors can discuss on the model, add arguments and decide which the best option is, considering economic and technical issues.

The innovative and refurbished tool proposed will provide increased added-value to a wide range of users since it will facilitate the sharing of this information through a collaborative network while ensuring simplicity in the data access. This will enable seamless communication among all actors and also will lead to a reduction of costs by minimizing set-up and ramp-up times.

Within the UiW project, tools will be developed for sharing a 3D visualization of parts where the inspection has taken place. This visualization system has to be linked to a database containing inputs from the maintenance companies, the manufacturers, the plant operational experience, and so on. In addition to these tools, some collaborative methods will be developed. The goal is for the stakeholder team to have a set of linked visualizations based around a common model that everyone can understand

This paper will present the results of the first iteration of the project, where a conceptual prototype of tools and methods has been evaluated.

DESIGN PROPOSAL

All the models in the present paper were generated through an iterative participatory process in which industrial experts in the cluster have challenged, corrected and validated these models during online meetings. With all the information collected from the company, a functional model describing the use cases was produced. A functional diagram approach based on SysML syntax (Object Management Group, 2012) for use case modelling has been used, where the functionalities required by actors are depicted as Use Cases. In addition to this process were produced dynamic models for relevant dynamic problems.

Uses Cases Description

This section describes a use-case model of a system which would solve the problem of information flow among the actors involved in the decision processes within turbine inspection and maintenance. The system that is expected to be developed would integrate a virtualized common system model that would provide mechanisms for information sharing and decision support.

The system described would act as complement to the virtualized model of every plant, supporting the existing applications in Tecnatom to provide 3D visualization and information sharing to support decision making.

Actors

- Tecnatom Inspection Team: This actor represents the team of Tecnatom in charge of planning inspections, execute them and inform about these results.
- Tecnatom Engineering Team: This actor represents the team of Tecnatom in charge of preparing and executing simulations, analysing the results and introducing them in the model.
- Power Plant: This actor represents the technical staff or management of the company that owns the power plant, or its subcontractors, i.e. Maintenance Team and Engineering.
- Plant Models: This actor represents the databases (DBs) that contain the model of the whole Power Plant. Only the part of that model representing the turbines and associated information is of interest for the UiW system.
- 3D Models: This actor represents the Databases that contain the 3D geometry of the different turbines.
- Finite element simulations tool: This actor represents the tools those are used by the actor Tecnatom Engineering Team to execute the simulations.

Use Cases

Use-Case: Post Inspection collaborative decision making

When a defect is discovered during the inspection of a turbine, a collaborative mechanism is started to give the actors the possibility to make different proposals to deal with this defect. Based on this proposal a discussion is started among the stakeholders to reach a consensus decision about which of the proposed solutions is best in terms of cost, risk of future failure and duration of power plant shutdown time.

Use-Case: Visualize information about general state of the Turbine

The actors wish to visualize the current state of a turbine and its parts. The system gives the actors the possibility to navigate through the turbine model and have access to visualization of all the information stored in the model about the state of the turbine, including plans, technical parameters, simulation results, etc.

Use-Case: Visualize the status of an inspection and its results

Using the system the actors navigate through the turbine model and are able to visualize the results of all the inspections realized in the past. They are also able to get information about one inspection in particular, its results and the state of the turbine after and before the inspection. The actors are also able to visualize all information of corrective maintenance that rose due the results of an inspection: repairs, replacements, etc.

Use-Case: Visualize 3D model of Turbine

The system provides an advanced 3D visualization tool by which the 3D geometry of the turbine is linked to the virtual model to allow spatially situated visualization of the turbine´s maintenance history.

Use-Case: Input of proposals, annotations and conclusions[1]

When a defect is detected during an inspection different actions are possible. The system provides a tool to allow every actor to register their proposal or annotations to solve a defect or defects. Proposal will be registered in a standard format, including estimated cost, execution time, etc. In the same way, the system provides to the stakeholders a tool to document all the decision making process.

Use-Case: Get information of model to simulations

If during an inspection a defect is found but a fix or a replacement are not possible, a simulation can be performed to predict the future behaviour of the turbine before reaching a decision. These simulations are done in external applications but based on the results of the inspection. The system provides a mechanism to export the geometrical results of the inspection in order to be imported in the simulation tools.

Use-Case: Input of position and size of defects[1]

When flaws are discovered, in an inspection, it is necessary to register their position and size into the model. In most of the cases if not possible to do this in an automatic way, so the actors have to be able to register the position and size of defects using a 3D graphic tool provide by the system.

Relationships

The use-case *Post Inspection collaborative decision making* has an include relationship with these four other use-cases: *Visualize information about general state of the Turbine*, *Visualize the status of an inspection and its results*, *Visualize 3D model of Turbine*, *Input of proposals, annotations and conclusions* and *Input of position and size of defects*.

These relationships show that the main use-case is that of helping in the post inspection decision making process. Analysis of this main activity results into five use-cases which are linked to external systems that provide information to support this process.

[1] The use-cases show here are the final and agreed-upon versions after the trial. See “Results” section.

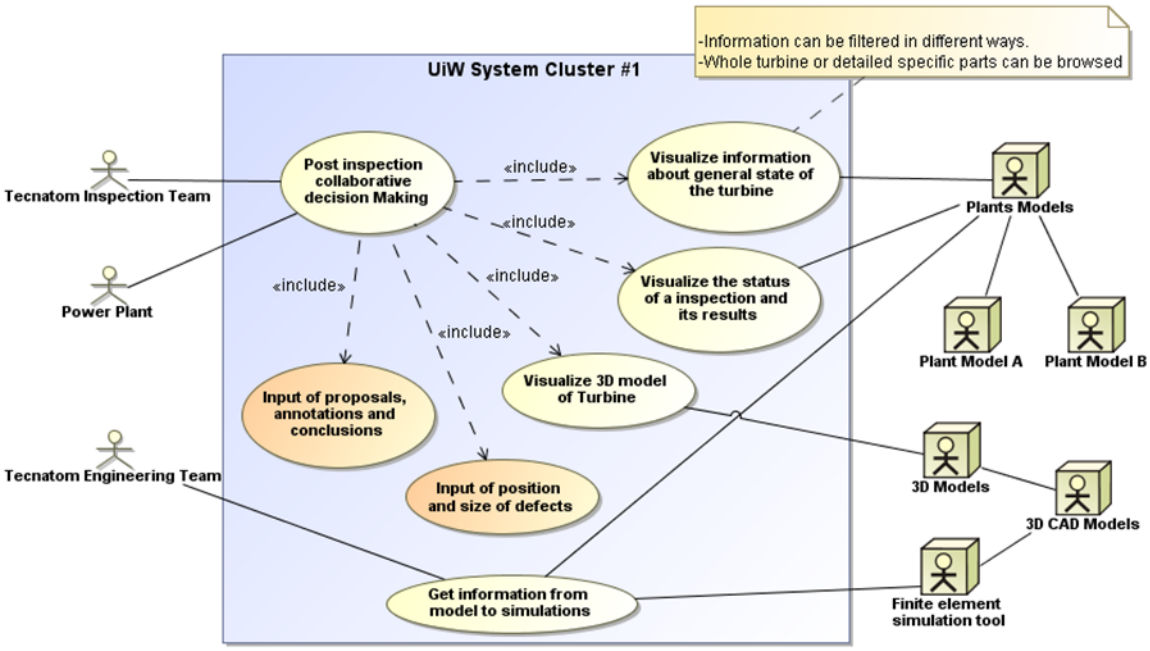

Figure 1. Diagram of the Use Case Model[1]

TRIAL

This section describes the findings of a cognitive walkthrough (Wharton, 1994) that took place to verify that the system modelled met the expectations of all stakeholders, i.e., that all of them could perform their daily tasks with the system. Was detailed a plan that contained a description of the actors, a first draft of the interfaces, and a diagram that depicted the usual work flow for the various actors. All this, together with the use-case that implement the system and the APS (Actor Product Service) data model allowed us to check if the actors could deal with these situations by using the UiW system.

Methodologically, the cognitive walkthrough took the form of a meeting in which attendants took three different roles: Facilitators who understand how the system works (or will work); Experts who understand the tasks at hand and perform the role of a certain actor; Secretaries who are in charge of recording everything that happens during the meeting.

Prototype Description: Interfaces

The draft versions of the application interfaces presented here will be used in the cognitive walkthrough. The first of these interfaces is intended for a situation in which the actors will likely have the priority to interact with model information through 3D visualization

[1] The use-cases shows in different colour are those which were modified after the trial. See “Results” section.

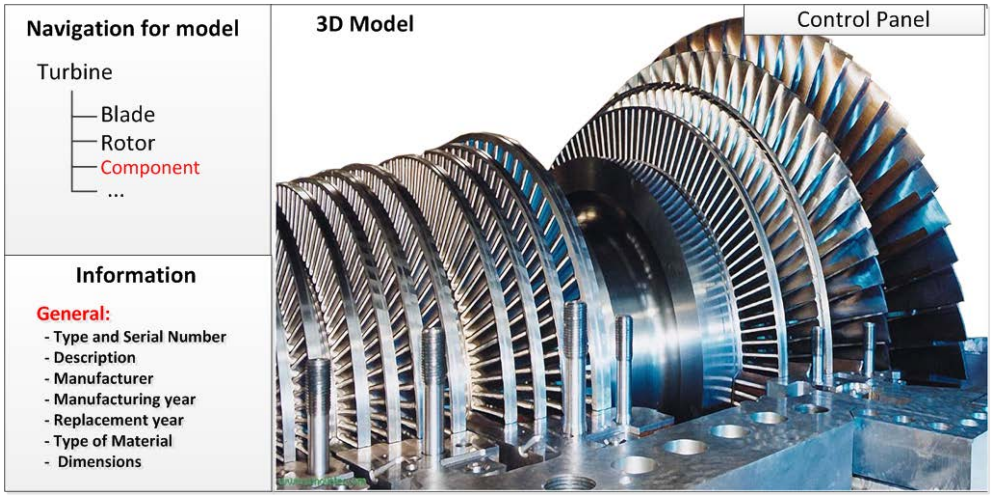

Figure 2. Interface prototype. 3D Visualization Use-Case.

The second interface is intended for a situation in which the actors need to access all the information related to the area selected: descriptions, technical parameters, defects, reports, etc.

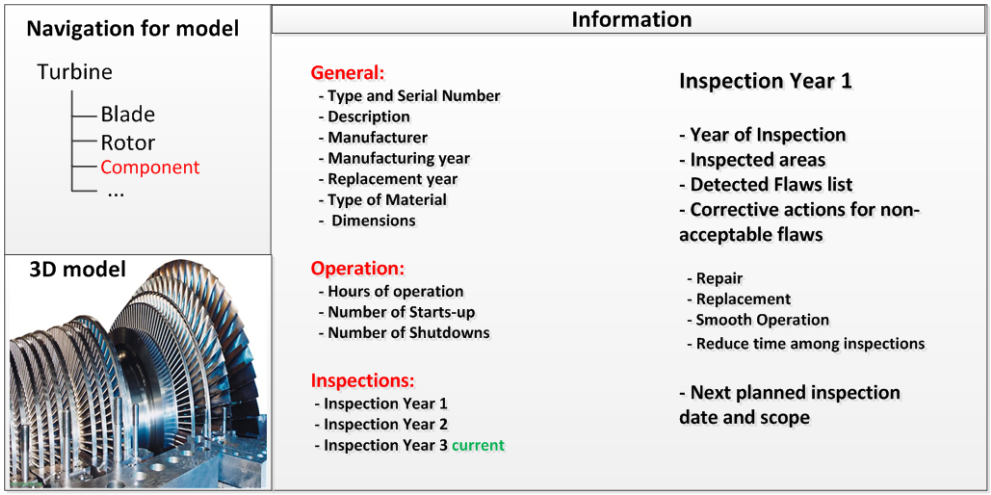

Figure 3. Interface prototype. Visualization of current status of the turbine

Prototype Description: System Model

During the first design iteration, in addition to this functional analysis, a draft structure of any relevant information that the system has to store and manage in order to provide that functionalities was also identified. This draft structure is a first attempt to define the elements of the APS System Model which will be developed during the next steps.

Table 1: Actor-Product-Service system Model

Equipment	Component	Inspections of elements	General
General: Type and Serial Number. Description. Manufacturer. Manufacturing and installation dates. Specification sheet: Power, Design and Operational Temperature, Design and Operational Pressure, Flow, Speed.	**General**: Type and Serial Number. Description. Manufacturer. Manufacturing year. Replacement year. Type of material. Dimensions: Drawings.	Year of inspection Inspected areas and inspection techniques. Techniques associated with areas. Detected Flaw list: Acceptable and non-acceptable: Position. Size. Flaw characterization Corrective actions for non-acceptable defects/flaws: Repair. Replacement. Modification of Start-up manoeuvre. Reduce time among inspections. Surveillance. Update Inspection Manual Next planned inspection date and scope. Defects/Flaw evolution Historical Inspections of similar components Proposals, Annotations and Conclusions	3D Models and Metadata Access Control and Rights Management Services Users Profiles
Operation: Hours of operation, Number and type of Starts-up. Number of Shutdowns	**Operation**: Hours of operation. Number and type of Starts-up. Number of Shutdowns. Operational conditions: Temperature and Pressure.		
Status: Summary of Inspection results. Planned date for next inspection. Year of last inspection. Number and Percentage of inspected areas. Percentage of acceptable defects/flaws. Percentage of non-acceptable defects/flaws			

Verification Methods and Procedure

The methodology of the verification trial will consist in following the usual decision-making process when the actors are confronted with a group of hypothetical defects found in the inspection of a turbine. The actors will try to do their job by means of the UIW system. This will take place in an in-person meeting that will take place in Tecnatom headquarters.

With this purpose a workflow of the decision-making process and the tasks that have to be resolved during the meeting by the actors were developed. This workflow summarizes the decision-making process that takes place among all stakeholders after inspection.

Next step was exhibit normal working situations involving different actors. The goal was then to confirm that each actor could do their job by means of the UIW system (with the use-cases set) and making use of the interfaces and data contained in the APS system model and following the workflow defined. Below are shown these tasks that the actors have to complete.

Task 1: When defects are found during an inspection, it becomes necessary to make a decision for action. The different stakeholders study the state of the turbine and the results of the inspections and are able to submit proposals to address the defect or defects found. Then a decision-making process begins.

- Defect 1: Cracks inside inner cylinder in areas near nozzle chamber (High Temperature)
  Flow: Acceptable under the procedure? → No
  Is operating with the defect feasible? → Yes

- Defect 2: Mild erosion of stellite layer in later stages of blades (without affecting the integrity of the blade).
  Flow: Acceptable under the procedure? → No
  Is operating with the defect feasible? → No
  Is repairing feasible? → Yes

- Defect 3: Indication for stress corrosion cracking in low-pressure turbine rotating blades.
  Flow: Acceptable under the procedure? → No
  Is operating with the defect feasible? → No
  Is repairing feasible? → No
  Is replacement possible? → Yes

Task 2: After an inspection various defects appear and simulations are needed. It is necessary to export geometric data of defects to the simulation tools.

- Defect 4: Subsurface axial indication inside the rotor
  Flow: Acceptable under the procedure? → No
  Is operating with the defect feasible? → No
  Is repairing feasible? → No
  Is replacing feasible? → No
  FEM Simulation is performed

RESULTS

Revision of the APS System Model

The trial started with a general revision of the APS system model. All the actors generally agree with what is going to be queried/accessed/displayed by the UiW system in every situation. However, in some cases it was necessary to qualify an element of the model, or even to add new elements to the model at request of some of the actors present.

Nevertheless, during the meeting it was discovered that many of the data required by the UiW system are at the moment not available: it is not considered in Tecnatom databases design or, more frequently, it is a non mandatory field and data are incomplete or user does not fill the information.

Revision of the interface prototypes

The trial continued with the revision of the interface mockups. It was shared and clarified that there exist situations where what is more relevant for the actors is the 3D representation of the components, with highlighted, relevant information spatially situated over it. So, in these situations the 3D figure will have to be shown in the main window. Secondary associated information or resources will have to be shown in small side windows. Conversely, in other situations, what is more relevant is the information associated to an area or a component, and consequently it is that information which will have to be showed in the main window.

Cognitive walkthrough

The cognitive walkthrough focused on Task 1 – Defect 1. All actors agreed that reaching a first decision on whether it is feasible to resume operation with a given defect is very complex. The expert playing the role of Tecnatom Inspection Team expressed that one of the main difficulties they face is making other actors understand the parameters of the defect, such as exact placement, size and others.

Placing and sizing the defects in the 3D geometry is a problem by itself. The experts agreed that, in general, it would be difficult to geometrically parameterize defects for the UiW system to represent these automatically, due to several reasons including the difficulty to recover information on reference coordinate-frames for components, and the near impossibility to measure the dimensions of some defects in real situations. Consequently, it was exposed that these parameters of position and dimension cannot always be stored in the current workflow. This would prevent the UiW system to automatically represent defects in 3D to support the decision making process. The discussion led to the discovery that was necessary to redefined a use-case, was required from the UiW system that will allow the actors to place and size the defects manually over the 3D visualization, then the system will have to store these parameters that will be later recovered during the decision making processes.

During the walkthrough of the decision process it was also exposed that the system should not only allow the actors to register proposals, but also other annotations to document all the making decision process, with the aim of being able to know in the future what was proposed and what decision was taken and, more critical, the reason o f such decision.

Other general points were raised by the actors during the walkthrough, including:

- The system will have to show/access all the information related with components and defects that will be stored in Tecnatom databases (GIPE system).
- The system will have to link a defect that is shown over the 3D geometry with the images of the defect stored in Tecnatom databases.
- The system will have to implement Access Control and Rights Management Services.

Lessons Learnt

The impact of the trial can be summarized as follows:

- The APS system model will have to be extended to include all the new requirements of information for components and defects. In Tecnatom Databases several levels are used to reach the smallest part of turbine, so that levels and related information to access a component/element should be detailed in APS model.
- Tecnatom databases will have to be extended or new databases will have to be created to support the entire APS system model.
- The use-case called *Generate Proposal* will have to be redefined to include the capacity to make annotations and document the decision-making process by the actors (for example *Input of proposals, annotations and conclusions*).
- The ability to link images and 3D geometry will have to be included in the use-case *Visualize the status of an inspection and its results*.
- The use-case *Input of position and size of defects* will have to be redefined to support the placing and sizing of the defects manually over the 3D visualization.
- It will be necessary to implement profiles to the users of the system with the aim of implementing Access Control and Rights Management Services.

CONCLUSIONS

As a result of the trial, the conceptual prototype was pre-validated and system specification can go on further details. Building an application for visualizing technical information linked to specific locations in a 3D model of the inspected machine, and supporting collaborative work, can produce a great benefit, improving the quality of the decision making process. At least, this has been foreseen by the selected experts during the evaluation of this conceptual prototype.

The process of this evaluation, presented in this paper, has been a good way of validating the specified use cases to be developed. The cognitive walkthrough technique, usually used for interface evaluation, has been successfully used in this context, validating the proposed use cases and detecting some missing details.

Work will continue in the next months by writing a comprehensive set of requirements, which will guide development and evaluation in further technical trials.

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Field of Actions of Industrial Engineering and of the Human Resource Management Influenced by Ageing People

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ABSTRACT

The demographic structural shift drives a change towards an increasing employee orientation, to which the German businesses have to find strategic and operative answers. Businesses acts and efforts are promising, if organizations make sure that ergonomic findings are kept. There is no unique standard approach to solve the demographic challenge yet. The following article represents core theses to a demographic personnel work, as well as possible fields of action, which guarantees businesses a solid handling of the demographic change. The consideration of due to the demographic change altered parameters at designing the qualification, personnel progress and career prospects, are an important field of actions and will be examined at full length as a result.

Keywords: Demographic change, personnel work, qualification, human resource management

DRIVERS OF CHANGE FOR BUSINESSES

Ever since businesses of all branches, dimensions and regions must be open to circumstances that are drivers of change. By the „drivers of change“, businesses are required to a consistent ability of reaction- and adaption. The nature of what drives the change varies and can be caused by external influences as for example legislative process´, customers, key- and finance markets, as well as being characterized or set off by internal circumstances, such as a change of the interior organization, leadership, availability of resources or performance fluctuations.

In the past decades the following drivers of change have mainly influenced the employment- and operation system of our German businesses (fig. 1):

- market demands for superior products forces new designs, an expanded range of functions or superior capacity.
- cost pressure forces the search for extravagance and measures of rationalization in all ranks.
- a variable number of pieces cause frequent and short term adaptations of capacity.
- individualization of customer wishes lead to a further more expanding number of varies and a shortened delivery time.

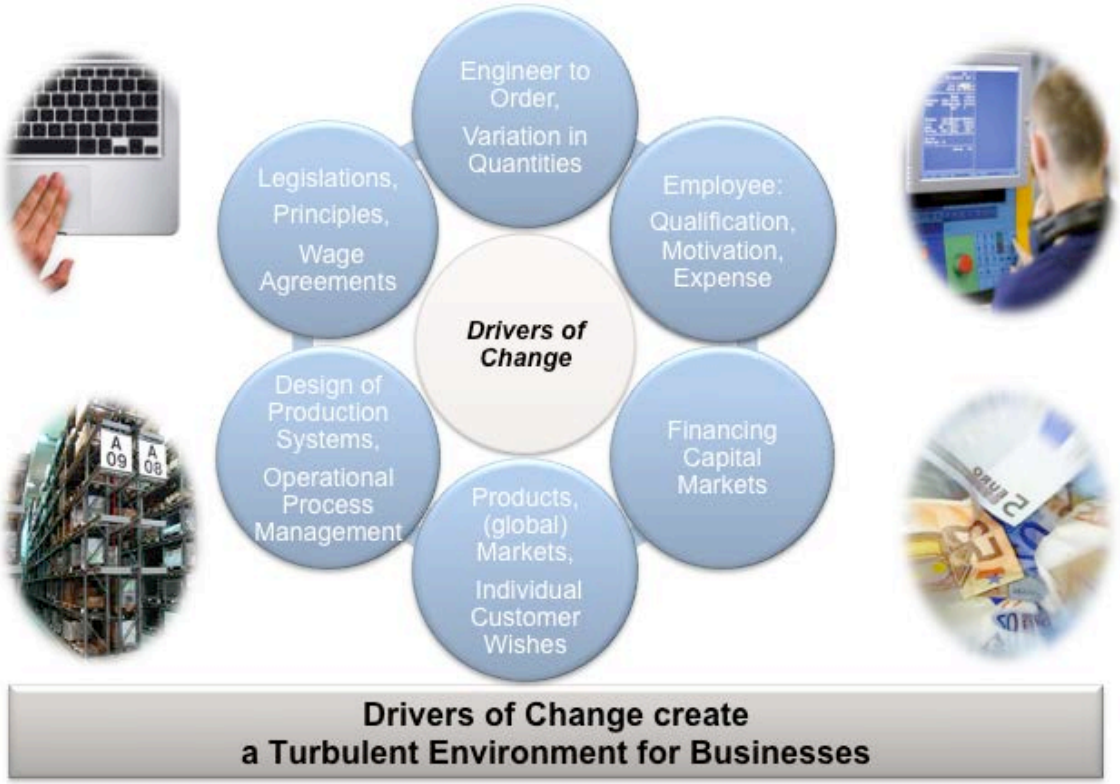

Figure 1: Drivers of change (Stowasser, 2012)

THE DEMOGRAPHIC STRUCTURE AS DRIVERS OF CHANGE FOR THE BUSINESSES AND FOR THE WORKING ENVIRONMENT

Currently and in the future, one driver of change deserves a special attention in economy and in science: the changing of demographic structures in Germany (compare fig. 2).

For the businesses the demographic change can cause:

- a growing absence of adequate skilled workers and work force as well as a shortage of education candidates/nominees as a consequence of the decreasing number of students;
- a deferral of the age structure and an ageing work force;
- a longer continuance in place for the employees in general, as a result of legal regulations – the elimination of government-funded partial retirement and the incremental elevation of the pensionable age to 65 or 67 years – to ensure the affordability of the social security systems.

The influence of the demographic development can be summarized in two core theses:

a) finding suitable education candidates/nominees and junior staff will be increasingly difficult (younger people are missing) and

b) the preservation of the personnel capacity will be even more important (longer continuance in place in businesses for employees and a growing percentage of senior employees in the work force).

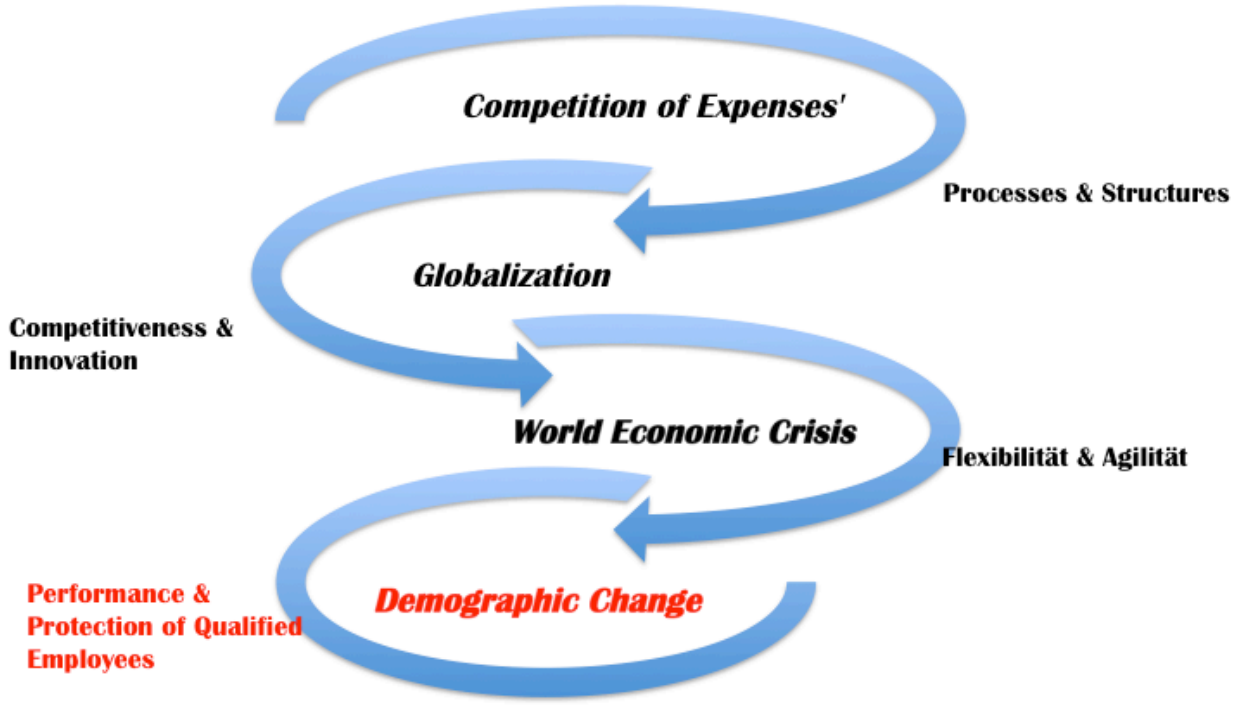

Fig. 2: Cascade of challenges in the recent past and in the presence.

THE CORE THESES FOR THE SECURE HANDLING OF DEMOGRAPHIC PERSONNEL WORK

The core theses for the secure handling of the demographic personnel work could be verbalised like this: (compare Adenauer and Stowasser, 2008):

(1) Businesses are affected by the impact of demographic change in different ways. An inventory is necessary in order to reason the need of action for each business seperatelly.

Further factors are to be taken into consideration:

- the initial starting position for the enterprises, namely the actual competitive position, its brand, its »attractivness as employer« as well as
- the areal differences, such as the location of an enterprise (rural area, city), the areal development of population and availability of younger junior staff.

(2) Secure handling of demographic personnel work under ergonomic aspects not only refers to ageing employees, but starts preventive (präventiv) already with the younger employees. Creative measures (e.g. workplace, work environment, work hours) subserve senior and junior employees. There is no general need to differentiate work systems based on age, more important are ageing conform work places, an ageing conform work organisation and an ageing conform deployment .

(3) The employees working ability and performance isn´t determinated according to the calendar, but is influenced by the biological age. Measures to obtain working ability and performance until 67 require an operation- und employee specific implementation. The requirement for capability and qualification is individually different and dependend on concrete work content. That requires the consideration of a distinguished capacity development of aging employees with the secure handling of demographic personnel management. For example securing the demand of younger junior employees and the operational health management, which starts preventative (vorbeugend) with the younger employees, to support their performance from early on and obtain it sustainability.

(4) With the implementation of measures for industrial engineering, the same laws and principles apply for senior employees as for all the the others. (Landau et al., 2007).

(5) Individuals sustain responsibility for obtaining their working ability - and performance (health and skills) as well - not only social instances like e.g. the employer or politics.

The businesses competitiveness depends stronly on how accurately the business agrees on the demographic change. The demographic structural shift is an increasingly personnel oriented driver of change, on whom German enterprises must react.

Entrepreneurial ambitions and actions are promising, if the ergonomic regulations are regarded. A single exemplary approach to resolve the demographic challenges doesn´t excist yet! Different approaches for the entrepreneurial fields of action (compare fig. 3) are described in detail in the folder "Der demografiefeste Betrieb" (Adenauer et al., 2009). It´s about considering and picking up on demographic changes in entrepreneurial fields of action, like e.g. obtaining the capacity of the personnel as well as winning qualified employees, human ressources development and qualification.

Fig. 3: Fields of action of a demographic business (Adenauer et al., 2009)

Qualification and Human Resources Development as an Important Field of Action for a Demographic Business

Qualification, human resources development and creative career aspects, in the fact of ageing work force and flat hierarchy, supports the longterm operational capability and operational readiness. In the following, this field of action will be emphasized in particular (compare Adenauer et al., 2009).

Skilled worker shortage and ageing employees confront the businesses with the task to secure the capacity and motivation of the employees, an adequate actualization of operating relevant qualifikations and by longterm concepts for human resource development (compare fig. 4). That means e.g.:

- Adjusting the qualification for ageing and middle age employees for their retention time in the business.
- Updating knowledge and qualification to the status quo.
- Counteracting dequalification and demotivation (the loss of aquiered qualification through non-application).
- Preventing a loss of learning habits by an ongoing advanced education and training.
- Creating alternative career perspectives and capabilities for ageing employees with an increasing of flat hierarchies

Basic conditions and requirements are e.g.:

- a management and corporate culture, which recognizes and supports senior employees´ potential;
- the sensibilisation of employees, that the learning curve doesn´t end with finishing school or education and they therefor accept offers of the business to obtain their working ability- and employability.

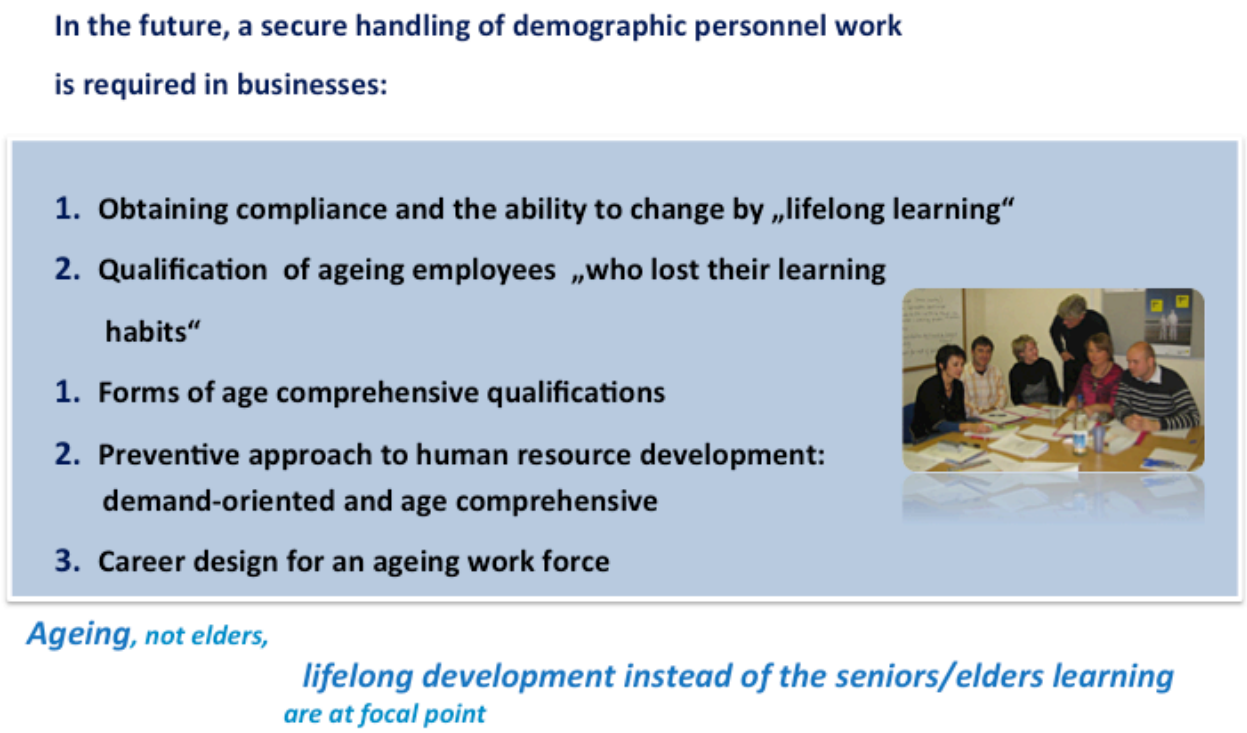

Fig. 4: Five requirements on education, further education and human resources development.

Obtaining Change and Learning Abilities through „Lifelong Learning“

In general, learning up to a great age is possible, dependent on the individual qualifikations for benefit. The ability to learn has to be obtained and suported by training.

Lifelong learning means a continuous, independent of age, demand-orientated, human resource development and qualification to obtain the preservation of capacity- and capability until 67. It relieves the process of change for businesses and employees.

The parameters, which are often requiered for “lifelong learning”, are after all not age specific, but to the greatest possible extent correspond with generally accepted didactic principals. To these belong e.g.:

- the selfmonitoring of learning is defined by a personal learning rate and individual opportunities for repetition and training;
- the conjunction of the new with the practical knowlegde, the praxis orientation and the personal reference;
- the proximity to enterprise- and workplace, which allows the immediate testing and usage of what has been learned;
- the individual, on personal interests and living conditions responding preparation of the subject matter.

Qualification for (Ageing) Employees who have Lost their Learning Habits

When ageing employees are having deficits in the qualification section, it´s less foundet in age, but rather in the missing training opportunities and poorly demanding operations, that lead up to the loss of qualification (so-called disuse-effect resp. dequalification) and can lead up to a loss of learning habits.

The willingness to a further education is less a question of the biological age, but rather of the individual learning habits and of the self-image. Employees, whose learning ability is not prompted by the business, understand/see themselves without learning abilities and have even lost parts of their learning abilities over time. Ageing employees learn unlike younger employees, if they haven´t taken part in qualification measures for a longer time and if their past occupation has not been connected with a learning incentive. In general it then get´s hard to getting used to a learning situation. So to speak, learning has to be learned all over again.

The employees integration into designing a learning method, the connection to excisting knowledge and shorter learning units, simplify the learning comback.

Preventive Approach to Human Resource Development: Demand-Oriented and Independent of Age

Human resource development should start with the younger employees and be of an age indepentend design. To these belong e.g.:

- Preventive approach with the young employees
  Developing learning abilities as well as the ability and willingness to change from early on, starting with the younger employees; raising the young employees´ awareness that there excists a necessity for lifelong learning. They can prepare themselves and wont have trouble with changes and alterations.
- Supporting lifelong learning
  Ageing, not elders, lifelong development instead of the seniors/elders learning are at focal point.
- Securing the promotion of young employees
  Continuous promotion of young employees in order to secure the demand of qualified workers with the buisinesses own employees.
- Individual promotion of young employees e.g. with sponsorships, whereby the direct supervisor accompanies the person of high potential by regular feedbacks and milestones. Some enterprises lay out an so called *goldfishpond* (Heinzelmann, 2004), which is a pool of young qualified workers, who will be prepared for their coming excecutive functions by a directed expansion of their field of duty and by assosiated external educations . It makes sense, to expand this pool by older qualified employees, so that careers don´t have to end at the age of 45. The past career model assumed that, if one had not reached an attractiv position in the business until 40, one wouldn´t manage to do so after. Especially for the generation 40+, in the context of a tessellated (mosaikartig)-employment with associated personnel development, inducements for further education and new fields of application should be offered. In this it orients on the demand of qualification and the fielding of skills and knowledge (Seitz, 2005).

Career Creating Personnel that is Growing older

Because of flat hierarchies an upward promotion will not always be possible. It is possible, that ageing employees do not have the motivation or the opportunities, to come further to the top on their career ladder. Though for motivation and employee loyalty it is more important to create the professional way for this employee group

furthermore interessting and challenging in order to avoid resignation. There are two kinds of career pathes: vertical („normal career“) + horizontal (job rotation on horizontal level). The horizontal career pathes gain importance.

In the future the longterm career planning will be an important aspect in the field of employee loyalty and the employee motivation. Beside that, the longterm career planning gains importance for operations with a higher physical load, whereby it´s a known fact right from the beginning, that the employee will not be able to accomplish this operation until the retirement age. This is where action is needed from early on, for instance by mixed operations, the change of work place etc. These facts should be taken into consideration, as convelescent (oder less demanding) workplaces generally don´t excist anymore in businesses and in case of loss of efficiency, a job rotation will be made non-systematic and ad hoc, so that this is where the work process often is disturbed sustainably.

Essential are horizontal development potentials -examples therefor and characteristics are:

- the acceptance of special tasks, e.g. project management, the responsibility and companianship of the process of change;
- the responsibility for the training, the further education;
- the operator as consultant for teams of experts;
- the granting of privileges, which to that point has been reserved only for excecutive personnel, such as accepting responsibility or taking part in management meetings.

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Section 3

Safety Management

Development of the Management Cycle and Supporting Tool for Assisting Organizational Workers in Learning Themselves How to Detect Safety-related Problems

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ABSTRACT

For employees to allow the improvement of safety in their own organization, researchers have developed a learning cycle to enhance the ability to notice that it becomes a safety hazard. Safety is important aspect organization's activities. Organization that had caused the accident has a sense of distrust. It will start losing users and customers as a result. It is necessary to have great safety promotion activities as an organization in order to avoid such a situation, but the activity can be conducted more efficient by personnel of a handful instead of driving, all employees to participate. However, some educators conduct safety training to all employees to avoid increasing costs. Therefore, by building a system that enables learning, employees devised a cycle to allow safety training while reducing the cost after finishing the initial training by building the software with the goal to enable employee to learn themselves. Finally, authors have devised a system that enables the safety training while reducing the burden on educators.

This system consists in a "factor analysis" and "analysis software". Factor analysis is a technique that a phenomenon might cause an accident (extracted factors). It is necessary to consider in a variety of perspective like relationships and working environment and so on for analysis. However, it is possible to achieve without the feedback of the analysis it is difficult. By entering into analysis software factors that have been extracted, the software will give us information, such as trends and perspectives missing. To repeat the cycle is performed factor analysis with reference to the information, and to enter into further analysis software. Then employees are going to learn a way of thinking about safety. Taking advantage of it, the employee is going to notice and avoid mistakes and accidents themselves and able to review the day-to-day operations or near-miss cases, and accidents. When applied to five groups of participants who have no experience of factor analysis at all the following results have been obtained. First, researchers compared the number of factors to be extracted. The second run time added a factor of 182% delay on average compared to the first. Similarly, the third run time was the result 252% of the second, and 456 percent for the first time for a third time. Researchers concluded that as the number of factors to be extracted increase, the more the information will be needed serve as a reference when to take safety measures.

INTRODUCTION

Safety is important in the organization's activities. Organization that had caused the accident is having a sense of distrust. It becomes a losing users and customers as a result. That the level required in recent years, particularly sophisticated, small events would also be treated greater many. It is necessary to have great safety promotion activities as an organization in order to reduce such a situation. In addition, need to take measures to such incidents

and near misses.

Rather than handful of personnel, it is possible to measure effectively all employees to participate in activities to do so. However, some educators to the safety training to all employees and to the measures of all cases take a great deal of cost. Therefore, by building a system that enables a learning own employees devised a cycle to allow safety training while reducing the cost after finishing the initial training. So By building the software with the goal to be able to learn own employees Finally, I have devised a system that enables the safety training while reducing the burden on educators.

ANALYSIS METHOD AND SUPPORT SYSTEM

This system consists of “Evaluation Software” on your computer and “Root cause analysis” on paper.

Root cause analysis is a method of extracting factors. And Factor is “Event that may cause an accident”. For example, work environments, Human relation and so on. When I analyze a factor, I start from the phenomena such as troubles and think "why it became so" "why the phenomenon happened". Furthermore, I apply analysis for the factor thought about.

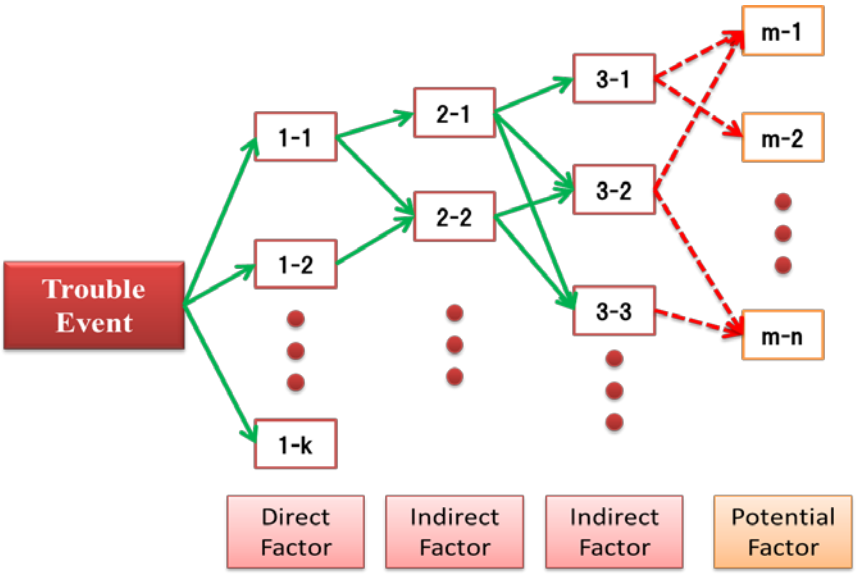


Figure 1. Root cause analysis

I want you to be careful about not being a method to investigate a single "cause" . You must find a factor not a cause to aim at not only the prevention of recurrence of the trouble but also the prevention of before the fact.

For example, a trouble occurs in a certain factory, and the cause thinks about the case "that I attached a different part" to. Measures "to check whether you attached a right part" will be thought about for the prevention of recurrence. However, this remains in content to prevent "an installation error of the part”. When I scheme before the fact prevention, it is necessary to think about "the factor that I attached a different part" to. When a factor "not to be ready to carry out the rearranging order of the part" is found, and measures "to perform the rearranging order of the part" are made. Other than an accident to attach a different part to, before the fact may prevent a trouble such as the loss of the part if I carry out these measures. In this way, I can widen prevention of before the fact activity by thinking about a factor to hide behind in the background.

For reasons of the said article, a variety of viewpoints are necessary for analysis. However, it is difficult work for without the experience of the analysis or few people. Therefore I use evaluation software. Various evaluations are accomplished by inputting the contents of the factor analysis into evaluation software. I repeat a cycle that I perform factor analysis and input for analysis software while taking an evaluation into account.

It is summarized as follows:

1. Tutorial about Root cause analyses by educators

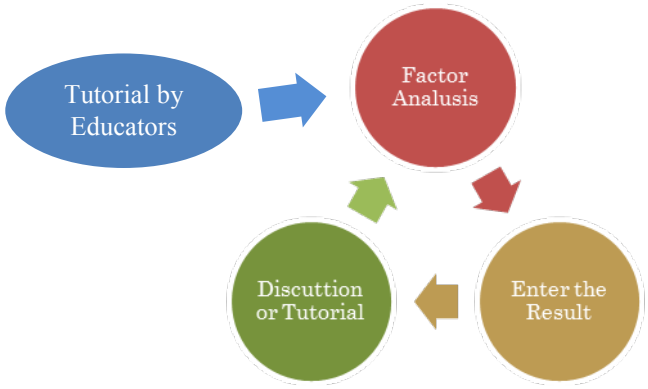
2. Factor Analysis by small groups

3. Enter the results in the evaluation software

4. Discussion or tutorial, was referring to the evaluation results

5. Go back to 2

Factor analysis is enabled while supplementing a former fault by maintaining this cycle. I review an accident and everyday duties by the factor analysis that is a high level and reduce an accident and a mistake. The employee during this cycle can observe things from various viewpoints ideally. Similarly, the employee can discover a factor to lead to danger by observing duties and before the fact can prevent a trouble. In brief, employees get ability to prevent a trouble by oneself.



Fihure 2. Management Cycle

IMPROVEMENT OF DIVERSITY AND QUANTITY AND QUALITY

I aim for improving the quality of an extracted factor, quantity, variety by the support to achieve the above-mentioned ideal.

Figure 1. Evaluation software

Diversity and Quantity

Using the classification methods of the factors as "4M" and "GAPWPO" in this support system, the system has advice on diversity of factors. Factors mentioned in the analysis are evaluated by the evaluation software, the classification is performed. If the bias of the point of view is found by classification, we analyze, taking care to correct the bias thereafter. For example, if factor that is classified as a "Media" in the 4M classification was small, do an analysis with a focus for the "Media" next time. Thus, the diversity of the factors to be found is ensured. A number of factors may increase further.

I will explain about the classification methods of each. Adopted taxonomies two types are classified factors in the evaluation software.

4M

4M is a classification method, which is named after the initials "Man", "Machine", "Media" and "Management". Classification is made in reference to the next point.

Table 1 :Point of Classification (4M)

Classification	Summary
Man	Refer to all human beings involved in some form and boss himself, subordinates, and colleagues, to work. Contain up to what physical factors related to the worker, psychological factors, qualities (such as personality), skill, and knowledge.
Machine	Refer to those of an object such as a device or equipment. Human-machine interface is also appropriate.
Media	Refer to those related to the media and the environment, such as a procedure or instruction manual. I and the like situation methods and procedures of work, including how to use the equipment, how to put out of work information, communication within the team and collaboration (such as instruction, instruction-contact) (and support check), work conditions, workplace.
Management	Refer to those related to the management and administrative organization and regulations. It is including rules and safety regulations, work plan, and education and training

GAPWPO

GAPWPO is a classification method, which is named after the initials "Gestalt", "Affordance", "Preview", "Workload", "Personnnel" and "Organization". Classification is made in reference to the next point.

Table 2 :Point of Classification (GAPWPO)

Classification	Summary
Gestalt	Items related to whether or not to have the correct image meaning of work, such as clarity of content, for the work.
Affordance	Such as clarity and intuitive ease of confirmation, items related to ease of use.
Preview	Items related behavior in anticipation of the status of the bit ahead from the moment can do, on whether there is a margin to predict.
Workload	Items relating to the load on the mind and body of the worker in the work. Such as working hours and working environment.
Personnel	Problem or illness of the worker's own, such as personal items.
Organization	Items on the issues such as the climate of the whole organization, the entire organization has.

Quality

In this support system, are also evaluated quality as well as quantity and diversity of factors.

It is a "factor that is easy to measure and operations planning" and high-quality referred to here. For example, factors referred to as "thought it was medical records of women in their 60s" are extracted during the analysis. When planning measures you have finished the factor analysis here, measures referred to as "to prevent medical record seems 60s woman" can easily be set up. But measures to of "should not regard" depends on the individual, it cannot be said that effective measures. Therefore, by the factor analysis and further factors "devise that can be distinguished at a glance that no age" that has been extracted. Then measures can be operated across the organization and specifically of "the laborer who can be distinguished at a glance of the age" is set. Thus, it is possible to extract factors as specific as possible is to improve the quality.

It is determined word, a sentence length of the quality factor in the evaluation software. Database word is present, the level is set for each word in the software within. The Search for a word from a source input, evaluation software to determine the quality based on the length of the sentence and word combinations. In addition, quality is expressed level 0, level 1, level 1 + (1.5), level 2... as of level 5.

Analysis support Manual

To facilitate further work was to create a "cause analysis support Manual". Evaluation software because only give an estimate only, I have the documentation and ideas specific method. By referring to this document, the analyst can know the concepts and specific techniques.

VERIFICATION OF BENEFITS

I have created evaluation software, the documentation as a method to support the factor analysis, but verifying that give be an effective means.

I asked three railroad companies, oil producer one, drug industry one, 1 medical group for cooperation as a subject of this experiment. The railroad company assumes it railroad A, railroad B, railroad C each.I constituted a group each in companies. One group collects chief grade of each post in four people. There is little experience of the factor analysis, but is the employee that it is thought that you should learn about factor analysis in future.

I used a support system depending on a company and divided mint condition in two. It is the group which does not use these that there are no using both "evaluation system" and "support manual", support that there is support.

Table 3 : Having support or not

	Company	Number of Groups	Total Number of Groups
Support	Railways A	7	12
	Railways B	5	
Without Support	Railways C	21	68
	Oil	9	
	Pharmaeceutical	14	
	Health	24	

Experiment Method

I work by a group unit. I prepared Japanese vellum and Post-it to have you analyze a factor and wrote in a phenomenon and a factor at Post-it and went by the method that I put on the Japanese vellum.

First, educators will be described briefly how the factor analysis.

Next, have one read examples of analyte prior to performing the factor analysis. In this study, the case was using the "electric shock of substation room" that is prepared here. It is a case without knowing that there's work is energized, that had an electric shock and would touch dangerous places.

And, subject to carry out the factor analysis actually. I was set to 2 hours' time. The analysis while using the evaluation system only group that has support, it is possible to see from time to time support manual analysis and the results of the current situation.

Result

Consider the quality of the factors, the number, diversity whether improved by support tool.

Quality

The evaluation system counts the total number of factors extracted, and the results were compared. The following figure is obtained by averaging the total number of extraction factor of each team in the group without the assistance and support group there.

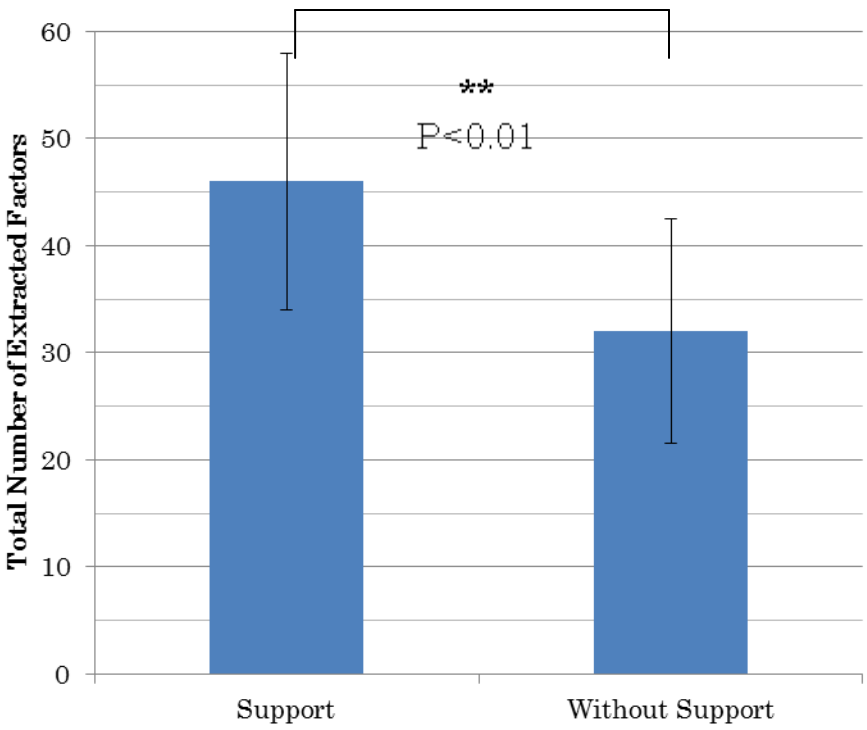


Figure 4. Comparison of the extraction factor total number

The result was a group there is support at 44.9 pieces, without the assistance group that 32.1 pieces. Is significant 1% the results of the analysis of variance, it can be said that the difference is that out of the average value by to help.

Quality

Levels are respectively given by the evaluation software factors. To assess quantitatively, were weighted to be level 0 to 1, level 1 to 2, Level 1+ to 2.5, Level 2 to 3, Level 2+ to 3.5, Level 3 to 4, Level 3+ to 4.5, Level 4 to 5, Lever 4+ to 5.5,Level 5 to 6 .

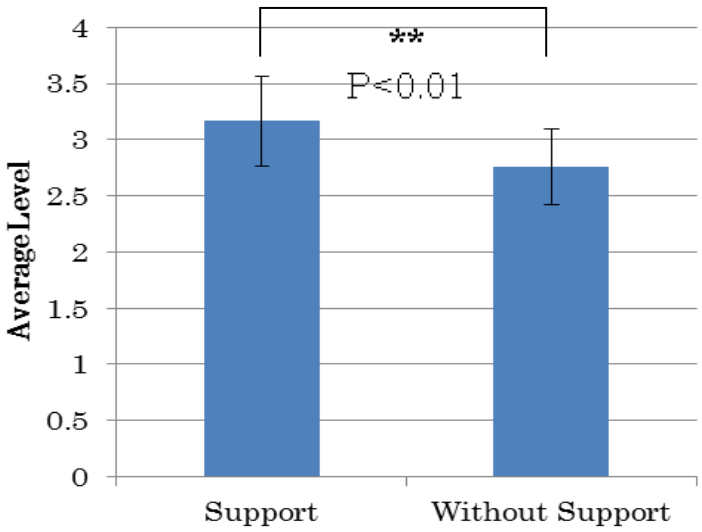


Figure 2. Comparison of the Average level

It is a comparison of the average level of extracted factors of the group without support and support group there.

Average factor levels, resulted 3.17 points there support, without the assistance that 2.75 points. Results of analysis of variance, it is significant at 1%. But the difference is smaller than I expected initially.

Factor does not lead to effective measures "accidentally" and "vaguely" is evaluated to level 0. Only factor leading to recurrence prevention activities "Check shortage" and "lack of confirmation" is evaluated to level 1. Therefore, I can be considered for factor level points are two points even if you extract only the factors that lead only to relapse prevention activities, differences were small. Difference itself was small in value, but it can be said that it was a significant difference in the 1%, that the average factor for level and rises in it to support.

In view of the prevention activities further factor levels to be the target is 3 or more. Therefore, it is not an average factor level point, and to compare the ratio of the group factors average level becomes 3 or more.

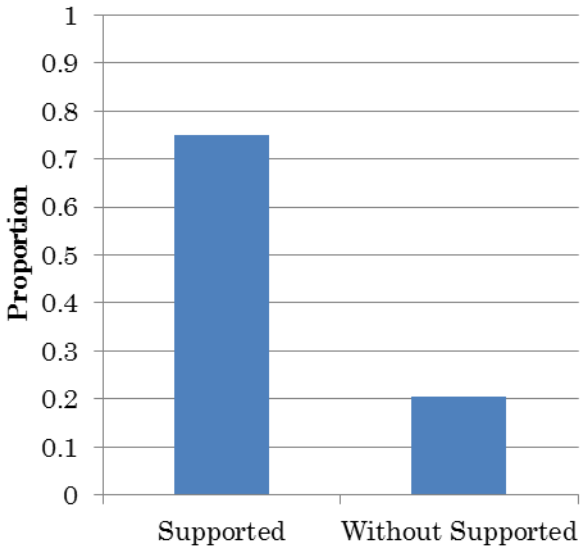


Figure 3. Comparison of Proportion of group where is higher than mean level 3

The group was shown 75% of the support group that there is at most average factors level 3 and above. Average factors level 3 was the only team of more than 21% group without assistance. Given the average level of the group three or more were able to sufficient analysis, a significant difference can be seen in the support without support and that there is support. The said analysis has been improved by the support.

From this result, the possibility by performing the support, can be extracted factors level 3 or higher increases. Therefore, it can be said that the possibility of extraction factors that can take advantage of as well as relapse prevention activities, to prevent activities has increased.

The proportion of the group average factors level, the average level of factors becomes 3 or more, a difference was present both. In addition, major changes were observed for the percentage of the group with an average factors level becomes 3 or more.

By evaluation system, it is possible to identify the source level of the extracted own. That it has made a conceptual description by the manual, it should be what kind of thinking. I is believed these subjects can understand how, and made it easier to raise the factors level.

From the above, evaluation software in this study, with the help manual, level of extraction factor in the factor analysis was increased. Factors level improvement will lead to improvement in the quality of measures that are contemplated from the factors. In other words, it is considered to become the help of safety management activities of the organization.

Diversity

I verify a factor of six category "Gestalt", "Affordance", "Preview", "Workload", "Personnel" and "Organization".

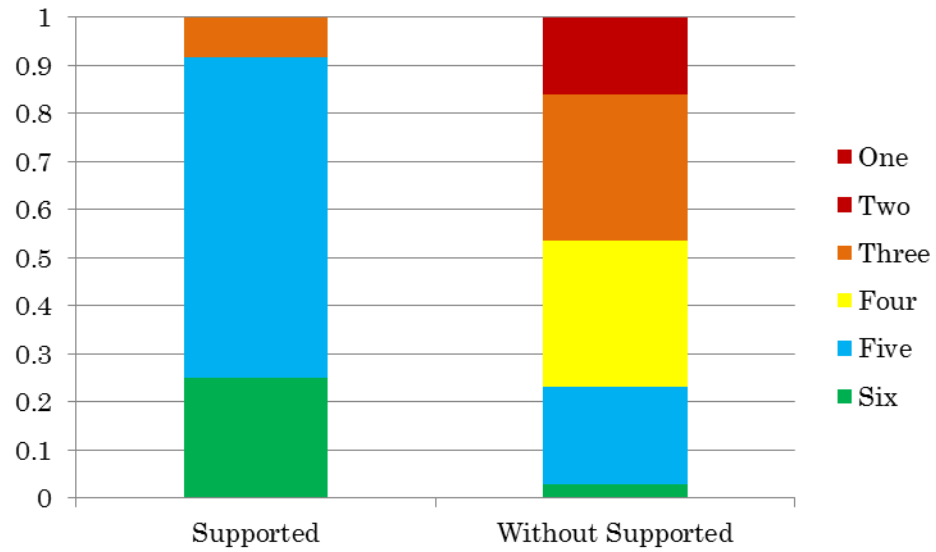


Figure 4 Comparison of the Diversity by GAPWPO

Figure represents whether the extracted what kind factors of the six kinds. According to the drawing, in the group have support, a group of 25% are able to extract factors all six. In addition, the group of 67% is to extract the five kinds, 8% is three kinds. On the other hand, without the assistance group is not able to extract the factors of only six group of 3% in the group. group of 46% has remained no more than three.

I also verify a factor of four category "Man", "Machine", "Media" and "Management".

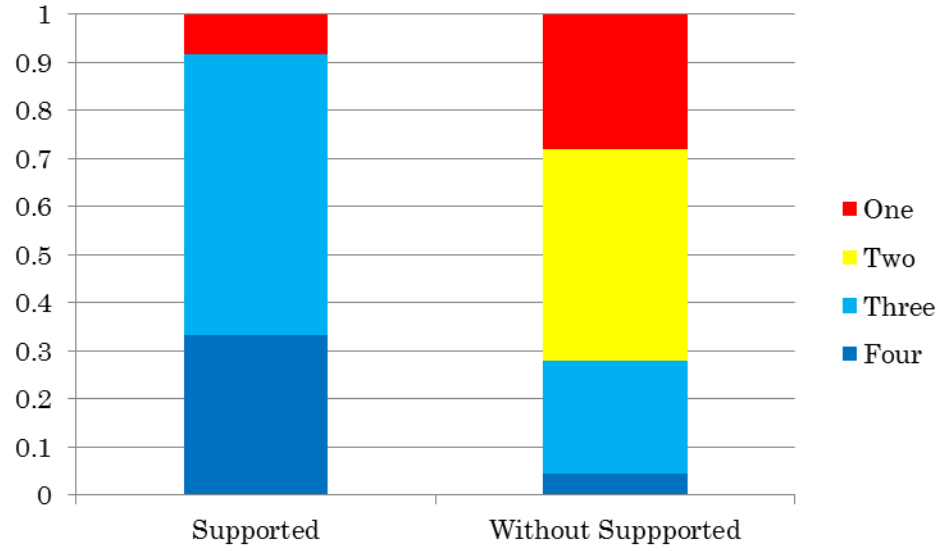


Figure 5 Comparison of the Diversity by 4M

There are support groups that are able 92% to extract the factors of three kinds or more. Group No support is not able to extract the three kinds or only 28%.

More than half is two or less in the group without assistance. Therefore, the possibility that the subject is not aware of this category in performing analysis is suggested. It is believed that the analysis is performed without regard to categories, the bias would occur in the subject. Since the both groups are dealing with the same case, there is no possibility in this experiment, factors that were not present.

The group that is not able to extract the factors of all four of 4M or six of GAPWPO, have missed factors.

CONCLUSIONS

In this study, in order to support the factor analysis to be performed only by employees, we have proposed a support manual and evaluation software.

By the evaluation software, I evaluated the diversity of the factor, quality, and abundance. In addition, with the attached manual, I showed the important way of thinking in the factor analysis.

I used a support tool together at the time of factor analysis and, based on an evaluation index to be provided one by one, carried out a method to review factor analysis based on an attached manual. As a result, I became able to extract a variety of factors with most cases, and the level rose with the total number of the extraction factor, too.

I think that an evaluation system and the support manual which I developed in this study than the above help the factor analysis of the company. In addition, in what can extract a variety of factors by factor analysis, I can take a variety of measures and think that I help the safety management activity of the company.

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An Evaluation of Human Factors on Confirmation/Check Tasks in Organizational Safety Management

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ABSTRACT

In organizations' safety management, it is most important to ensure workers check their own work so that they can detect human error as early as possible. We study the checking task from the viewpoint of human factors with the aim of identifying factors impeding the performance of the checking task and proposing a method for mitigating the effects of such impeding factors. The checking task does not always play a good performance, making workers desirous of performance improvement. However, few attempts have been made to study the checking task beyond analyzing individual, concrete work contexts. We, first, identified and categorized problems regarding the checking task by statistically analyzing the result of the survey covering over 20,000 workers of 15 companies from several industries such as railway and general hospitals. The survey included distributing questionnaire and on-site interviews, both targeting site workers. We, next, got down on to further study the result of the above analysis as that we developed advice/tips data that can assist those who prepare a checklist. Based on the result of these analyses, we compiled a guideline on what to discuss and how to address it when adding new items to an existing checklist.

Keywords: Confirmation/Check Task, Human Factors

INTRODUCTION

Background

Today, Safety management in most industries in Japan is keeping a high standard, and they are considering measures for troubles and accidents from various angles. Thanks to their untiring efforts, the number of huge accidents such as the crash of a JAL MD11 aircraft in Japan which occurred in the late nineties is declining. The standard of Safety management is changing over the years, however, a slight incident far from serious accidents and troubles are handling as an object of Safety management. Therefore, many industries and organizations are facing with the challenging issue with work efficiency and confirmation/check tasks enhancement.Confirmation/check tasks play an important part before operators continue a following process, and regardless of skill which an operator possesses, you can finish a task completely with a last confirmation. Thus, confirmation/check tasks provide a work process management system that reliably confirms for errors and so, they can recovery and evade an accident and a trouble. Moreover, operations with checklists can avoid communication errors between an operator and his/her successor, omission errors and commission errors. That is why most organizations take it in every operation as the last process of it.I particularly put a focus on confirmation/check tasks in safety management, and considered and examined rearranging of the information of checklist, the process efficiency through the past study and the experiment of the human factor.

History

HEP(Human Error Probability) is positioned in a human error assessment based on the theory of probability and used over various areas. It is not an evaluation system having a quantitative evaluation index, but it is one having a qualitative evaluation index, so operators can develop their ability to consider logically for human error and improve their sensitivity and recognition for the risks on their own initiative.Then, this section presents an introduction of TESEO(Tecica Empirica Stima Errori Operatori) and HEART(Human Error Assessment and Reduction Technique).

Tecica Empirica Stima Errori Operatori

TESEO is a method to estimate a probability of human error. In 1980, Bello,G.c and Columbori V conducted it as a method to estimate errors made by operators in a power station based on experiential data. To lead the probability of human error, they defined identification of the error, quantification of the error and reduction of the error as main factors. And, based on these main elements, they evaluate the state of five following parameters and estimate the probability of human error of the whole operation by the product of five evaluation level.

K1: Type of Activity
K2: Temporary Stress Factor for Routine Activities
K2: Temporary Stress Factor for Non-Routine Activities
K3: Operator Qualities
K4: Activity Anxiety Factor
K5: Activity Ergonomic Factor

TABLE 1.1: TESEO Parameters

Type of Activity	K1
Simple, routine	0.001
Requiring attention	0.010
Not routine	0.100

TABLE 1.2 TESEO Parameters

Time available Factor for routine activity	K2
2 sec	10
10 sec	1
20 sec	0.5

TABLE 1.3: TESEO Parameters

Time available Factor for non-routine activity	K2
3 sec	10
30 sec	1
45 sec	0.3
60 sec	0.5

TABLE 1.4: TESEO Parameters

Operator's typological factor	K3
Carefully selected expert, well trained	0.5
Average Knowledge	1
Little knowledge	3

TABLE 1.5: TESEO Parameters

Activity anxiety factor	K4
Situation of grave emergency	3
Situation of potential emergency	2
Normal situation	1

TABLE 1.6: TESEO Parameters

Activity ergonomic factor	K5
Excellent microclimate and excellent interface	0.7
Good microclimate and good interface	1
Discreet microclimate and discrete interface	3
Discreet microclimate and poor interface	7
Poor microclimate and poor interface	10

$$(\text{Probablity of error}) = K1 \cdot K2 \cdot K3 \cdot K4 \cdot K5$$

Human Error Assessment and Reduction Technique

HEART is a method developed by J.C.Williams working at central power center in the UK. And it is consisted of 5 steps to estimate the probability of error.

1. Select Generic Task
2. Select candidate: Error Producing Conditions (EPCs)
3. Check for GT with EPC
4. Calculate PoA for each EPC

$$EPC' = ((EPC - 1) \times PoA) + 1$$

5. Multiply GT by adjusted EPCs

$$p(E) = GT \prod EPC'i_{i=1}^{m}$$

INVESTIVATION AND ANALYSIS

Evaluate the Level of Human Error Management

By evaluating the level of the safety management, we could know the workers' motivation for confirmation/check tasks and find potential problems through it. For 7 steel companies, 5 railway companies, 7 general hospitals and 2 oil refining companies, we made survey of the workers' understanding level about safety activities/management and confirmation/check tasks for all employees. A content of the survey is 20 questions (Fundamental Principle) to evaluate depth of understanding about safety management and 10 questions (Confirmation/Check System) to evaluate a system confirmation/check tasks. How to answer to these question is select a number (1~4); Disagree(1), Partly agree(2), Agree(3), Strongly agree(4).

TABLE 2.1: Survey

Fundamental Principle	1	You never make a mistake.
	2	Low skill leads errors and mistakes.
	3	You want to hide your mistake.
	4	A fault of a mistake is whose make the mistake.
	5	Careless/absent minded mistakes are responsibility of a person.
	6	Making efforts enables to reduce human error.
	7	Making person never mistakes enables to reduce human error.
	8	You have no luck when you make a mistake.
	9	It is troublesome to write human error and a trouble report, and I write only necessary minimum.
	10	You do not understand the reason why you have to write about an incident.
	11	You have no opportunities to learn about safety management.
	12	You have never received a lecture about human error research.
	13	An investigation of human error is time-wasting for you.
	14	You do not know a purpose of analysis of human error.
	15	You never analyze a cause of human error.
	16	Only prevention of recurrence of error is enough.
	17	Human error prevention activities performed now are enough.
	18	You are not interested in other companies' safety management.
	19	Human error prevention activities should be considered and coped individually.
	20	There is no necessity of managing human error as an organization etc. (Or it is hard-pressed)
Confirmation/Check System	21	Actual work of Confirmation/check tasks is just "writing checks".
	22	Items of checklist have no priority.
	23	Capacity of Confirmation/check tasks is irrelevant and not administrated.
	24	The contents of checklist are periodically maintained.
	25	A checker is not familiar with the characteristics of operations and operators.
	26	There is little communication between a checker and workers (operators).
	27	There is no difference between check-mistakes and human errors.
	28	There is no feedback of errors and mistakes occurred.
	29	A training period is not enough to use appropriately a checklist.
	30	There is a difference between checkers.

THE RESULT OF THE SURVEY

A totaling the results of the survey is below.

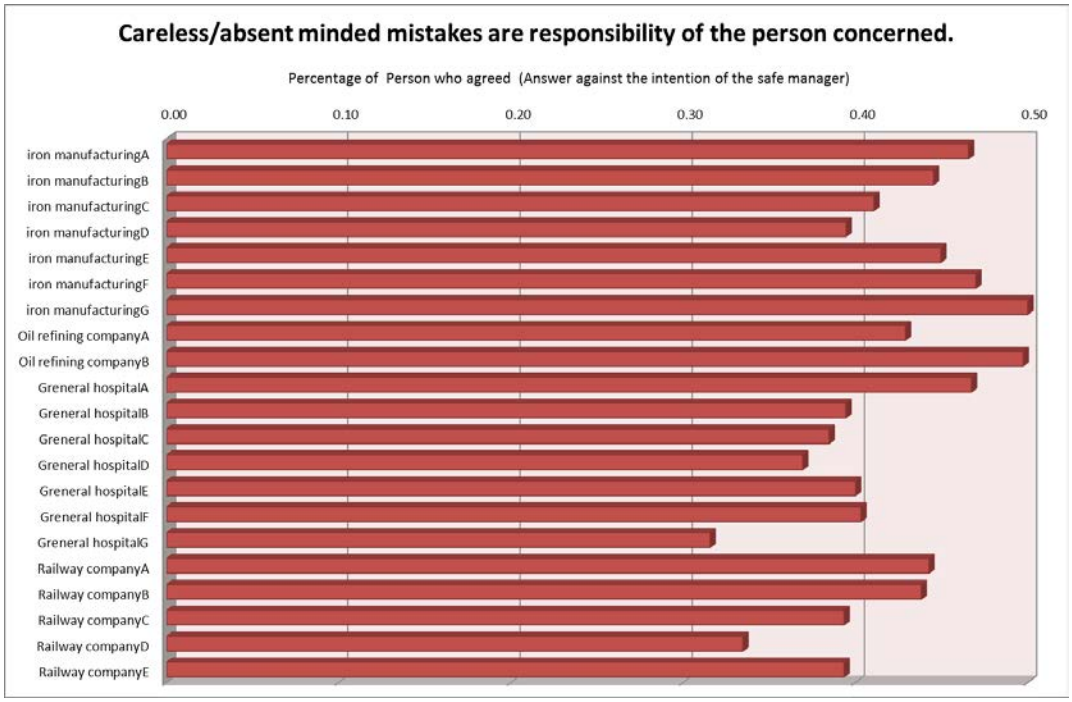

FIGURE 2.1: Q5

You can see from Figure 2.1, most workers think that “a person who committed an error should responsible for it”, so errors are inclined to be dealt as individual problem and be thought none of concerns with other persons by them. Moreover, as safety management actively advances, lectures/instructions on human errors tend to increase, and so dissatisfaction “I am enforced the new countermeasure because of somebody made a mistake.” is increasing as well. Eventually, if a safety manager considers that human error belongs to the person concerned, he tends to make a new countermeasure to prevent it by reinforcing confirmation/check tasks. Then confirmation/check tasks are continuously gradually adding in volume. Too much capacity and too often alteration of countermeasures are hardly pressing workers, and in the result they are worn out from stress and have negative image for safety management.

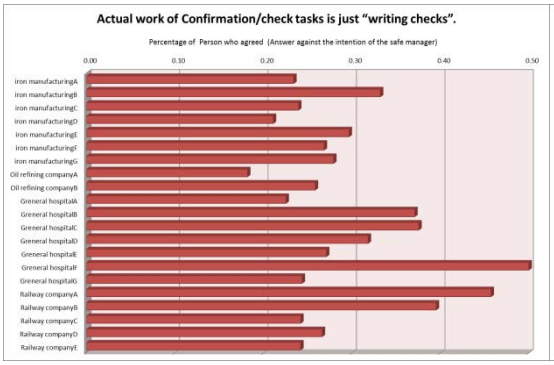

FIGURE 2.2: Q21

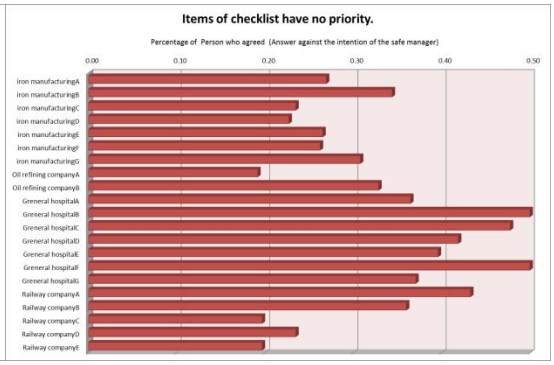

FIGURE 2.3: Q22

The result showing by Figure 2.2 and figure 2.3 explains that most companies have a confirmation/check system that makes workers bored and soul-destroying.

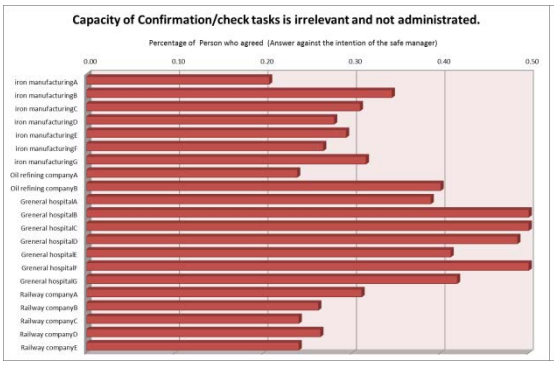

FIGURE 2.4: Q23

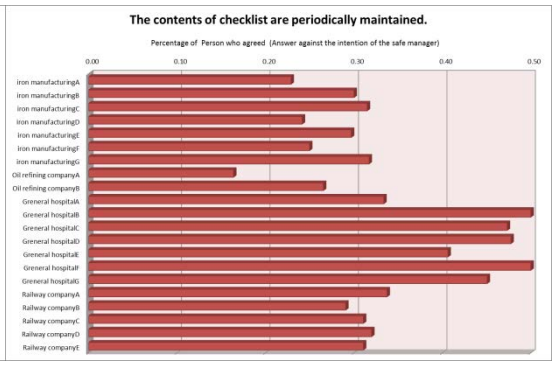

FIGURE 2.5: Q24

According to Figure 2.4 and Figure 2.5, when it comes to confirmation tasks, there is no regular/routine maintenance and safety managers do not take capacity of site-workers into consideration. Then, an inappropriate quantity of confirmation/check tasks is left that as is all along. At least 20%, at most 60% of workers answered in the affirmative.

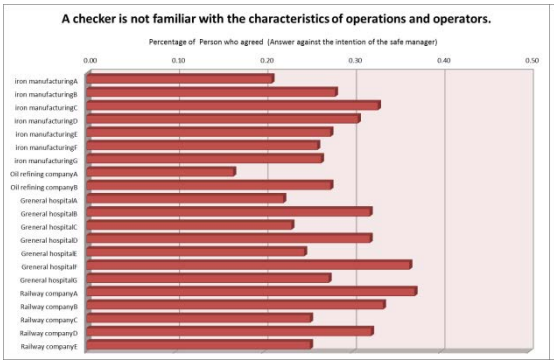

FIGURE 2.6: Q25

FIGURE 2.7: Q26

Figure 2.6 and 2.7 explain that some workers who do not have enough skill play confirmation/check tasks. That is because training period is not enough long for workers and a safety manager who made checklists is not able to understand each workers' situations. Insufficient skill leads commission errors.

INTERVIEWS WITH COMPANIES

Railway Companies

- The number of confirmation/check tasks with checklist is increasing in these years due to troubles and accidents. That is because most departments easily put in force new countermeasures with checklists.
- Even though improvement plan of checklist are carried out, a similar accident and trouble could often happen. They felt limit on effects of checklist.
- Instead of increase of the number of items/types on checklist, it is necessary to change it understandable and easier to use.
- A problem of use of checklist is that workers are inclined to become mannerism.
- Double check does not completely perform. A second checker depends on the first checker too much.
- Young employees have never experienced serious troubles and accidents, so they are so ashamed of their own failure and mistake that they often hide it. Thus, a delay of their report of mistakes led a situation to grow more serious.
- There are a lot of types of checklist. It makes difficult to improve an existing checklist.

General Hospitals

- There are many checklists to confirm a status before taking over.
- Because the number of checklists is getting more and more, employee have no time to spare to carefully check each items of checklist.
- A director of nursing service department notice that nurses are suffered from stupendous capacity of

checklist, but he/she is resistant to any change of checklist because of a threat of accident.

- It is good for employee to responsible for what they have done with checklist because confirmation/check tasks enable to make clear who have done the operation. And then, they would perform with a high level of awareness.

SUGESSION

Countermeasure Guidance System

We compiled keywords to guide countermeasures which were made by not only safety manager but also site-workers in case of consideration of measures to prevent recurrence.

TABLE 4.1: Countermeasure Guidance Keywords

A	Use inappropriate tool/mistake procedure/miss process
B	In a condition of being weakened not to correctly judge
C	Perform without imaging of the result of the performance
D	Perform with little regard to the risk of performance
E	Perform without standards for judgment/unreadable figure
F	Insufficient preparation for information/tool
G	Operation in an invisible manner
H	Difficult task with current system

Writing report with countermeasure guidance keywords makes easier that safety managers and employees can make up with countermeasures except for reinforcing confirmation/check tasks.

Guideline

This guideline is composed in a case assumed, where employee want to make up with countermeasures to improve checklist based on human, reliability knowledge except to reinforce confirmation/check tasks. Therefore, the guideline has information on supplementation of past accidents and troubles. There two types of guideline.

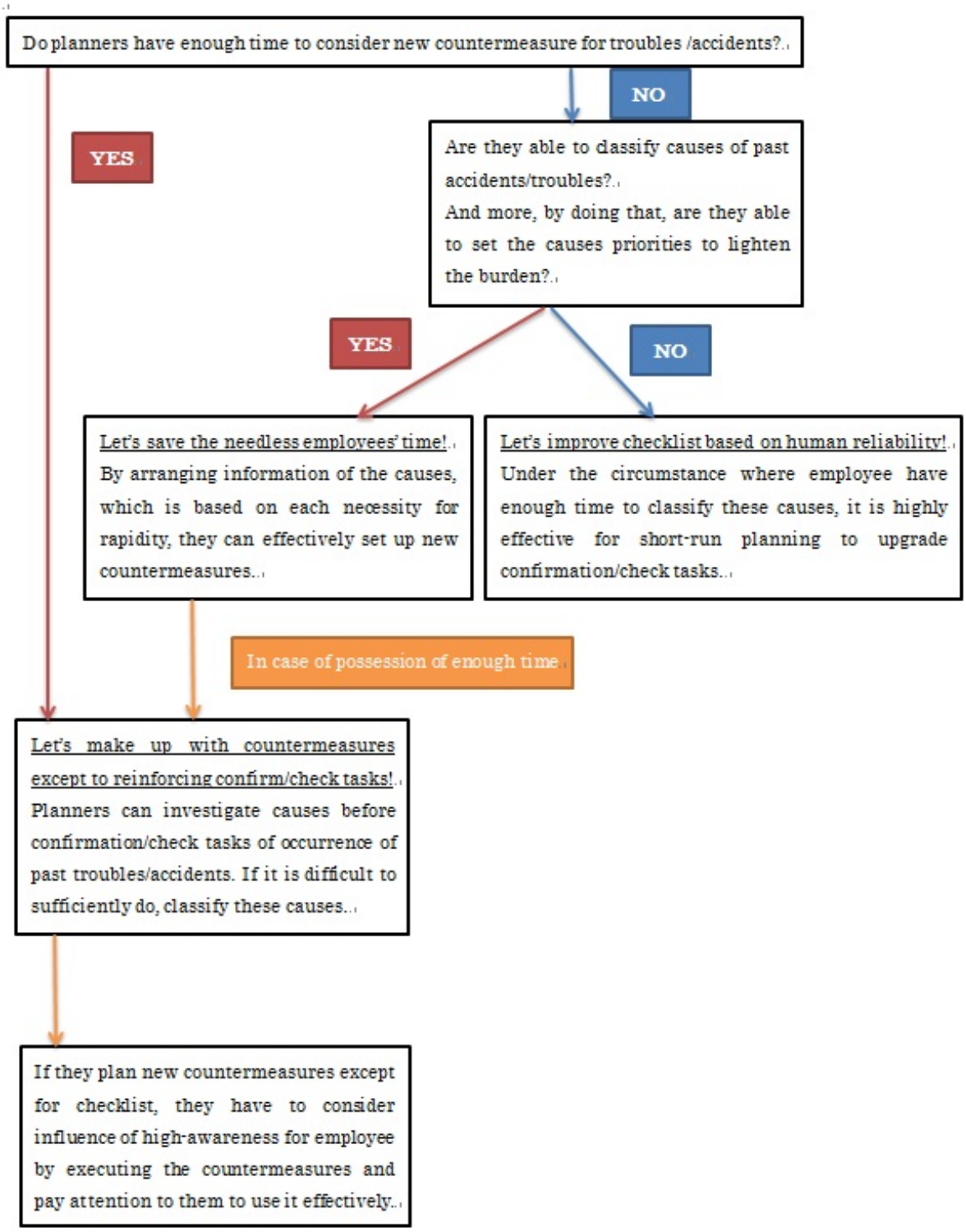

FIGURE 4.1: Guideline1- A Case Where Employee Have Enough Time To Set Up New Countermeasures

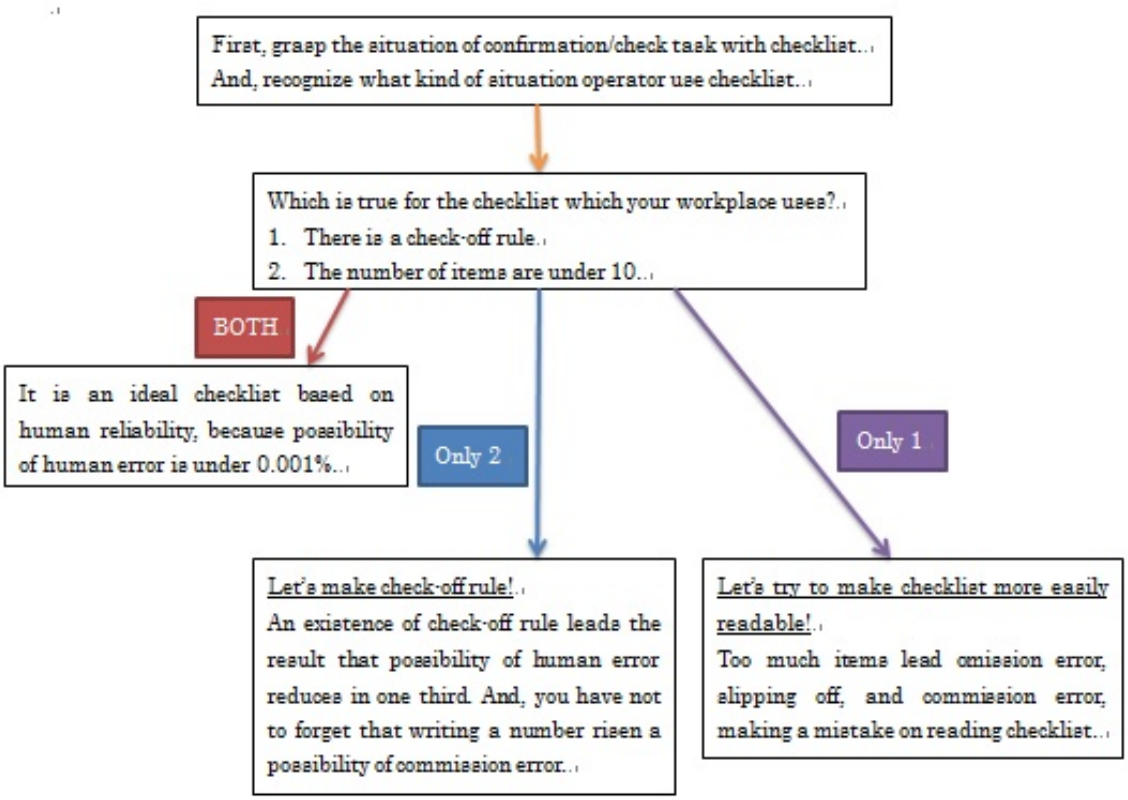

FIGURE 4.2: Guideline2- A Case Where Employee Is Unable to Plan Countermeasure Except for Checklist Because of Lack of Time

CONCLUSIONS

In this study, we are focusing on confirmation/check tasks with checklist and analyzing factors that inhibit performance from different points of view, in the result, we could clarify them. Moreover, the compiled guideline has been presented to the surveyed companies and now put into practical use on a trial basis, assisting those who prepare checklists.

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An Analysis of Drug Administration Tasks on Safety Management in Medical Centers

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ABSTRACT

The safety management in various hospitals recently has begun in order to reduce the incidents and prevent human errors. Among incidents that occurred in hospital, many are related to drug administration error. Drug administration error is a type of human error that occurs somewhere in the process spanning from medicine prescription by the doctor through administration by the nurse. We examined whether there is any problem with the incident report on the drug administration error in the hospital. Then, we found that it is difficult for safety manager with little experience, to find the problems in drug administration task. Also we found that they didn't know how they would discuss countermeasures. Therefore we studied to help safety manager find and take measure in work including dangerous factors at drug administration tasks by evaluating the risk of the work. The method is evaluating the risk of the work in the drug administration tasks by using Factors List, Risk Score and Influence of the Factors. By using this method, it helps safety managers in the hospitals understand problems of the work in the drug administration tasks and activate the recurrence prevention activities of medical accident.

Keywords: Human Error, Human Error Possibility, Human Reliability, Performance Shaping Factors, Safety Management

INTRODUCTION

In medical institutions such as hospitals, there has been great interest in safety activities for medical services related to the patient's life. Therefore, safety activity is important in hospitals in order to continue to protect safety. One of major safety activity in hospital is recurrence prevention activities of medical accidents. This is activities in which medical safety manager investigate the accident and discover the dangerous factors and take measures. Because there are many personnel, money, time, and equipment in large-scale hospitals, safety manager can easily takes measures. But because there are not much personnel, money, time, and equipment in small-scale hospitals, safety manager cannot easily takes measures. For this reason safety manager have to take measures against the most dangerous factor included in the work. The most dangerous factor is decided by safety manager. If safety manager don't have much knowledge and experience of accidents, it is difficult that safety manager takes measure against accident. Figure 1 is ratio of the number of accidents in about 400 hospitals.

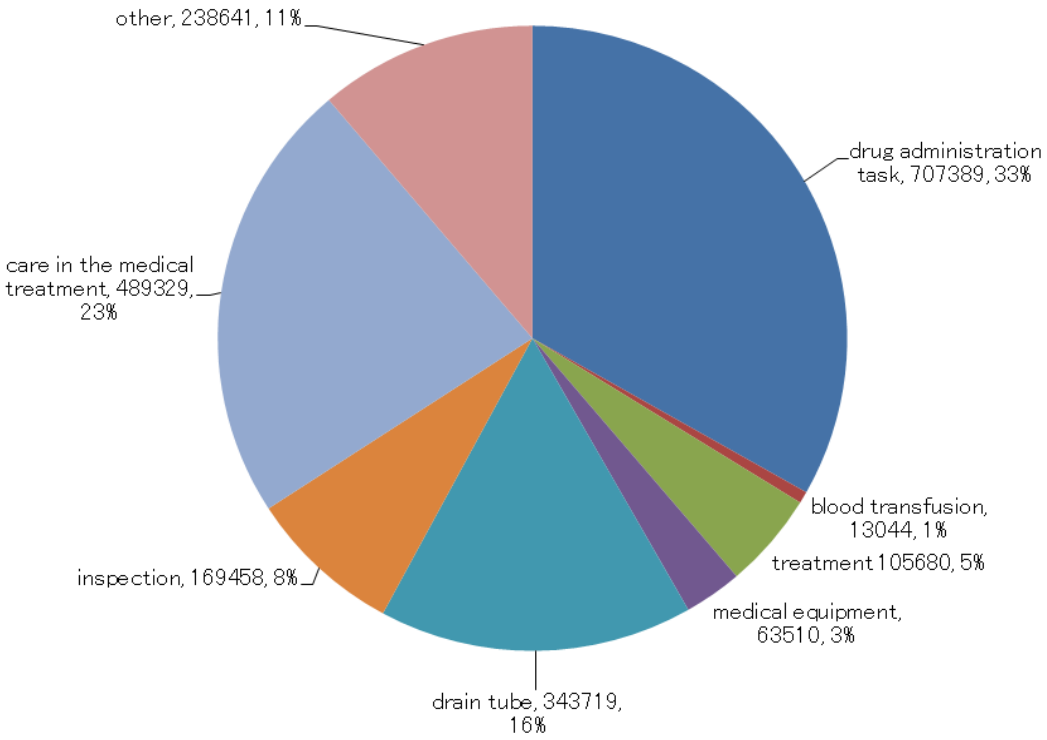

Figure 1: Ratio of the number of accidents in about 400 hospitals. (January 2010-June 2013)

It is found that drug administration tasks have the largest percentage from Figure 1. From the above, we studied to help that safety manager find and take measure in work including the largest dangerous factors at drug administration tasks. In this paper, we wrote about methods of evaluating risk of work and how to use them. We call risk of work as Human Error Possibility.

THE METHOD OF EVALUATING RISK OF WORK IN DRUG ADMINISTRATION TASKS

Factors List

First, we investigated what kind of dangerous factors is in drug administration tasks when an accident occurs. In that case, safety manager can soon conceive factors that directly affect the accident. Certainly when an accident occurs in medical field, it is important for safety manager to find factors that directly affect the accident. But it is important to find not only the clear factor but also a lot of factors that lurk in the back side of the clear factor from a past accident. Decreasing these latent factors leads to the prevention of a severe accident. In a word, it means that taking measures based on analyzing incidents will consequentially prevent a severe accident. This idea is based on the Heinrich's hierarchy "There are accident of 29 medium degrees and 300 slight cases in the back side of one severe accident ". When an accident occurs, the possibility that a lot of incidents have been lurking till then is high. Then we examined a lot of factors that lurk in the back side of the clear factor from a past accident. First we analyzed 30 incident cases with 30 persons concerned with 10 hospitals (safety managers, nurses, pharmacist, etc…) by using Root Cause Analysis. Root Cause Analysis is method that can extract a lot of potential factors by prompting that analyst to consider many times why accident happened. Also analyst can understand structure of cause and effect of the accident. Figure 2 is an example of the result of the Root Cause Analysis. By using this method, we were able to extract 666 factors lurking in the accident of drug administration task.

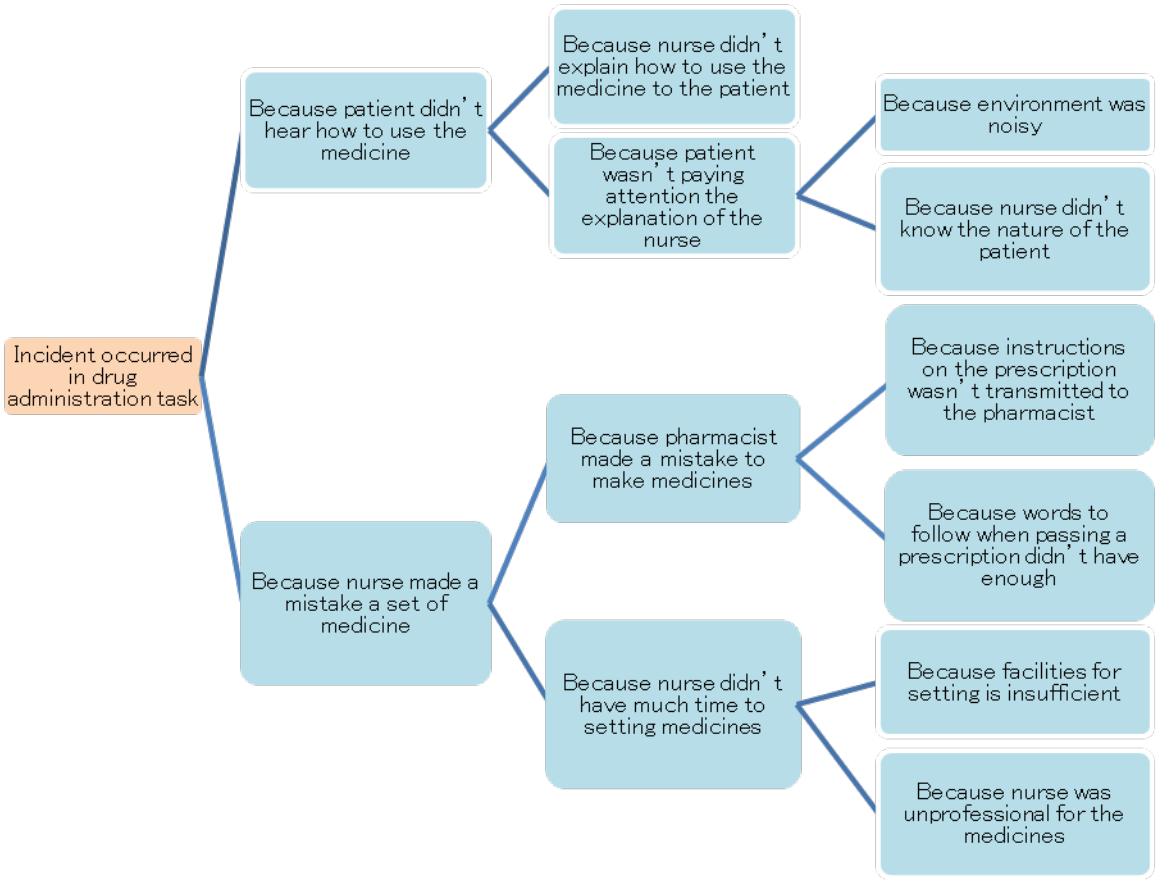

Figure 2: An example of Root Cause Analysis

Next we counted the number of 666 factors included in the 236 incident reports in 10 hospitals. And we narrowed down 666 factors to 64 factors. We define 64 factors as "Factors List". Table 1 is the Factors List created. We have set the references and keywords to each factor.

Table 1: Factors list (excerpts)

Factors	Reference	Keywords
Noise environment	Always be big sound in hospital ward	noisy, sound, ears
Ventilation difficulty	Have a bad odor in hospital word	smell, nose, odor
Lack of temperature control	Setting injection in the cold cannot be well for hands grow numb with cold	hot, cold, temperature, chilly, warm
Poor lighting environment	Working room with drowsiness in the dark	dark, light, lightning, hard to see
Lack of vibrant	Some people don't come back to say good morning	good morning, vibrant, energetic, voice
Lack of opinion exchange opportunities	Opportunity to bandy the opinion on an equal basis is less	field, title, objective, management, boss, exchange of opinion, leader

Risk Score

Next, we examined the degree of danger for each factor included in Factors List in drug administration tasks. We define this as “Risk Score”. Therefore we set the Risk Score of each factor by referring to the data of NUREG/CR-1278. NUREG/CR-1278 is the data indicating the probability of human error in the work and used in nuclear power industry. In addition, we also used HEART (Human Error Assessment and Reduction Technique) with the aim of complementing the NUREG/CR-1278. Table 2 is a one case. In this way, we established Risk Score of 64 factors.

Table 2: Risk Score (see NUREG/CR-1278)

Risk Score	Factors	Reference
0.001	Noise environment	Always be big sound in hospital ward

Influence of the Factors

Next, we examined the degree of influence of each factor in Factors List that affects the accident. We define this as “Influence of the Factors”. Influence of the Factors is the degree to which the factors are affecting incident. Therefore, in the present study, we calculated the degree of influence of each factor by using the following formula.

Influence of the Factors = the number of factors obtained from incident reports / the number of incident reports

The calculation was based on the keywords included in Factors List.

Calculation of the risk of each factor

It is possible to calculate a risk of factor by using “Factors List”, ”Risk Score” and “Influence of Factors” as defined previously. We show the formula below.

Risk of each factor = presence or absence of each factor (0, 1) × Risk Score of each factor ×Influence of each Factor

By this formula, risk of each factor can be calculated.

Table 3: Risk of each factor

Factors	Degree of influence	Risk of each factor(10^-4)	Factors	Degree of influence	Risk of each factor(10^-4)
Noise environment	0.002	0.02	Hazardous work	0.008	1.17
Ventilation difficulty	0.002	0.02	Short-distance management	0.020	0.10
Lack of temperature control	0.005	0.05	Poor identification	0.055	1.66
Poor lighting environment	0.002	0.12	Management of multiple standards	0.011	0.11
Lack of vibrant	0.113	13.58	Standards change	0.005	0.55
Lack of opinion exchange opportunities	0.096	38.41	Irregular preparation	0.009	4.29
Not penetration of safety	0.009	2.15	Risk areas in	0.022	2.19

management			management		
Deterrence of observer	0.014	14.05	An optimistic plan adopted	0.027	13.27
Not understanding concept of safety management	0.040	15.93	Work site is narrow	0.027	0.27
Deficiencies of Education system	0.215	43.09	Equipment use hard	0.149	74.55
Time pressure	0.158	157.69	Other intervention	0.062	62.45
Working alone	0.024	2.42	Other management products use	0.020	0.41
Small number of people	0.018	13.47	Other departments for work	0.021	52.69
Not consideration of	0.056	42.15	Poor contact between departments	0.073	36.30
recovery time	0.016	1.64	Rare working	0.015	7.42
Many work steps	0.008	1.17	Prepare early	0.019	0.75
Placement of unhealthy workers	0.098	49.18	Check excerpt	0.428	12.83
Getting used to work	0.012	0.12	Simple work specialization	0.200	199.84
Penetration of local rules	0.087	43.72	Own way work reduction	0.012	5.85
Step priority	0.012	6.25	Bad work request	0.031	9.37
Non-consideration of personal characteristics	0.165	24.82	Cooperation unsuitable	0.030	0.30
Bring materials management system deficiencies	0.063	6.32	Recovery overconfidence	0.012	1.05
Difficult interpretation of article	0.161	4.82	Information difference	0.029	2.89
Lack of information at the time of instruction	0.011	32.79	Bulk management	0.084	67.45
Instructions view differences	0.013	3.32	Equipment operation difficulties	0.045	4.53
Unclear instructions	0.074	2.22	Poor grasp	0.052	1.55

Verbal instructions corresponding	0.034	134.27	Subordinated discovery of anomalies	0.092	92.12
Additional work requested	0.039	0.39	Lack of action for understanding	0.060	75.14
Lack of information aggregation	0.023	11.32	Working for unknown	0.137	13.66
Changing instructions shared	0.136	13.58	Correspondence to unreasonable	0.006	6.25
Similar iterations	0.012	2.50	Correspondence unexpected behavior	0.170	170.18
Amount of the work is different from day to day	0.008	1.17	Inadequate planning	0.025	62.45

Calculation of Human Error Possibility (risk of work)

By calculating risk of each factor, it is possible to calculate a risk of work. A risk of work consists of many risks of factors. And a risk of work shows Human Error Possibility. Since each factor included in Factors List is independent, the following formula is obtained.

Human Error Possibility = 1-Π (1- risk of factors)

=1-Π (1- presence or absence of each factor × Risk Score of each factor ×Influence of each Factor)

In this way, we can calculate Human Error Possibility.

Evaluation

Safety manager can tell that the higher the Human Error Possibility, the higher the priority, which means they should take measure for that work.

VERIFICATION

Actually, we verified this method in the A hospital. Figure 3 is the flow of drug administration tasks in the A hospital.

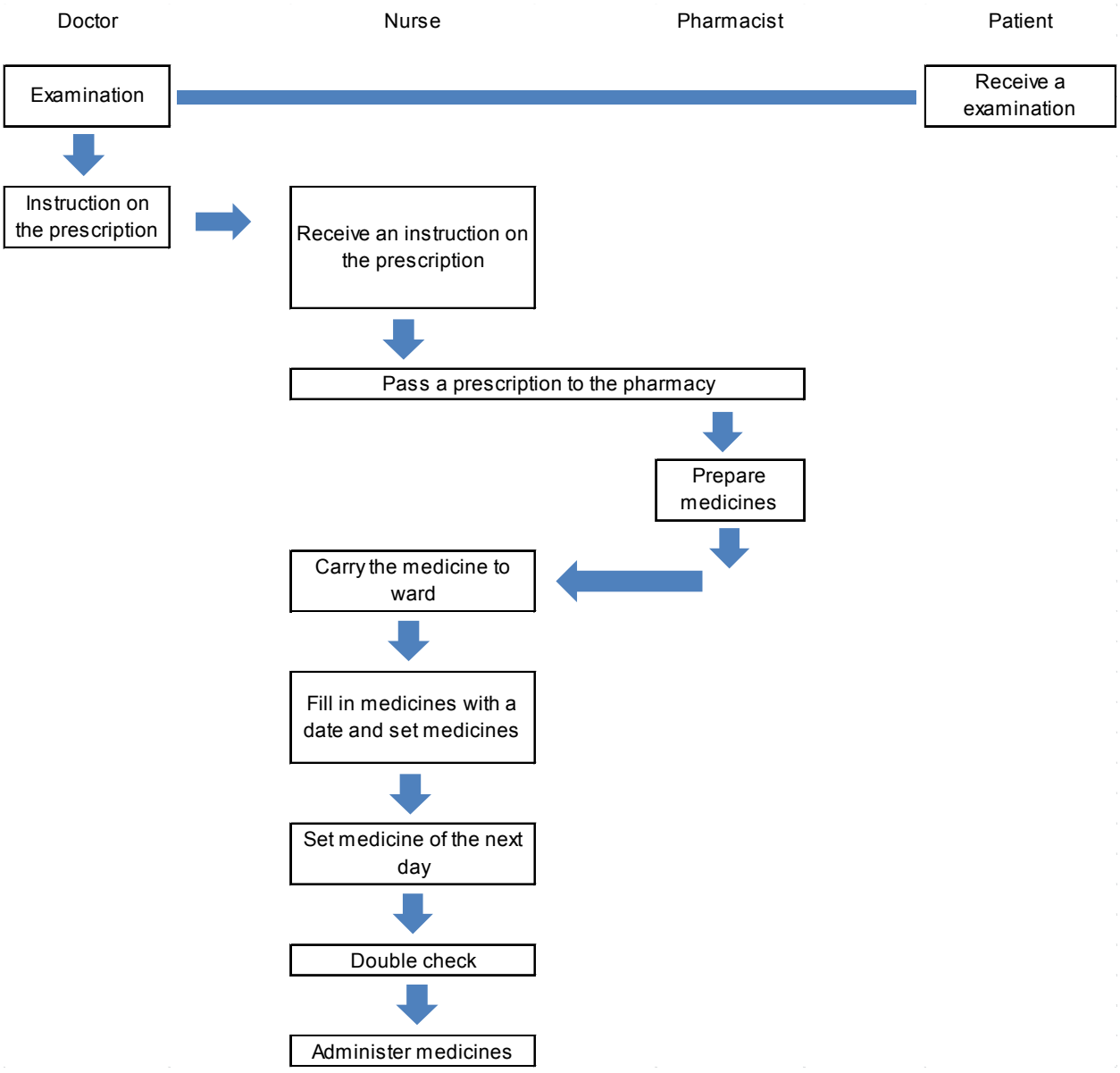

Figure 3: The flow of drug administration tasks in the A hospital.

The safety manager in the A hospital pick all the factors that are true for Factors List in drug administration tasks of their own hospital. Factors whose degree of risk is higher become factors against which they should take measures. Figure 4 show Human Error Possibility in the A hospital. And figure 4 show that the risk of "Receive an instruction on the prescription" is the highest.

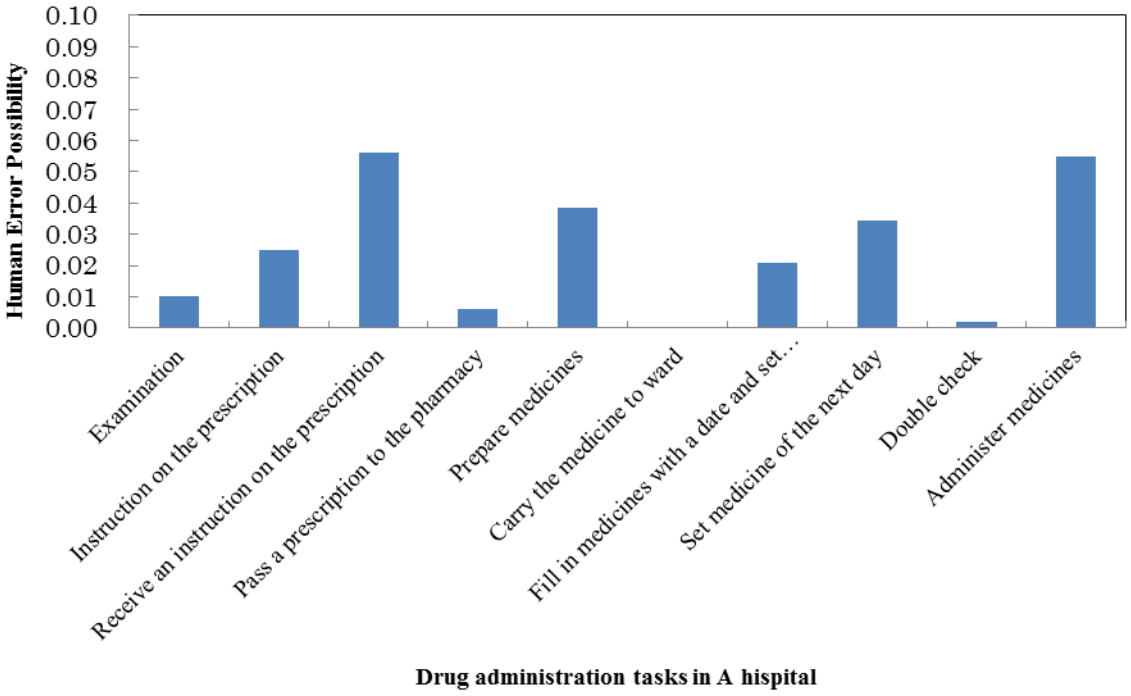

Figure4: Human Error Possibility of each work in drug administration tasks

Table 4: Dangerous factors included in "Receive an instruction on the prescription"

Dangerous Factors	Human Error Possibility
Time pressure	0.0158
Verbal instructions corresponding	0.0134
Other intervention	0.0062
Other departments for work	0.0053
Lack of information transfer	0.0049

By looking at the table 4, we can evaluate that factor of "Time pressure" included in "Receive an instruction on the prescription" should be addressed in the A hospital. Furthermore, by comparing Human Error Possibility of the one hospital with Human Error Possibility of the other hospitals and finding the work that has the highest Human Error Possibility, it also will be possible to help safety managers in the hospitals to improve the work. As a result of using our method, safety managers said that finding a weakness in the drug administration tasks became easier by the presence of the indicator of the risk of work, and that it was very convenient when taking measures. Further, safety managers said that they could take better measures by being able to find problems that they didn't care when taking measures.

CONCLUSIONS

One of major safety activity in hospital is recurrence prevention activities of medical accidents. This is activities in which medical safety manager investigate the accident and discover the dangerous factors and take measures. What is important in this activity is to discover the dangerous factors. Safety manager have to discover the dangerous factors and understand the problems exactly, or recurrence prevention activities does not work. Also by understanding which work has problems, safety manager can use the past measures and studies. But in fact, for the inexperienced safety managers, it is difficult to discover the dangerous factors and understand the problems exactly.

From the above, we studied to help safety manager find and take measure in work including dangerous factors at drug administration tasks by evaluating the risk of the work. The method is to evaluate the risk of the work in the drug administration tasks by using Factors List, Risk Score and Influence of the Factors. By using this method, safety managers in the hospitals can easily understand problems of the work in the drug administration tasks and activate the recurrence prevention activities of medical accident.

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Evaluation of Working Postures in Mexican Rural Workers and Their Effect on Musculoskeletal Discomfort

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ABSTRACT

The study population consisted of workers who live in areas considered rural (less than 2, 500 people and have no regular water service, electric light, street paving, according to INEGI, 2010), distributed in the municipalities of Poncitlán and Ocotlan, Jalisco. Its economy depends to be workers or peasants in small family plots. Objective: To relate the positions taken and musculoskeletal discomfort in workers of a furniture industry in Ciénega region of Mexico, in 2011. Methods: Cross-sectional prospective analytical component. 258 workers participated. The instruments used were socio-demographic survey, Standardized Nordic Questionnaire (CNE) and OWAS method. The data were analyzed using basic statistics and correlation, organizing data in tables and graphs. Results: The greatest inconvenience positions were presented in sewing, upholstery, assembly and shipping. Variables in the correlation of the anatomical region of the back and expressed seniority factor had the highest risk, followed by positions with action category 3 and 4 OWAS and age. Conclusions: These are the positions derived from the task which causes musculoskeletal discomfort and not the activity itself. Reengineering posts, ergonomic education intervention, and automation of high-risk areas is proposed.

Keywords: rural workers, musculoskeletal, OWAS, odds ratio.

INTRODUCTION

Since late last century is considered that novel occupational health problems are composed of two emerging diseases, job stress and ergonomic injury to the musculo-skeletal system, according to the Workers' Commissions of Castilla and Leon (2008), one of every four workers referred complaints regarding their musculoskeletal system. The European OSHA reports that musculoskeletal disorders are the most common work-related health problems, with non-neutral postures as the cause for cumulative trauma disorders.

The purpose of ergonomics is to adapt the work to the man, and one of the ways to do this is to study the risks of labor in a physical environment. This paper aims to contribute to understanding the positions and their effect on the presence of musculoskeletal discomfort in male and female workers in the furniture industry. This has not been studied in Mexico, and reported studies focus on male workers in heavy industry, as expressed by nurses and dentists treating the patients.

This research proposes improvements to ergonomic working conditions and contributes to the knowledge of the characteristics of rural labor populations for further study of causality. The lack of information on this subject and its

impact on the local population is reflected in the ambiguity with which employers implement appropriate ergonomic adjustments. Due to insufficient training, workers are unaware of the ergonomic risk factor. Also in scientific, medical and business areas in the writer's country, needs are unknown regarding the use of ergonomics as an instrument of satisfaction, wellness and prevention.

The Cienega region, in the state of Jalisco is located on 2 major corridors for commercial activities: the runner Tepic-Guadalajara-Morelia-Mexico and Manzanillo-Guadalajara-Lagos corridor Moreno-Lion-San Luis Potosi leading to U.S. border. Industrial production reached 4. 3% of the industrial production of the State focuses on the area of Ocotlán and its area of influence, emphasizing the furniture industry that has national importance (National Development Plan, 2007-2009).

Despite being a thriving industrial area, some have studied the processes that occur in the area, in the literature only focused on studies of social conditions and the economy that generates the furniture industry are reported. Results indicate precarious and far from the quality standards, risk factors for work-related pathologies working conditions. Most employers recognize that within the main risks to damage the health and safety of its employees associated with physical fatigue or stress positions (40.5%) is found, and that, in fact, what causes these risks are primarily tools, machinery, and equipment (46.6%) (Cuellar, García, & Hernandez, 2008).

A high percentage of the furniture industry in the area is not eligible for export or inserted competitively in the domestic market which is reflected in lower incentives to modernize machinery; the 73.3% do not acquire, modify or replace equipment individually or collectively protection provide poor training of workers, generated few change in its organization, minimum adjustments aimed at the health and safety of workers; the 88.5% of employers do not consider jobs modification to improve their ergonomics aspects, plus an undercount accident and occupational disease (Cuellar et al., 2008).

The continuous development of science and technology seeking to satisfy human needs makes the world economic order subject in a significant percentage to the industrial sector. In 2007, according to a report of the total world population, 48% are employed, of which 17% are female, and 31% are male. In Mexico, the rate of total labor force in 2008 is 68%. The state of Jalisco, one of the most industrialized countries, had the sum of 1.9 million people paid workers in 2009 according to the Economic Census, which covers manufacturing 35.1% of workers. In June 2010, provides for the processing industry 3'885, 280 workers and specifically in the manufacture of furniture 81, 590 workers (INEGI, 2010).

The interrelation of media production and the worker presents risk conditions capable of producing disorders related to the work (Piedrahita, 2004). Physical strength man development for survival in the early days was lost for the sake of the bipedal position, designed to walk on two legs. The requirements in job performance may cause damage to health when tasks exceed the capacity of man, injuring him (Kumar, 2001).

Precarious conditions of the work environment in México, more pronounced in rural areas bring disease and accidents. Employers do not have the financial means or the intention of providing a healthy work environment and if any worker not immersed in a culture of prevention does his best to avoid them, creating a vicious circle suitable for risk factors lead to damages for worker health.

The transition from livelihood industrialized and highly skilled jobs has led to an increase in the presence of psychosocial factors, biological, physical, chemical and ergonomic risks related to accidents and illnesses. The study of human biomechanical performance against requirements demanding jobs to the economically active population is studied by ergonomics (Gutiérrez, 2009).

The World Health Organization (WHO) encompasses musculoskeletal discomfort in a group of conditions defined as "work-related disorders, which may be caused, aggravated, accelerated or exacerbated by exposure at the place of work and they may be associated with work conditions. Personal characteristics and other socio-cultural factors play a role as a risk factor in triggering these conditions." (Piedrahita, 2004). The International Labour Organization (ILO) included musculoskeletal disorders (MSDs) in their list of occupational diseases in 2002.

Viikari-Juntura, Rauas, Martikainen, Kuosma, Riihimäki, Takala, & Saarenmaa, K. (1996) refers to the proportion of musculoskeletal diseases attributable to work is about 30%. Luttmann (2004) for his part, points out that in industrialized countries, one third of sick leave for health reasons are due to musculoskeletal ailments, including cumulative trauma disorders. OSALAN (2008) reports in its 2007 report that the health damage found 47.8% are

risks of muscle-skeletal injuries. In 2007, in Mexico, 2.6 per 10 000 workers have occupational diseases (3,681 cases), of which 56 were reported as back pain, since musculoskeletal disorders are not classified as such (IMSS, 2008).

In this absence of classification by both medical and legal in México and because of the economic conditions in which the industry develops in Mexico, Small and Medium Enterprises (PyMES) are a good source of job creation but also the origin occupational diseases, including musculoskeletal. Within this area, the position that the employee takes in carrying out their work fits working conditions. The imposed load, working hours, job demands, in clear contrast to what gives the definition of the ILO Occupational health. The work must be adapted to the worker and not the reverse, creating the conditions sufficient for an occupational disease develops. The effects of good or bad fit between the object and the user used in each of the activities will have very different consequences, from mild to severe and disabling (Prado, 2006).

The need to study working postures in an industrial environment is usually based on three premises: a) inadequate postures alter the way to work or cause pain or fatigue, b) inadequate postures are associated with workplace accidents, and c) poor posture are harmful to health (Prado, 2006). The postures that are adopted in the workplace have a goal, a purpose outside themselves. This is because the positions are related to external conditions (Kuorinka, 2004). So the posture analysis should include the working environment and the task itself.

The posture is closely related with balance and stability. In fact, the posture is controlled by a number of nervous reflexes, in which the arrival of tactile and visual sensations from the environment has an important role. It is defined as the organization of the trunk, head and extremities (position) that takes a person to perform an activity, in this case the performance of their work. Posture is the basis of the precise movements and the visual observation, as well as being a source of information about events taking place at work (Kuorinka, 2004).

The neutral position is the most appropriate because the anatomical regions maintain the natural position of the body. The posture is intended to facilitate the work, and therefore has a purpose that influences their nature, their temporal relationship and its cost (physiological or otherwise) to the person. Posture is the source of musculoskeletal load. Except when we are relaxed, whether standing, sitting or lying down, the muscles have to exert force to balance our position or control movements.

Kuorinka (2004) points out that, in reality, it was observed that a "typical" or "optimal" position, e.g. manual handling, is a thing of fiction. For each personand each work situation, there are a number of "best" alternatives from the point of view of different criteria postures. Awkward postures are positions of work involving one or more anatomical regions longer in a natural comfort position to move to a position that generates forced hyperextension, hyper-bending or musculoskeletal rotations and can cause overuse injuries. They include a) fixed positions or restricted body, b) the positions that overload the muscles and tendons, c) the positions loaded joints asymmetrically, and d) positions that produce static charge on the musculature (Cilveti, & Idoate, 2001).

Aaras (1998), Burdoff (1991), Keyserling (1988), Reyes (2000), and Ryan (1989) have shown that non-neutral postures are the leading cause of musculoskeletal disorders industry. Some musculoskeletal problems can be considered ergonomic diseases that can result from simple episodes of overexertion, overuse, or both cumulative (Pheasant, 1991).

The PyMES are the mainstay of Mexican industry, a large percentage came from family businesses; their expansion is in relation to market demand, so do not go hand in hand with a vision-mission competitive and globalized which include protection of worker health. López (2007), in a study conducted ergonomic practices in PyMES in Ensenada, concluded that little attention to the ergonomic design of the workplace is provided, and therefore, the care of the safety, health, and quality of life workers.

STAGE I. DETECTION OF MUSCULOSKELETAL DISCOMFORT

Population

The study was conducted in a furniture company in the municipality of Ocotlán, located in the Cienega region. Census with the entire working population was performed.

Type of study and procedure

The study is prospective with cross-sectional analytical component. From the results and observations made during the pilot study, it was decided to proceed with the application of both questionnaires in the form of an interview to all workers. From this post and distribution work area, presence or absence of musculoskeletal discomfort and background to apply the exclusion criteria was obtained. Ten interviews were scheduled per day, individually, in an office.

Instruments

Questionnaire for demographic, anthropometric and labour variables.

A questionnaire was used for collecting information which included data such as gender, age, weight and size, marital status, education, sport, work at home, care of children, a history of accidents or prior injuries, as well as general musculoskeletal disease. Labour variables were a history of similar jobs, seniority in the job, seniority in the company, work and working hours, area and job, as well as if you have another job in another company.

Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms

Musculoskeletal-related work, symptoms were identified with the Nordic Questionnaire Standardized (Kuorinka, Jonsson, Kilbom, Vinterberg, Biering-Sorensen, Andersson, & Jordensen, 1987) which was created for the analysis of musculoskeletal symptoms ergonomic origin in the context of occupational health. It consists of two parts; one is general, and the other is specific for the shoulder and neck. The limitations of the questionnaire are related to the person completing the questionnaire, including the length of time that he/she has submitted a questionnaire. The hassle and appreciation of the intensity are subjective to the person.

Results

The results of Table 1 describe the socio-demographic characteristics of the subject; it finds that most are male and with one whose age is less than 30 years.

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Table 1 Socio-demographic characteristics of the subject,

Variable	Characteristics	Percentage
Sex	Male	60%
	Female	40%
Age	17 to 30 age	61%
	More than 30 age	39%
Education Level	Elementary	38%
	Middle or more	62%

Laboral characteristics

Regarding the distribution of job characteristics of the sample, it was found that workers were divided into 2 areas: rooms (79%) and bedrooms-kitchens (21%). There are 15 jobs that cover the processes for preparing the wood, furniture assembly, finishing, packaging and distribution. The average length in the company is 5 years (± 4) and in the position of 4 years (± 3). The 75% have up to 5 years in the company and 25% over 5 years. 84% have up to 5 years in the job and 16% over 5 years.

Detection of musculoskeletal discomfort

The results of detection of musculoskeletal discomfort referred through the Standardized Nordic Questionnaire, and their relationship to gender, age, education level, length of service and work area are presented below. In addition to the classification that gives the instrument on the presence of discomfort, the last 12 months which related to chronicity and the mention of discomfort in the last seven days is considered an expression of the actual presence of the disease and whether these have limited performance in their workplaces and non-work activities.

Areas with the highest percentage of musculoskeletal discomfort in the past 12 months were upper back (10.4%), and hand and finger (10.2%). The lower back was the area with the greatest discomfort in the last twelve months (19.7), past 7 days (10.4%) and is the largest impediment to the activity (16.1%).

Relationship of musculoskeletal discomfort with other variables

The female has a greater percentage musculoskeletal discomfort in both recent and chronic forms and prevent their activities. In terms of age, no statistically significant differences as subjects older than 30 years had more discomfort in the elbow and knee in the last 12 months (chronic symptoms), and discomfort in the elbow that prevents activities.

The presence of musculoskeletal discomfort relating to schooling was statistically significant on the neck for the last 12 months and impedes activities of the neck and ankle in the group of middle and high school. For ankle discomfort in the past twelve months and hip in last seven days (acute discomfort), the significance was in the group of elementary school.

The presence of musculoskeletal discomfort regarding seniority was statistically significant for shoulder and ankle in the last 12 months and ankle in the last 7 days for the group with more than five years of seniority.

Also, musculoskeletal discomfort that had a statistically significant relationship with length of service was shoulder in last 12 months in the group with less than five years old in the post. Ankle discomfort in the last 12 months was significantly lower in both groups but was more prevalent among subjects with more than five years in office activities than subjects with five or fewer years in office. Most workers have less than five years working in the position. In the case of musculoskeletal discomfort in the upper back, subjects employed in the area of rooms were found to have the most developed symptoms.

The jobs that were significantly associated with musculoskeletal pain in the past 12 months in order of the decreasing number of cases were sewing and polishing, upholstering, carpentry, pre-assembly, padding, and packaging.

Jobs shown to have a significant impact on the neck muscles included sewing, assembling, polishing and shipping, whereas for upper back areas they included sewing, polishing, rubber, foam, shipping and assembly (Table 2).

Table 2. Distribution of discomfort musculoskeletal according to sex, age and seniority in the post

		Sex		Age		Seniority	
Body zone		Female (n = 99)	Male (n = 150)	17 - 30 years (n= 153)	More than 30 Years (n= 96)	Under 5 years	more than 5 years
Neck	Last 7 days	9	3			3	6
	Last 12 months	11	2	10	3	8	5
	Inhibit the activity	9	3	8	4	6	6
Shoulder	Last 7 days	0	3	3	2	0	5(.010**)
	Last 12 months	10	4	7	7	4	10.(.023*)
	Inhibit the activity	0	3	7	5	4	8
Elbow	Last 7 days	5	4	2	2	4	0
	Last 12 months	6	4	2	8 (7.495**)	6	4
	Inhibit the activity	5	4	1	8(10.308***)	5	4
Wrist /Hands	Last 7 days	13	11	8	6	8	6
	Last 12 months	14	12	15	11	13	13
	Inhibit the activity	13	11	13	11	11	13
Upper back	Last 7 days	16	3	6	5	7	4
	Last 12 months	20	6	12	14	15	11
	Inhibit the activity	16	3	10	9	11	8
Low back	Last 7 days	22	18	16	10	14	12
	Last 12 months	24	25	34	15	29	29
	Inhibit the activity	22	18	27	13	25	15
Hips /thighs	Last 7 days	1	3	1	1	0	2
	Last 12 months	2	3	3	2	2	3
	Inhibit the activity	1	3	2	2	1	3
Knees	Last 7 days	4	5	1	5	2	5
	Last 12 months	7	13	8	12 (4.222**)	11	9
	Inhibit the activity	4	5	4	5	6	3
Ankles / /feet	Last 7 days			3	4	3	4
	Last 12 months	5	9	7	7	4	10 (.023*)
	Inhibit the activity	4	7	6	5	4	7

STAGE II. RELATIONSHIP BETWEEN MUSCULOSKELETAL DISCOMFORT AND INADEQUATE POSTURES.

Sample

The sample was made up of subjects who has answered the musculoskeletal questionnaire, selected per job that had major musculoskeletal discomfort, and were of age, with at least one year in the job position.

Removal and exclusion criteria:

Temporary workers, workers with physical scars from accidents, workers heavily pregnant from the second quarter onwards, workers who had other medical conditions involving musculoskeletal symptoms of general work-related origin such as diabetes, rheumatoid arthritis drop leukemia, thyroid disease and aplastic anemia, were all excluded from the study. Workers with less than one year in the company were also excluded. Those workers who answered less than 85% of the items were eliminated.

Instruments

Postures Data Collection by Using Video Recorder

Subject Working postures will be recorded by a video recorder (Kivi & Mattila, 1991; Saurin & Guimaraes, 2006). Observations should be made at 30 second intervals. The observer maintains a recording distance of approximately two meters from the subject so as to ensure a full view of the body. The advantage of using a video recorder is that the observer has sufficient time to look at the observed postures.

OWAS Method

The OWAS method is collects observation information on worker postures on back, arms and legs. It has 252 posture, which are combination of four back postures, three arm postures and seven leg postures with three estimate loads. Each posture of the OWAS is determined by the four digit code in which the numbers indicates the postures of the back, the arms and the load needed. Observer need to identify OWAS posture code of each selected posture from the video image for each work task.

Each OWAS posture code will then be analysed using individual OWAS classified posture combinations in order to get the action category for each work phase. The classification for individual posture combination indicates the level of risk or injury for the musculoskeletal system. If the risk for musculoskeletal disorder is high, then the action category indicates the need and urgency for corrective actions. The action categories for each individual postures are presented in Figure 2 and explanation about OWAS action categories for prevention shown at Table 2. Prolong time spent in one particular posture may cause musculoskeletal injury. Therefore, the next analysis is identifying the OWAS action category by calculating the total time spent in different postures for each body part for one complete work task. WinOWAS software will be used to identify the OWAS action category.

Results

Postures adopted in the work

Based on the results of employment data obtained from the questionnaire and applying the selection criteria specifically the presence of musculoskeletal discomfort, a total of 208 workers was obtained. From this selection workers were matched by job, sex, age and education. Was designated as a case worker with the maximum score of musculoskeletal discomfort as a case and was appointed as its torque control a worker without musculoskeletal discomfort.

Both cases and controls were filmed in their area of work for a period of 30 minutes during which a total of 80 observations in that period was obtained. Of all the places filmed, six workers were female, and 9 were male.

Table 3. Percentage of postures by category method OWAS.

	Case				Control			
Job	Category 1	Category 2	Category 3	Categoríy 4	Category 1	Category 2	Category 3	Categoríy 4
Polisher	80	20			81	19		
Sellador	82	18			44	43	12	
Sealer	81	18	1		79	21		
Carpenter	81	19			80	20		
Rauter operator	82	18			80	20		
Robot operator	81	19			81	19		
Patchcord	80	20			80	20		
Owner	63	32	4	1	46	53	1	
Packer	81	16	3		82	17	1	
Shipment	55	1	40	4	81	6	11	1
Cushions	81	19			81	19		
Foam operator	81	18	1		82	18		
Cloth cutter	81	19			82	18		
Sewing		100			16	84		
Upholsterer	80	2	18		80	12	8	

Logistic regression analysis for the musculoskeletal discomfort.

The variables age, seniority, and categories three and four in action in OWAS in risk analysis (odds ratio) for the presence of musculoskeletal discomfort (Table 4) were considered.

The variables that were significant with crude risk were adjusted to each other. After this process, three variables remained significant, two increased their significance: seniority in the company (OR 5.9) and back (OR 4.2). Category Three remained with an equal OR (1.3). The variables age and Category Four lost the stastistics' significance, and were adjustable with other variables (Table 5).

The age and Category Four variables lost significance when adjusted with the other variables (OR 1 and 1.4, respectively).

Table 4. Crude estimate of odds ratio.

		Odds ratio estimate	
		OR	IC 95%
Age	17 - 30 years More than 30 years	1.7	0.346-8.038
Seniority	Under 5 years More than 5 years	5.3	1.079-26.429
Category 3		1.2	0.594-2.263
Category 4		1.4	0.676-2.923

Table 5. . Estimate adjusted of odds ratio

		Estimate adjusted	
		OR	IC 95%
Age	17 - 30 years More than 30 years	1	0.145-7.490
Seniority	Under 5 years More than 5 years	5.9	1.051-33.280
Category 3		1.3	0.623-2.608
Category 4		1.4	0.679-2.923

CONCLUSIONS

No gender difference was found. No relationship of musculoskeletal discomfort was indicated by gender because the morphology and physiology of the musculoskeletal system are not different between the sexes. In addition, the scope of the study did not show these data, but the reference of musculoskeletal aches percentage was higher in women. Even if you can mention that the jobs are not designed from the variable anthropometry and gender are not able to adjust to this feature.

All jobs studied were positive for the presence of non-neutral postures, although not all workers reported musculoskeletal discomfort, as an expression of anti-ergonomic industrial design areas. The work area was statistically significant for inconvenience rooms.

The group in middle school and high school was the statistically most significant, as the majority of them were workers in jobs with more manual handling of loads are the largest schools, highlighting that during the development of research observed.

In the investigation of musculoskeletal discomfort the Standardized Nordic Questionnaire divides the body into seven anatomic regions, the results of this study in the furniture industry craft was found that the back is the one that showed statistical significance and scored highest category level the method of observation (OWAS) at level three.

It was found that back problems are directly related to the position adopted, age greater than 30 years and the oldest in the post, including damage caused by degeneration of the very conditions of the person together with cumulative damage by wear due to the workload and not neutral postures I am subject to the same exposure time, in line with the theory of Biomechanics Musculoskeletal disorders. Prado (2006) mentions that although there are degenerative changes due to aging that normally occur over time due to biological and biochemical changes resulting from the burdens lumbar joints, it has also been shown that if the loads or compressive forces exceed a degree that would be considered appropriate to the physical and biological capacity of the functional unit, the degeneracy will be greater and at an earlier age. Pheasan (1991) classifies musculoskeletal damage cumulative and instantaneous, entering the first lumbar discomfort considered from the ergonomic approach.

Therefore it is concluded that they are not neutral postures that produce musculoskeletal discomfort and no job, ie required by the task and by the physical conditions of the post positions.

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PUMA - Development and Application of a Tool for Supporting Nuclear Power Plant Operating Teams in Unexpected and Unknown Situations

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ABSTRACT

The method PUMA was developed to help operating teams coping with potentially critical situations that are unexpected and unknown, that means, situations that cannot be handled by standardized procedures. The method was developed with the participation of the operating teams of a nuclear power plant in Switzerland within the project TeamSafe (see also: Kleindienst, Brüngger, Koch & Ritz, 2014). By participation of the operating teams good practices were collected and condensed to the method PUMA, which consists of two essential components: "structure problem-solving process" and "coordination/communication during team discussion". Especially the encouragement of reflexivity and inclusion of all team members for information collection, situation assessment and planning of measures is supported by the tool. The method PUMA has been introduced to 10 operating teams (n=53) in the nuclear power plant. During the annually held simulator trainings in 2012 and in 2013, all control room teams of the plant have been trained theoretically and practically in applying PUMA for two simulation scenarios. After both training units all participants have been asked to evaluate the PUMA tool in a questionnaire. Analyses of the results clearly show that the tool is seen as a useful supplement to the existing standardized procedures.

Keywords: Adaptive behaviour, team situation awareness, system safety, resilience, nuclear power

INTRODUCTION

Operating teams in the control room of a nuclear power plant (NPP) use standardized procedures to handle in a safe way potentially critical situations that are unexpected and unknown. On the one hand, reliable processing of standardized procedures (manuals, checklists, etc.) helps to handle a wide range of potentially critical situations. On the other hand, the future is not fully predictable, so it is not possible to develop appropriate action plans for all future critical situations in advance (Ritz, 2012). Standardized procedures might not be safe in unexpected and unknown situations that have not been anticipated while designing the procedures.

The basic idea of the PUMA method is to facilitate safety in a nuclear power plant by facilitating the operating teams' ability to adapt to unexpected and unknown situations. Safety and reliability are often considered the same. It is assumed that safety can be established by reliably following pre-defined action plans (standardized procedures, operation manual, checklists, etc.) that have proven to be safe in the past. By taking a closer look, this assumption can be proven as incomplete. The reliable functioning of a system and the following of pre-defined action plans can only guarantee safety if the given situation is known or was anticipated by the creation of the plans. In unexpected and unknown situations the reliable execution of pre-defined action plans will not ensure safety (Leveson, 2011). Such situations can happen when multiple faults in a system combine and the different pre-defined action plans demand different or even conflicting measures. Due to the many systems involved in the processes of a NPP, interactions can be very complex when faults occur. It is impossible to anticipate all possible interactions of the systems and pre-define action plans for all these cases. Only by flexibility and adaption a team can manage such unexpected and unknown situations in a control room. A team has to make use of the knowledge and experience of all its members to elaborate a solution to cope with an unexpected and unknown situation in a safe way. The PUMA method was developed to support control room teams in a NPP in these situations.

The method PUMA was developed to encourage operating teams in a nuclear power plant for coping with unknown situations that have not been anticipated in the available procedures by giving guidance for team processes. It was developed in the project TeamSafe in cooperation with a nuclear power plant in Switzerland (see also: Kleindienst, Brüngger, Koch & Ritz, 2014). There are two core elements included in the PUMA tool and its application. First, the acronym PUMA represents the steps of a problem-solving process: Problem (problem) - Ursache (cause) - Massnahme (measure) - Ausführung (execution). Each of these steps in the PUMA structure comprises four to five questions that should be answered by the team in order to adapt to an unknown situation in a safe way. Second, PUMA includes recommendations for a coordinated discussion of the PUMA steps within the team. The tool especially encourages to involve all team members in the processes of information collection, situation assessment and planning of measures as well as to act in a flexible manner.

Usually the Operations Manual (OM) serves as a guide and facilitates collectively shared situation awareness (Team Situation Awareness, Endsley, Jones, Schneider, McNeese and Endsley 2001) in NPP operations teams. This allows a team to act in a coordinated way. When a team is confronted with an unknown situation while applying the OM this is no longer the case. The PUMA method helps a team independent of the situation to create team situation awareness. It gives all team members the orientation how information should be gathered and interpreted as well as how to collect, select and execute measures to deal with an unknown situation.

DEVELOPMENT OF THE PUMA METHOD

For the development of PUMA we have used two main pillars. On the one hand, we used existing successful practices of control room teams in unexpected and unknown situations, on the other hand we based the method on existing psychological knowledge. PUMA therefore connects existing good practices with existing theoretic knowledge.

A basic assumption for the chosen procedure is that the knowledge and the skills to cope with the potentially critical unknown situation are in principle available in the operating teams. Teams and their members have different strengths for coping with difficult situations in the control room. When dealing with unknown situations some teams are more effective and efficient than others. The PUMA method strives to make strategies of those teams available for all teams. The focus is on recognizing one's own strengths and learning from the strengths of others.

The development of PUMA took place in a three year process. The collecting of successful practices of the available operating teams was conducted by video during special training units. The aim of the developing process was to create a tool to cover the specific needs of the operating teams in the participating power plant. During several iterative loops it was reviewed by training instructors, operating teams, engineers and psychologists until a final version was released.

The elements of PUMA (steps of a structured problem solving process and coordination of the collaboration in the team) have been derived from the observations of behavior in control room teams during simulated potentially critical unexpected and unknown situations. During these observations the structuring of the situations as well as the coordination of the problem solving processes of the most successful teams have been analyzed. After identification, these practices have been condensed to the PUMA method that is presented in this paper.

The purpose for the active inclusion of all the operating teams in the development process was twofold. First, it was necessary to involve subject matter experts for the correct understanding of the processes involved in managing

unexpected and unknown situations in a NPP. Second, giving the teams the opportunity to express worries and discuss problems at an early stage was considered being important for the later acceptance of the developed method.

The PUMA method is also based on theoretical concepts. Situation awareness respectively Team Situation Awareness (Endsley et al., 2001) being the most important of these concepts. The structure of the PUMA steps was influenced by the situation awareness concept. In unexpected and unknown situations the team has to build up a new construct of the situational conditions as part of an adaptation process (Waller, Gupta and Gianbatista 2004). The individual knowledge and information each team member holds about the state of the specific systems of the plant can be valuable for building up an accurate image or map of the whole situation. Interaction and communication processes are in the center of this re-construction process within the team. Coordination of the interaction process is one of the main tasks for the team leader (shift supervisor). It should be ensured that all the relevant information is gathered and social inhibition processes like groupthink (Turner and Pratkanis 1998) will be controlled. The gathering of information from the operators needs an atmosphere of openness, so that operators also have the courage for speaking-up (Kolbe et al. 2012). Formal interventions can help to structure this process and to open a "window of opportunity" for information collection, discussion and reflexivity within the team (Okhuysen 2001; Okhuysen and Eisenhardt 2002). PUMA fulfills the function of giving the operating team and the team leader an opportunity of withdrawing attention from the task execution to the opportunity of discussing and reflecting the actual situation and serves as a "formal intervention" for the reflecting process within the team.

By means of several iterative loops the method was reviewed by training instructors, operating teams, engineers and psychologists until a final version was released. During the development, emphasis was laid on the use of (verbal) expressions reflecting actual used language of the operating teams that are to apply the method in practice.

The PUMA method is now a part of the NPP control room in which it was developed. Is has become part of the regular training for all members of the control room teams.

The two elements of the PUMA method

PUMA regulates two different elements of the teamwork during unexpected and unknown situations in the control room of the NPP. First, the steps of a structured problem solving process. Second, the coordination of the collaboration in the team.

The acronym PUMA represents the steps of a problem-solving process: Problem (problem) - Ursache (cause) - Massnahme (measure) - Ausführung (execution). Each of these steps in the PUMA structure comprises four to five questions that should be answered by the team in order to adapt to an unknown situation in a safe way (see Figure 1).

The coordination of the problem solving (or decision) process is assisted by recommendations for the application of the PUMA steps in team discussions. The intention is to give all team members the opportunity to participate in the process of answering the questions of the above mentioned structuring steps. Especially the encouragement of reflexivity and inclusion of all team members for information collection, situation assessment and planning of measures is supported by the tool.

APPLICATION OF THE PUMA METHOD

For the use of PUMA in the operating room a short manual (11 pages) has been written. It answers the most important user questions and gives application instructions as well as a detailed description for all questions of the four PUMA steps (problem, cause, measure and execution). The following section of this paper is structured according to those user questions and application instructions.

One of the first questions for the application of PUMA is; when should it be used? In short, when there is the feeling that it might be helpful. Of course there is also a long answer to this question witch is given and specified in the following. As already mentioned above, the PUMA method is made to be used in unexpected and unknown situations. For an operation team in a NPP it can be very difficult to realize that it is in such a situation. There are standard operations procedures for most unexpected situations in the operations manual and on several checklists. Training is also heavily focused on using standard operations procedures in unexpected situations, since most of them can be processed by such in a safe way. This leads to a very high trust in the given standard operations

procedures. Also is it very difficult for team members to spot the deviations in NPP system behaviours from what was planned in the standard operation procedures. The possibility of such inconsistencies and how to interpret them is rarely mentioned in the standard operation procedures. It also is reasonable to expect unexpected and unknown situations to show similar symptoms like known situations (that are covered in the operations manual). Recognition of incongruities from the expected (symptoms, values, system behaviour, inappropriate suggestions in the operations manual, etc.) therefore becomes a signal to make use of the PUMA method. Every member of the operating control room team can propose the use of PUMA to get rid of ambiguities. A trigger for this can also be a "gut feeling" that something is just not right (see Klein, 2004).

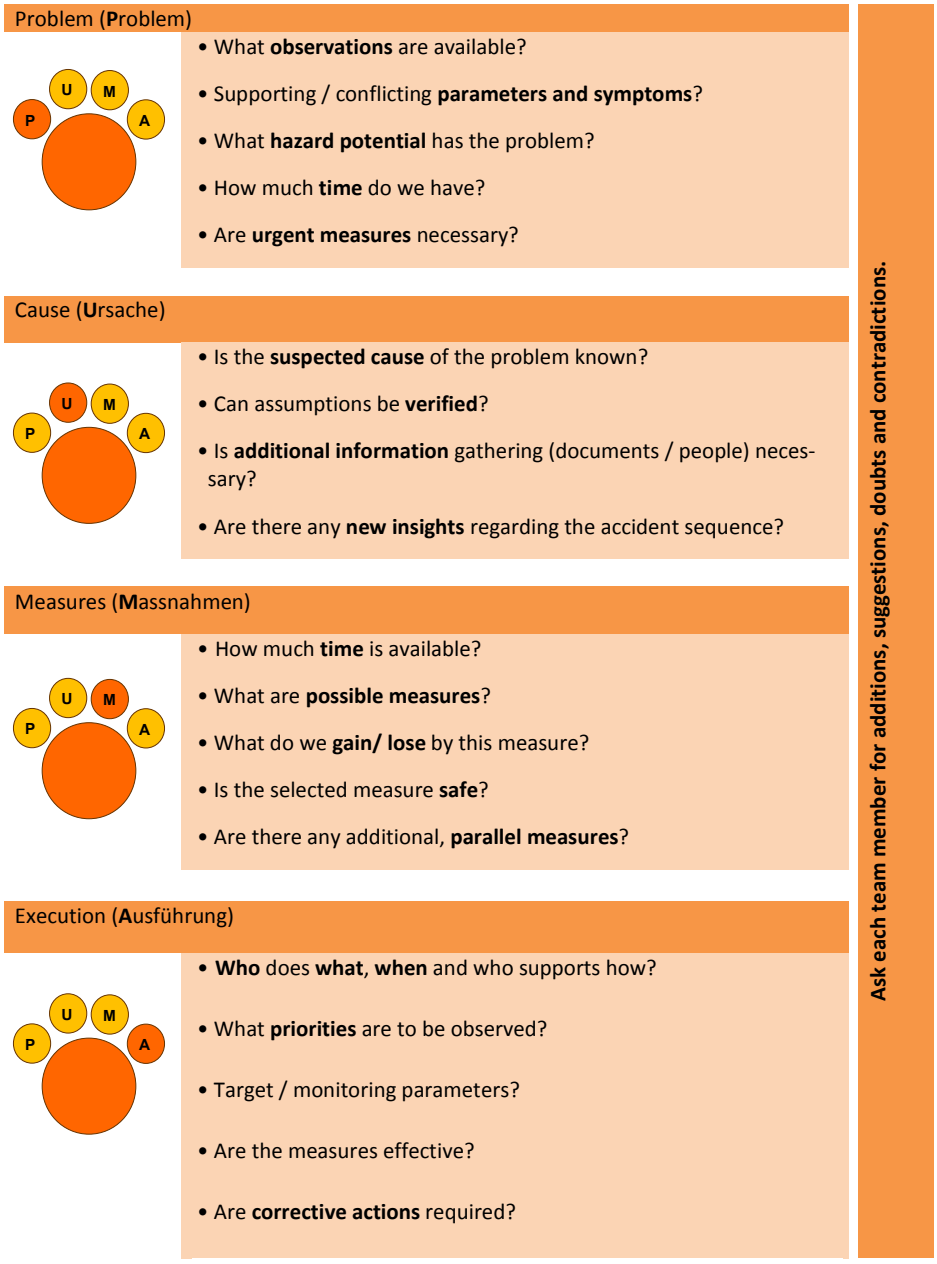

Figure 1. The PUMA method (translation from German version)

Other important application questions are who should start PUMA and how to do it? In the control room the shift supervisor usually has the task to coordinate the team and to make decisions about how to proceed. The PUMA method also acknowledges the shift supervisor in this role. The shift supervisor can initiate the use of PUMA at any time. If the proposition to use PUMA comes from a team member the supervisor has to decide if PUMA actually is

going to be used.

To proceed according to the method, all team members should be called together. It is best if the team members already know they are going to perform PUMA, so they can take out their own PUMA documents. This can be achieved by including this information in the call: e.g. "everybody come to me, we're going to do the PUMA method."

The shift supervisor should seek a place for this so the operators that are occupied with urgent tasks (e.g. regulating the cooling water feed of the reactor core) can still participate in the discussion or at least listen what gets discussed while working off the PUMA method.

Too much information to be handled in time by a single person comes together in the control room of a NPP. Therefore, it is important that the whole control room team works together and shares the important information so team situation awareness (Endsley and Jones 2001) can be formed. It is recommended that while working off the steps of the problem solving process with PUMA the questions should be clearly formulated for all to understand. As far as known, answers, doubts, contradictions and uncertainties or even "gut feelings" should also be given. All team members are called up to supplement the answers, point out doubts and contradictions.

The discussion of the questions in their respective steps (see Figure 1) follows specific purposes. At the first step of the structured problem solving process ("problem") the observations of all team members are collected and the reason for the use of PUMA is stated. Coherent and conflicting observations and symptoms should be discussed. If there are any not already applied urgent measures (e.g. evacuation of the containment) that have to be taken immediately (e.g. due to quick situation escalation) they should be taken here.

At the second step ("cause") the operating team tries to understand the cause of the collected observations and symptoms. If assumptions can be made the team should try to verify these by additional information.

At the third step ("measures") the possible measures to cope with the situation are discussed with consideration of the available time. The discussed measures are evaluated for safety as well as time and resource requirements.

At the last step ("execution") tasks are assigned, priorities and monitoring parameters are set.

Shift supervisors are advised to note the collected information, possible risks, causes and measures as well as the allotted tasks. Such notes can later on be particularly useful as a help against forgetting something of importance. If the assessment of situation allows enough time for taking notes it is recommended doing so.

In most of the cases it makes sense to process the questions on the given order of the PUMA method structure. In the practical application there will be situations where the discussion of one question also answers another question in advance at the same time. The team will then be able to skip this question later on. In other cases the developments in a situation might lead to new information concerning an already discussed question. If this happens, the team should go back to the concerned question and supplement the answers according to the new information. For the practical application a team can expect that some of the PUMA questions will have to be answered in several iterations.

It is recommended to process all questions of the PUMA method in the team. Nevertheless, there is no obligation for a team to answer all the questions. If questions are skipped or omitted it is recommended to inform the team about this and also give a reason as to why they have been omitted. E.g. "I skip the question about the urgent measures because we have already diagnosed that we have enough time to discuss further measures first".

The PUMA method can be aborted at any time. The PUMA method should support a team in handling an unexpected and unknown situation by allowing a maximum of flexibility and adaption. To be able to handle an unknown situation adaptively, the PUMA method itself should not have a limiting effect on the operating control room team. It can make sense to abort PUMA when a team finds out that the situation they are confronted with is actually covered and can be safely conducted with the standard operations procedures.

For the processing of PUMA there is no defined endpoint. In principle the decision when to end PUMA is with the shift supervisor. The method can be stopped or cancelled at any time. The processing time for all questions of the PUMA method in the recommended way in several different simulated scenarios and with different teams was on average about 10 to 20 minutes.

PUMA is not intended to be used as an alternative to pre-existing tools in the control room. The PUMA method is intended to be used for unexpected and unknown situations when the pre-existing tools do not support the operating team. The decision if a given situation is such a situation lies in the competence of the shift supervisor.

Material

Several PUMA documents for the control room have been created for facilitating the application of the method:

(1) A size A4 paper,

(2) four pocket sized riveted together cards (one for each step),

(3) a big writing pad size A3 also containing information about procedures used in accidents, communication and important telephone numbers,

(4) a desk blotter with the same information as the writing pad. All these individual documents contain the four PUMA steps, the corresponding questions and information about the recommended coordination of the cooperation in the team.

These PUMA documents have been created in close coordination with the control room teams, engineers and training instructors. Wishes of the teams on what kind of documents should be created have been considered and implemented. The documents are now resident in the control room to enable further and constant familiarizing with the method.

EVALUATION RESULTS

The method PUMA has been tested and introduced to 10 operating teams (each in two different configurations) (n=53) in the nuclear power plant. During the annually held simulator trainings in 2012 and in 2013, all control room teams of the plant have been trained theoretically and practically in applying PUMA for two simulation scenarios.

After both training units all participants have been asked to evaluate the PUMA tool in a questionnaire. All items in the evaluation questionnaire have been presented with a five level discrete visual analog scale (DVAS). The poles of the scale are 1 "do not agree at all" to 5 "I agree completely". The usefulness of the PUMA method had a mean score of 3.88 (SD = .88). The usefulness of the PUMA documents for the control room (cards, page A4, big writing pad A3, desk blotter) had a mean score of 4.17 (SD = .70). The mean score to the question if the team members will use PUMA in the future was 3.97 (SD = .79).

CONCLUSIONS

The available time of three years for the project and the development of the PUMA method as well as the mixed participative and theoretical approach of its development have led to success. The inclusion of all the persons concerned (operating teams) during the development process is considered to be essential for later application in a non-simulated environment. It is seen as a result of the participative way of development that there was almost no resistance regarding application from the operating teams at the end of the development process. It is important to point out that the participative way used for the development process of the method is probably a necessity for its successful implementation. Analyses of the evaluation clearly show that the tool is seen as useful supplement to the existing standardized procedures. The fact that PUMA has become a fix part in the NPP control room in which it was developed and of the regular training for all members of the control room teams shows need, trust and usefulness of the method. The authors presume that a need for such a tool also exists in other NPP's.

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Section 4

Macroergonomic Innovations

Macroergonomic Premises for Organizational Innovations in Business Corporations

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ABSTRACT

The paper discusses the issue of so-called multiagent systems ergonomics. This approach is addressed for organization structures that combine human societies and the organization and technological component. Such multiagent systems, called macroergonomic systems, concern only the internal organization of the enterprise. However, they can also enclose structural business conglomerates of groups of many enterprises. These systems, represented by modern business corporations, can have not only an organized functional form, but also a form of composite network relations, hybrid, or even (seemly chaotic) swarm. The macroergonomic interpretation of the functioning of modern business corporations shows the particular role of the Human Factor, represented by White and Blue Collars, which have the innovative, who have the innovative technology and innovative managerial solutions, social and business objectives. The article shows a case study of organizational innovations in two Polish business corporations in order to form a three-stage sequence of such events, enclosing: classic innovations, a so-called "new wave" and "creating a proposal for the buyer". Conclusions of the paper present the idea of "macroergonomic organizational innovations' matrix". Such matrix can be treated as a theoretical generalization of the problem of implementing macroergonomic innovative solutions. These solutions have been illustrated in a form of two models: process and structural innovations. Each of them can be realized in two variants of events: endogenic and exogenous.

Keywords: Macroergonomics, Organizational Design & Management, Corporate Management

INTRODUCTION

In the dichotomous division of the contemporary knowledge on *science* and *technology,* ergonomics could be placed in the second mentioned area, because we call it *Ergonomics* or *Human Factors Engineering* or *Human Factors in Engineering*. Ergonomics works not on knowledge acquisition about what is, but rather on forming engineering solutions, that does not exist yet (Marras, Karwowski, Smith and Pacholski, 1993).

It is obvious that Aristotelian dichotomisms (*science vs. technology*) are some sort of classified simplification of the real world dominated by dispersion. Hence, s*cience* and *technology* often operate on the same field. *Science* enters into creative processes of practical implementation of own discoveries and evolves in a fuzzy way into the sphere of technology. The same happens in the opposite direction: the process of technological, organizational and constructional progress allows technology discovering (cognition) new phenomena, for which it solves appearing problems and, in the same time, feeds the sphere of science.
Such situation can be observed for year on the ground of the modern ergonomics, which, as a field of knowledge with a contextual character, constitutes an almost demonstrative example of the clash of "enchantments of the pure science" and "temptations of the obtuse utilitarianism". The character of scientific research in the area of ergonomics does not characterize with typical features of *science*; cognitive processes have usually a quasi-empirical character. Cognitive research within ergonomics focus on creating methods for solving problems that result from the phenomena that is already well known but too complicated to find an accurate scientific solution of issues related to it. Today's ergonomics focuses mainly on solving problems, using both knowledge and experience and intuition. Ergonomics must be often featured by a technological pragmatism, which results from the necessity of finding solutions before science fully explains some phenomena (Pacholski, 1986).

MODERN MACROERGONOMIC STRUCTURES

In seventies of the last century, the author of this article made an attempt of universal defining the **subject of the research and ergonomic applications**. He has determined this subject as a relation (system, network, hybrid) combining human societies and the organizational and technological component (see Figure 1). In his works from the mentioned period and further (which concerned ergonomics of industrial manufacturing processes), the author consequently named this relation a *Multiagent Manufacturing System* (Pacholski, 1977), (Pacholski and Jasiak, 1998), (Pacholski, 1998). This approach has a universal character because in both encloses *man–machine unit* or *man-machine interface technology* systems (reduced to the unitary form) and *overall organization-machines technology*. In eighties H.W. Hendrick called these interfaces macreoergonomic systems (from the third generation ergonomics) (Pacholski, 2009).

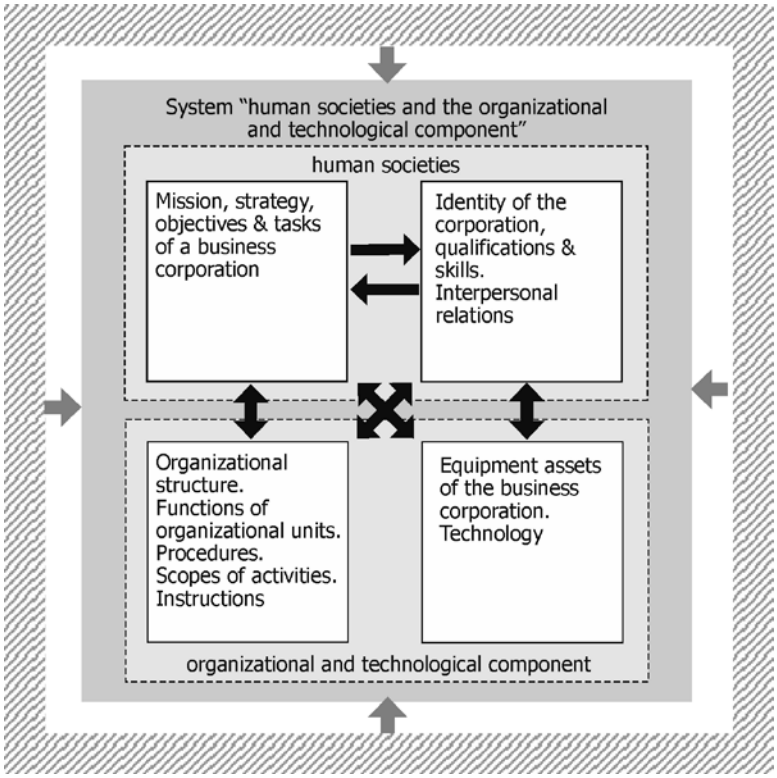

Figure 1. Model of the system "human societies and the organizational and technological component"

If to treat historically the problem of the subject of research and ergonomic applications, then, according to the universal proposal presented before, one could say about four stages of the evolution of this interface. The first stage would refer to pre-industrial societies and the technological and organizational component in form of methods and tools for hunting or simple agricultural techniques and tools. The second stage encloses industrial societies, which have machines, energy and electronics on their disposure. The modern, third stage, information societies use computer networks and new media. The further, fourth stage might refer to creative and empathic societies and to the technological and organizational component in form of nanotechnology applications and of artificial intelligence (Pacholski, 2006), (Pacholski, and Mateja, 2010).

Current technological-organizational "partners" of human communities can be also identified more precisely on the basis of the concept of economic cycles. These "partners" usually have the form of following so-called "fundamental innovations" (the steam machine and railways, the electricity and the internal-combustion engine, aviation, energetics and electronics, computer networks, pro-ecologic solutions, artificial intelligence and nanotechnology). These innovations, constituting the technological and organizational reaction to the evolution (into the humanocentric direction) of "social imperatives and needs" (like improving the efficiency of work and trade, the availability and mobility of assets, increase if the standard of life, energy networks, travelling, ecology, knowledge networks, psychological and social fitness, human health and quality of life) .

Today's multiagent macroergonomic systems (linking societies and the technological and organizational component) concern the internal organization, but they can also enclose structural business conglomerations of groups of many enterprises. These systems, represented by modern business corporations, have an ordered functional form, but they also can be network complex interrelation, hybrid or chaotic connections. The macroergonomic interpretation of the functioning of such corporations focuses on the particular role of their "essence", which is a composition of human communities with their technological innovation and innovative managerial solutions, social and business objectives (Pacholski, and Trzcieliński, 2007), (Pacholski, and Jasiak, 2011).

The modern period of transition into the fifth or even sixth economic cycle is characterized with a radical change of contemporary "human component": cohesive, structurally complete and ordered, which constitutes the **subject of ergonomics**. The figure number 2 shows the evolution of human societies' behavior within macroergonomic systems of modern business corporations (see Figure 2).

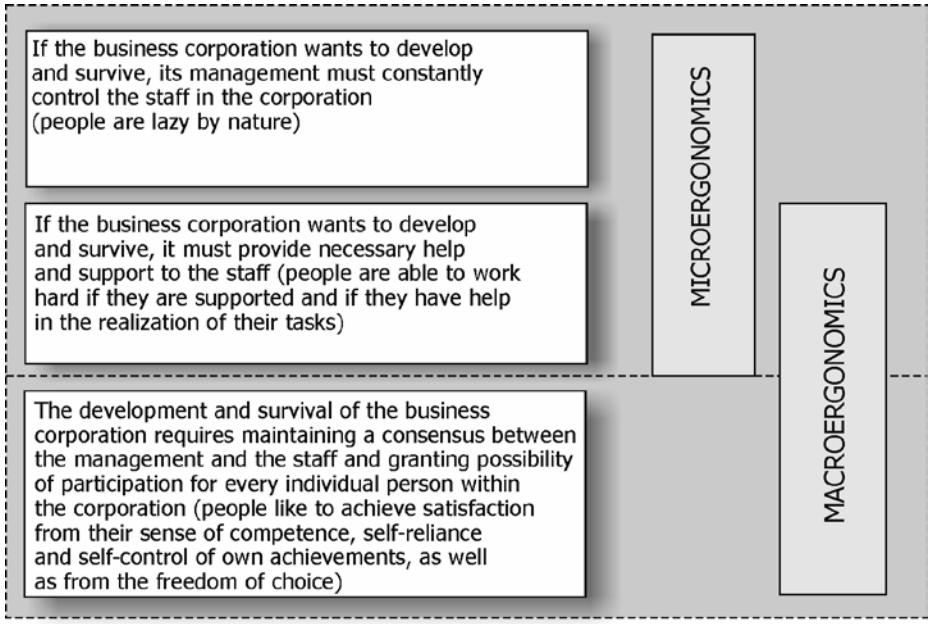

Figure 2. Evolution of the behavior of human societies in modern business corporations

Democracy and market freedom have caused that societies where fascinated by the concept of the network, but next they started protesting the functional, structurized order. Today, democracy and market are ruled by the research of the "buyer". Societies leave traditional hierarchies and authorities in favor of a so-called „guru", who does not have to convince us, he only needs to be popular. There is chaos appearing within the "human factor: of ergonomics. The contemporary, "pro-society" order of the organization is being replaced by a formation called a "swarm". Modern ergonomics has been forced to transfer observations from the world of life beings (evolution algorithms and neuronal networks, behaviorism taken from bees, ants or other swarms) to the ground of ergonomic methodology of research and applications, in order to find the key for survival and to the development of such syncretic solution of own corporative multiagent systems (Pacholski, 2012).

Today, structural business conglomerations of gathered modern macroergonomic systems evolve do the form of a corporation. This process can have a form of *reengineering* (*Business Process Reengineering*).
Organization of the corporate type (where people with the technique, structural solutions and objectives of the organization in their disposal) can be confronted to organizations of the *company* type, where the substantial component is the non-human element (like the capital).
The formation of business corporations is based on cooperation between organizations, which leads to the synergy effect as a result of: sharing assets (especially the expensive or hard to reach ones), integrating actions on different levels of the chain of values and reinforcing the market position. In the Polish economic reality, one can fins following typical formal solutions for business corporations: holding, consortia and economic clusters.
A holding means an organization that gathers various legally independent economic organizations (units) with more or less distinct connections, while one of these units has a dominative position in this combination and it

subordinates other organizations. The essence of a holding is that it is managed by one organization over other units and controlling the activity with use of capital or personal dependencies. A holding is a form of capital accumulation (Pacholski, and Piotrowski, 2008). The accumulation can take place by takeovers of weaker enterprises, first in own sector and familiar branches, next – in other areas of economy. Intentional differing parent company and its subsidiaries, independent from the legal point of view, yet economically dependent, is another way. Dependencies between the parent company and its subsidiaries have a tree structure and they can be largely developed. It is accepted to state that one deal with a holding, when the parent company own more than a half of the share capital. According to the criterion of the method of arise, one distinguish holding that were formed in result of a distinction of companies, join of enterprises and incurred on the basis of multiagent enterprises (see Figure 3).

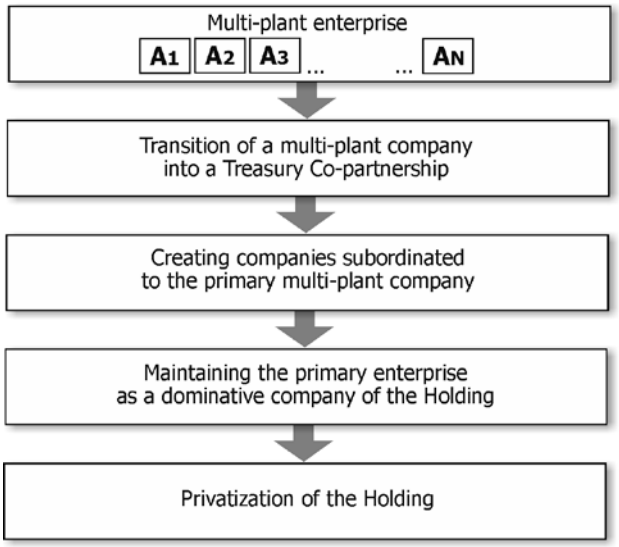

Figure 3. Process of development of the business holding company on the basis of the multiagent enterprise

A business consortium is a corporation created on basis of a contract between economical units, which undertake to aspire together for achieving the determined economic purpose. The consortium does not have to have a determined organizational structure. It does not have to have own capital, selected from the capital of its participants. A consortium does not have to be registered anywhere. The only document confirming the fact that it exists is the contract signed by its members. Signing the contract does not take economic, neither legal independency from consortium's participants. The contract covenants to a positive, mutual operation for achieving the assumed objective.

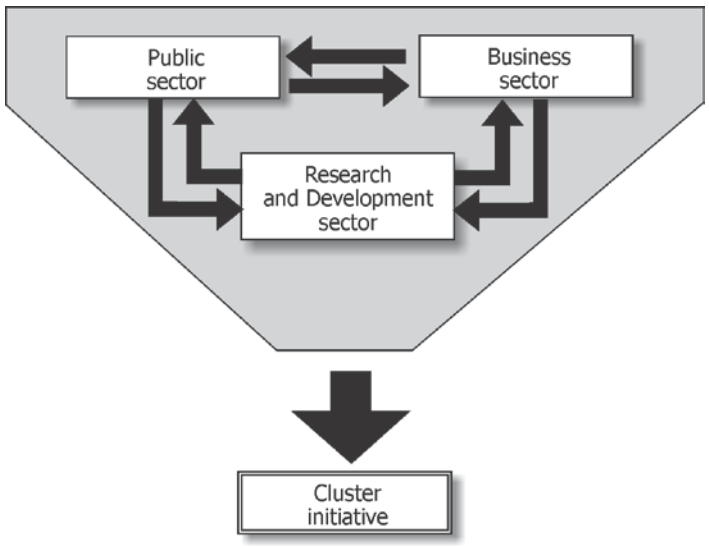

Figure 4. Model of trilateral reports within the business cluster

A business cluster is a geographical gathering of organizations (mainly small and medium units) that operate in similar sectors, and their suppliers and other organizations (universities or centers of research and development), which are competitors and cooperates in the manufacturing (or service) process and in the chain of values in the same time, between which one can observe network relations (based on trust and cooperation), for which the participation in the cluster represents an important factor affecting their individual competitiveness. Economic clusters have enlarged into trilateral relations (particularly on the level of regions) from contemporary bilateral relations between science and the public sector, science and business, business and public sector. A model of such trilateral connections is called in the literature a triple helix because three areas cooperate on a basis of a specific alliance for the purpose of preparing and implementing innovative solutions (see Figure 4). Economic clusters are open groups. Each participant can enter or go out in any moment. Usually, they have a local leader accepted by all members of the cluster (Pacholski, Trzcieliński and Wyrwicka, 2011).

RECAPITULATION OF TWO CASSES OF INNOVATION

The example of macroergonomic innovation in two Polish business corporations (the shipbuilding holding company and the cluster of the electronics industry) illustrates the author's attempt of characterizing macreoergonomic organization premises of innovative ventures in business corporations. These operations, examined from the point of view of the time horizon, form a certain type of a three-stage sequence. It starts usually from innovations from the technical and economic range of improving the work process and which take from the classics of the contemporary management (Taylor method, Le Chatelier law, H. Fayol's rules, ideas of M.Weber, etc.). Innovations resulting from the system approach and of concept of the organizational game and the theory of the functional organizational balance are a continuation of this movement (system theory of organization, operational research, economic cybernetics).

The second stage of this sequence encloses reaching experience and achievements of authors of the so-called "New wave" (K. Matsushita, H. S. Geneen, B. Hewlett, D. Packard, R. Kroc, T. Watson, R. McPherson, L. Iacocca, J. Sculley, S. Jobs and S. Woźniak). Basic macroergonomic organizational innovations of two Polish corporations mentioned before were connected with using following eight "new wave" features of most efficient enterprises: obsessive operating, close and direct contact with the client, autonomy and entrepreneurship, efficiency of people, focus on values, professionalism of action, little staff, straight structure, formal and informal organizational forms co-existing within one structure. The third aspect of organizational innovations implemented both in the shipbuilding holding mentioned before and the cluster of the electronics industry was based on concepts of redefinition of key assets and processes and on preparing a new formula of profits on the basis of the "formation of a proposal of value for a buyer" (see Figure 5). Similar ideas are rather popular today in the group of corporations from B.R.I.C. countries (Brazil, Russia, Indie and China).

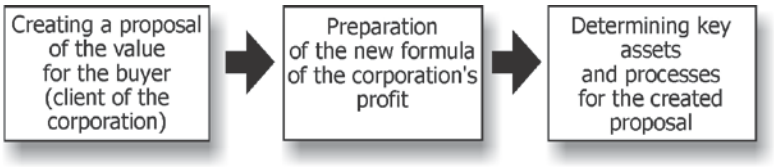

Figure 5. The method of creating new business models for B.R.I.C. corporations

The three-stage sequence of organizational operations for innovation has directed today's corporation to the issue of the "human factor" (which determines the business success) within the macroergonomic relation combining societies with the technological and organizational component. The context of knowledge-based economy and models of a so-called "intelligent corporation" opened entrepreneurs to the importance of such *social ergonomics* aspects, as: morality, professional competences and social intelligence of the worker, fulfilling his social needs (membership and a recognition needs) content from the situation at work, friendly approach to matters of subordinates.

There has been an attempt to implement *Workgroup Computing, Task Management, Process Modelling, Business Process Reengineering* within frames of organizational systems and work distribution in both transformed corporations. It has been also used such procedures, like flattening the management structure *Leadership,* implementation of the intranet and the internet, decision support systems, with special consideration of solutions based on expert system techniques. Also process solutions were innovated, for example *Total Quality Management,*

Concurrent Engineering, Total Production Maintenance and the entire group of pro-qualitative standards - *International Standards Organization,* which refer to the production, occupational safety and environmental ecological protection. The first presented business corporation (shipbuilding holding) took also attempts of external cooperation or fusion, business takeovers or strategic alliances.

CONCLUSIONS

Processes of organizational innovation proceeded in two business corporations concerned relations combining the human community and the technological and organizational component. Thus, they had an explicit macroergonomic character, specific for the movement of the modern ergonomics, called *social ergonomics*.
From the other hand - in the managerial sense, these processes could be enclosed to a structural or procedural aspect of the functioning of the corporation. These aspects can constitute the basis for the creation of a generalized matrix model of organizational macroergonomic innovations. Both mentioned aspects are classified as those, which refer the "insight" of the corporation, or which might concern "the game with the environment" (see Figure 6).

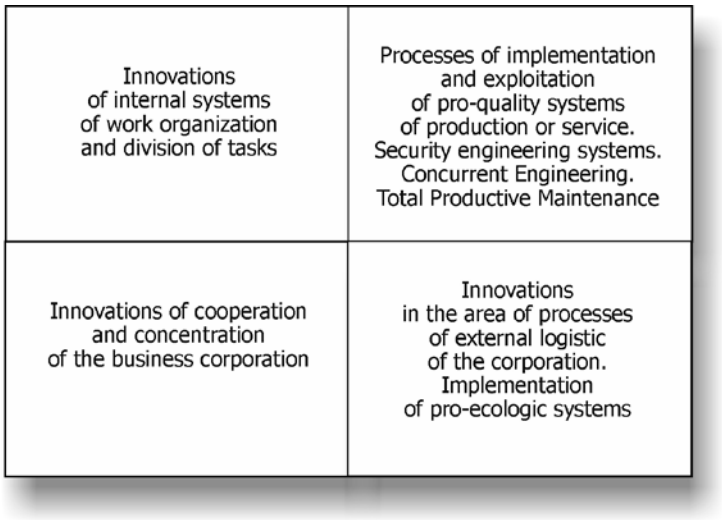

Figure 6. Organizational macroergonomic innovation matrix

An "innovation game with the environment" can be presented on the example of cooperation initiatives and concentration ventures. The cooperation of small business forming the structure of the cluster for the company of the electronics industry can be a good example of a cooperative innovation. In this scope, the shipbuilding holding was realizing strategic alliances. It was also interested in strategic alliances and fusions, and takeovers of other business units.

In the procedural scope, the innovative game with the environment of the business corporation can be directed on the "new wave's" obsession of being active and on the close and direct contact with the client, ideas of *B.R.I.C.*: "forming a proposal of a value for the buyer", logistic supply chain management, ideas of *Just in Time* and *KANBAN*.

Structural internal innovations of organization systems and work distribution consist in using principles of the classics of technical and organizational improvement of work and on system theory of the organization, operational research and economic cybernetics. The management of business corporations can use fragments of the *New Wave* concept in form of premises for the efficiency, like: the autonomy and the entrepreneurship, little staff and a straight structure, formal and informal organizational forms co-existing within one structure. One can implement also modern *Workflow* systems as a source of *Workgroup Computing*, *Task Management*, *Process Modelling* and *Business Process Reengineering*. It is suggested to make attempts of implementing expert systems, *Decision Support Systems* and organizing teamwork in accordance to the idea of *Leadership*. It seems necessary to implement today Internet and Intranet networks, essential for needs of the modern organization (Pacholski, Cempel and Pawlewski, 2009).

One can enlist following process solutions to the process aspect of the "internal functioning" of the corporation: *Total Quality Management, Concurrent Engineering, Total Production Maintenance* and the entire group of pro-qualitative standards - *International Standards Organization,* which refers to the area of production, occupational safety and environmental ecological protection. Practical applications of the idea of the organizational game and the theory of the functional organizational balance and concepts taken from the "new wave" authors: efficiency, close and direct contact with the client, autonomy and entrepreneurship, efficiency of people, focus on values, professionalism of action.

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Influence of Macroergonomic Factors on Production Systems Organizing in Automotive Industry

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ABSTRACT

The paper discusses the need to recognize factors determining the ergonomic conformity of production systems. The focus has been found to be vital for the design of such systems. To help adopt the approach, the authors have identified factors which affect the ergonomic conformity of production systems in the automotive industry and subsequently had them verified by experts. Furthermore, they employed the network thinking methodology to analyze the time and severity of impact of the individual factors. The studies carried out by the authors have made it possible to develop a model for the management of ergonomic factors. The authors additionally proposed conclusions on ergonomically-driven measures intended to eliminate barriers in designing production systems and on opportunities for enhancing the ergonomic conformity of working environment in manufacturing plants.

Keywords: Macroergonomics, Macroergonomic Factors, Production Systems, Automotive Industry, Network Thinking Methodology

INTRODUCTION

One of the roles of management is to ensure proper organization design. Such design combines the planning of activities and their proper deployment associated with carrying out and controlling of e.g. production. While organization sciences date back to the 19th and 20th centuries, their principles should continue to be upheld on par with the latest management methodologies and the proactive strife for continuous improvement.

Over forty five years ago, the classic human-machine model was redefined to produce a multi-faceted system better suited to embrace third generation ergonomics, i.e. macroergonomics [Pacholski L., Trzcielinski S., Wyrwicka M. K., 2011, pp. 147, 148 [based on:] Hendrick H.W., Kleiner B.M., 2002; Jasiak A., 1993, p. 15]. As an ergonomic science, macroergonomics deals with sets of physical and social factors encountered in the working environment. Its focus is on relationships among complex production systems. Such systems, which provide e.g. regional and local technical support, constitute classic examples of macroergonomics [Pacholski L., Trzcielinski S., Wyrwicka M. K., 2011, pp. 147, 148 [based on:] Pacholski L., Wyrwicka M.K., 2006]. Furthermore, macroergonomics is a study of the impact of technical subsystems on organizational and worker subsystems complete with the details of the related deployments. “Macroergonomics has come to focus on the design of organizational and work system structures and related jobs and human–machine, human–environment, and user–system interfaces of new technique to the interaction between organizational factors and the technology used in the organization” [Erensal Y. C., Albayrak E., 2007, p. 6, [based on:] Hendrick H.W., 1994, pp. 713–718; Hendrick H.W., 1995, pp. 1617–1624]. Macroergonomics emphasizes the interaction between organizational and psychological and social factors as well as

the implementation and operation of technical items in the overall system [Erensal Y. C., Albayrak E., 2007, p. 6, [based on:] Hendrick H.W., 1994, pp. 713–718; Hendrick H.W., 1995, pp. 1617–1624]. Socio-technical design of work and macroergonomics are closely related. [Erensal Y. C., Albayrak E., 2007, p. 6, [based on:] Ingelgaêrd A., Norrgren F., 2001, pp. 93-105]. At the level of the organization of production systems, macroergonomics is a pivotal factor for effectiveness.

Businesses and other organizations as well as the people involved in them in various capacities (such as as employees) operate in a complex environment of mutual interactions. The links among them can be analyzed by means of the network thinking methodology which is a total approach. Studies relying on that methodology adopt a systemic view of issues with proper account taken of any such specific factors as affect the environment in which a given focus of research is embedded.

Penc noted that Polish enterprises do little management while focusing heavily on ruling. For that reason, the analysis centers on identifying approaches which enable one not only to operate a business but also to protect human health and lives, specifically those of the enterprise's labor force. It is therefore the aim of this paper to find ways "to boost the significance of ergonomic compliance in the design of production systems of automotive plants". The discussion highlights the role of any stakeholders for whom addressing such issues should become central as well as any decision-makers in a position to influence their plant's conformity status. Further in the study, the authors defined the mutual interactions and links among factors affecting ergonomic conformity of production system design. The outcome of this exercise was a network of mutual interactions. Subsequently, experts were used to assess:

- the relationships and the nature of interactions among factors affecting the matter at hand (adversely or positively),
- the type of such relationships and interactions (two- or one-way),
- their intensity (ranging from no impact, defined as "0", to very strong impact, assigned the value of "3")
- the duration of impact of individual factors on the matter at hand (ranging from short to long).

All of these factors were brought together to devise an impact matrix featuring active, passive, critical and indolent factors, as well as an intensity map differentiating between managed and unmanaged factors.

Today's business organizations operate in a network of relationships and links between themselves and the external environment. Similarly, affected by all-encompassing globalization, people are part of greater entities (such as universities or industrial plants) which also interact among one another. Such links can be researched by means of the network thinking methodology, which offers a comprehensive approach. Studies carried out by that methodology rely on the systemic approach to the issues at hand. They additionally recognize any factors which significantly affect the examined environment. When employing the network thinking methodology, it is essential to use precise and understandable language. Terms and notions should only be defined after a debate involving all concerned parties. This is essential to ensure that the resulting view is consistent across the board. The methodology helps identify barriers and limitations of various sorts as encountered in the decision-making process [Grzelczak A., Werner K., 2011, pp. 21-22; Zimniewicz K., 2003].

The network thinking methodology rests on 7 theoretical foundations which are [Grzelczak A., Werner K., 2011, pp. 21-22; Zimniewicz K., 2003]:

- the whole and its parts,
- network characteristics,
- openness,
- complexity,
- order,
- management, and
- growth.

Procedurally, the methodology is followed through six stages which, in addition to adhering to the sequential order of the stages themselves, require responses to feedbacks which allow one to make adjustments in any completed stages. The stages involve [Grzelczak A., Werner K., 2011, p.24]:

- defining goals and developing a model of issues,
- analyzing mutual interactions,
- identifying and interpreting opportunities to modify current status,
- explaining options to gain control,
- devising an action strategy,
- adopting solutions to problems in business practice.

PRODUCTION SYSTEM ANALYSIS

Defining goals and developing a model of issues

The study consisted in analyzing the production system of a selected automotive enterprise based in the Polish Region of Wielkopolska. The organization is a member of a large corporate group which emphasizes extensive customization of products and exports its goods to a dozen plus countries around the world.
In examining the system in macroergonomic terms, the authors set out to find ways to:
"ensure better recognition of the importance of ergonomic conformity in the design of production systems in automotive plants". Their intermediate aim was to define any factors affecting the ergonomic conformity of production systems in the selected enterprise and to examine such systems in depth. The intended outcome of applying the method is a set of measures (scenarios) indicative of the decisions that need to be taken to achieve the ultimate goal. Although universal in its design, the solution will nevertheless be company-specific.
Step one was to investigate the problem environment which is a complex process requiring a multifaceted approach. A roundup of the key issues is provided in Figure 1.

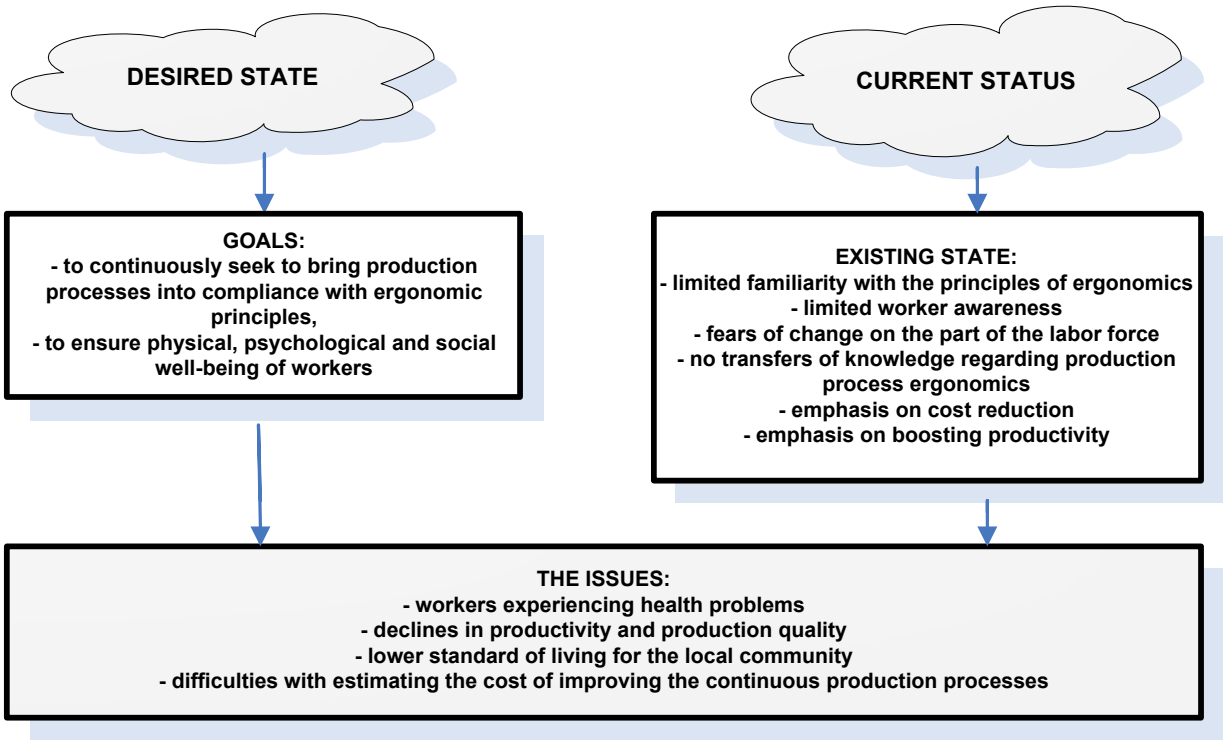

Figure 1. The challenges faced (authors' work).

Defining scenarios

The next stage of the study was to define scenarios by identifying any individuals and/or institutions having influence on the ergonomic conformity of production systems in Company X. The findings produced at this stage are summarized in Figure 2.

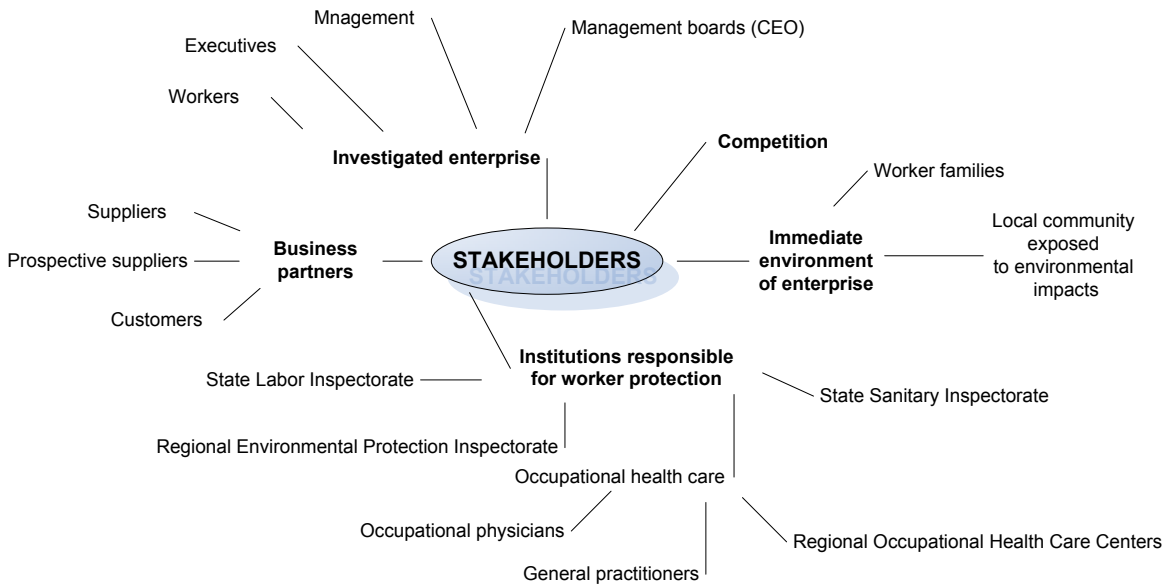

Figure 2. Individuals and institutions having influence on ergonomic conformity of production systems in Company X (authors' work)

In keeping with the above, the authors distinguished the following five key stakeholder groups:

- the enterprise in question – the persons concerned with the ergonomic conformity of production systems within the company are not only the workers (who are the target group directly exposed to the company's production system) but also the management (responsible for the choice of production methods and production system design as well as ergonomic compliance). A properly designed production system would benefit these stakeholder subgroups: the workers would see health improvements, the Management Board and other levels of management would achieve reductions in absenteeism and worker turnover (which has been high), the organization would gain a renewed image as a friendly employer and a company which cares for safe employment and ergonomically designed work;
- the competition – interested in any ergonomic solutions that boost productivity and reduce production costs. With no ergonomic system in place on the production floor in the examined company, the competitors are in a position to attract workers who resign, distraught over serving an organization that shows little care for the health of its employees, experts in their respective fields;
- business partners – as ergonomic conformity depends largely on machinery, tools, semi-finished products, etc. which the company procures from its suppliers, it is essential to incorporate ergonomic considerations at the stage of supplier selection. Customers, in their turn, have an interest in receiving a compliant product at a specified time, produced in an effective manner with full respect for ergonomic principles;
- the company's immediate environment, which, for the purposes of this study, was defined as including worker family members (who ultimately want their close ones to suffer no health issues as a result of their work) and the local community whose members care to ensure the company does not pollute the local environment;
- institutions responsible for worker protection – these include any institutions in charge of overseeing compliance with occupational health and safety requirements; the system is designed to reduce insured and uninsured costs which are borne by society at large.

Analyzing mutual interactions

The study of mutual interactions began with the pivotal factor. This was found to be the ergonomic conformity of production systems. Relationships among the factors at play are shown in Figure 3.

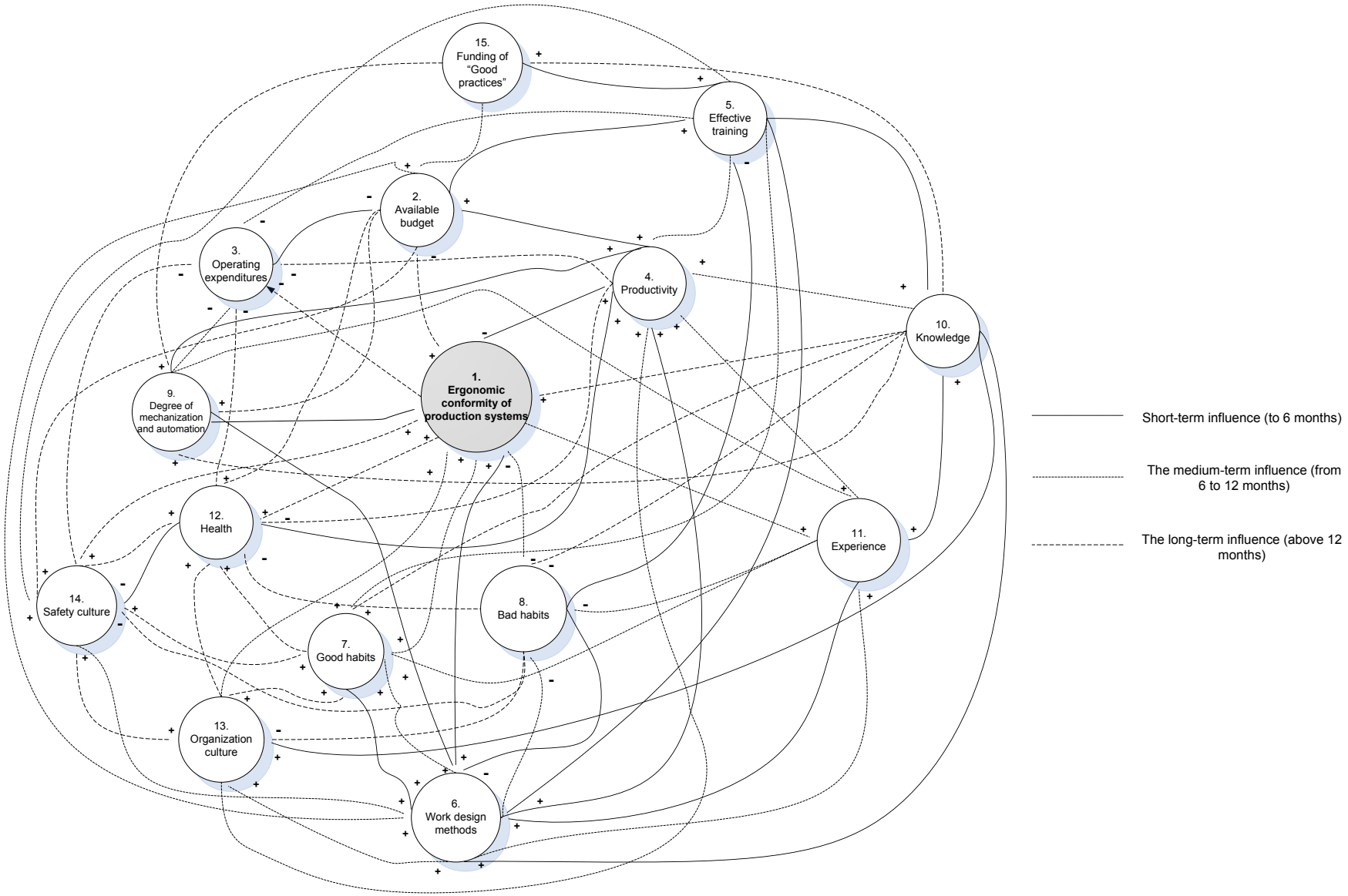

Figure 3. The network of interactions among factors at play (authors' work)

Figure 3 depicts the relationships and the nature of interactions among individual factors which affect the ergonomic conformity of production systems in the selected enterprise and mutually impact upon one another.
The influences have been denoted as "+" to denote any directly proportional impacts and "-" to denote any impacts found to be adversely proportional. The factors applied in developing the network of interactions were identified by examining the current status and by accounting for all stakeholders. In today's approach to ergonomics, ergonomic quality does not depend on any single factor or any set of multiple factors which a user may be able to influence. Rather, such quality is a function of multiple components in the macro-environment [Butlewski M., Tytyk E., 2012, pp. 298-306]. For that reason, the issue of quality was not dealt with separately. Instead, it was assumed to be an upshot of a well-functioning production system. Table 1 brings together the overall descriptions of factors which affect the ergonomic conformity of production systems complete with a numerical value of help at further stages of the study.

Table 1: Interpretation of factors identified in the interaction network (authors' work)

Name	Description
Ergonomic conformity of production systems	A collection of features of a production system which enable a business organization to ensure the psychological, social and physical well-being of any affected individual
Available budget	Funds appropriated to maintaining and improving production systems
Operating expenditures	Funds spent to operate production systems
Productivity	The quantity of products compliant with applicable standards per unit of time
Effective training	Training courses designed to raise worker awareness of ergonomic issues and enhance organization culture
Work design methods	Consistently and deliberately employed methods for selecting best measures and ways to utilize company resources to generate operating profit [Gryffin R.W., 1996, p. 329; Martyniak Z, 1976, p.16]
Good habits	A set of means and ways of conduct conducive to compliance with ergonomic requirements
Bad habits	A set of means and ways of conduct conducive to incompliance with ergonomic requirements
Degree of mechanization and automation	The level of mechanization and automation of any production processes carried out within a system
Knowledge	The overall information acquired, among other things, through effective training and from lessons learned, defined as the body of knowledge on ergonomics. Such knowledge makes it more likely for a company to produce innovations to improve the ergonomic conformity of production systems
Experience	Any acquired skills and competencies affecting worker behavior
Health	A state of complete physical, psychological and social well-being – the notion extends beyond being free of illnesses, disease and disabilities [Dahlke G., 2013, p. 5 [based on:] Preamble to the Constitution of the World Health Organization, 1946]
Organization culture	A system of values and rules of conduct constituting an integral part of an organization. Organization culture manifests itself in ways of thinking and conduct which are properly ingrained and approved by a team [Wyrwicka M., Stasiuk A., Drzewiecka M., Masadyński M., 2011, p. 176 [based on:] Malinowska, 2004, p. 56; Nogalski, 1998, p. 95; Wiernek, 2000, p. 24].
Safety culture	An approach to one's own health and life as well as that of persons in one's environment, defined as: "a set of psychological, social and organizational factors which activate or sustain activities which protect lives and health at work and beyond" [Ejdys J., 2010, p.17 [based on:] R. Studenski, 2000 , p. 1]
Funding of "Good practices"	Programs of funding projects aimed at improving working conditions and ergonomic conformity, e.g. European Union financing or funding by the Polish Social Insurance Authority (e.g. http://www.zus.pl/default.asp?p=4&id=422)

To identify the detailed interactions among the individual factors, a study was conducted in terms of:

- the types of interactions (two-way, one-way), as marked with arrows in Figure 3;
- the severity of impact measured on a scale of 0 to 3 (where 0 denotes no impact; 1: low impact; 2: high impact and 3: very high impact);
- impact duration ranging from short (up to 6 months) to medium (6 to 12 months) to long (above 12 months).

The following stage is to examine the impact matrix which divides all of the analyzed factors into the four groups of [Zimniewicz K., 2003]:

- active factors which very strongly affect other influences but which themselves are unlikely to succumb to any influences (great A total);
- passive factors having little effect on others but likely to be influenced by them (low A total);

- critical factors which strongly impact upon others and are strongly influenced by other factors (high P total);
- indolent factors which poorly impact on others and are only slightly influenced by them (low P total).

An analysis of the impact matrix is shown in Table 2. The numbers assigned to individual factors correspond to the numbering given in Table 1.

Table 2: The impact matrix (authors' work)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL A
1	**X**	**1**	**1**	**2**	0	**2**	**1**	**2**	0	0	**1**	**2**	0	**2**	0	**14**
2	**3**	**X**	0	0	**1**	**1**	0	0	**3**	0	0	**1**	0	**1**	0	**10**
3	0	**2**	**X**	0	0	0	0	0	0	0	0	0	0	0	0	**2**
4	**2**	**1**	**1**	**X**	0	0	0	0	0	0	0	**1**	0	0	0	**5**
5	0	0	**1**	**1**	**X**	**1**	**1**	**1**	0	**3**	0	0	0	0	0	**8**
6	**3**	0	0	**2**	0	**X**	**1**	**1**	0	0	**2**	0	**1**	0	0	**10**
7	**2**	0	0	0	0	**1**	**X**	0	0	0	0	**2**	**1**	**2**	0	**8**
8	**1**	0	0	0	0	**2**	0	**X**	0	0	0	**2**	**2**	**3**	0	**10**
9	0	0	**2**	**3**	0	**2**	0	0	**X**	0	**2**	**2**	0	0	**1**	**12**
10	**2**	0	0	**1**	0	**2**	1	1	**2**	**X**	**2**	0	**1**	0	**2**	**14**
11	0	0	0	**2**	0	**2**	**1**	**1**	0	**2**	**X**	0	0	0	0	**8**
12	0	0	**1**	**3**	0	0*	0	0	0	0	0	**X**	0	**1**	0	**5**
13	**1**	0	0	**2**	0	**2**	**1**	**1**	0	0	0	**1**	**X**	**3**	0	**11**
14	**2**	0	**1**	**1**	0	**1**	**1**	**1**	0	0	0	**2**	**1**	**X**	0	**10**
15	0	**2**	0	0	**1**	**1**	0	0	**2**	0	0	0	0	0	**X**	**6**
TOTAL P	**16**	**6**	**7**	**17**	**2**	**17**	**7**	**8**	**7**	**5**	**7**	**13**	**6**	**12**	**3**	**133**

* no disabled persons are employed in the production system in question

The selected factors should also be shown on an intensity map (Figure 4) which serves the purpose of identifying their nature. The position of a given factor is a value shown on the map by marking intersections between value A (severity of impact) and value P (factor responsiveness) [Ziemniewicz K., 2003]. At this stage, a decision needs to be made as to where to place the dividing lines (borders) to delineate on the severity map four fields which correspond to the individual factor categories. The simplest division would be to select the maximum A and P values and divide them by two [Ragin-Skorecka K., Grzelczak A., Werner K, Mroczek B. 2011, p. 106]. By following this presumption, the authors originally arrived at A = 7 and P = 8.5. This network line arrangement was then debated bringing the authors to the conclusion that the lines should remain unmoved. This choice was based on:

- a thorough analysis of all borderline factors,
- the need for unambiguous assignment of all individual factors to a given category.

The tool allows one to observe the characteristics of impact factors. Where active and critical factors prevail, the current situation may be modified to a great extent by means of these very factors. In the converse case, however, the options for interfering are considerably more limited. This is because the use of passive and indolent factors will, expectedly, result in little impact on the overall system [Piekarczyk A., Zimniewicz K., 2010].
The factor severity map is shown in Figure 4.

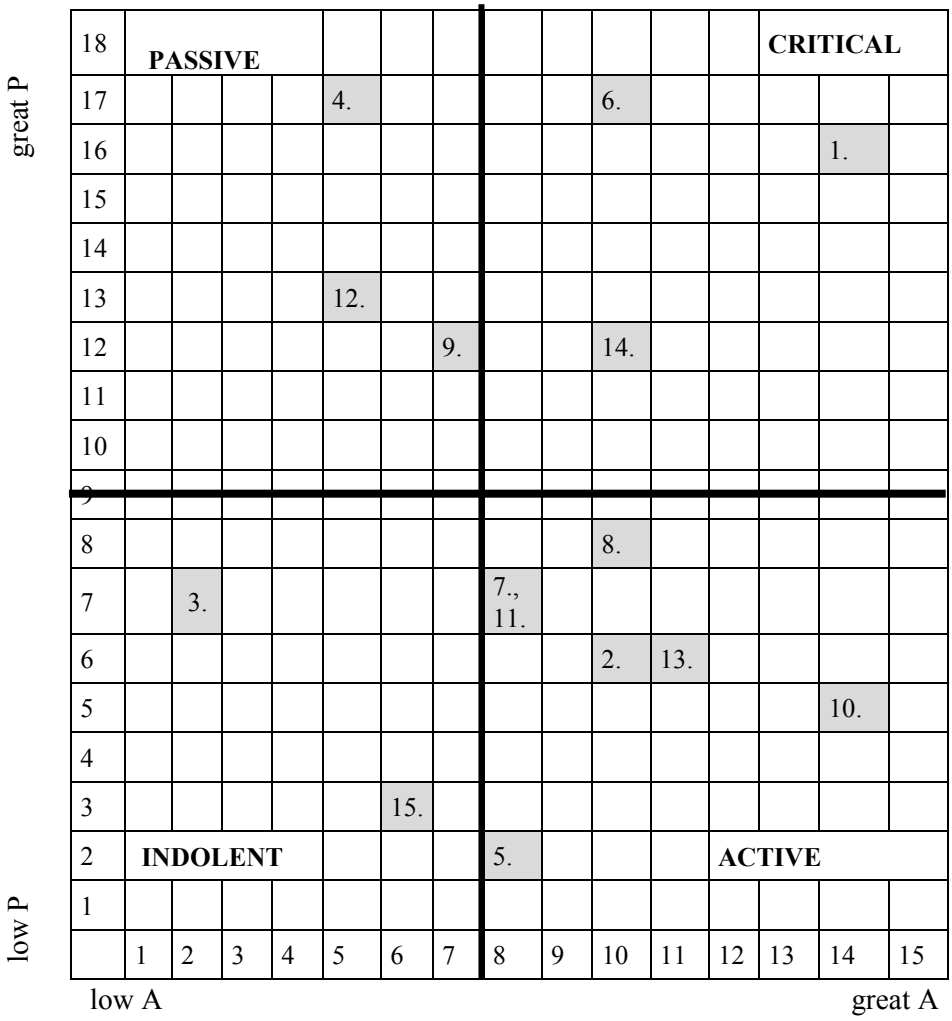

Figure 4. Factor severity map (authors' work)

Once the findings of the factor severity study have been placed on the factor severity map, the distribution of factors turned out to be disproportional. The assignment of individual factors into groups and preliminary conclusions are shown in Table 3.

Table 3: Interpretation of individual factors (authors' work)

GROUP	NAME OF FACTORS	CONCLUSIONS
ACTIVE	**2. Available budget**	The factors can be managed to bring the production system to a state of ergonomic conformity. The factors have strong influence on others but are only slightly influenced by their impact. **Available budget**, i.e. funds appropriated to the design of production systems in an ergonomically-compliant manner may have a substantial impact on ergonomic conformity. However, the choice of whether or not to spend the funds rests with the Management Board of the company in question. It is therefore necessary to point out the potential impacts of establishing a system which greatly conforms with
	5. Effective training	
	7. Good habits	
	8. Bad habits	
	10. Knowledge	
	11. Experience	

GROUP	NAME OF FACTORS	CONCLUSIONS
	13. Organization culture	ergonomic standards. In designing new solutions, use should be made of the design tools which aid manufacturing (CAD CAM, such as Delmia, JACK or RAMSIS) and which rely on ergonomic conformity assessment methods. **Effective training** has unquestionable impact on a system's ergonomic conformity. It is difficult, however, to assess the effectiveness of such training before it is held. It is therefore advisable to verify training effectiveness and learn proper lessons to help formulate any future training plans. Preference should be given to the forms of improvement which ensure a positive results. The difficulty with guaranteeing such results is reflected in the impacts matrix (the borderline with indolent factors). One should nevertheless note the importance of training and ensure its consistency bearing in mind that a one-off course of training will not result in a permanent improvement of worker awareness. **Good habits** have a huge impact on the ergonomic behavior of workers but, unfortunately, cannot be easily influenced. The only way to ensure good habits is to instill in the workers themselves a deep-ingrained conviction about the importance of their system's ergonomic conformity. Once acquired, good habits have the potential of preventing a great number of undesirable situations. Unfortunately, the top management have little influence on such habits as it is the workers themselves who need to acquire them based on years of experience and knowledge. **Bad habits** in workers are a formidable barrier to developing safe and healthy working conditions. Such habits have a powerful influence over new hires. In the production system in question, some of the difficulties with eradicating bad habits lie in the great variability of the jobs performed by employees as well as diverse locations of the work zones. It is therefore impossible to define (design) worker workflows and adopt special tools for the tasks they perform. **Worker knowledge**, as gained through training, should result in ergonomic awareness – however, such knowledge is not always utilized in a proper way. The communications passed on to the workers should be coordinated with new technological and work design solutions. **Experience** – similarly to training and good habits, experience has much positive impact on the system's ergonomic conformity. Top managers should therefore make every effort to properly shape such experience. However, due to the specific nature of this factor, interference comes with certain restrictions. This is because experience is a personal characteristic of each individual worker. Certain measures can be taken during induction and continued to build experience through training. **Organization culture** – shaped largely by the workers, organization culture is compromised by the bad habits of persons who have served the company longer. Such culture can be impacted in a number of ways, including by effective training and by implementing new work design methods while upgrading work and production factors.
PASSIVE	**4. Productivity** **9. Degree of mechanization and automation** **12. Health**	While the above factors can be influenced strongly by others, these factors themselves remain passive (exert little influence on other items). Such factors are of little interest as they offer little potential for affecting other values in the network. Nevertheless, they should not be ignored. The factors may motivate stakeholders to support the drive to establish an ergonomic production system. **Productivity** has little impact on the issue at hand but is itself susceptible to many influences (see Table 2). **Degree of mechanization and automation** – surprisingly, this factor has no significant effect on the ergonomic conformity of the production system. This factor is tied closely to productivity. **Health,** itself a function of many factors, has little impact on the investigated issue. An ergonomically friendly production system should avert health problems among workers.

GROUP	NAME OF FACTORS	CONCLUSIONS
CRITICAL	**1. Ergonomic conformity of production systems**	These factors are key to the study. It is these factors that predominantly determine the ability to achieve the desired ergonomic conformity of the production system. The factors strongly impact upon others as well as being strongly affected by them. **Ergonomic conformity of production systems** is the purpose of this study and its central aim. The factor powerfully influences other components in this study and is vulnerable to be strongly affected by them. **Work design methods** are ways to achieve the final outcome (purpose) of the company's activities which is operating profit. Proper methods are certain to help produce an ergonomic and highly efficient system. This factor is also open to a number of influences. **Safety culture** – provides information on the way the workers and shareholders approach worker safety. Safety culture is influenced by multiple factors including any existing good and bad habits. It also has the capacity to strongly affect other factors that strongly influence the issues at hand.
	6. Work design methods	
	14. Safety culture	
INDOLENT	**3. Operating expenditures**	These factors rank as indolent, meaning they have minimal impact on others and are hardly influenced by external impacts. **Operating expenditures** are largely a fixed value or one whose variability is limited (they are difficult to reduce). Hence, the factor offers few possibilities for modifying the system and ensuring ergonomic conformity. **Funding** – although funding may help adopt good practices and increase the budget, it is hard to acquire (in the amounts applied for). The majority of "good practices" in the production system in question can be found in training arrangements rather than in building the ergonomic conformity of work and production factors.
	15. Funding of "Good practices"	

IDENTIFYING AND INTERPRETING OPPORTUNITIES TO MODIFY STATUS

Explaining options to gain control

Once an issue has been analyzed (and the network has been developed and examined in terms of the types, durations and severities of impacts and the pace and aims of improvements), it is necessary to identify opportunities for managing change. A simplified management model is provided in Figure 5. To ensure proper change management, a management model has been developed made up of seven components: a manageable item (the ergonomic conformity of production systems), decisions (made by the automotive enterprise), manageable and unmanageable factors, indicators or early response measures, the feedback loop and a preemptive action system [Borowiec A., 2013, p. 66].

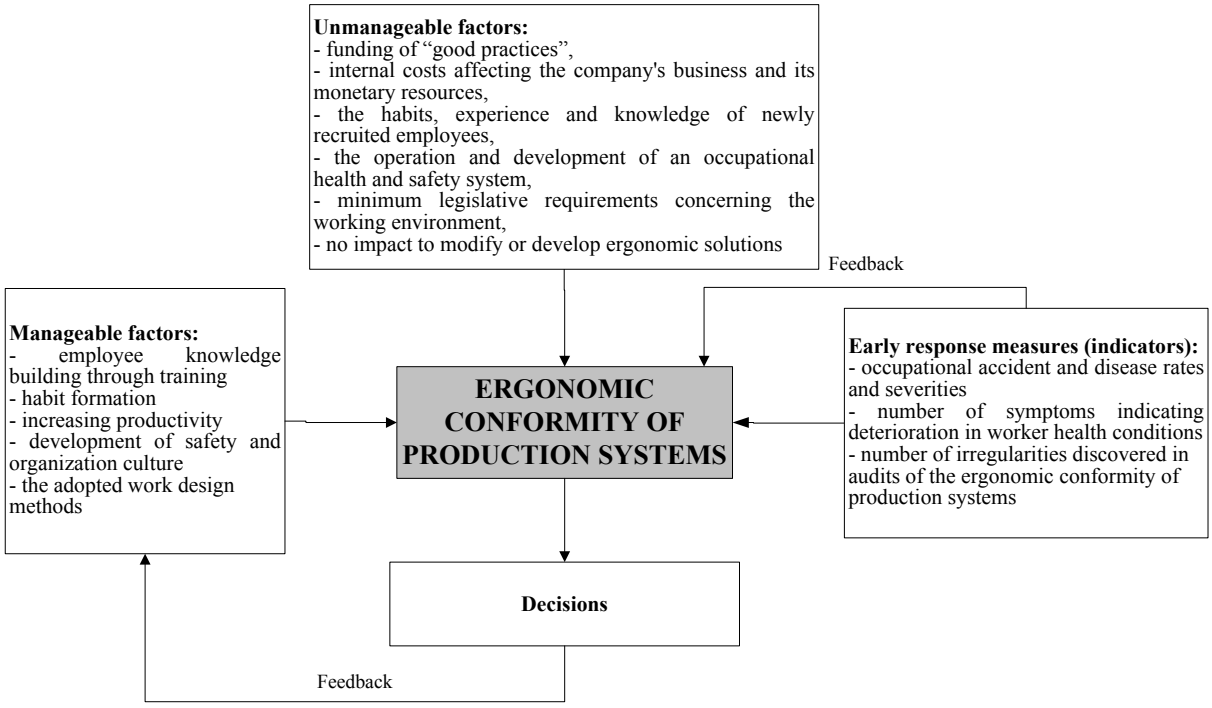

Figure 5. A model for managing the ergonomic conformity of production systems (authors' work)

The foregoing model shows the factors available to decision-makers to influence the ergonomic conformity of production systems as well as the measures they can use to assess the degree of such conformity. Also specified are unmanageable factors which will not allow decision-makers to modify the system.

CONCLUSIONS

The main goal of the paper has been described as aimed at: "identifying ways to foster the significance of ergonomic conformity in designing production systems in the automotive industry". To achieve this goal, the authors have carried out a case study by the network thinking method. Although they adhered to the standard stages commonly applied in the method, the factors selected by the engaged expert team were specific for the enterprise in question. What is also notable is that, despite the fact that specific criteria differ from one company or industry to another, the solution presented in the paper may well serve as a basis for other (similar) studies.

Expectedly, the factors of great significance for the investigated issue included finance ("the available funds") and "organization culture". What was not foreseen, however, was just how powerfully "experience", "knowledge" and "effective training" would affect ergonomic conformity. Of equal significance is the formation of good and bad habits which the literature rarely recognizes as central for the development of production system macroergonomics.

To build an awareness of ergonomics among individual stakeholders, it is crucial to promote positive and eliminate negative factors. It is not advisable, in this context, to dwell extensively on operating expenditures and the financing of "good practices". While such practices may well attract extra funding, even the best tools, machinery and equipment will do little to improve the ergonomic compliance of systems without proper knowledge and employee training.

As a science of the future focusing on complex systems, macroergonomics brings together a wide range of issues associated with organizations' activities. It is therefore best not to view increases in the level of ergonomic conformity as a single isolated set of characteristics but rather as components tied to a number of other factors which interact in various ways, at different times and with varying intensity.

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The Use of Web Application “Mobilne Miasto” [Mobile City] in the Conveyance of Information About Urban Space in the System Human Factor – Technology

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ABSTRACT

This paper describes selected aspects of the research work carried out within the research and development project called “An integrated system for supporting the access to information". The objective of the study were the possibilities of using the web application "Mobilne miasto" in an urban space. Particular attention was paid to increasing the efficiency of access to information about the urban space, as well as to allowing impact on the environment through the application. The article discusses the issues related to a study of information needs, where key features which states have been optimized were analyzed, that is: usefulness of information (obtained by studying the needs), the reliability of information used in urban areas (accuracy, comprehensiveness) and the time of access to that information (analysis of the amount of necessary information).

Keywords: Mobile devices, Usefulness of information, Reliability of information, Crowdsourcing

INTRODUCTION

A range of user’s interference reaches nowadays not only to the nearest place of work and residence, but every environment in which he resides. The increasing mobility of workers, the development of information and communication technologies have changed the structure of employment in macroeconomic terms. Dynamically changing challenges should be accompanied by technological solutions that will provide necessary information tailored to the users, their perception, knowledge, skills, and the situation in which they will be used (Pacholski, 2012).

The use of mobile devices is becoming more and more common, and also increasingly indispensable in the professional or personal life. Smartphones or tablets with Internet access are already being used in the EU by about 60% of the population aged 16 to 24 years (Seybert, 2012). Such a widespread use of mobile devices contributes to the increase of competition in both the improvement of mobile devices themselves and the ways of processing information.

The result of the research and design activities on the application was also the patent application for an invention that was associated with the influencing the formation of the immediate environment. The web application features

were used not only to capture information, but also to generate on convey information. Making information, which is often the professional knowledge, publicly available is used in the crowdsourcing - implementing such functionality was also foreseen for the application "Mobilne miasto".

Information about the immediate environment, as well as the ability to influence its formation, enhances safety, efficiency of performed activities and as a result also the quality of life. Facilitating the use of equipment and solutions that provide information about objects, events and opportunities of functioning in the area, provides a practical tool for shaping the environment. The possibility of shaping the environment, especially in urban space is an important issue not only for economic reasons (access to needed products, commercial buildings), but also to sensitize society and allow the social participation of people residing in a given environment. The use of the "Mobilne miasto" application allows for the implementation of such activities.

SELECTED ASPECTS OF RESEARCH WORKS REALIZED WITHIN "AN INTEGRATED SYSTEM FOR SUPPORTING THE ACCESS TO INFORMATION "

Preliminary research based on secondary sources

The major goal of the project "Integrated system for supporting the access to information in public space" (Mobilne Miasto) was to satisfy the information needs of user of mobile devices moving around the urban area. The scope of the project included the definition of range, format and manner of presentation of required information. Research in this area were conducted over several years. This article is based on the monograph "Integrated support system for access to information in urban space with use of GPS and GIS systems" (Goliński, Szafrański, 2012) and uses the results of research, which was conducted for the needs of this projects (Report from the quantitative…, 2011, Report from the qualitative…, 2011).

The first studies conducted for the purpose of the Mobile City project took place before the project application was filed. They concentrated on the use of in-formation by a user of information in urban space. Apart from that, the features of an IT system were analyzed, taking into account the issues of the user-IT sys-tem interaction as an ergonomic feature of the system. Also, it was tested what factors influence the quality of life in urban space. In 2009, the results of these studies were included in the following publication: "Chosen systems of access to information and their influence on formation of the quality of life in municipal space". (Goliński et al., 2009). Also before the application was filed, selected information technologies supporting access to information in urban space were analyzed, with focus on the kinds of information needs, the functionality of the available solutions and the criteria for the evaluation of these solutions. These works were used in the publication entitled "A comparison of selected information technologies supporting the access to information in urban area." (Graczyk et al., 2009) and "Analysis of the possibility to use information about urban space in mobile devices" (Goliński et al., 2012).

The most important research areas concentrated around the following issues:

- improving the quality of information about objects in urban space available with the use of mobile devices,
- Focusing on the user by shaping the human-system interaction
- Combining the hardware and software are and creating the logical and functional connection of human-computer tasks (Prussak, 2012)
- improving the functionality of the use of information related to locating objects in urban space,
- distinguishing a set of useful pieces of information related to location and concerning the improvement in the quality of life in cities,

The aforementioned issues were the subjects of a thorough and regular analysis conducted by the project team. In designing the application, the needs of users were taken into account, yet without disregard to the principles used in designing of new products (Golinski 2012). Research requiring specialist research tools and technical facilities was - for the sake of efficiency - commissioned to external entities.

User-oriented design is important when creating new systems providing information in mobile conditions, which must be useful and accepted by the users. Popularity of mobile applications, the scale of their use also entails the need to evaluate their ergonomics, which is expressed by taking into account the human anthropometric, physiological, biomechanical and psychological capabilities (Drzewiecka, Tiggy, Pacholski, 2012)

Qualitative research into information needs

The fundamental aim of the qualitative research was to identify categories of information related to urban space for which there is demand among the inhabit-ants of Poznań and visitors to the city The general research population included the inhabitants of Poznań and incomers or commuters – divided according to age, gender, professional status, knowledge of technical solutions and attitude toward innovation.

The basic scope of the research concerned a detailed specification of the range of information required by users, preferred by the respondents, the preferred ways of using a mobile device in order to obtain information, the preferred user's interface in mobile devices, and learning about the respondents' needs concerning the quality of information and the quality of the user's interface.

Basing on the words of the respondents, information which may be sought for by the users of mobile applications and which concerns the life of the city and urban space may be divided into the following groups:

- transport and location - information related to getting around in the city, timetables of means of public transport, information on traffic jams, road works and other traffic difficulties, as well as about ways to reach a given destination,
- leisure activities - cultural and entertainment activities (cinemas and theaters, concerts, exhibitions, festivals), sports (sporting events such as games and competitions), tourism (information about historic places, places to visit, hotels), weather (weather forecast),
- services and administration - administrative matters, the applicable law, opening hours and contact details of offices, institutions and services (shops, hairdressers, etc.), information on restaurants, pubs, cafes,
- local - planned investments (housing investments/ investments related to infrastructure, space development projects), advertisements (job market, private lessons, exchange of handbooks),
- hobby - information related directly to free time, including information about the history of Poznań or information related to sports and Poznań sports clubs.

Grouping of the topics of requested information is also related to how often they are sought. Information needs and frequency of searching for certain information was juxtaposed basing on the opinions of the respondents - this is presented in Fig.1.

Fig.1. Types of information needs and frequency of searching for information. (Adapted from: The qualitative research …, 2011).

Knowledge on the respondents' information needs and their validity - as specified by the respondents themselves - was very precious for the project team and made it possible to plan the structure of the database and potential sources from which to feed it. Another useful piece of information included differences in information needs depending on the time of the week. The respondents indicated that on working days the most sought information was information related to transport and travel within the city, as well as information related to services and the opening hours of particular shops, pharmacies, etc. In the case of students, the information sought at that time included also culture and entertainment, as students look for opportunities such as cheaper cinema tickets and lower pub prices on weekdays (as opposed to weekends). The information searched for at weekends is mostly needed to plan free time activities, so cultural and entertainment information, as well as weather forecast are among the most desirable. Another useful piece of information for the team designing the application was different information needs in a week. This may translate into organizational requirements related to the schedule of feeding the database but also - allows to plan the server access load.

Another conclusion from the research was that the designed application is an example of an innovative use of a web application. At present, more popular applications are native ones, dedicated to a given platform, whereas the solutions based on mobile sites, despite their smaller share in the market, indicate the direction into which mobile solutions will develop. One visible disadvantage, with slow internet connection, is a slower data trans-mission rate. Therefore, a significant part of the qualitative research was devoted learning about the plans of the respondents concerning the use of the internet and the telephone in the nearest future.

The respondents declared that at present they use the mobile internet mainly in situations referred to as "emergencies" - when they need to connect the inter-net fast and have no possibility to use a stationary connection. Such situations take place mainly when they want to locate a place, find out about route directions or check emails, which is important mainly for people whose work requires them to stay in constant touch with their customers and check emails frequently. The group of people using the internet intensively is constantly growing. "In the first half of 2011, as many as 66% of households had a computer and 61% of them also the internet access. Over 50% of all households have constant internet connection, 15% uses mobile access offered by mobile operators. In the first half of 2013 computers were present in 70% of households and Internet access in 66,9%, 18% uses mobile access and mobile phones are used by 87,4% (Batorski, 2013). Those people use the Internet in mobile devices in their spare time, communicating with friends, checking emails or simply surfing the internet. There is a group of people who prefer the mobile internet to the "stationary" internet precisely due to its mobility, which makes it possible for them to access it in any situation and at any time. Such people are a potential group of the so-called "heavy users" (regular customers) of the Mobile City application.

The reason for which some people who use the mobile internet only occasion-ally is the inconvenience of data viewing, related to problems with connection speed and the insufficient technological parameters of devices. Another significant barrier is also the conviction that the price of such connection is very high.

One of the tasks of the project is to integrate data already available on the internet. The conducted research confirmed that there is a need for a guide with comprehensive information concerning the life of the city. Among the main factors characterizing the ideal system, the respondents mentioned a clear form of presented information, brief and concrete content, a good data loading speed (thanks to modest graphics) and the topicality of the presented content.

The scope of the qualitative research involved also the shape of the interface of the application in question. The respondents mentioned that it was important that desired information was presented both in the form of an internet website and an application. A guide in the form of a website was a solution presented relatively more often and preferred by the respondents due to its obvious, natural and more familiar image. The respondents mentioned the examples of already existing integrators / information portals such as www.epoznan.pl, or www.mmpoznan.pl. People often using the mobile internet on mobile phones were more enthusiastic about the creation of mobile applications which would offer quicker access to information.

The mobile application the respondents would appreciate should be free of the existing problems of similar applications, including:

- no up-to-date contact details of companies and institutions,
- the accumulation of obsolete and outdated information concerning past events,
- the lack of one place - a portal / website with all the necessary information about the city,
- no information concerning the practical aspects of getting around the city, such as parking bikes.

The respondents, apart from indicating problems with the existing information and forms of its distribution, described also their own preferences concerning the form of urban information obtained via mobile devices. Their comments concerned both the form and the functionality of solutions, and among the most frequent suggestions were: a) as far as information features are concerned: concrete, brief, up-to-date, b) as far as graphics is concerned: avoiding "heavy" elements, more text than graphics, headlines and key words in bold, maps and logos for location, discrete colors [black and white], a large, clear font, c) as far as the functionality is concerned: no or only a limited number of advertisements, relevant hits, the size of the page should automatically adjust itself to the screen size.

In the course of the research, the respondents were divided into two groups: occasional and regular users of the mobile internet. Selected situations and arguments for the frequency of using mobile applications are presented below for the two groups: (A) occasional users and (B) regular users of mobile applications.

A) The respondents who declared that they use mobile internet only occasional were usually very pragmatic with this respect. They only used the mobile internet in emergencies, when it was impossible to use stationary

connection. They focused on: obtaining directions / navigation, reading emails or checking the inbox, or doing a bank transfer. Their reasons for limited use of the mobile internet were as follows: the inconvenience of mobile devices [a small screen, limited battery strength], problems with the speed of the connection and its low quality [frequent disconnecting], insufficient level of technical parameters of mobile devices preventing the proper display of some websites, faulty operation of selected applications; the respondents were often convinced of the high cost of the mobile internet connection, fear poor antiviral protection when connecting from mobile devices and - quite frequently - declared that they were not used to using the mobile internet.

B) People who used the mobile internet more frequently described a wider range of occasions when it could be useful. Apart from purely practical motivations they mentioned entertainment (social networking sites, YouTube and similar sites, visiting sites in relation to hobbies). Entrepreneurs reported their need for continuous internet access. Among students there were people who declared using the mobile internet while being at the university - during classes or exams. The main reasons for the frequent use of the internet on mobile devices included: the possibility of using free internet thanks to the Wi-Fi technology, the conviction that the costs of mobile internet connection were low [in this context, respondents pointed out at Internet service packages, talked about their desire to relieve boredom or about laziness (manifested in reluctance to switch on a stationary computer to check emails), the conviction that some information may be faster found on the mobile phone than on a computer, as starting the latter takes a certain amount of time].

A number of ideas can be drawn from the analysis of the results of the qualitative research. Many of them were already designed in the solution and their useful-ness was now confirmed by the respondents. Among them are:

a) the system of categories and subcategories - the respondents claimed that the city guide website must be as readable, clear and user-friendly as possible. Moving within a category would be possible through links - having clicked on a given category the user would be redirected to the list of subcategories and then - the “deeper” content of a given subcategory,
b) data selection and personalization – an idea emerged to increase the functionality of the solution through customization and storing of the previous searches, which would result in a quick access to concrete, preferred information corresponding to the needs of the user. Users would choose fields and subcategories of their interest and then they would receive information filtered in accord-ance with their assumptions. The system could store the settings of a given user and every time he logs in - redirect him to the parts and categories he has read the most so far.
c) application with speech generator - an ideal system should be based on the al-ready existing guides and use source data from services such as gazeta.pl, epoznań, of the websites of offices and institutions. A given piece of information would be searched for by the criteria entered. The user would not have to go through different categories but would be immediately given the information he or she is looking for. The innovativeness of the system would involve the system of location services using a speech generator. At the user’s command, the system would search for places corresponding to a given voice command and located in the vicinity of the user. In the advanced version of the system, it would also show the directions in Poznań taking into account the location of objects which would be of interest for a given user.
d) the respondents also pointed out the following necessities: a clear interface, minimum graphics, calm colors

In the conclusion, the respondents listed their expectations towards a potential phone - the most important desired features:

- a durable battery - about 7 days without charging for talks and 2-4 days for the internet,
- a good processor/ operational system to ensure efficient work of the phone,
- a camera capable of taking good quality pictures,
- a good display screen - of sufficient size and appropriate resolution,
- a touchpad and an in-built keyboard / touchpad,
- a good speech synthesizer - so that you do not have to touch the keyboard if it is not necessary,
- a durable case/ a thin case - so that the phone does not get damaged easily when it falls,
- Wi-Fi, Bluetooth, calendar, voice recorder, alarm clock, waterproof, slots for two cards.

The comments which the respondents made during the qualitative research became the basic material for developing a set of issues to be included in the quantitative research.

Both qualitative and quantitative research constituted an important support in the development of functional solutions and creating the database structure for web application "Mobilne Miasto".

Quantitative research into information needs

The objective of quantitative research, which involved a group of 400 respondents, was to gather information on the type, frequency, and places in which the respondents search for information related to urban space, the use of Internet in searching for information related to urban space, use of the Internet on mobile devices, the preferences of respondents to the features of the sought information. The profile of the GPS user was determined. The key questions in the survey were: type of information searched for, the intensity of the information sought and determining the desired features of information.

The participants of the research usually sought information concerning: transport [timetables of means of transport, routs to given destinations], events taking place in Poznań and directions. Needs related to this kinds of information were declared by 68%, 62% and 48% respondents respectively (Fig. 3.4). Another group of information concerned urban topography, including the location of retail and service outlet [also catering points], offices and institutions in the city, centers providing emergency assistance, restaurants, pubs, cafes, promotions and prices, traffic jams in the city, road works and other transport difficulties in the city, as well as the location of historic and simply interesting places in Poznań. Occasionally, respondents declared information needs related to the location of car parking spaces, objects in the vicinity of the place where the information seeker was at a given moment, accommodation addresses, hotels and bicycle paths.

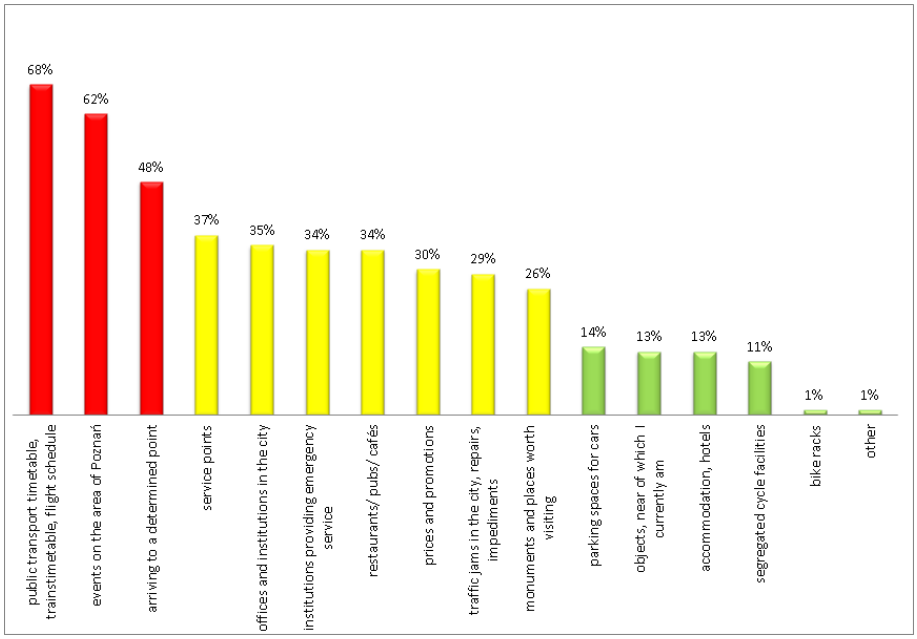

Fig. 2. Topics of desired information. (Adapted from: The quantitative research ..., 2011).

An important information for application design was that the respondents sought information in the internet with different frequency - half of them did that at least once a week, and the rest - less than once a week. The most often sought subjects include timetables (public transport in the city/ trains/ planes) - 25% of the respondents needed this kind of information at least twice a week. Another useful kind of information was information about traffic jams, road works and other traffic obstacles - 33% of the respondents sought this kind of information at least once a week - fig. 3.

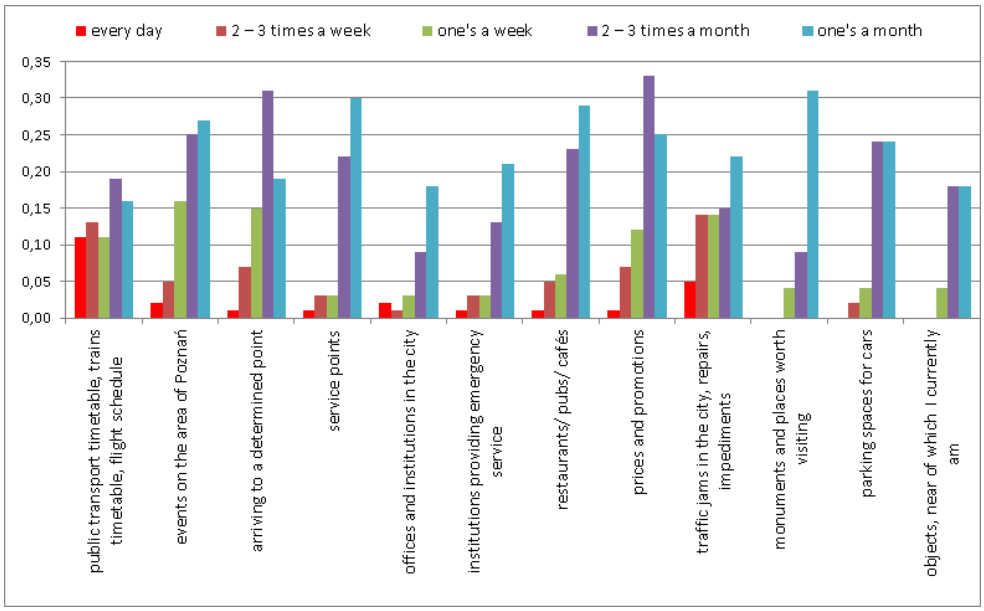

Fig. 3. Frequency of desired information. (Adapted from: The quantitative research ..., 2011).

From the respondents' answers, the researchers could conclude that it was not difficult to find the desired information but the correctness of the description of a desired destination might vary significantly. The estimation of the time needed to reach a destination appeared to be the key element of the desired information. The remaining aspects are a bit less important [the route, distance, opening hours] – Fig 4.

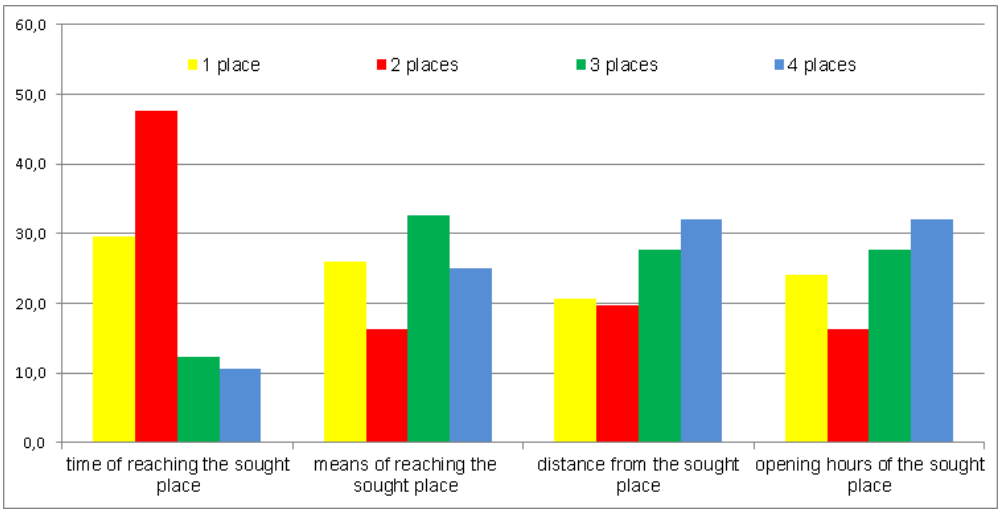

Fig. 4. The importance of information on how to reach (on foot or by car) a given point, in the respondents' categories (Adapted from: The quantitative research ..., 2011).

The key finding from opinions of the respondents regarding the characteristics of information, whether they were students, businessmen or other respondents, was the need to ensure in the mobile application the validity, completeness, and availability of data - Fig 5

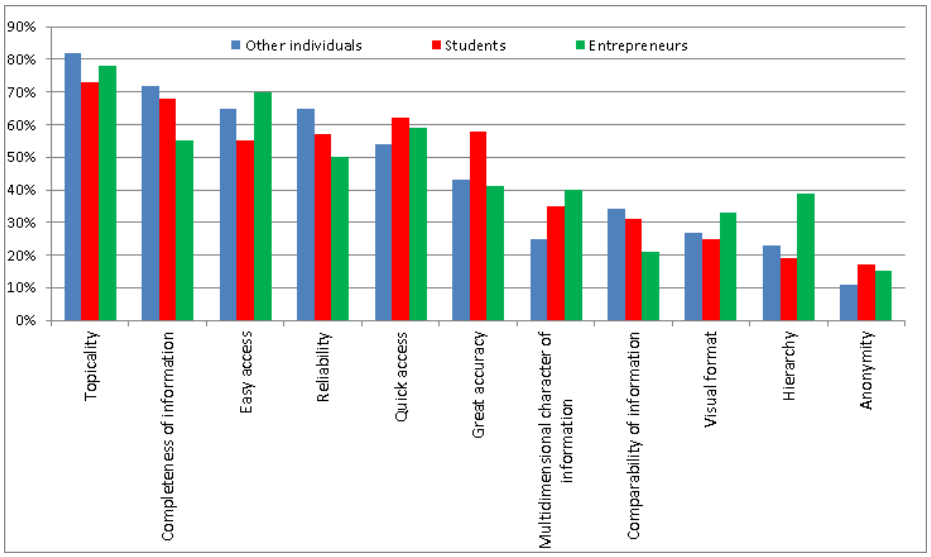

Fig. 5. Preferred information profile, in the respondents categories. (Adapted from: The quantitative research ..., 2011).

Among the main conclusions summarizing the results of studies that have taken into account the full range of user needs including technical, economic, organizational, environmental, ergonomic, and social criteria, the most important aspects should be stressed:

- the respondents usually sought information concerning transport e.g.: timetables of means of transport, routes to given destinations, and concerning events taking place in Poznań. Apart from that, the desired in-formation included also the topography of the city, retail and service outlets, e.g. food outlets.
- the estimation of the time needed to reach a destination appears to be the key element of this kind of information. The remaining aspects, such as the route, distance, opening hours, are a bit less important.- The internet is the key source of information. Notice boards and friends are much less frequently used as sources of information.
- The respondents sought information in the internet with different frequency - half of them did that at least once a week, and the rest - less than once a week. The analysis of the results indicates that it is not difficult to find desired information
- the most popular device used to seek information on the internet is still a computer. With this respect, mobile devices are used definitely less of-ten - every third student and fewer than every fifth individual user or entrepreneur. Among mobile devices used to seek information on the internet the respondents usually mentioned mobile phones.
- the users of mobile devices use them to seek information on the internet every day or almost every day. This is, basically, the same information as in the case of searching via other devices - information about how to get to a selected destination or about events in the city,
- the key element of information is its up-to-datedness. Due to the nature of the information sought and the fact that it is necessary in a given moment - 2 groups of attributes appear equally important: the speed and ease of access, and reliability and completeness of the information acquired,

The results of the qualitative and quantitative research confirmed to a large extent the assumptions concerning the expectations of users of mobile devices.

Information needs about the immediate environment, as well as the ability to influence its shape increases the safety, effectiveness of working and studying, gives greater satisfaction from leisure, and as a result also improves the quality of life. Facilitating the use of equipment and solutions that provide information about objects, events and opportunities for functioning in urban space, is a practical tool for increasing the comfort of functioning in the modern world. The use of mobile devices also allows the people in agglomerations to increase their conscious participation in the shaping of their environment and influencing their social life. An example of such situation is the described below proposal to use the web application "Mobilne Miasto" in shaping and analyzing the market.

HOW TO VERIFY THE RESULTS OF SPATIAL METHODS OF MARKET ANALYSIS

Today, more and more technical solutions require close association with economic and social components. An example of such approach was the use of web application "Mobilne Miasto" to verify the results of the use of spatial methods of market analysis. Publicly available information and knowledge derived from smartphone users is an example of the use of information in crowdsourcing. The use of web application " Mobilne Miasto " is thus both an example of a solution using ergonomic assumptions and taking into account the socio-economic determinants associated with ergonomics (Pacholski, Jasiak, 2012).

There are many methods of market spatial analysis and spatial statistics, related to the topological, geometrical or geographical descriptions of objects. They vary in the degree of complexity, use various modern technologies, such as telecommunications technology, statistical software, computer technology, the Global Positioning System and Geographic Information System, enabling the management of geographic data, creating own data, using of GPS data, performing spatial analysis or creating maps. There are well known methods based on interpolation, regression or autocorrelation (based on the study of spatial relationships and using the idea called "Tobler's first law of geography", which can be shortly described as " Everything is related to everything else, but near things are more related than distant things ").

The application of spatial analysis models is very broad and applies to a variety of areas: demographic analysis, organization of marketing activities, tourism planning, forecasting and correcting activities of a social nature. Using the results obtained based on spatial models should complement the demographic, economic and social modeling strategy.

In the solution using the web application "Mobilne Miasto", the use of a computer program was assumed, which makes it possible to create subsystems of spatial analysis, subsystem of geographic information, database of infrastructure elements connected with a specific location, database ("data mining") serving as a "repository of ideas" how to develop or improve existing infrastructure or how to plan new infrastructure elements and a system of data mining that reveals knowledge, draws ideas, suggestions from available databases.

A tool for predicting the location of infrastructure elements contains such elements as: the first storage tool (eg smartphone) for storing location information concerning the changes in the infrastructure in the area, the second storage tool (eg, a server) for storing specific data associated with characteristics of changes in the infrastructure and a processor coupled with both the first and second storage tool, that identifies the elements of the infrastructure which require repairs, changes, and processes location information from both storage tools. .

Web application "Mobilne Miasto " allows for the development of a method that will efficiently and effectively support decision-making processes related to the positioning of objects of commercial and public use purpose in the particular agglomeration. Verification of the results of the use of spatial methods of market analysis according to the developed method is implemented in several steps. The base server collects the spatial analysis models developed in the form of mathematical algorithms and creates a database of models. Database of spatial analysis models is subject to continuous development. The base server also hosts the dedicated software and contact databases containing the addresses of the objects to be evaluated . The user of a mobile phone device with Internet access, equipped with a GPS transmitter and dedicated server software, sends information describing the objects to the base server. Database of spatial models, database of objects, dedicated software and database of description standards are connected by relationships which, thanks to the functionality of a dedicated software, are used to verify the results of the application of spatial methods of market analysis. Transfer of information between the mobile phone and the base server through a dedicated software is bilateral, which provides feedback and gives other system users access to a verification.

The use of the web application "Mobilne Miasto", as a way to verify the results of the application of spatial methods of market analysis fulfils the assumptions of the crowdsourcing method. Use of the application is a convenient solution, allowing to reduce the size of the study population during the implementation of spatial analyses. By examining the dependencies in one location/object we can be predict values or expectations for another location/object without performing simultaneous observations in both places. The above-described usage of the application is just one example of the possibilities of using web application "Mobilne Miasto", which was developed in the project "An integrated system for supporting the access to information", done as a part of the 10th contest of development projects funded by the National Research and Development Centre.

CONCLUSIONS

Designed application and its implementation were an R&D undertaking, of a unique, highly dynamic nature, yet very sensitive to environment factors. An important conclusion from the study is that while designing a technological solution we must take into account the technical, economic, organizational, environmental, ergonomic , and social criteria (Pacholski, Jasiak, 2012). In the course of realization and development of each project such issues as changes in customer requirements (due to the growing needs and greater awareness), legal conditions, the emergence of new knowledge and updating of economic assumptions, should be considered on an ongoing basis.. The basic goal of the project, which was to create a pilot version of the system of providing urban space users with a comprehensive and up to date spatial information along with the ability to supplement the descriptive attributes have been realized. An interdisciplinary look at the transfer of information confirmed, already at the research stage, the need to connect the human-centric approach, focused on the care for human needs, with the engineering way of practical problem solving. A manifestation of this approach was including research and testing in the design of a set of attributes and criteria sought by mobile device users. Working on the design of the application confirmed that improving the quality of life is largely based on the potential use of information and communication technologies in improving communication and decision-making processes, but indispensably requires a comprehensive-holistic approach to analyzed projects.

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Macroergonomics in the Design of the Quality of Work Environment and of Human Life: Examples of Practical Applications

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ABSTRACT

The purpose of this work is explaining what is the essence of macroergonomics, on basis of the analysis of the world achievements from the scope of disciplines: human factors ergonomics, project studies, science studies, organization theory, psychology and sociology. Moreover, what is the role of macroergonomics in the formation of not only the quality of the technical environment or the work environment, but also the quality of life of individuals, as well as entire populations. Macroergonomics is, according to the classification recognized in world, the third phase of the evolution of ergonomics, which is the most current and modern generation of ergonomics. In other words, macroergonomics is an organization – machine interface technology. Elements of macroergonomics (criteria and determined scientific areas, as well as tendencies that contribute the creation of the essence of macroergonomics) are presented from two sides: the conceptual and methodological side and the side of possibilities for practical implementations (the set of works realized by the author along with works made under her direction). The paper is composed from four integral threads. The first part presents views on the quality of life and the quality of the work environment. The second part is dedicated to the genesis of macroergonomics and to prospects of its development. The third part, in view to its limited volume, illustrates the general image of different possibilities to apply macroergonomics into practice in determined areas of technique and economy. The paper presents an example of a demand of enterprises for ergonomic knowledge in relation to the process of designing the company's strategy and marketing plan, presented for the case of authorized passenger cars dealer companies. The work ends with a conclusion on the role of macroergonomics in the creation of the man's quality of life and possibilities of the development of this discipline in the future.

Keywords: macroergonomics, framework, quality of life, quality of the work environment, benefits of the practical implementations

INTRODUCTION

Before macroergonomics has been created, the traditional European ergonomics was focusing on problems of integrating man and technique using Maslow's hierarchy of needs as a point of departure. This meant fulfilling basic needs, like physiological and safety needs. Macroergonomic interferes more in the area of so-called higher needs, like: belonging to a group, respect or self-actualization. In the process of designing manufacturing processes in accordance to traditional criteria, the human factor criteria had a very small share of proportion. Modern proportions assume that social, ecological and ergonomic criteria consist in total 25% of all – next to technical and economic criteria.

A concept of quality of working life QWF grew on the ground of organization theories and psychological and social sciences. The aim of this idea is to augment the participation of the staff in the process of making decisions that affect their everyday work and their quality of life in their place of work. Increasing efforts for raising the quality of working life results from the recognition (acceptance) of fundamental values, like: safety, justice, honesty, loyalty,

partnership, tolerance, independence, freedom, satisfaction and self-actualization of an individual person (Misztal and Butlewski, 2012). The presented idea in a sense a challenge for macroergonomics, which should form rules of a design that would be "friendly" to a worker of the company, taking into account the external and internal environment, based on the system and holistic approach.

In practice, the application of macroergonmic theories can refer to various spheres of technique and economy, for example: elements of macroergonomics in companies following the pro-qualitative policy, within frames of ISO 9000 standards, including TQM implementations and their impact on macroergonomics. Next, elements of macroergonomics in the reduction of the stress at work – on basis of the example of the management of companies, and the concept of the examination method and results of research in practice. Moreover: economic transitions of the country's region and changes of the structure of the labor market presented by the example of universities graduates in Greater Poland.

QUALITY OF LIFE AND QUALITY OF WORK ENVIRONMENT

The term quality of life is used in many scientific disciplines. However, it is important to say that despite the variety of existing concepts, none of sciences (even psychology) had formed an unequivocal stand on the way to interpret the quality of life (Kowalik, 1993). Many scientists, especially from the area of economy, treat the quality of life as a indicator of the level of life standard for individuals or social groups. Thus, it might include different partial indicators, and each of them refers to one of arbitrarily selected spheres of the life, e.g.: family, psychical, professional, somatic, environmental or residential. The reduction of the global characteristic to only one dimension leads to an excessive simplification of the case. Therefore, objective indicators are supplemented by a similar set of subjective measurers, which encloses people's opinions on the way they evaluate selected areas of their own life.

The work environment is a term difficult to define in a firm way. Each discipline focusing on man and his activity interprets this term in a way that fits to its scientific and methodological view (economy, law, work organization, occupational medicine, psychology, sociology, etc.). It is relatively easier to find certain categories and dimensions that would describe these terms, than to find their definitions. The author has found only one definition of the work environment. It determines it as natural physical and chemical parameters that characterize a technological process and the place, in which the process takes place, and biological and social elements, which often cannot be measured, added by man into production and organization of work as additional elements (Jethon and Krasucki and Rogoziński, 1982).

The work environment is mutually created by both categories (Bańka, 1985): the objective and subjective one. The so-called objective work environment is formed by physical and tangible criteria: room, machine, raw material, factor of the physical environment. Other category is immaterial criteria, independent of the will of the man, i.e. organizational criteria, like fast tempo of work, multiplicity of different tasks. The remaining category constitutes a set of criteria that can be called socio-technical and which come from the human environment, like the influence of the group to an individual that works in it, the ambience at work that is formed by the performance and attitude of others, etc. The so-called subjective work environment is shaped by a set of subjective factors, i.e. determined by people, which establish the final form of the physical and psychical structure of an individual and which decide on the personal perception of the quality of work.

Psychological approaches stress the subjective character of the quality of life, which means its dependency from the point of view of from the opinion of the assessing person on the physical and psychical reality. Therefore all psychologists and other scientists say most often about the sense of quality of life. Psychological normative approaches take under consideration external objective conditions and determined methods for dealing with stress, types of social relations, etc. (Derbis, 2002). People that have different level of accordance with determined psychological models are assumed to have a suitably higher or lower quality of life (fig.1).

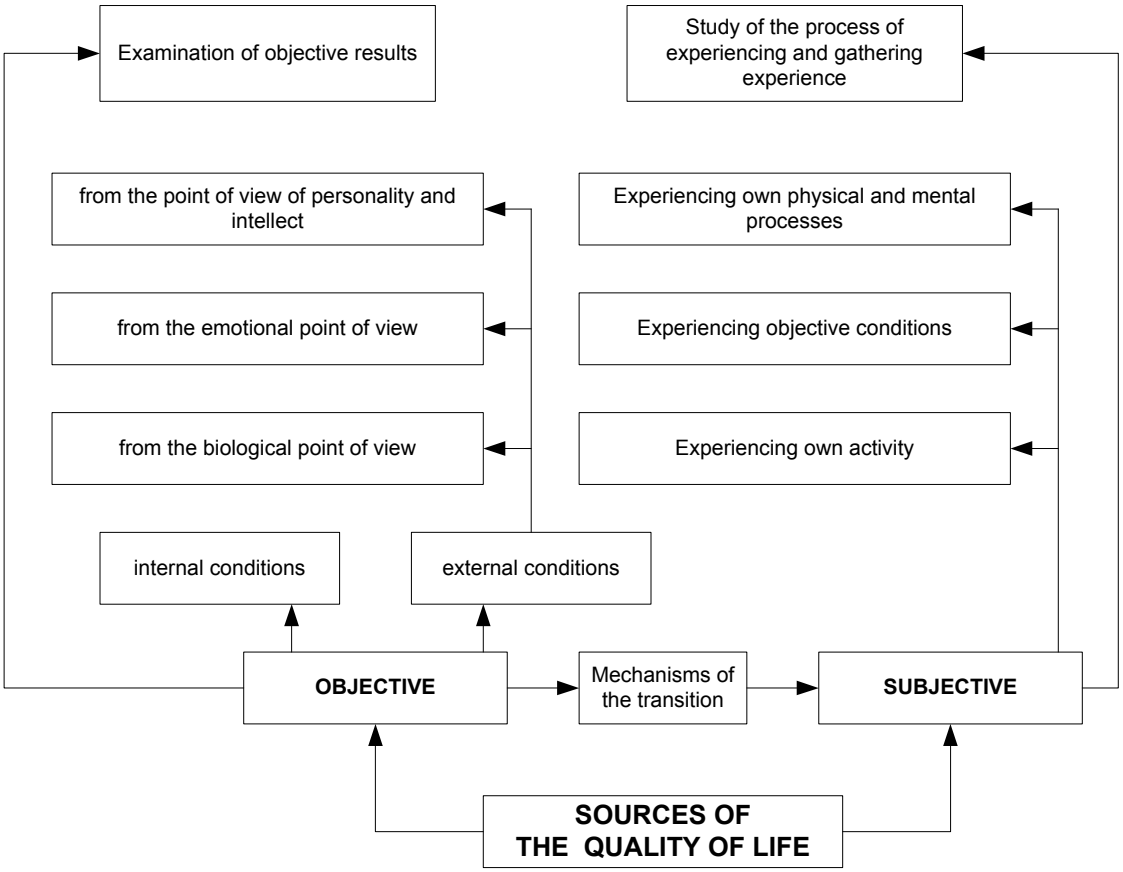


Fig. 1. Prototype of the model of sources and quality of life measurement (Derbis, 2002)

According to some authors, the term "work environment" is deceptively identified with a much wider term – work conditions. The author thinks that the present stage of development of ergonomics and macroergonomics already explicitly settled with holistic system including various environments that co-create the composite nature of the work environment of man as an individual.

At present macroergonomics does not have finally formed methodological output. However, taking under consideration scientific approaches consisting the found of modern trends for the economic development and achievements from other domains of human science, we could form following premises – criteria for design that would be friendly for the worker and his composite environment:

1. Preference of technologies safe for the man and the natural environment;
2. Safety on workplaces and their external environment (these criteria are affected mostly by: time of work, material and physical factors of the work environment);
3. Diversity of performed tasks and possibility of widening workers' comprehensive tasks, which would enclose several stages of one process;
4. Possibility of continuous self-actualization – this category includes conditions for continuous formation and gaining new skills, as well as possibilities of implementing them in the workplace and chances for promotion;
5. Certainty of the place of employment (enterprises);
6. Interpersonal relations and the atmosphere of the workplace – with particular attention on following elements: level of tolerance for individual habits, the atmosphere in the team of employees, friendliness, openness, etc.
7. Range of participation in the decisive process within companies;
8. Preference of so-called „stress on a level acceptable by an individual" – it is about obtaining the effect of the projection of negative phenomena of the process of the work to other spheres of the life of the individual in order to allow a worthy way to fulfill other social roles;
9. Prestige of the enterprise in the opinion of the employee – this criterion refers to the way employees evaluates their company – e.g. whether it works in a legal and responsible way;
10. Appropriate and fair wages – this criterion concerns not only "the objective amount of the remuneration"; it

also refers to the sense of justice in distributing wages among workers.

Presented suggested list of criteria does not exhaust the entire scale of criteria for a design that would be friendly for the worker and his composite environment. It is rather aimed at illustrating how much the problem of methodological frames in macroergonomics is different from the classic range and essence of first generation of ergonomic research and what problems should be in the center of interest of macroergonomics to make this area of knowledge useful in solving problems of the current and future economic and social reality.

GENESIS OF THE ERGONOMICS

Ergonomics is a composite empirical science directed on many aspects of cognition of the man-to-technique system and on preparing a set of guiding statements for implementing in practice the bilateral adjustment of participants of the system, in order to guarantee the most profitable conditions of its functioning. W.F. Taylor, at the turn of the 19th and 20th centuries, was the first, who initiated attempts of organizing work on scientific bases and of research on forming possibly efficient tools and work conditions for man. The publication of work "The trait of the ergonomics, i.e. theories about work, based on truths taken from Natural Science" in 1857, written by Wojciech Jastrzębowski, Polish naturalist, was a fundamental fact for the history of ergonomics. Ergonomics in Poland is also connected with the name of Tadeusz Kotarbiński, who put ergonomics on the list of so-called ergo-logical sciences, even though he did not enriched significantly its theoretical or practical aspect (Pacholski, 1977). Ergonomics in Poland had a particular character, from the point of view of its methodology. In first years after the Second World War there was not many system approaches and initiated studies and implementations were initially connected with ideas of engineering psychology, industrial psychology, occupational medicine and anthropology. Polish scientists had a big input in the development of the theory and practice of ergonomics. However, their works were not entirely comprehensive and system character in the object scope. They were rather focused on partial problems of the system man-to-work. Problems associated with occupational medicine, psychology and anthropology were dominating research issues.

In the history of ergonomics, we can distinguish three stages of euduction: first, second and third generation of ergonomics. The first generation ergonomics (human – machine interface technology) was oriented on examining phenomena of the perception, issues of anthropometry and analysis and design of relatively isolated systems man-technical object. Enlarging this range of research and analysis with systems man-computer, including among others focusing on the study of cognitive and decisive processes of man constituted the beginning of a so-called second generation of ergonomics (user – system interface technology). The growing scale of automation in the process of production and computerization of clerical work and the increasing level of awareness on the impact of technique on industrial organizations accompanying these processes and, in consequence, affecting decisive processes, was the initial factor for creating the concept of a so-called macroergonomics, which constitutes the third generation of the ergonomics' evolution.

It is accepted to call H.W. Hendricks a creator of macroergonomics because he has formed and justified the fundamental assumptions of this concept (Hendrick, 1987). Pioneering towards the macroergonomics concept of production systems design, which can be treated as an equivalent of socio-technical systems, was formed on the Polish ground relatively long time ago – in 1977. Leszek Pacholski and Konstanty Rogaliński have formed it; in their fundamental works from the year 1977, these authors formed a notional apparatus related to the study of socio-technical systems, called ergonomic industrial systems (Pacholski, 1977, Rogaliński, 1977). Pacholski is also the author of a methodology for ergonomic diagnosing and for the unique scientific instrument – the ergonomic problem list. Rogaliński focused on problems of formalization of parameters of the ergonomic industrial system and on forming mathematical models of its future states. Both scientists prepared methodological basis of the electronic processing of data and ergonomic information.

Macroergonomic design is a process based on the engineering design in its wide interpretation. The designer creates new production systems and enters into the role of an organizing and decisive person. Such form of design provides a fully efficient functioning of the system, not only because of its elements, but also in view to its users and their environment that affects them. This aim can be reached thanks to integrating different methods of designing. Methods, which recently were contradictory towards themselves, i.e. from one hand – product design, machine and device construction, and technological processes design, from another hand – organization design, co-create at present the macroergonomic design. Organization design is also a technical design with a much higher degree of

complicating and difficulty. It results from the fact of existence of many criteria for examined systems. Macroergonomic design has the major advantage of making decisions in relations to all elements that form the system and perceiving them as mutually affecting and co-functioning with the environment subsystems instead of treating them as isolated objects.

The table 1 presents a comparison of fundamental features of the micro- and macroergonomic design.

Table 1: Features diversifying the micro- and macroergonomic design (personal elaboration)

Methodological awareness of the designer	**Microergonomics**	**Macroergonomics**
Concentrating the attention of the designer	examining cognitive and decision-making processes of man	Uses achievements of microergonomics and in addition examines relations between elements of the system and the influence of the external environment
Object of the design	Relatively isolated systems man - technical object	system that includes several systems man – technical object and takes under consideration their mutual influence on man and on conditions created by the external environment
Criteria of the design	Ergonomic criterion, which consists the specific feature of the system man – technical object, and which reflects relations between the human and the technical factor	Human factor criterion – the entire image of relations between man and technique that forms man's environment
Required knowledge of the designer	the knowledge and experience, mainly in the area of anthropometry	The designer uses basis of anthropometry, but also achievements of psychology, sociology, work organization, technical design and many other areas of science

AREAS OF PRACTICAL APPLICATIONS OF THE ERGONOMICS

Elements of macroergonomics, i.e. criteria and determined areas of research and tendencies that co-create the essence of macroergonomics, have been taken into two directions: from the side of the concept and methodology and from the side of possibilities for its practical application (a set of research works of the author or coordinated by the author). The fundamental motive for preparing the present work was that neither in Poland, nor in the world, there has been précised the methodological statute for macroergonomics and its essence and importance for the creation of the quality of the modern world. The essence of macroergonomics can be explicitly presented on examples from the practice. This requires presenting concepts and results of practical research referring to several spheres of elements of macroergonomics.

1. The first aspect refers to the strategy of the enterprise and its marketing activity. Therefore, the author presents a dissertation on the development of macroergonomics in view to modern strategies of the company.

2. The second example refers to enterprises that realize a pro-quality policy in accordance to ISO 9000 standards. The author paid attention on the impact that implementation of the TQM in companies has on the development of macroergonomics. The author also focused on work design in TQM systems in reference to needs of the human factor.

3. The third example from the practice shows elements of macroergonomics in the formation of the level of organizational stress at work on the example of the management of the company. The managers' stress was determined as a form of barrier in exploiting the potential of the human factor for the development of the company.

REQUIREMENT FOR THE ERGONOMIC KNOWLEDGE IN RELATION WITH ENTERPRISE STRATEGY DESIGN AND FORMATION OF THE MARKETING PLAN FOR AUTHORIZED DEALERS OF PASSENGER CARS

The problem of ergonomics constitutes a center of interest of industrial enterprises for years. These are particularly companies in a good financial shape and with a stabilized position on the market. Another problem that traditionally dominates the modern sphere of demand for ergonomic knowledge is the question of quality of work conditions in the range of work analysis and assessment of workstation, as well as preparing engineer solutions that would eliminate basic nuisances. In general, the need for this type of classical ergonomic topic comes from two groups of enterprises:

1) The first group encloses firms rich enough to invest in the improvement of the quality of work conditions and work environment.
2) The second group enlists companies with an expansive strategy of product, which maintain systems of quality management. In this case, an appropriate quality of work conditions and its periodical control constitutes an integral element of the system (determined by standards ISO 9001, OHSAS 18001, ISO 26000), and the improvement of the work environment is usually a consequence of modernization of technologies and production processes organization.

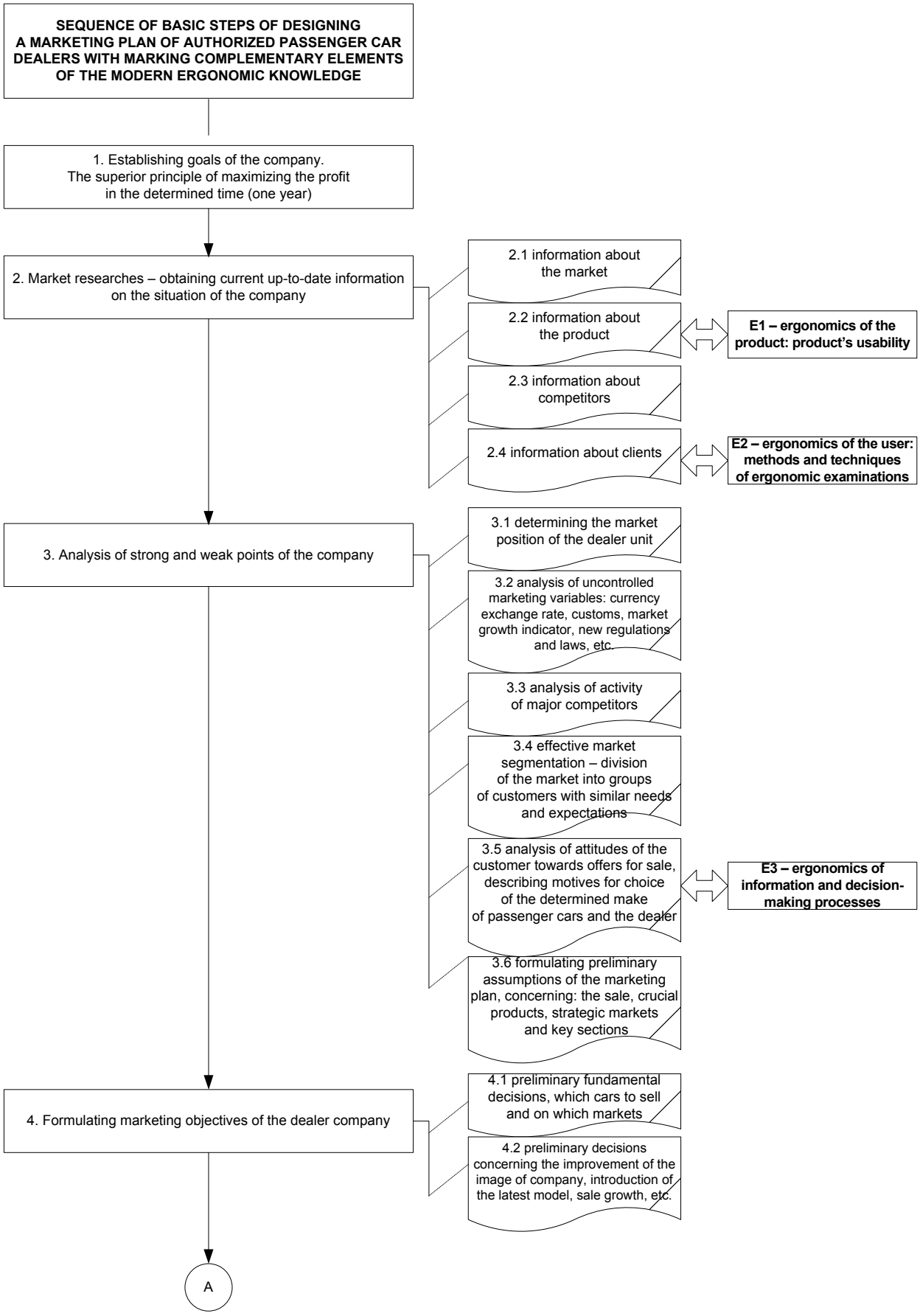
The presented characterization demand to the ergonomic knowledge on the market of enterprises explicitly shows two general, complementary conclusions result:

1. Enterprises are interest in problems of ergonomics as long as ergonomic knowledge is useful in solving problems directly or at least directly affecting the improvement of their profitability.
2. Companies focus only on aspects of ergonomics that integrally and naturally constitute components of their designed processes of modernization and reorganization. Looking at the problem from the wider scope – it means designing strategies for actions determining pattern for realizing established goals of the firm in accordance to the superior principle of maximizing the profit in determined periods of time.

The crucial difference between traditional and strategic planning is in the fact that the traditional planning accepted that all necessary information can be obtained in the beginning of the process of planning. The modern, strategic approach determines ways to use current pieces of information obtained in time and shows how to react to it and use it. A good marketing plan should determine specific market goals of the company and explicitly point at particular strategies and methods of reaching these goals.

Designing marketing activity is a very good example of both determined direction and possibilities of solving modern dilemmas from areas of human factors and ergonomics. It also illustrates the role that ergonomic knowledge can and should have in the domain of design of modern strategies of enterprises. Moreover, designing the marketing activity in reference to authorized dealers is an interesting problem because of the specification of these enterprises (relative autonomy in reference to the producer) and because of the multiplicity of forms of activity of the human factor. Presented characteristics cause that, in the process of designing, next to the so-called problem of industrial ergonomics, appear a whole range of questions concerning humanization of the technique and work that go significantly beyond the mentioned traditional area of ergonomics. All these problems or areas of ergonomics, both classic and modern, co-create the modern concept of macroergonomics.

Requirements for the marketing plan differ depending from the size of the company. A small enterprise does not have such means as a big company. Therefore, in comparison to a big firm, a small company's marketing plan is suitably less developed or detailed. However, independently from the range, reach of the plan and degree of its accuracy, the procedure itself of preparing the design of a marketing plan, along with all components of its structure, can be presented in a form of a general graph, as shown on the figure 2.


SEQUENCE OF BASIC STEPS OF DESIGNING A MARKETING PLAN OF AUTHORIZED PASSENGER CAR DEALERS WITH MARKING COMPLEMENTARY ELEMENTS OF THE MODERN ERGONOMIC KNOWLEDGE
1. Establishing goals of the company. The superior principle of maximizing the profit in the determined time (one year)
2. Market researches – obtaining current up-to-date information on the situation of the company
2.1 information about the market
2.2 information about the product
E1 – ergonomics of the product: product's usability
2.3 information about competitors
2.4 information about clients
E2 – ergonomics of the user: methods and techniques of ergonomic examinations
3. Analysis of strong and weak points of the company
3.1 determining the market position of the dealer unit
3.2 analysis of uncontrolled marketing variables: currency exchange rate, customs, market growth indicator, new regulations and laws, etc.
3.3 analysis of activity of major competitors
3.4 effective market segmentation – division of the market into groups of customers with similar needs and expectations
3.5 analysis of attitudes of the customer towards offers for sale, describing motives for choice of the determined make of passenger cars and the dealer
E3 – ergonomics of information and decision-making processes
3.6 formulating preliminary assumptions of the marketing plan, concerning: the sale, crucial products, strategic markets and key sections
4. Formulating marketing objectives of the dealer company
4.1 preliminary fundamental decisions, which cars to sell and on which markets
4.2 preliminary decisions concerning the improvement of the image of company, introduction of the latest model, sale growth, etc.
A

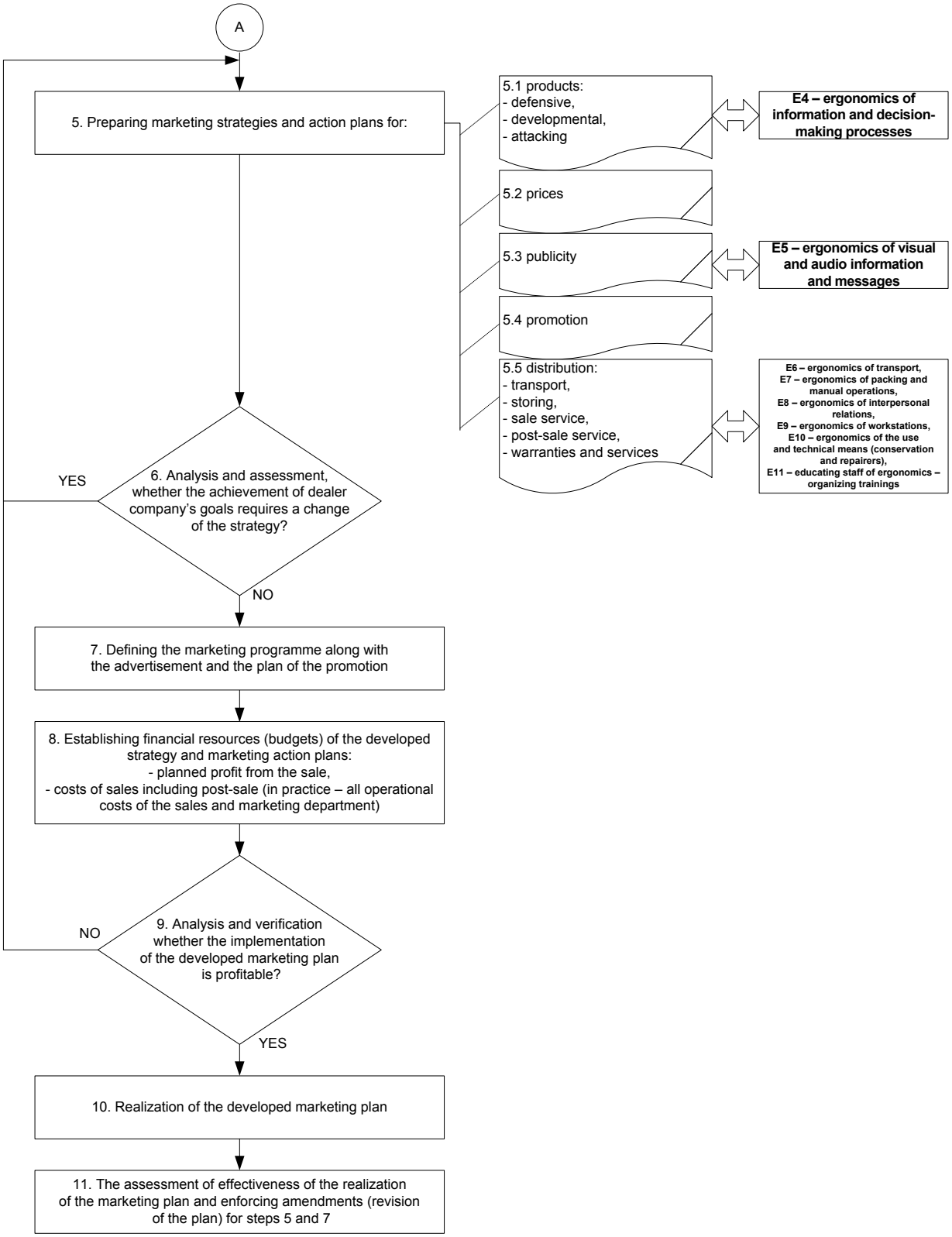


Fig. 2. Generalized scheme of the preparation of the design of a marketing plan (personal elaboration)

Distinct elements in the scheme of the ergonomic knowledge are integral elements of the knowledge necessary in designing a marketing plan for a company. The structure of these elements is presented in the table 2.

Table 2: Structure of problem co-creating the essential range of macroergonomics (personal elaboration)

Symbol	Type of problem
E1	Product ergonomics
E2	Product usability
E3	Product development
E4	Consumer products
E5	Ergonomic research methods and tools
E6	Decision making, Information processing
E7	Cognitive ergonomics
E8	Information management
E9	Driving behavior and safety traffic safety
E10	Package and wrapping industry ergonomics
E11	Ergonomics of human interface
E12	Ergonomics of workplace design
E13	Maintainability
E14	Training at the workplace

The table does not deplete all possible ergonomic criteria. It is being assumed that along with the development of macroergonomics and new needs appearing, new criteria will be also prepared.

CONCLUSIONS

Man and his intellectual capacities becomes the more and more important in modern social and economic processes realized in industrial enterprises. However, the shape of health of a modern society is constantly decreasing. This problem becomes particularly important in view to the growing number of freelancer professions, the rapid pace of life and work, information overload, great motivation for the fast professional career, and therefore: workaholism, inappropriate nutrition, insanitary lifestyle, lack of skill for organizing own life in a way to combine the professional and private life. These are problems, on which currently macroergonomics should focus on, interpreted both as a science, and as a practical discipline of knowledge.

Today's human techniques of design are characterized with more and more psychology. This means that the organization approach combined with the macroergonomic design of work systems should focus mainly on:

- Changing ways of performing tasks,
- Changing physical work conditions,
- Introducing participation methods of management,
- Introducing possibilities of free deciding on choice of methods of wok by the employee himself,
- Introducing possibilities of choosing patterns of professional career and promotion,
- Analyzing the role assigned to workers and adjusting ranges of their responsibilities to individual

expectations and abilities,

– Reinforcing connections between workers on levels: superior – subordinate – work partner.

It is not possible to present macroergonomic guidelines that would be internationally suitable. Every country has its own set of economic sectors and specific character of the level of technical civilization. Macroergonomics in a way solves current problems in specific localizations. However, that does not change the fact that macroergonomics remains an international discipline and its frames are still universal for workplaces all over the world.

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Efficient Control Tool of Work System Resources in the Macro-Ergonomic Context

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ABSTRACT

The article analyzes macro-ergonomic methods in order to build a model that will enable the creation of patterns used during the monitoring of system resource deficits. Usage of ergonomic approach for this purpose has proved to be necessary due to the fact that the character of the system implies not only a very detailed knowledge of the various subsystems (e.g., technical subsystem, biological subsystem, psychological subsystem, ecological subsystem, etc.), but also above all knowledge about the relationship between the various subsystems and the overall structure of the whole system, such as an organizational unit. The tool obtained in this manner includes the following areas of activity: defining the problem, modeling the work subsystem structure, creating event scenarios, and gathering information during experiments using the previously established at the first stage work situation models and models of the course of objective tasks. The results of these experimental studies are the basis for the creation of systematic mechanisms of work system resource control, taking into account the context of tasks and the environmental influence on the organizational unit. The developed method of system analysis taking into account macro-ergonomic aspects is also presented in the form of a practical example.

Keywords: man-machine object system, system analysis, control over the ergonomics of work, linguistic modeling

INTRODUCTION

In the anthropocentric approach to technical design, the human is treated as a specific element of the system, responsible for its organization and achievement of preset objectives. Accomplishing objectives in an efficient manner requires the application of complex technical-organizational structures. In such structures, the technical elements of the designed system are considered as a means of implementation of planned activities and may also provide information about the effects of operation of the system. Due to the high complexity of most human centric systems, it is necessary to use holistic analyses, which can be performed using macro-ergonomic tools. The macro-ergonomic approach includes aspects of resource management of interdependent structures, while taking into account the dynamics of phenomena occurring in socio-technical systems and ensuring a high efficiency of human activities. Understood by the term “resources” are the variables of the system whose properties can be selected (amount of space in the workplace) and that will have a potential impact on other parts of the system, particularly on the operator. Controlled resources may have a technical and/or organizational character and by their modification one can pursue the achievement of objectives during the implementation of work processes, while simultaneously observing the impact of changes on the other components of the system.

Evaluation of the costs that were suffered while fulfilling one's tasks is essential for managing the resources in work system. A decrease in the quality of performed tasks, worsened state of being, a threat to life or safety (followed by Tattersall, 2003, pg. 205) are also classified as such costs. The main goal here is for management over human resources becomes planning this process in such a way that tasks are performed at a satisfying cost level – in other words estimate all cost of work performed (including indirect cost). It becomes important to prevent the outcome of work overload in the situation when human resources become insufficient in order to meet demands of a technical object. If rational management is used, this means to reach once set goals and get the best possible results by using

the tools one already has then and only then one must presuppose accomplishing the highest productivity of the chain of action. This is a systems characteristics that shows all the possibilities of the system for achieving goals. The level of reaching goals, ergo the effectiveness or relation between expenditure and gain (the economics itself) might be an indicator of effectiveness. It also can be expressed by the following (Niziński, 2003, pg. 333):

$$E_F = f_c\,(W_u, W_R, P_s) \qquad (1)$$

where W_u stands for the characteristics of the appliance that are technical, dynamic, provision property functions and so on; W_R stands for the set of conditions for usage, i.e. a group of chosen effects of the surrounding that influence the appliance; P_S stands for the set of steering activations, for example activations generated by the decision maker and ones that force the appliance to accomplish all goals.

Knowledge of the effectiveness function allows the designer to select such a set of stimuli so that one may achieve the desired or at least close to desired effectiveness in a defined group of conditions as well as with a defined set of appliance characteristics. Thanks to this it is possible to conduct a system analysis that's goal is to recognize a possibility to ensure a balance in the system of work through among others: ensuring that the process of exploiting machine objects is in line with ergonomics. Evaluation of effectiveness is considered the first stage to ensure basic ergonomic standards or to define needs in order to modify the human-machine object relation. Macro-ergonomic analysis seems to be the perfect instrument to investigate effectiveness in ergonomic systems because of the considerably complicated structure of such relations as well as them being oriented on the human factor.

In the article it was decided to use human efficiency-oriented methods, due to the fact that the human is the weakest and most unreliable part of the system, and simultaneously is the last to conclude activities. This analysis is further justified by the fact that human reliability is a feature closely related to the systematic context of human operation, thus employee tasks are treated as the reference plane in the assessment of the effects of management and efficient control of work system resources.

REVIEW OF RELEVANT LITERATURE

Macro-ergonomics is a new approach in ergonomic actions. It is oriented on complex social engineering systems (followed by Pacholski, 1995, Pacholski 2000; Pacholski and Jasiak 2011). Macro-ergonomics takes hold of the work system design. Macro-ergonomics allows us to manage resources with respect to mutual dependencies and also the dynamics of phenomena occurring in complex social-technical structures and in the same time ensuring conditions for high effectiveness of most fallible part of the system which would be the human (followed by Wrzesińska, 2012). One may observe the following results after a macro-ergonomic modification (Sławińska M., 2010, pg. 212): increase in productivity, decrease in work time loss, a decreased number of accidents and employee injuries. The increase in productivity is happening with a decrease in cost of human resources (followed by Górny, 2012). As a result the macro-ergonomic approach boosts the ergonomic quality of work (followed by Misztal and Butlewski, 2012). On the other hand quality management can be a path to achieving business excellence by setting goals and consistently striving to achieve them, but in the case of its abandonment it does not yield any added value (Drożyner et. al. 2011, Jasiulewicz-Kaczmarek 2012). This results in a connection of ergonomic quality issues, managing quality and macro-ergonomics which allows us to use exchangeable the developed methods.

Well known research on employee organization and behavior are reflected in the most commonly used and at the same time are the most effective methods. Macro-ergonomic Organizational Questionnaire Survey (MOQS) is a suitable tool for a quick and inexpensive way to find problematic issues in working system design. Questionnaire research can be an integral part of the ergonomic organization program. Other, partially structuralized surveys are used to recognize the level of mutual adaptability for such system elements as: interface, man-machine system, man-environment interactions. The organizational unit imperfections are discovered while research and experiments and carried out in the field of macro-ergonomics. Experiments are a effective way for validating respective modifications in both micro- and macro-ergonomic range in respect to the defined work system. The obtained results can be a guide how to reorganize as well it can show which technology improvement design will benefit the organizational unit as a whole. The MOQS method is helpful in identifying the cause and effect relation between elements and pairing them with practical problems in the organization itself. In this method the key is to let the experiment take its own course. Participatory Ergonomics (followed by Brown, 2002) can also play a identifying role. During the work system analysis it checks participation of employees that are hired on the researched job positions. Thanks to this the developed changes are more acceptable and supported by employees. This can be observed when one carefully looks at macro-ergonomic implementations (followed by Imada, 1991) and the work system safety culture.

A comparison of methods is provided in Table 1.

Characteristics category	(MOQS) Macro-ergonomic Organizational Questionnaire Survey (Carayon, Hoonakker, 2001)	(PE) Participatory Ergonomics (Brown, 2002)	(CWM) Cognitive Walkthrough Method (Sears, 1999)
form of results after the validation of implementation of modification	rational grounds for choosing	documenting the diagnose and consulting project for the concept of reorganizing enterprises	The documentation provided during designing and analysis of ergonomic factors which is conducted in the environment constructed for establishing an evaluation (with the diffentiation: individual and team)
specificy for implementing the method	questionnaire to examine the organization	during work system analysis employees hired on researched job positions and field experts participation is implemented	identify the range of knowledge and adaptation that comes to user's mind thusly increasing the possibility of success during the product research/ performing procedures
difficulties in gathering experimental data	finding symptoms of problems in work systems design is inexpensive	examination of the impact on roles in an organization, changes introduced in an organization should be well developed and implemented	recognition of various problems in the prototype and pre-commissioning stages or of pre-implementation
sustainability of full research	quick recognition of mutual adjustment of work system elements	depending on individual organization characteristics: information regarding employees knowledge, reward system, organizational behavior, task effectiveness and the extent of liability	develop detailed scenarios based on how the intentional tasks go and conduct patterns for appropriate processes that are essential to complete given tasks

In macro-ergonomic work system projects Cognitive Walkthrough Method (followed by Sears, 1999) is also applicable. It assumes that designers are capable of adapting the user's point of view as well as they can go over the scenario from a potential contractor's point of view. They also estimate the designed system. Thanks to this one may successfully identify various problems in the prototype and pre-commissioning or pre-implementation. The method is highly structuralized and it requires careful planning as well as preparation for every step of the project. Design and analysis of ergonomic features is conducted in an environment specially designed for evaluation (with the distinction to group and individual evaluation). Another method – Computer- Integrated Manufacturing,

Organization and People (Karwowski et. al. 2002) is used for practical reasons in plants where a technical, organizational and human factor integration is at a high level. This works on the basis of IT technology integration of all these elements serving this purpose. The method needs employees involvement in the designing process. It provides specialized knowledge concerning management of changes in a working environment in the range of for example: work system structure, evaluation of effectiveness of rationalization as well as in the range of motivating to introduce and acceptance expected changes considering estimation in the profitability.

The next method is the System Analysis Tool (SAT; followed by Mosard, 1982) and it is a instrument for system analysis which gives the grounds for choosing the best strategy for implementing changes in a work system. The methods is designed for macro-ergonomic evaluation of work processes. It is focused on well-balanced design and the adaptation of the traditional approach to task assignments in the workplace. In consolidates theory of analysis and systems design in the process of organizational decision-making policy. SAT gives grounds in the macro-ergonomic approach to defining problems occurring in the work system and their relation to employees occupational environment. This method creates potential alternative work system solutions and delivers the profit and loss sheet. Is serves as a evaluation tool looking for compromises on the level of macro- and micro-ergonomic interventions and modifications. Graphic display of the goals and alternative solutions often leads to hybrid solutions, which determine traits of preliminary formulation. Modeled solutions are based on case studies, on experimental research and extensive work in the researched field. Each alternative is evaluated in terms of defined set of conditions as well as various affordable level of financing. Ambitious projects are developed for a high level of financing, often with drastic solutions. For low level financing a more practical approach is recommended. An additional leverage of SAT is creating timetables with B plans. It provides plenty of data for ergonomics. It requires multifunctional group of specialists, which provide different points of view during system analysis and during making economic decisions, they take under consideration multiple factors and measurements in evaluation of organization functioning.

One must also mention the Macro-ergonomic Analysis of Structure (MAS; followed by Stevenson, 1993) which enables to evaluate work structure in the sense of compatibility with individual socio-technical conditions. It encompasses key aspects of technology, personnel subsystem also the outside environment considering which the organization must act on in order to manage through and accomplish success. MAS makes it easier to detect loopholes in the system and provides data in order to design improvements to them for the purpose of accomplishing maximum effectiveness in the work system. It is set to recognize variations between the designed structure and the one existing in the organization and simultaneously provides tips for correction. In evaluation work system structure often three dimensions are taken into consideration, and they are: the level of intricacy, the level of formalization and the level of centralization.

MODELING WORK PROCESSES

System analysis

System analysis is the creative procedure of research which is to recognize the standing of the process of human labor with machine object. Basic characteristic is complex describing of researched occurrence, modeling subsystems and the associated with them processes. Also very important is to create conditions for concurrent evaluations of enterprises and evaluation of the introduces rationalizations. In the scheme procedure of system analysis (Figure 1) the first place takes considering the problem: what problem needs to be solved and what is the goal of its solution? Answers to the following questions are looked for: how does the current system work? What are the defects in its function? What limitations and demands are important in the system?

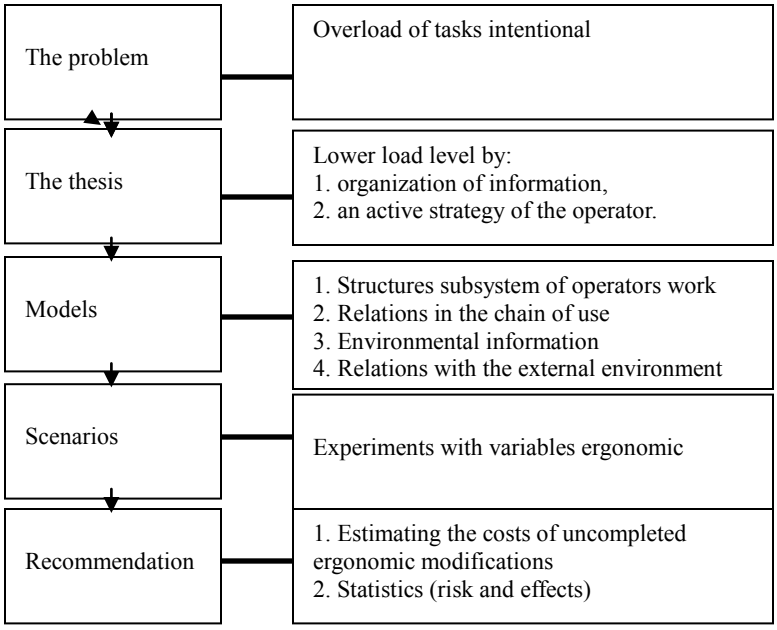

Figure 1. Diagram of system analysis of actions chain [own elaboration].

Knowledge about the subject of interest essence is supplemented with function analysis. Answers to hereby questions are being sought: what is the operational concept of the system? What functions should the system cover? What are the imperative factors which are essential in fulfilling certain functions? What are the relations among essential factors? Due to knowledge obtained in this field schemes of solving system problems are being worked on and the awareness of competitive systems is on the raise. It is important to state that the domain of system analysis is creating a model allowing to evaluate the system. With that comes developing evaluation criteria, the identification of essential system relation, and establishing characteristics of the environment impact. All of these above is the starting base for next initiatives: estimating the quantity's worth for a model, testing the model, appraising the proportions of costs, risk and insecurity analysis. Additional alternative solutions are expected for the researched system and finally substantiation of the rational choice of most adequate system. System analysis is especially useful in fast paced changing environment which is typical in our times. The purpose of that is achieving appropriate actions and or the direction of action by considering and recognition available options and comparing them to the predictable outcomes.

While conducting research according to the system analysis scheme it is required from the researcher to carefully formulate the issue, a clear line of action, precise hypothesis. In the attempt for solution attention has been focused on the problem and not on the model, and what is important not to overrate the mathematical model and results obtained from calculations. In solving the problem using system analysis is also important to develop solutions' options and conduct comparison analysis (followed by Quade, 1985). While choosing the right option, it is important to predict the cost of it. It has been assumed that the new way has significantly higher value; insignificant number of evaluations conducted non-system.

Linguistic modeling in ergonomic engineering processes

In the human-machine object we are dealing with non-linear multidimensional processes. These are unfolded processes specifications. As compared to industrial processes there is no quantity and quality repetition of conducting various biological or biochemical processes. In complex social-technical relations interferences occurred. Which cannot be measured nor we are aware of what created lesser or greater unpredictability of system. The number of reasons which may cause such system functioning increases with its level of complexity. At that point combinatorial solution explosion emerges. Such complexity cannot be contained into mathematical model. In such circumstances less essential reasons are abandoned contributing to wrongs (margin of definiteness) in a model. In such situation seems reasonable the use the theory of fuzzy set in modeling processes and steering working conditions. Fuzzy systems are used mainly there, where we do not have sufficient knowledge of exact mathematical model of the developed system or there is a need to make decisions uncertain or incomplete information about the environment. Getting acquainted with the system by easy-imaginable rules of linguistics is easier in many cases than

implementing the strict mathematical formulas by which it is govern by. Fuzzy information creates numerous possibilities. We can name:

- creating artificial intelligence similar to human one and equipping with it technical objects
- using the information about optional grit in modeling, steering, optimization and diagnosing systems and object
- a grater grit enables reduction of processed and stored information and acceleration in algorithm functioning
- fitting the grit of information depending on required precision of the model, steering, optimization, diagnosing, and so on

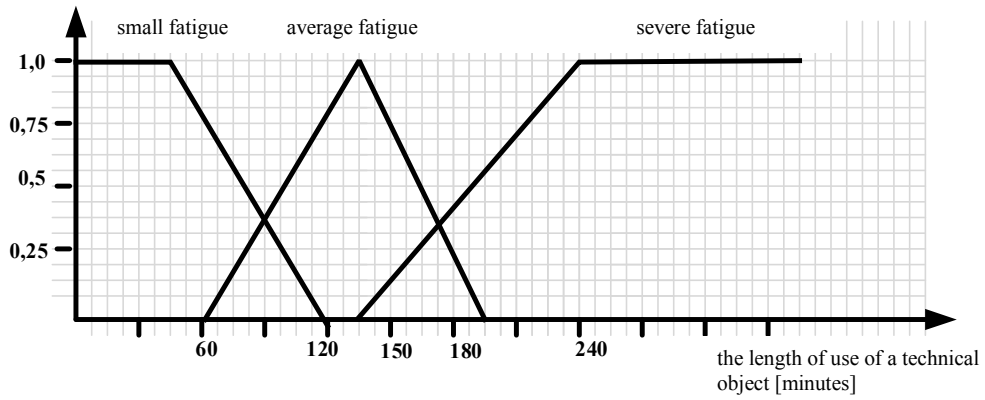

Figure 2. Function of membership of a fuzzy set on the stage of data collection [own elaboration].

For the description of processes having place in the chain of action we can successfully use the structure of predictable linguistic model of recommended by Takagi and Sugeno (Yager and Filec, 1995). The starting point during forming processes model is the knowledge of the measurement results measuring effectiveness of set goals, for example: longativity of performance, reaction time to feedback, traditional ergonomic factors such as: the timeframe for standing up without excessive tiredness, the extend of peripheral vision for designed work process, the correlation between the tiredness and the excessive time of using a machine objects, etc. The function model inherent to fuzzy set in the stage of gathering information is shown in Figure 2.

OUTCOME OF EMPIRICAL STUDIES

Ergonomical reengineering (ER)

The subject of ER is the chain of action: man-interface-technical object and the relation of this system with the environment. Essential for the research are processes which have influence on human effectiveness, that is goal-orientated action. The engineering problems are concentrated around finding the ways to help the user, in most cases easing his strained physical effort as well as mental, or sometimes adding more effort if diagnosing specified it was too low.

In the beginning phase of algorithm ER (Sławińska, 2011, pg. 59) in the first step there occurs an analysis of a specific situation and setting a goal which after modification the elements enables us to achieve the desired workload. Considering the nature of mental load it is necessary (step 2) to create an environment for projected changes. During the simulation of projected goals the regularity is being checked and various means of increasing or decreasing worker's load. Because there might be too many ways to achieve beneficial changes, the range of ergonomic modification should encompass only the essential factors (step 3). The more precise the set goals are the

more successful will the team work be. During the 4th step the modeling ER goal context is done and preliminary hierarchy of ergonomic factors is made for the established previously design. Then, we base on workplace documentation, interviews and surveys. Accuracy of characteristics planned for existing systems has impact on effectiveness of the ergonomic engineering. Next, in the 5th step mapping of the goal context is done; and because of that we gain information confirming reasons for mental overload. Knowledge of this should be systematically enlarged. Simultaneous modeling of work situation is done and first attempts to reconfigure chain of actions. During the 6th step characteristics of the state emerge. Basis of merit are established for projecting strategy of action designed for difficult situations at work and their preliminary verification of prototype solution. Step 7 is related to modeling of information structure about work environment and leads to recognition of psychological mechanisms in developing mistakes of men. Then one deals with modeling of information structure working environment. During 8h step one gains experience and additional information. Ergonomic subsystem is built and data of ergonomic knowledge. Step 9 is connected with choosing tools to evaluate the level of mental load of employee coexisting with technical object and conducting numerous experiments (followed by Sławińska, 2011, pg. 161). Step 10 seeks optimal solutions. One can achieve satisfactory level towards set goal, but simultaneously recognize additional and better solutions; insignificantly differentiating in the frame of research and acceptable cost. In the next step (11) more experiments are conducted on the research station, also for the extreme conditions; due to which precise strategic actions are developed, for example active operator. Then occurs using programing projected for ER in the system of exploiting the technical object. Ergonomic modifications are conducted for planned reconfiguration of chain of users. The estimated budget is necessary to accept the technical organizational offers for ergonomic modification. Ergonomic variables are analyzed in that respect, also are connected with minimum critical potential allowing to keep the system safe. The economic character is revealed also in the step 13, where are the estimated sets of predicted profits and losses which substantiate the next action in ER practice. The 14th step is implementing ergonomic variables essential for leading the safety of usage of system. In most cases it applies to information system structure and means to present the information. The simulations of work conditions of the experimental site enables evaluation of required modification. During the 15th step multiple tries for optimizing ergonomic stress load are conducted. In each instance chain reconfiguration of the user in relation to economic conditions occurs.

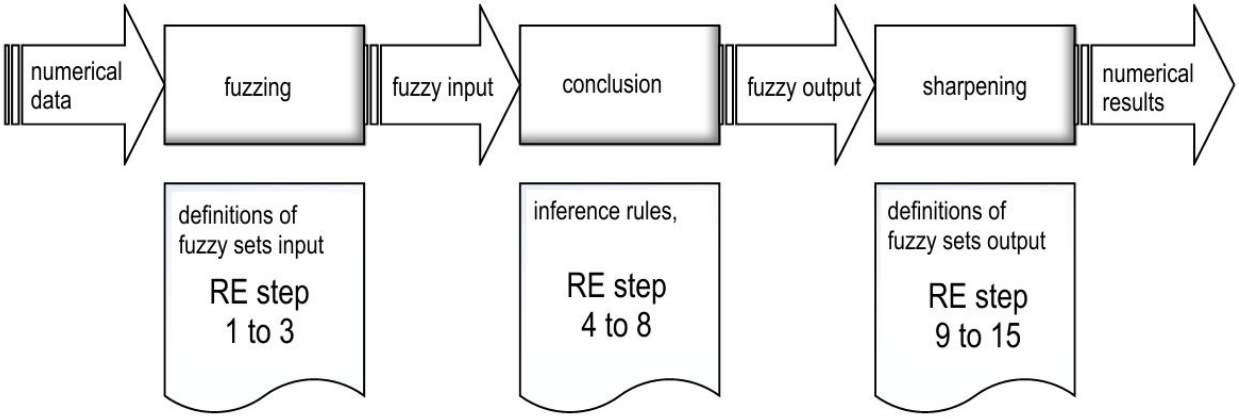

Figure 3. Diagram showing how FLC (fuzzy logic controller) works [own elaboration].

Implementation of load evaluation methods is imperative during introducing new technology also for evaluating severe impacts which are imposed on employee by automated work processes. ER in technical object design is a chance to introduce regulations mechanism of employees actions based on fuzzy deduction – Figure 3.

Ergonomic knowledge base

Macro-ergonomic actions allow to create ergonomic knowledge which gathers data concerning work system structure, characteristic elements of work system such as: 1) requirements concerning installations; 2) work processes requirements; 3) systems relation. Gathering data is useful for creating goal-orientated functional structure of work system. Because of that one can precisely present planned goals and evaluate level of technical objects' effectiveness. Designing technical elements are being analyzed and organizational elements of technological process are being analyzed as well. The gathered data can be used to examine extreme conditions.

The next important element of the data is knowledge about what information a worker is using in the decision-

making. The information should be precise and relate to specific flow of interaction. This data can also be used to evaluate conditions of planned load for which the programing and interface are design. A subset of leading stimulations recognized during evaluation of reliability of set goals using modeling is connected with said set. Research of stimulations allows us to set the man-technology reliability factor. It is very important for the completeness of the data is the information about users' conditions which are gained during modeling work situation. Operator's ability evaluation to meet harsh situation in work system (stress, physical overload, overload of the informational channels) allows to simulate conditions of the utilization process and securing from degradation of the work system (followed by Bajda et. al., 2011).

CONCLUSIONS

The dynamic development of technology creates a situation where in most working positions change of occupational character of responsibility is observed. Most working goals has a decisional character: it requires quick orientation and making immediate decisions. A man is overloaded with information, and in the working process he is accompanied by numerous undesired events causing mental overload which puts his health and/or life at risk, economic losses, natural environment contamination or distraction of the production installation. Thanks to ergonomic approach in modeling working places limiting the above risks and leading working conditions are developed. Increasing mental load in work processes develop the need for mechanisms stimulating keeping the right level of load during work. Considering such situations system solutions are being introduced based on macro-ergonomic methods which are designed as optional projects and alternative processes for fulfilling set objectives. Because of that the system effectiveness in on increase not only in terms of ergonomics (expressed in cost assuring well-balanced relation between requirements and gained efficiency improvement) but also in the categories of strict economics.

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How Quality Management supports Sustainable Development?

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ABSTRACT

In the following paper an attempt to present the role of quality management in enterprises following sustainable development strategy was taken. Methods striving for quality(defined in their broadest meaning) are the basic catalyzer for changes which enable identification of new opportunities and definition of alternative actions to be taken. They focus on the best practices and means leading to improvement in the areas jeopardizing economic, environmental and social infrastructure.

Keywords: Sustainable Development, Quality Management System, Stakeholders, Integration

INTRODUCTION

Analysis of changing management paradigms from workshop through mass production, customer orientation and mass customization to the current mass collaboration idea leads to the conclusion that the main cause for them is striving for increased competitiveness of enterprises in dynamic conditions reflecting critical changes in the market. And even though today because of increasing non-linearity (and complexity), and discontinuity as well as pace of changes, forecasting is almost impossible, we still can try to forecast directions of changes, which is simply identification of mega-trends that are likely to appear in the future.

The term "mega-trends" was coined and popularized by John Naisbitt in 1982. He defined (Naisbitt, 1997) mega-trends as broad processes embracing the world, having socio-economic or structural character and influencing a unit and shaping its future. Broader definition was introduced by (Frost and Sullivan, 2011) as they defined mega-trends as "global, solid and macroeconomic development forces which influence business, economy, society, culture and private life and by that defining our future world and its growing pace of changes".

Research on mega-trends refers to thinking about future with application of so-called "oriented forecasting". The perspective enables building scenarios and provides managers with guidelines which can be used in decision-making processes concerning future development and investments. Analysis of mega-trends from time perspective leads to understanding external challenges which are unavoidable for a given region or market and have global consequences and results. The external challenges are to influence functioning of enterprises and decision-making. The model similar to the well-known model of product's life-cycle by (Rozen et al, 2012) can be used for their analysis, with application of its characteristic stages including:

- stage 1 - Definition, which is convergence of trends connected, leading to creation of mega-trend
- stage 2 – Growth, which is fast manifestation of mega-trend and spreading its influence on business, industry and lifestyle.

- stage 3 – Domination, the stage refers to the results of mega-trend and its influence on all the areas of social and economic life.
- stage 4 – Decrease, which is a period in which mega-trend is so common it is treated as a normal thing.

The scope of the hereby paper results in necessity to characterize two mega-trends: sustainable development and pro-quality actions. Analysis of the literature leads to the conclusion that "sustainable development" mega-trend is in its growth stage, so it will shape trends and enforce changes in methods of conducting research and building competitive edge of companies. The second mega-trend mentioned is now in its decrease stage, so it is taken as something "normal" from company's point of view. Its role is then supportive (Figure 1).

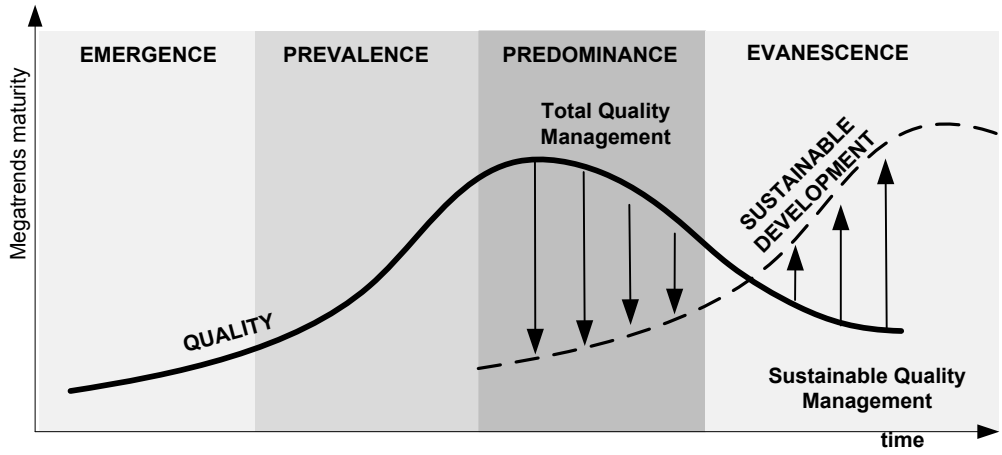

Figure 1 Life cycle of a mega trend „Quality" and "Sustainable development" (Jasiulewicz-Kaczmarek, 2013a)

The question arises: how actions focused on quality support striving for sustainable development?

SUSTAINABLE DEVELOPMENT

Sustainable development is a very wide idea and it has numerous interpretations (Clifton, 2009). The term "sustainable development" was used for the first time in the Brundtland report developed by World Commission on Environment and Development, also called Brundtland Commission, in 1987. There, it was defined as a process aiming for development aspirations of contemporary generation meeting, and in the same enabling meeting these aspirations by the future generations as well. Thus sustainable development is about reaching a balance between economic, social, and environmental goals, as well as people's participation in the planning process in order to gain their input and support (Sneddon et al, 2006) (Figure 2).

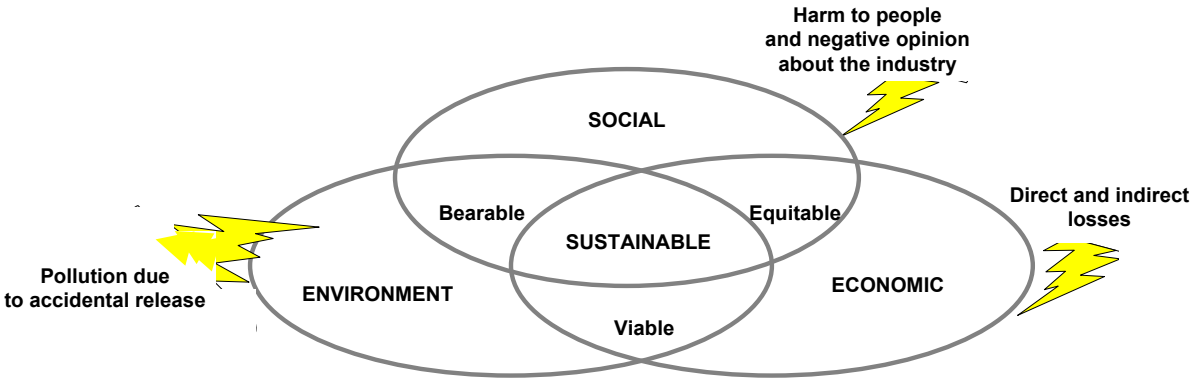

Figure 2. Three constituent parts of sustainable development (Vaidogas and Juocevičius, 2008)

For many years the term "sustainable" was mostly connected to ecological issues and problems analyzed were usually

damages to natural environment caused by civilization. Today, companies striving for sustainable development are the result of more utilitarian and anthropocentric rationales such as protection of environment and surviving.

The concept of sustainability is becoming more operational at the company level, whereas earlier, the concept was primarily discussed at national and international level. For a company sustainable development means adoption of such business strategy and such actions that contribute to satisfying present needs of company and interested parties, as well as simultaneous protection, maintenance and strengthening of human and environmental potential which will be needed in the future (Sidorczuk-Pietraszko, 2007). A broad interpretation of sustainability at the company level has many factors, including:

- impact on the environment.
- health and safety of employees, visitors and the surrounding community.
- corporate citizenship.
- quality and efficiency of products and processes - not only to increase profitability but also to reduce consumption of raw materials and energy.
- design of new machines, equipment and systems.
- research into the use of different types of fuel and energy, materials handling, heating and cooling processes, the storage and pumping of liquids and gases, and environmental controls.
- research into the use of different types of raw and transformed materials.
- specification, selection, installation, management and maintenance of factory production and machinery.

Since sustainable development is becoming an increasingly popular concept, there is a growing need to ensure the possibility of its implementation. To operationalize the economy-environment-social triad, the manager should integrate the following initiatives as one (Figure 3):

- total quality of product and process,
- environmental protection,
- total process safety.

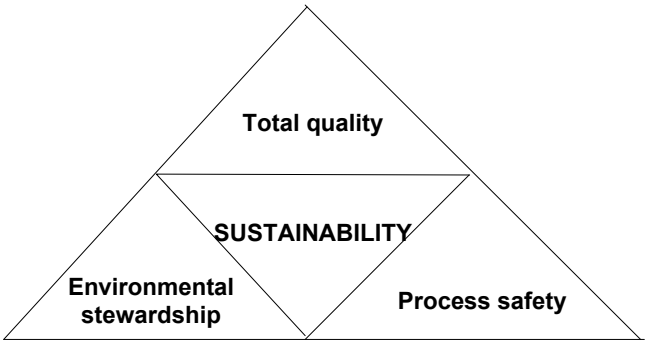

Figure 3. Components of Sustainable operations (Ferrer, 2008)

The way to help companies improve their economical, environmental and social performance is by:

- minimizing production of waste – less waste generated and increased waste re-usage or recycle (Golinska and Kawa, 2011; Dostatni et al, 2013),
- using resources such as materials, water and energy efficiency,
- avoiding or at least improving management of metalworking fluids, lubricating oils and hydraulics oils (Szafrański, 2011),
- improving environmental, health and safety performance (Lind and Nenonen, 2008;Górny, 2011; Sadłowska-Wrzesińska, 2013),
- adopting lean manufacturing and other sustainable engineering techniques (Jayal et al 2010; Jasiulewicz-Kaczmarek, 2013b)
- improving working conditions (Hamrol et al, 2011; Mazur, 2013),
- using best practice in the process of producing and maintaining movement (Rui et al. 2009; Jasiulewicz-Kaczmarek and Drożyner, 2011; Narayan, 2012)
- training all employees about sustainable practices (Misztal and Butlewski, 2012).

Corporate sustainability in the dynamic complexity of the twenty-first century economy means that businesses need to, through developing and sustaining relationships with key stakeholders, establish a corporate culture "consistent with the concept of sustainable development". To achieve this, (Welford, 1995) identifies the "six shifts": from objects to relationships; from parts to the whole; from domination to partnership; from structures to processes; from individualism to integration; and from growth to sustainability.

Hence, sustainable development can be defined as capability of an enterprise to adjust to changes in business environment to catch currently best performance methods and to achieve and maintain predefined level of competitiveness. It is not revolutionary approach, however it proves capability to use and improve competences, activities and values, which states for building future, without discrimination of previous achievements but with their help as a strong basis for future success

QUALITY MANAGEMENT

Evolution in approach to actions towads quality

Quality is a relative term as it depends on culture, ethics, civilization, it refers to time, place and is multi-dimensional. Many ways of defining and interpreting quality term in utilitarian sense refers to the level of noticing and range of problems it contains in a company. According to L. Wasilewski (1998) „if for any reasons we have to define the term quality, we have to adjust it to the level of system development in a company". As their quality system is developing, companies change main dimensions of quality definition and measures they use. Such evolutionary character of the tem quality can be found in scientific works of (Dale et al, 2000; Hellsten and Klefsjö, 2000; Lagrosen and Lagrosen, 2005).
D. A. Lubin and D. C. Esty (2010), defined actions undertaken in companies to achieve quality as one of mega-trends in management. Development of management ideas can be presented in the form a life cycle as in the scheme (Figure. 1). In the first stage of this mega trend development, quality was mostly connected with products and the focus was on inspection of some critical characteristics of final products referred to predefined requirements – specifications. Along with economic development and production scale growth inspection costs have been growing and did not give the results expected by the owners. It was noted that by inspection it is impossible to provide an appropriate level of quality. The scope of activities charged to the quality started to extend the processes of production. This stage of development and the perception of quality in the company in the literature is called quality control. In actions for quality employees were included in the production, drew attention to the skills of workers supervised by them formally established requirements and standards for their implementation. Feedback was created between the result of control and production line. Based on the results of checks production process was modified so as to obtain products that meet the specifications. As in the run-up, the producers did not have much difficulty in disposing of the products, and therefore did not have to take into account customer feedback. Therefore, during this period primarily refined receiver subsystems and supply the current and final product inspection, not paying attention to the information coming from the market. The next step is the development of quality assurance. It was characterized by a gradual moving away from a narrow perception of quality, treated as compliance with the requirements and technical standards for the quality, expected by the users of the products. During this period there was a significant change of views on the concept of quality and its place in the management of the company. The essence was to build a quality system, which purpose was aimed at preventing non-conformity, and managers started to be involved in system functioning. Although management involvement was limited, the first declarations for the management of enterprises in the form of so called quality policies, systems and internal evaluation of compliance between declarative and actual commitments, covering all areas of the company appeared. The fourth stage, therefore, can be described as quality management, where quality has become a strategic issue and its scope extended to the quality of the organization and the quality of the relationship with the environment of an organization (customers, suppliers, competitors, the public in general). Managers began to look for new methods and tools to support collaboration between departments, taking into account information from the market and improve manufacturing processes (Mazur and Gołaś, 2010).

The discussion on the future and the role of quality management in the enterprise is ongoing for almost ten years. In the literature we can find two views. The first of these relates to the concept of Total Quality Management (TQM). This paradigm states that the responsibility for quality lies not in one department or one person (the representative of the management), but the whole organization needs to take responsibility for quality and take it as a common value. The second trend is related to the evolution of the semantic, which speaks of "excellence" and not a "quality". The idea of quality has become insufficient for the development of enterprises, many companies benefits from the awards and excellence models and uses them as guidelines. Hence, the term "quality" becomes insufficient for companies' development, and many of them focuses on awards and excellence models taking them as directives or guidelines. Both trends despite of differences have some common elements. They both introduce the next term important for identification of the role of quality management in a company. The term mentioned is "transactivity" (Foster and Jonker, 2007). It originates from the basic connection of organization and its broader sociological

context and consequently is the key relation between the idea of quality management and more and more important aspect of social corporate responsibility. It is also an attempt to draw attention of managers to necessity to react to needs and expectations of more and more various groups of stakeholders, providing in the same time value for shareholders.

Customers and stakeholders in organization

In ISO 9000:2006 standard customers are defined as „an organization or a person who receives a product". Hence, there are internal and external customers. Though the standard gives some further explanation for the definition its range is quite narrow. A broader definition was suggested by J. Juran (1988) who defined customer as "anyone who is affected by the product or by the process used to produce the product").

While according to Ishikawa (1985) customer is simply the process that follows („the next process is your customer").

The above definitions indicate a diverse range of conceptual, from a narrow set out in ISO 9000:2006 to a wide proposed by Juran, where the customer can also be a local community, the environment, and even future generations . This broad definition of "client" is close to the notion of "stakeholder". The term is often used in the sense of those who have a "stake" in the organization. The most famous, but the most general definition of stakeholders was presented by E. Freeman in 1984. According to Freeman (1984): "a stakeholder is any person or group that "can affect or is affected by the achievement of the organization 's objectives". This definition has been the subject of discussion and deliberations in literature (Clarkson, 1994; Donaldson and Preston, 1995; Freeman, 2002; McVea and Freeman, 2005). In the final model of excellence Malcolm Baldrige National Quality Award (MBNQA) 2011-12 (NIST, 2012) the term "stakeholders" refers to all groups that are or may be affected by the activities of the organization and its success. The key stakeholders in the organization are, among others: customers, employees, partners, associates, shareholders, donors, providers, payers, regulators, policy makers, trade unions, local community .

The EFQM Excellence Model 2010 (2010), defines stakeholders as: "a person , group, or organization that has direct or indirect ownership or interest in the organization because it can affect or be affected by the organization or its influence." This approach is close to the definition of Freeman. In addition, in the EFQM model , a division of the interior and external stakeholders was made. Examples of external stakeholders are the owners (shareholders), customers, suppliers, partners, government agencies and representatives of the community or society, while examples of internal stakeholders are people or groups of people. Taking into account the above considerations, stakeholders can be defined as a person, group of persons or organizations that contribute and put requirements, and thus affect the organization, expecting the results - satisfaction that will satisfy their requirements are, therefore, under the influence of the organization (see Figure. 4)

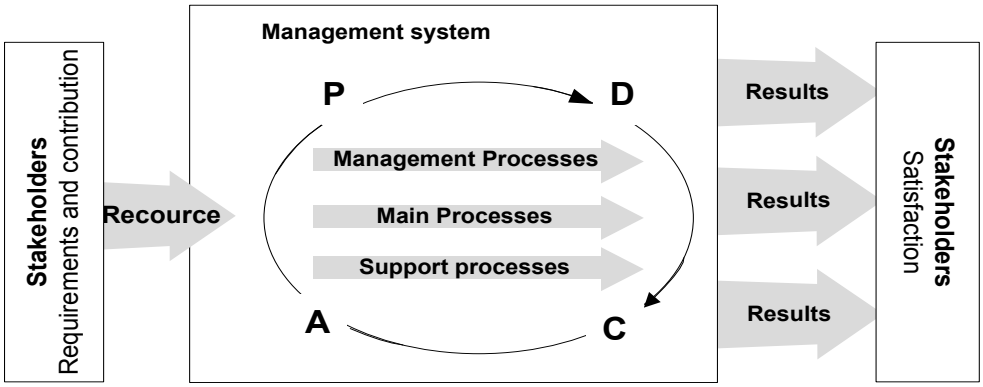

Figure 4. Relations between organization and stakeholders

According to the International Organization for Standardization, the organizations depend on their customers and therefore, should understand them current and future need, they will meet these requirements, while taking care to exceed customer expectations. On the other hand, emphasizes that "the success of an organization is based on meeting current and future needs and expectations of current and potential customers and end users, and the

consideration of other stakeholders" (ISO 9004:2009). Now, expectations of stakeholders do not refer only to the direct transaction between the parties, but also to participation in the debate on social and environmental problems, and proactive thinking about the effects of business in society.

This growing concern for the public is a part of the change in thinking about quality. In this new way of thinking about money should go back to the definition of the client by Crosby and to the old TQM definitions contained in ISO 8402:1992 as a starting point to define the next dimension of quality. This new dimension of quality must support businesses through the challenges of the next mega trend of "sustainable development". Binding part of the old with the new and the new with the old is the concept of stakeholders and the organizations responsibility for its impact on society.

Integration of requirements and expectations of stakeholders

Over a half-century ago, quality pioneers Edwards Deming and Joseph Juran encouraged organizations to ask better questions about corporate challenges and enabled companies to redesign systems for improvement. They started with a systems approach and then grounded quality in practical analytical tools to foster product, service, and organizational improvements. Today's sustainable development frameworks encourage businesses to ask better questions about impacts to stakeholders, society, and the environment, and they seek to develop the tools and measures needed to demonstrate improvements.

In recognition of these challenges, a number of management systems (MS) have emerged to help managers systematically address an organization's key stakeholder requirements (Misztal, 2009). After the introduction, in 1987, the ISO 9000 series of standards for quality assurance, other standards were developed for environmental management (ISO 14001), health and safety (OHSAS 18001) and corporate social responsibility (ISO 26000). It's just a few examples. It is obvious that the new standards will continue to appear, and those that have already been issued, are and will be subject to periodic updates. Organizations are therefore face difficult decision of which or which of the standards to enter and how to enter to meet the needs and expectations of stakeholders and effectively implement the integrated management of the organization. Integrated management "means understanding and effective targeting every aspect of the organization so that the requirements (needs and expectations) all parties were satisfactorily met within the available financial resources, organizational and technical" (Poskrobko, 2007).

In practice, the concept of integrated pro-quality management is often referred to the integration of formal management systems and building integrated management system. Miller (2003) defines an integrated management system as "one, clearly defined, documented and consistent system that enables efficient and simultaneous management of multiple aspects , by establishing and implementing a uniform policy and the resulting targets for these aspects". British Standards Institution (BSI, 2000), in the guide on the integration of management systems , sets out an integrated management system as "a combination of processes, procedures and practices utilized in the organization to implement its policies, which may be more effective in achieving the objectives of the policy approach than by separate systems". Integration in this document is understood as the ability to connect systems used in the company and specified in separate norms and standards .

Thus, if the policy of the organization is focused on meeting the requirements of its stakeholders it is the only way for organizations to design and implement an integrated management system. The purpose of this system will be maintaining competitiveness and ensuring sustainable development through optimal management requirements of stakeholders and equitable balance their needs and expectations (Figure 5).

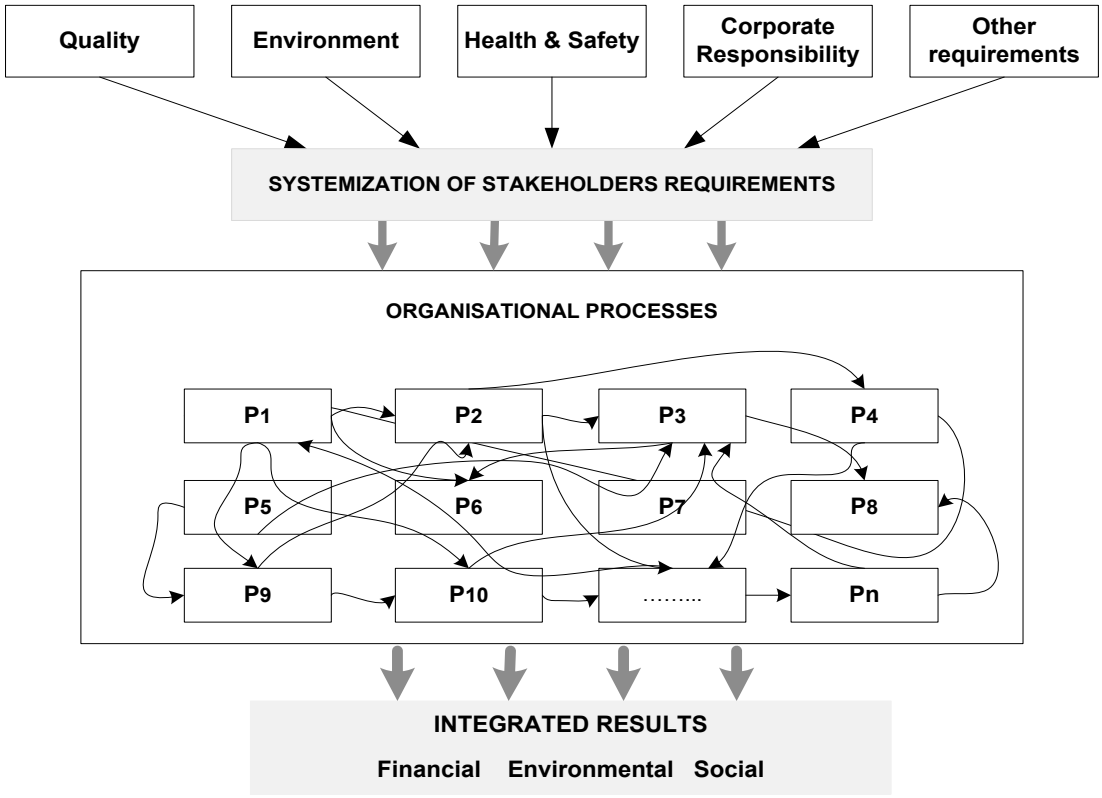

Figure 5. Systemization and integration of stakeholders requirements

Analyzing the requirements and guidelines contained in the formal management standards and content stored in the proposals of new releases such as ISO 9001 and ISO 14001 (eg, a new edition of ISO 9001 is planned in 2015) can formulate general principles that should be taken into account when building an integrated system management aiming at meeting the challenges arising from the context in which the organization operates (market impacts, economic, social and environmental). These include:

- orientation to stakeholders;
- systemic approach;
- process approach;
- focus on the risks and opportunities;
- targeted improvement.

CONCLUSIONS

Analysis of both mega-trends, sustainable development and quality (Jasiulewicz-Kaczmarek, 2013), leads to the conclusion that they much in common:

- both have gone through a historical and conceptual progression from passive reactivity to proactive, strategic integration;
- both impact satisfaction, well-being and safety of customers, employees and other stakeholders
- both are based on a core set of values, such as “create zero waste,” “make external costs visible,” and “drive out fear” between management and employees. Like quality, sustainable development also has a strong focus on people - not just in terms of customer satisfaction, but related to the quality of working life and employee satisfaction;
- both impact, and are impacted by, every function in the organization. Just as a customer’s perception of quality is affected by everything including product design and development, manufacturing, logistics, interactions with marketing, sales, customer service and more, so too is sustainability impacted by every function within the organization.

- both are based on continuous improvement towards a performance ideal: a company will never reach perfection in either quality or sustainability, and it is also never "done," but rather always striving to improve towards the goal of perfection;
- both, if done well, help drive significant financial and strategic benefits to the organization in the form of scrap and rework reduction, cost reductions, increased profitability, improved reputation and customer loyalty. Done poorly or insufficiently, however, both can lead to waste, increased costs, lost customers, degraded company reputation, and other adverse business impacts
- in both, senior management holds complete responsibility. The majority of quality problems are the fault of poor management rather than poor workmanship. Likewise, corporate sustainability success is directly related to CEO commitment. Value creation is driven through executive buy-in and execution throughout the organization. Similar to chief quality officers, the chief sustainability officer must lead an effort to institutionalize this new thinking and processes into the company.

I think that there are three main ways in which experience in quality managemnt and knowledge in the area can support enterprises in realization of the challenges emerging from sustainable development realization. They are the following:

- knowledge and experience in applkying methods such as.
- experience in managing key process and
- knowledge and experience in imlementation of organizational and cultural changes.

However support seems not to be enough. It is necessary to define activities in the area of quality management which need to be taken not to exist for managers only as „somtehing obvious and normal" (fourth stage of a lifecycle), but also as the source of inspiration in creating value for stakeholders and and support in solving potential and existing problems. What can sustainable development teach quality? In which direction quality management systems should develop? Taking the fact that quality standards according to ISO 9000 and branch specific standards are extremely popular within companies into consideration, necessity to update and improve them is obvious. Increasing standards and making them more detailed should refer to: including „risk based thinking" to activities and processes of a companyand better alignment with business management processes which means taking context of corporate operations into consideration.

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Macroergonomic Improvement the Development of Agri – Food Sector Company

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ABSTRACT

Article aims to develop a methodology for obtaining logistical improvements contained within the discussed scientific discipline. An attempt to establish macro ergonomics logistics improvements micro-enterprises ,should therefore be supported by strict social approach . Strategy is to focus on these aspects in an environment of both internal and external . This can be achieved by proper selection of methods for answers , which is the most important component and is of utmost importance for the development of the company. Developed methodological selection can be operational and strategic . The results of the analysis may include lifting factor , such as correction recipe for the final product as well as the change in the technology park , which will translate into the quality of the final product. Raised the issue of concern is the micro company engaged in farming and breeding pigs, to its processing and trade. The company is local. The owners are considering a number of innovations, including expansion of the business in the other region, the development of a technology park and the creation of logistics and management.

INTRODUCTION

Positive aspect of ergonomics is its holistic relations between man and technique, what gives opportunities to identify all their components and relations taken place in man-machine unit. Information gathered during macroergonomic improvement habituation translate on adequate working stations, machines and technology designing. (Pacholski, Mateja, 2010)

Primary, ergonomics was engaged in information perception, anthropometry, work physiology and man-machine unit analysis. Contemporary ergonomics developed creating macroergonomics (third generation ergonomics). Key assumption is multi agential analysis of designing, exploration and. Every system taken into researches should consist of several units (man-machine units) related with each other and staying in relation with the surroundings. Important is to identify complication level. (Jasiak and Misztal, 2004)

Presented solutions affect micro company from agri-food sector, which deals in manufacturing and services. The elaborate company is a small family business for last 30 years, which deals with pig breeding, its processing and trading. Company from its beginning play main role on local market containing medium city counting about 50 000 people. Founders conduct agriculture processes are taking place. Because of good shape of market sharing potential is specified as promising. What is more, there is no full automated process, which makes human the fundamental base reaching purpose of the company and making its financial dreams come true.

Methodology & case study

The collection of macroergonomic information includes all data, which are applied to working community and organizational-technological components. Unlike to macroergonomics, these information describes human work in reference to purpose and function of the company. Very important is the holistic rendering of man work in the company. For this purpose, occur processes, their characteristic and threat identification are needed. It is necessary to preserve objectivism during optimization planning. It expects appropriate strategy of action, financial situation description and capital information. (Pacholski and Jasiak, 1998)

As a part of researches action proceeding schedule was designed (Figure 1)
The base of algorithm is macroergonomic processes identification, so it is indicated to use method including human factor. This requirement will gain relations project between components of different processes. Analysis perform on that data will allow to reveal dependence between every process and the priority of basic factors past each. Idea is to design information, which have influence on human factor and work environment introducing the direction of macroergonomic improvements.

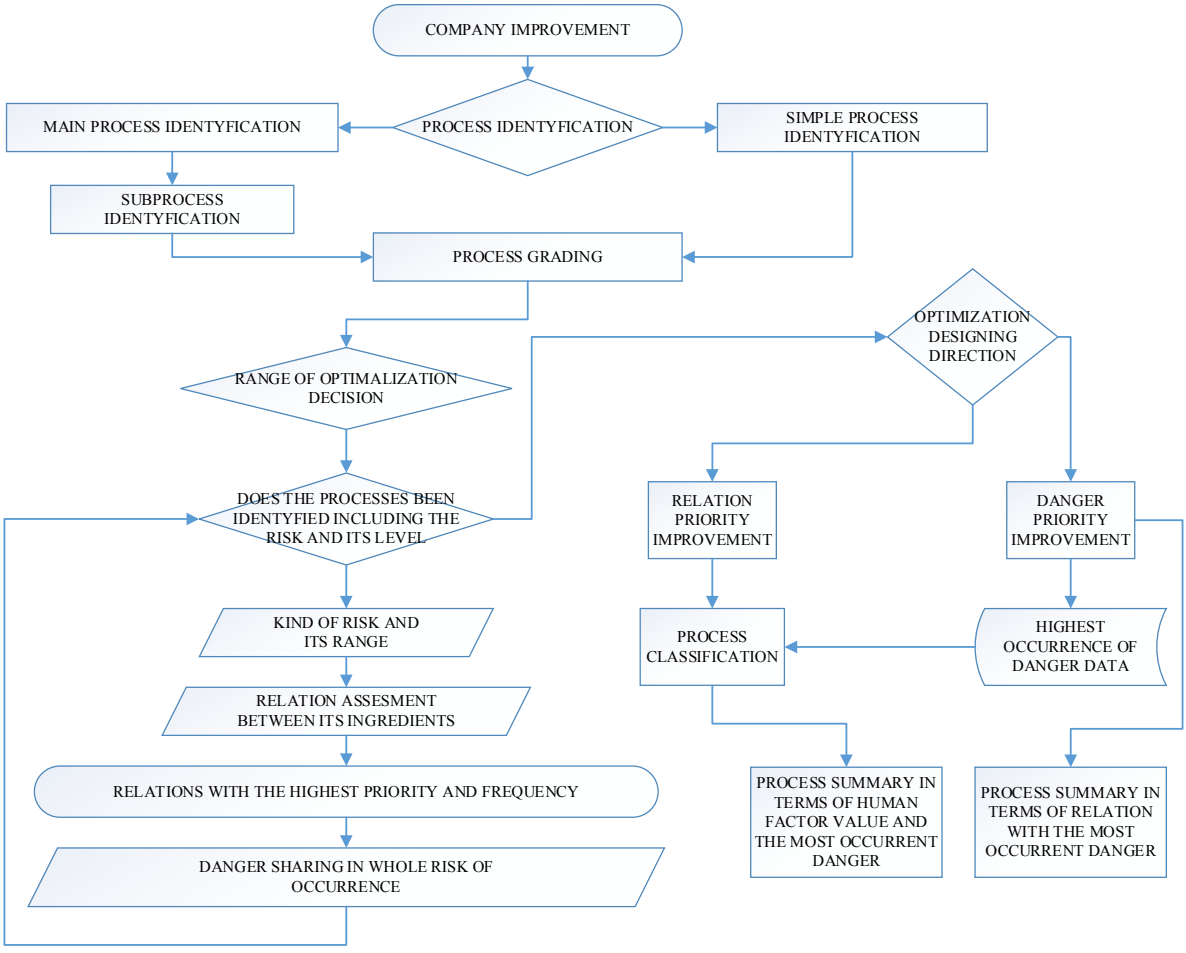

Figure 1 Algorithm proceedings. Own elaboration.

Information received from the algorithm concern areas of the company, where the most important factor is human and also that show direct danger in high risk of occurrence. This schedule was created with a view of describing all processes in the company, reorganization would be required and agriculture actions should be included.
Fundamental action is identification and description off all processes of business activity in agri-food sector. Depending on kind of activity a group of key processes may be identified, as also subgroups of simple processes
Article dimension relates to both types of business activity. Proper juxtaposition and analysis will restrict

macroergonomic optimization.
Production activity have been divided into three stages: material preparation, technologic actions and transport. Ergonomic danger is assign to proper sub process.
Production activity have been divided into three stages: material preparation, technologic actions and transport. Each of these components will be transcribe on sub processes and ergonomic danger.

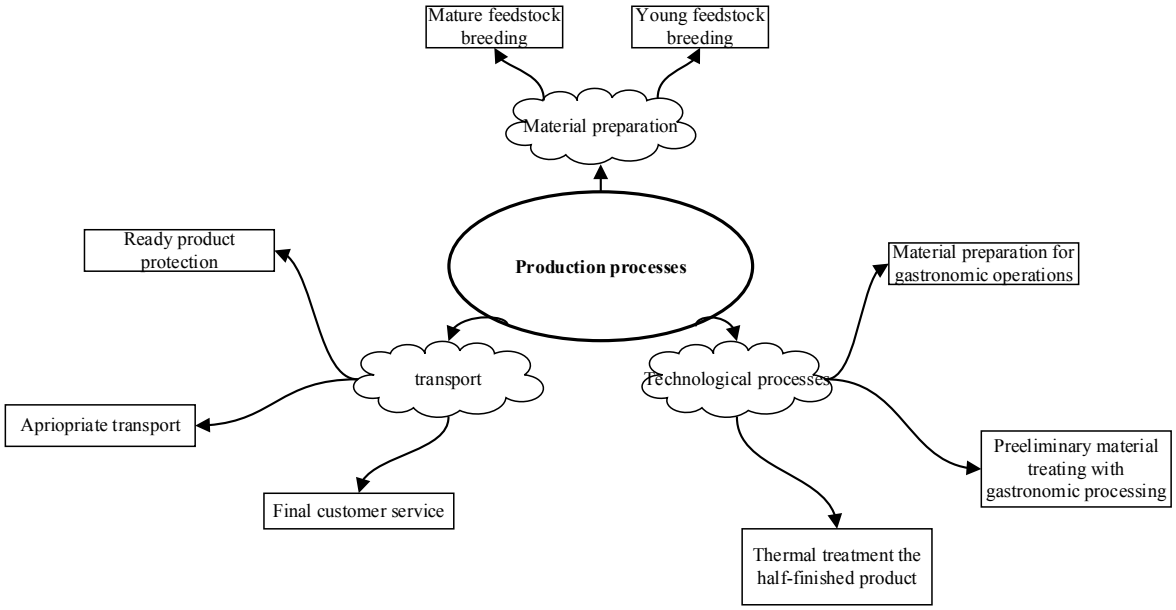

Figure 2 General processes diagram. Own elaboration.

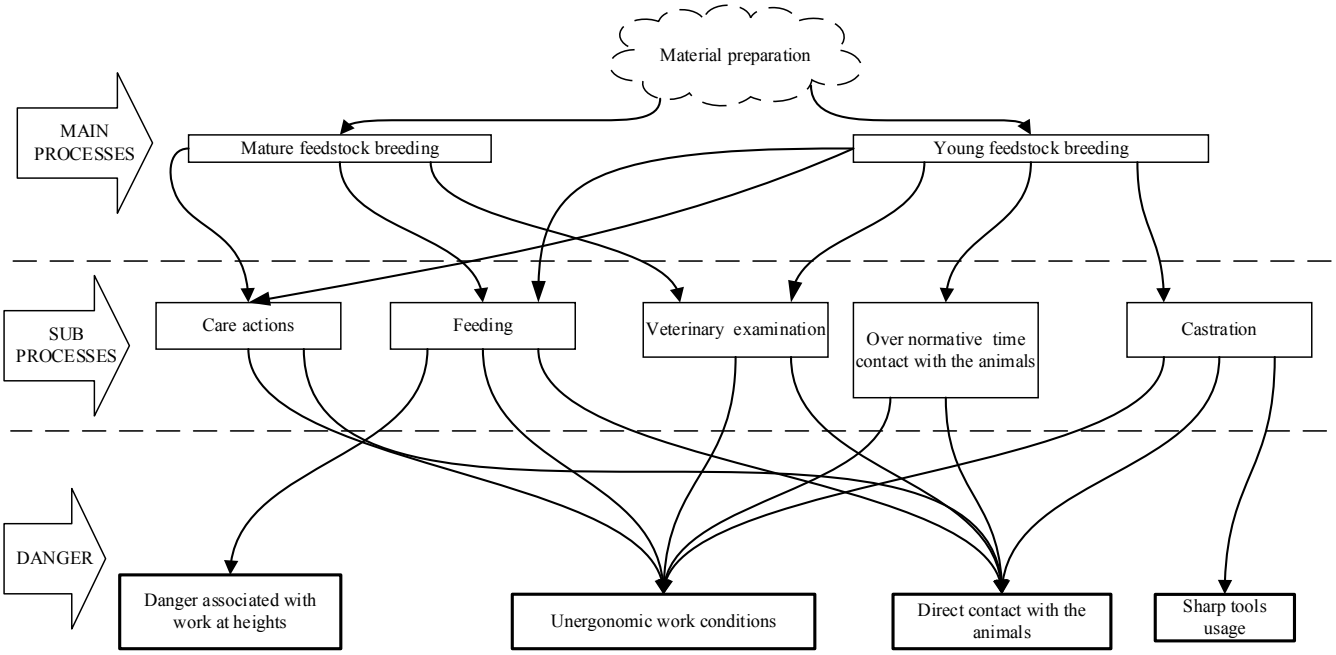

Figure 3 Material preparation processes. Own elaboration.

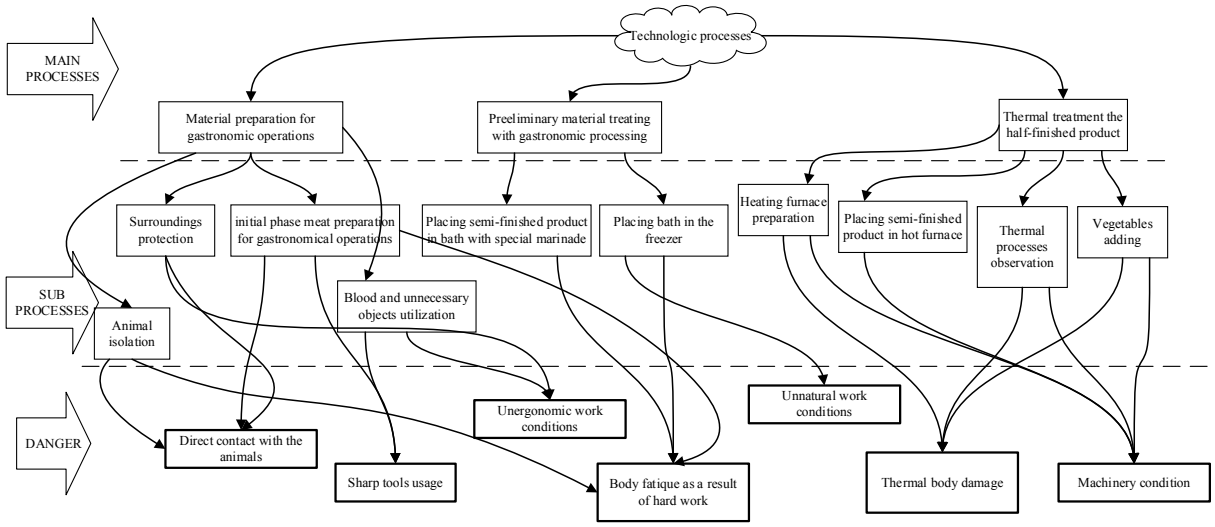

Figure 4 Technologic processes diagram. Own elaboration.

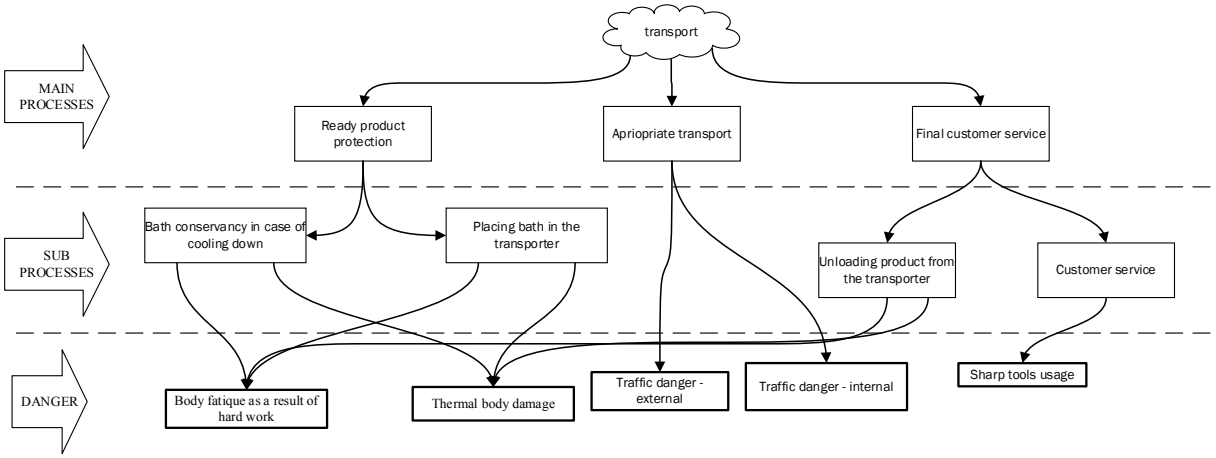

Figure 5 Transport processes diagram. Own elaboration.

Elaboration diagrams (figures ... vined with particular area of the company. Additionally relations between distinct dangers are visible and they rank. Likely is to receive answer about the risk intensity associated with singular process and also what is the cause of each work safety danger. Analysis performed on grounds of all diagrams explain the occurrence of each danger. Results are placed in chart 1.

Direct contact with the animals	8
Sharp tools usage	4
Unergonomic work conditions	6
Body fatigue as a result of hard work	7
Thermal body damage	6
Machinery condition	4

Table 1 Risks occurrence including all business actions. Own elaboration

Next step of macroergonomic analysis is to do relationships researches between components of all six working safety danger during process identification. Literature interchanges techniques, that can be used to achieve production processes designation. If these procedures fulfill requirements to define business activity, relevant is to use them during danger recognition. This assumption can be explain by strong affiliation risk factors with process stages, which are the reason of threaten danger.

In order balancing all endangered zones of the company, theoretical foundations of Ishikawa diagram was used. This technique is based on process transcription with aspects such as: machines, management, men, technology, materials and environment.

Table 2 Relations between danger components. Own elaboration.

Direct contact with the animals	**Machines**	**Management**	**Men**	**Material**	**Technology**	**Environment**
Machines	x	0	0	0	0	0
Management	0	x	0	0	0	0
Men	0	0	x	24	16	16
Material	0	0	1/24	x	16	8
Technology	0	0	1/16	1/16	x	8
Environment	0	0	1/16	1/8	1/8	x
Sharp tools usage	**Machines**	**Management**	**Men**	**Material**	**Technology**	**Environment**
Machines	x	0	12	12	12	0
Management	0	x	0	0	0	0
Men	1/12	0	x	12	8	4
Material	1/12	0	1/12	x	8	4
Technology	1/12	0	1/8	1/8	x	0
Environment	0	0	1/4	1/4	0	x
Unergonomic work conditions	**Machines**	**Management**	**Men**	**Material**	**Technology**	**Environment**
Machines	x	18	18	18	18	6
Management	1/18	x	18	18	18	6
Men	1/18	1/18	x	18	18	6
Material	1/18	1/18	1/18	x	12	6
Technology	1/18	1/18	1/18	1/12	x	6
Environment	1/6	1/6	1/6	1/6	1/6	x
Body fatigue as a result of hard work	**Machines**	**Management**	**Men**	**Material**	**Technology**	**Environment**
Machines	x	7	21	0	0	0
Management	1/7	x	21	0	0	0
Men	1/21	1/21	x	21	21	21
Material	0	0	1/21	x	0	0
Technology	0	0	1/21	0	x	0
Environment	0	0	1/21	0	0	x
Thermal body damage	**Machines**	**Management**	**Men**	**Material**	**Technology**	**Environment**
Machines	x	0	18	0	0	0
Management	0	x	12	0	0	0
Men	1/18	1/12	x	0	18	6
Material	0	0	0	x	0	0
Technology	0	0	1/18	0	x	0
Environment	0	0	1/6	0	0	x
Machinery condition	**Machines**	**Management**	**Men**	**Material**	**Technology**	**Environment**
Machines	x	12	12	12	12	8
Management	1/12	x	0	0	0	0
Men	1/12	0	x	12	8	4
Material	1/12	0	1/12	x	8	0
Technology	1/12	0	1/8	1/8	x	8
Environment	1/8	0	1/4	0	1/8	x

Table 3 Summary of table 2. Own elaboration.

	Machines	**Management**	**Men**	**Material**	**Technology**	**Environment**
Machines	x	37	81	42	42	14
Management	1/37	x	51	18	18	6
Men	1/81	1/51	x	87	89	57
Material	1/42	1/18	1/87	x	44	18
Technology	1/42	1/18	1/89	1/44	x	22
Environment	1/14	1/6	1/57	1/18	1/22	x

Table 3 includes balance of factors particular treatments. Matrix values have been received in regard to mathematical pattern:

$$x_1 = a_i \times o_i, \text{ where:}$$

x_1 – relations value,

a_i – number of processes related with at least one risk (chart 1),

b_i – relation rating between components in scale 1 -3 (0 – no affiliation, 3 – strong affiliation).

Values summary for work safety danger relationships and their collation in similar matrix will give data, which associations are the most powerful against the background of all of them. Table 3 contains information, which can be source of conclusions, that men is the most important factor, because it has big advantage over the rest of components. This data have shift on proposals, what part of the company is expose on the most possible activity risk. The conclusion also shows significance of domination of human factor over the rest of organizational-technological aspects Further phase of macroergonomic proceeding algorithm is to classify possible working safety danger in relation to chance of it appearance. The result of this action will be danger hierarchy compared by percentage value.

Table 4 Comparison of components describing most occurring dangers. Own elaboration.

Relation							
	Value of component relations						
	Human factor						
	value	Direct contact with the animals	Sharp tools usage	Unergonomic work conditions	Body fatigue as a result of hard work	Thermal body damage	Machinery condition
Machines	81	0	12	18	21	18	12
Management	51	0	0	18	21	12	0
Material	87	24	12	18	21	0	12
Technology	89	16	8	18	21	18	8
Environment	57	16	4	6	21	6	4
SUMMARY	365	56	36	78	105	54	36
Percentage meaning		15,34%	9,86%	21,37%	28,77%	14,79%	9,86%

Chart above suggests body fatigue as the most important risk for the company. unergonomic work conditions are placed second.

Direction of the chart 5 is to point these processes, which are the most important in order to human factor value. Figures are calculated because of human meaning in particular action multiplied by priority of each component.(Pacholski, Trzcielinski and Wyrwicka, 2011)

Table 5 Production processes rated in terms components. Own elaboration.

		Machines		Management		Material		Technology		Environment		
	PRIORITY	3		1		3		2		1		
		rate	rank	rate	rank	rate	rank	rate	rank	rate	rank	% participation
Material preparation	Care actions	1	3	1	1	3	9	3	6	0	0	6%
	Veterinary examination	0	0	3	3	3	9	3	6	0	0	5%
	Feeding	1	3	1	1	3	9	3	6	0	0	6%
	Castration	3	9	3	3	1	3	3	6	0	0	6%
	Over normative time contact with the animals	0	0	0	0	3	9	0	0	0	0	3%
Technologic processes	Animal isolation	0	0	1	1	3	9	3	6	1	1	5%
	Initial phase meat preparation for gastronomical operations	3	9	3	3	3	9	3	6	3	3	9%
	Surroundings protection	1	3	1	1	1	3	1	2	3	3	4%
	Blood and unnecessary objects utilization	3	9	3	3	1	3	0	0	1	1	5%
	Placing semi-finished product in bath with special marinade	1	3	3	3	1	3	0	0	0	0	3%
	Placing bath in the freezer	3	9	1	1	1	3	0	0	0	0	4%
	Heating furnace preparation	3	9	1	1	0	0	1	2	3	3	5%
	Placing semi-finished product in hot furnace	3	9	0	0	1	3	0	0	0	0	4%
	Thermal processes observation	3	9	1	1	3	9	3	6	0	0	8%
	Vegetables adding	3	9	0	0	0	0	1	2	0	0	3%
transport	Bath conservancy in case of cooling down	1	3	1	1	0	0	3	6	1	1	3%
	Placing bath in the transporter	1	3	1	1	0	0	3	6	3	3	4%
	Appropriate transport	3	9	3	3	0	0	3	6	3	3	6%
	Unloading product from the transporter	1	3	0	0	1	3	1	2	0	0	2%
	Customer service - catering	3	9	3	3	3	9	3	6	3	3	9%

Table 5 identifies which processes play the main role including criteria mentioned earlier, which are initial phase meat preparation for gastronomical operations, meat roasting observation and final customer service. Percentage participation was calculated in regard on mathematical pattern;

$$x_2 = \frac{a_i}{\sum_{i=1}^{j} a_i} \times 100\%, \text{ where:}$$

x_2 – value percentage,

a_i – sum of values for particular process,

$\sum_{i=1}^{j} a_i$ – sum of values of all processes.

This stage of researches points processes, which should be improved. Continuation will depend on describing selected areas and comparison their value for meaning of final product. An addition could be collation actions characterized by percentage leverage and creating optimization for them including their meaning, costs and profitability.

CONCLUSION

Designed methodology macroergonomic improvements receiving allows strategic planning and habituation multi criterial. Procedure data receiving embraces process identification taken place in the company, their parameterization and determinants redound to possible dangers. Big asset of created procedure is its versatile and universalism, also rotation of information in a mathematic conceptualization, what can bring to wide range of interpretation of input data. Significant stages algorithm executing are based on common-sense approach to the problem, what is the most serious restriction of current situation interpretation.Techniques applied in the article belong to group of common ways of converting and receiving data. Specificity of action order rely on unconventional method of using them. (Pacholski, 2012)

Macroergonomic improvement methodology was designed in order of work safety danger occurrence. The most important comparing factor is based on Ishikawa diagram. It allowed comparison of risks including their relations in work safety danger and their size. That direction of company improvement has it purpose during optimization reducing the most occurring work safety danger. Sampled development affects machinery correction, work station improvement or human factor rotating.

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Macroergonomic Model of the Quality of Life of Elderly Employees for Design Purposes

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ABSTRACT

In the lives of the elderly, work and the related socio-economic conditions are a significant, and often essential, part of life. The quality of life is a cumulative and multifactorial indicator. Therefore, to evaluate it, macroergonomic analysis is particularly applicable. Quality of life is thus an aggregating factor, which generally describes factors in an undoubtedly subjective manner. Currently existing methods propose to ask questions about the quality of working life in categories such as: wages, incentive systems, relations with supervisors and co-workers, market position of the company, opinions on the organization expressed by others, and organization and nature of the work. However, the evaluation of individual categories helps to a small extent to identify particularly important systemic relationships as well as expectations directed at the technical and organizational environment. Therefore, this paper presents a synthesis of methods, utilizing, among others, Macroergonomic Organizational Questionnaire Survey (MOQS), Karasek's Job Content Questionnaire (JCQ), NIOSH Job Stress Questionnaire and NASA Task Load Index. This combination results in a research tool that not only assesses the fulfilment of each category, but also recognizes the needs of people surveyed in the specific areas.

Keywords: Ergonomic design, elderly, quality of life

INTRODUCTION

The issue of working in elderly age is a matter of controversy. This is due to a perceived decline in strength as one ages, while also to the sentiment that one deserves a rest after a lifetime of working. The quality of life is a cumulative and multifactorial indicator. Therefore, to evaluate it, macroergonomic analysis is particularly applicable. It allows to not only attain an assessment of specific dimensions of satisfaction with the experienced work conditions, as is the case with currently existing methods, but also to reveal relationships between various technical and organizational systems which are present in the workplace. The macroergonomic approach seems even more appropriate when designing for groups with specific needs, such as the elderly, because of the development of a number of approaches and methodologies in the realm of design such as: universal design, inclusive design, design-for-all, barrier-free design and accessible design (Goldsmith 2000, Meyer et al., 1998, Branowski and Zabłocki, 2006); however, despite the existence of these methods, the widely used solutions still to a small degree address the needs of a wide range of users, and are limited to at most one of the most obvious needs (e.g., physical access), with no regard to the less visible, but not necessarily less important, needs (Eichhorn et al., 2007). The elderly are selected as the target group, because they constitute a specific group of recipients, for whom the technical environment is often not very amiable, and the time of acquisition of certain solutions – considerably longer.

In the article it is assumed that quality of life (Misztal and Butlewski, 2012) is the result of many factors, such as satisfaction with the achieved social status, professional stability, achieved income, social relations at work and the characteristics of the performed activities, technical environment and safety culture, yet simultaneously it is also a function of aspirations, personal determinants and experiences. An additional matter essential to consider when describing the quality of life of elderly people are the factors adversely affecting them, such as health problems, decreasing psychophysical abilities, and in the subsequent stages of life – traumatic experiences such as the death of loved ones or the loss of an achieved position to younger co-workers. Quality has both a measurable as well as unquantifiable nature, one can make a very parameterized description of it or leave a qualitative description (Mazur, 2013). Quality management, also in terms of the quality of life of workers, can be a way for companies to achieve perfection, setting targets and consistently striving for their achievement, but simultaneously their omission does not give any added value (Jasiulewicz-Kaczmarek, 2012).

Quality of life is thus an aggregating factor, which generally describes factors in an undoubtedly subjective manner. Currently existing methods propose to ask questions about the quality of working life in categories such as: wages, incentive systems, relations with supervisors and co-workers, the market position of the company, opinions on the organization expressed by others and organization and nature of the work. However, the evaluation of individual categories helps to a small extent to identify particularly important systemic relationships as well as expectations directed at the technical and organizational environment. Therefore, there is a need of synthesis of methods, utilizing, among others, Macroergonomic Organizational Questionnaire Survey (MOQS), Karasek's Job Content Questionnaire (JCQ), NIOSH Job Stress Questionnaire and NASA Task Load Index.

The weight of the undertaken subject also arises from the fact that the demographic situation not only encourages people to undertake various activities (including work) but also creates the necessity for them to work. The question of whether elderly people should work to function as part of society is of the past - the present question is how they can work efficiently and at an optimal psychophysical cost. In order to answer this question it is necessary to know the model of the quality of life of elderly people, which the macroergonomic approach can help discover.

DESIGN FOR THE ELDERLY

Problems of old age and their scale

According to the WHO organization starting at the age of 60 years we can consider the border of old age (Steuden, 2012). However, this border is contractual, thus some data refers to the border of 65 years, while others point to the beginnings of the division of old age from adulthood at 50 and 45 years (Bromley, 1969). Regardless of the accepted boundaries, the problem of old age, perceived as the ratio of elderly people in society, is growing in the vast majority of European countries. Currently in Poland there are nearly 20% of people over 60 years of age. In the year 2035 the percentage of those over 65 years of age will reach 38%, and for all of Europe this factor, the so-called demographic load, will achieve a level of 43% (CSO, 2009). The estimated life expectancy of people over 65 years (until recently the retirement age) is 17.3 years for men and 20.9 years for women (IIASA, 2012).

The problem of an aging population has at least a few dimensions. One of them is revealed at the economic level and results from the load on the adopted social security system, which assumed only a progressive age pyramid in society. In this growing population model the vast majority of working people through deducted premiums supports a minority that has stopped working (assuming no accumulation of the contributions). In such populations, the elderly accounted for a relatively small burden on a significantly growing population of active people. The problem of an aging society manifested itself at a time when the relationship began to turn, and the means of people who ended their professional activity had become inadequately protected. This problem of an economic nature does not remain in traditional ergonomic design for the elderly, but is included in the issues of macroergonomics. As part of its approach, one may consider organizational models of work throughout life, and the validity of the existing solution which causes some of the most effective years of life to be spent outside of the labour market during studies, after which often the knowledge gained is not applied.

Another group of problems is the quality of life in old age. The increasing life expectancy will result in the need for a range of supporting and mobilizing aids especially during advanced old age. Some researchers even suggest that it is quite possible to achieve the age of 120-130 years for a significant portion of the female population (Duda, 2013). This will raise almost Gulliverian problems and will trigger the need for an economic and social consensus, which will prevent possible perversions such as "encouraging" euthanasia or activities with similar effects to euthanasia (no treatment due to the patient's age).

With the demographic changes there will be more problems, such as elderly workers' labour, which itself also has many dimensions. In addition to the economic and moral (forcing elderly people to work) as well as medical problems (impact of work factors on an age-weakened body), ergonomic problems also appear. One of them is the ergonomic dimension of adaptation to a safe and efficient working environment for the elderly. This is inevitable, because during the collapse of the current system of financing the elderly will be forced to stay longer in an employment or monetary situation. On the side of ergonomic design lies the problem of the technological divide resulting from ubiquitous technological measures and the decreasing psychomotor and cognitive properties of the elderly. Ergonomic quality influences productivity (Butlewski and Tytyk, 2008). Increased work efficiency through an improved ergonomic quality takes place at the same or lower human cost. One can also achieve the same profit without consequences (Górny, 2012). Ergonomic design must therefore replace regular design, and all other forms, such as the approach to the problem by placing an age limit for the use of individual measures, are no longer sufficient (e.g., proposals for a maximum age limit of persons entitled to drive), which had previously been doubtful "only" morally.

Specificity of ergonomic design for the elderly

Contrary to appearances, designing for the elderly is not easy due to several methodological problems. The first one is a fairly obvious problem of a decline in physical and mental faculties with age. Aging is associated with changes such as (Duda, 2013): decreasing adaptation to various physical, biological and psychosocial loads, decreasing organ reserves, increasing morbidity, and rising mortality. The changes of a physiological and psychological nature also cause personality changes, the course of which is largely defined by elusive factors such as self-assessment of personal performance and satisfaction with life (Halicka, 2004, Steuden, 2011). These changes will have an impact on the demand for quality of products and services. The problem in this respect consists of mapping needs without stigmatization, in such a way that the proposed solutions allow for development and not act as a barrier. In terms of problems related to the decline of intellectual properties it should be noted that if it is scientifically detected and physiologically determined (Bromley, 1969, Lewandowski, 2013), it is still the subject of scientific discourse (Steuden, 2011).

Another factor next to the issue of matching the technical environment to the identified needs of the elderly is to obtain information on unquantifiable characteristics, needs and specific modes of action of the elderly. This problem is solved, among others, by design methodology from the realm of ethnographic design (Richard et al., 2013). However, despite the utilitarian use of these methods, there are a number of objections to the generality and reliability of the results obtained with their use (Vinck, 2003). Certainly, the use of information obtained from small design groups should be approached with caution. However, the observation used by ethnographic design is a much better form of obtaining information regarding the operation of elderly people than interviews and questionnaires.

Another important factor in ergonomic design is the scale of the results achieved by a suitably deep redesign of the considered systems. Achieving the desired effect using the traditional approach is too inefficient hence the opportunities offered by heuristic methods (Butlewski, 2013). These methods are partly reflected in the above-mentioned ethnographic design, but the scale of the effect achieved is dependent on the innovation of the changes, and these are often faced with constraints in the case of the older and more conservative audience. This means that in the case of the elderly, ergonomic design must also take into account the cultural context and habits, which will involve overcoming considerable resistance and thus the reluctance to proposed solutions. This again begets opportunities for macroergonomic methods.

The specificity of ergonomic design for elderly people is also apparent from the fact that certain properties of a group of elderly people may arise not so much from the aging process, but from the specific conditions to which the given human society was subjected to. In other words - each cohort is aging in a different way (Riley, 1987). This implies the need for adaptation and for not predetermining specified differences.

MACROERGONOMIC APPROACH TO QUALITY OF LIFE OF THE ELDERLY

Macroergonomics represents a new approach in the activities of ergonomics, whose objects of interest are complex socio-technical systems (Pacholski 1995, Pacholski 2000, Pacholski and Jasiak, 2011). The macroergonomic approach takes into account not only the physical work environment factors but also the elements that form the broader context of the design situation in the fields of (Butlewski and Tytyk, 2012): sociology, economics, politics, culture, religion and ecology. This means that in this sense macroergonomic design must use a number of different

tools to achieve its goals. It is this wider context which provides the opportunity to respond to the needs of elderly people and to deal with the problem of the "greying" of the workforce (Stanton et al., 2004). The macroergonomic principle which consists of considering a multi-faceted problem at each stage of design (Hendrick, 1995) allows to refer to not only a particular position or object for an elderly person, but also to the indirectly and directly related objects and organizations. From the macroergonomic viewpoint, in the case of ergonomic design for the elderly the identification of the limits of the elderly should serve the application of these properties so that it is possible to obtain a greater efficiency of the system than would be the case for other users. For example, one can indicate that ergonomic measures for people with a limited level of auditory perception are associated with the adjustment of the level of emitted signals, and the macroergonomic activities are associated with the answer to the question of where such restrictions can be used (work in environments with specific acoustic characteristics), how these limitations affect the other actions of the user, what changes should be made to turn the dysfunction into an advantage rather than a disadvantage, how to manage older and younger employees. It should be remembered that the macroergonomic approach requires not only participation in the design processes themselves, but organizational and managerial processes as well. Only then can ergonomics reach its full potential (Hendrick, 1997).

The quality model, and thus the reflected needs of the various dimensions of life, allow for choosing specific design courses of action to improve the quality of life in general, including satisfaction from the performance of activities such as work. In terms of the latter, various models are adopted of groups of factors indicating job satisfaction (skill variety, task identity, task significance, autonomy, and job feedback) (Lepper et al., 2012). It should also be noted here that the general cognitive theories of quality of life for design purposes have a low value. The indicated groups of factors (Hyde et al., 2003): Control, Autonomy, Self-realization, Pleasure, which were obtained from 19 questions of CASP 19 have a rather low value when it comes to the needs of design, but they do represent an interesting cognitive model in psychological terms. The low cognitive value of the model results from the grouping of questions about completely different characteristics such as: “I choose to do things that I have never done before” and “I feel satisfied with the way my life has turned out” which are included in Self- realization, while from the design point of view, these two sentences have completely different consequences. As a useful model questions could be used from the fields of Control and Autonomy (Hyde et al., 2003): “My age prevents me from doing the things I would like to; I feel that what happens to me is out of my control; I feel free to plan for the future; I feel left out of things; I can do the things that I want to do; Family responsibilities prevent me from doing what I want to do; I feel that I can please myself what I can do; My health stops me from doing the things I want to do.”

The carried out studies point to different targets perceived by elderly people because of the changing perception of self. The needs for development as well as the possibility of promotion are reduced as well, while larger needs occur in the social context. Needs and assessment categories for the elderly are listed Table 1.

Table 1: Elderly ergonomic needs model (Parasuraman et al. 1993, Stroms et al. 2001, Heo et al. 2013, Butlewski et al., 2014

Work need	**Leisure need**	**Service need**
psychological demands skill discretion decision authority supervision support co-worker support physical exertion hazardous conditions toxic exposure job dissatisfaction job insecurity	perseverance career progress career contingency personal enrichment self-actualization self-expression of abilities self-expression of individuals self-image self-gratification-satisfaction self-gratification-enjoyment recreation	tangibles (e.g., physical appearance, proper conditions), reliability (e.g., dependable and accurate service, safety and confidentiality), empathy (e.g., responding to individual needs of each customer), assurance (e.g., qualification and knowledge of service provider, customers understanding of the service provider;) responsiveness (e.g., willingness to help, fast response).

Work need	Leisure need	Service need
	financial return group attraction group accomplishment group maintenance unique ethos identification	

The presented three categories can provide a list of requirements for the model proposed later in this article. Differences in perceptions of each category will be only partially dependent on the age, because other variables will include gender, education, experience, and the previously mentioned cohort effect.

The macroergonomic perception of the quality of life of the elderly should therefore, in the author's opinion, be due to the identified needs of the general public (such as CASP 19), but giving the idea regarding the individual components of the environment (Butlewski 2014 in press): relationships, technical and IT environment, level of understanding of the environment and the desire to learn, a feeling of the importance of the goal – task in society, a sense of prestige and dignity, compliance of own activities and work with own interests and development opportunities. This model better reflects the design needs, although it still operates at a fairly high level of generality.

MACROERGONOMICS AND DESIGN FOR ELDERLY

Macroergonomic methods aiding design for the elderly

Specific macroergonomic tools can be used for design purposes for the elderly, e.g. by identifying environmental factors related to the work and leisure of the elderly. One of the most frequently cited methods is MOQS (Macroergonomic Organizational Questionnaire Survey). This method is used to collect information on various aspects of the work system (Salvendy et al., 1997) and it is recognized that it is very useful in determining the quality of working life (e.g., job satisfaction). MOQS does not have a specific structure of questions while the recommended steps in the method are (Carayon et al., 2001):

1. Conceptualization
2. Operationalization
3. Sources of questionnaire
4. Constructing the questionnaire
5. Pretesting of the questionnaire

The source of questions that can be used to assess the quality of working life of elderly people in terms of macroergonomics is Karasek's Job Content Questionnaire (JCQ). Assessment shall be subject to the standard set of questions that measure these two job dimensions (Karasek, 1985), including questions on psychological demands and nine questions on decision latitude. These two scales of the JCQ are partly based on the IS-item questionnaire of the three U.S. Quality of Employment Surveys (QES) (Brisson et al., 1998). The JCQ method has many modifications, using different sets of questions. The aim of the method is to evaluate job strain, which according to researchers translates into cardiovascular diseases (Karasek et al., 1988, Hall et al., 1993, Steenland et al., 1997). The degree to which the test subject agrees with the provided questions is evaluated in specified areas and sub-areas:

1. Skill discretion (Learning new skills, Repetitive work, Creative job, Skill level, Variety, Skill

development)

2. Decision authority (Ability to make decisions, Freedom of choice, “a say”)

3. Psychological demands, Work fast, Work hard mentally, No excessive demands, Having enough time, No conflicting demands, Continuous concentration, Tasks unexpectedly broken off, Hectic job, Wait on others to complete tasks.

Macroergonomic methods have a holistic way of action, however, to assess differences between groups of younger and older users we need comparative studies. Thus, research relating the differences deserves attention – for example between design features and performed activities of younger and older workers (Kupritz, 2000), which show that older and younger workers associate similar design features with facilitating work activities. However, these studies do not overlap with other related factors causing the desire for further work by the elderly (McNair, 2006). The question then arises whether the described methods allow to reveal the real needs of the elderly and whether it is an adequate way to obtain information regarding factors indicating satisfaction with the undertaken actions.

Proposed method for assessing the needs of the elderly

A disadvantage of the previously listed methods is a limited valuation of individual characteristics and the often occurring in elderly people lack of the ability to recognize certain criteria (Butlewski et al. in print in 2014). This results in the validity of using a method of comparing individual factors. Helpful in this situation are the assumptions of the NASA TLX method, modified for the needs of perception of elderly people. This tool can be used as a verification of the identified needs of the elderly (quality of life model) and to identify differences in perception of individual factors. In the first part, an assessment would be made of non-compliance with the individual requirement parameters, on a 5-point scale (according to the author's experience a greater number of categories is difficult to assess for the elderly). Next, the individual pairs of characteristics are evaluated, which will indicate their level of importance. The product of the level of non-compliance and importance presents a picture of the gaps in the perceived quality by the elderly.

CONCLUSIONS

The macroergonomic approach to the problem of ergonomic design for the elderly offers a wide field of possible solutions and provides answers to problems which are currently without a proper solution. Even the most tailored positions and items will not provide an adequate level of desired quality without the adjustment of content and the surrounding environment to the needs of the elderly. The proposed model of study will determine the needs for individual groups of elderly people, however, the author believes it is not possible to obtain it in a universal way. The diversity of the aging process makes it impossible to find a universal solution for the needs of the elderly, however, the development of methods for their investigation will yield significantly improved results in the achieved ergonomic quality of the designed solutions.

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Need of Safety Integration in Robust Design

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ABSTRACT

Nowadays systems include more and more components and their variables. The effects of their changes tend to accumulate and may lead to unacceptable risks. Thus, the objective is to reduce the sensitivity of the design to uncertain or randomly varying factors. In order to achieve it robust design methods can be applied. They have already found many industrial implications mainly because of their simplicity and practicality. In this paper an attempt was made to show how to place safety issues in such design. For this aim a theoretical model was elaborated and its practical implication was shown.

Keywords: Prevention through Design, Product process design, Robust design, Safety

INTRODUCTION

In the last decades, an introduction of a huge number of innovations in technology and management has been observed. This rapid development has contributed to new opportunities for man-machine-interaction. Modern machines are equipped with compound controlled units what enable advanced production processes. Furthermore, they are also designed to be used in more and more severe working conditions (Singh and Kazzaz, 2003). However, a human being is still necessary to perform the whole system. His role is invaluable as human decisions are required to proper co-operation between human and advanced intelligent devices. For example, they are needed to support production processes by machine monitoring (Oborski, 2004). Furthermore, in spite of all these technological advances human life is often endangered to many hazards in workplace.

Accidents occur as a result of a process involving a combination of technical, personal, behavioural, environmental and work process factors. Areas of particular concern are exposures to biological agents, chemicals, extreme temperatures, noise, radiation and vibration. In order to assure appropriate working conditions and minimize the risk of occupational accidents and injuries many legislative regulations, standards and guidelines have been elaborated. They concern not only workers performance but mainly production processes and products (Murthy et al., 2008; Rausand and Utne, 2009; Mrugalska and Kawecka-Endler, 2011; Mrugalska and Arezes, 2013). Following them, all possible hazards related to the product during its life phases should be identified and eliminated, and remaining risk associated with those hazards alleviated (Directive 2006/42/WE). For instance, it can be assured by implementing Prevention through Design (Gambatese et al., 2009; Gambatese et al., 2013). Nevertheless, the analysis of manufacturing practices shows that it is almost a custom to technically design the product at first and then add safety aspects to its original version (Hsiao, 1998; Fadier and De la Garza, 2006; Butlewski, 2012). For manufacturers it is a challenge to elaborate a product which meets clients' requirements in the scope of functionality, quality and reliability, but also safety (Cordero and Sanz, 2009; Górny and Mrugalska, 2013; Mrugalska, 2014).

Currently, a lot of efforts is put in determining design variables to satisfy individual product performance, its variable requirements which are often in conflict (Murphy, et al., 2005). In the literature various product robust design methods and approaches can be found (Phadke, 1989; Isermann, 2005; Ding, 2008; Mrugalska and Kawecka-Endler, 2012; Mrugalska, 2013a). Their aim is to reduce sensitivity to variations and that especially in early design stages of products.

In this paper a particular attention is paid to showing the role of safety issues in robust design. Therefore, a model which combines these two approaches is elaborated and widely discussed. In order to develop it design methodology principles suggested by Bonsiepe (1984) and Tavares and Silva (2012) are used. Its practical application is shown on the basis of a machinery.

FRAMEWORK FOR DESIGN AND MODELING

The definition of design has a very broad scope as it can be discussed in the terms of various societal contexts such as career-design, community-design and product design. Following engineering design, design is "the human power to conceive, plan, and realize products that serve human beings in the accomplishment of any individual or collective purpose" (Pahl and Beitz, 1988). It refers to the aspects of preparation of drawings and/or its specifications for the final product and the issues concerning the execution of product project (European Federation of Engineering, 2006). Thus, design is a thoughtful process based on the laws and insights of science, which enables finding solutions to the problems which have "a common a goal, some constraints and some criteria, which lead the definition of successful solutions" (Filippi and Cristofolini, 2010). The actions, which have to be undertaken, can be presented as shown in Figure 1.

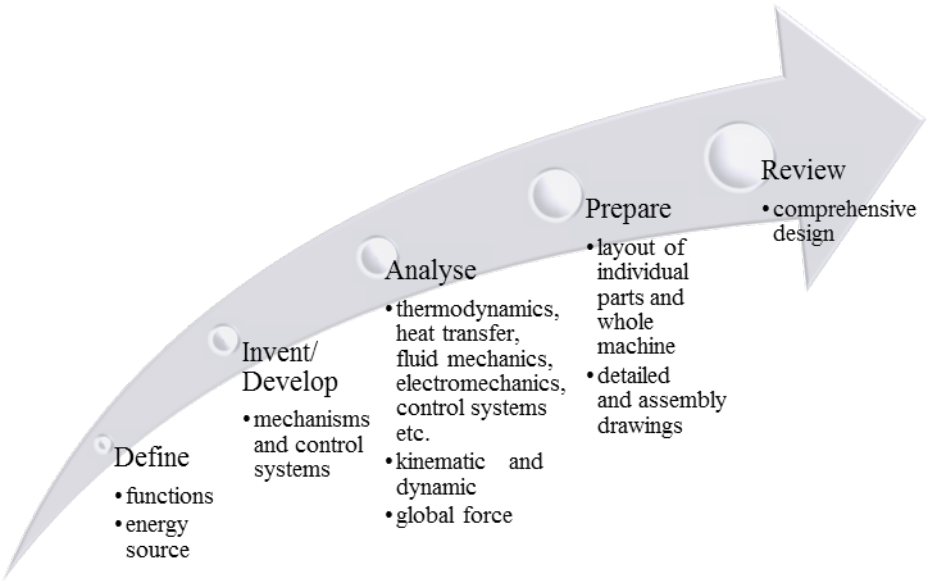

Figure 1. Steps of machinery design process (Adopted from (Collins, 2010)).

Traditionally, design process is viewed as a sequence of actions which follow step by step. But nowadays more and more often it is seen in practice that design process can be parallel or in reverse sequential (Madsen et al., 2004). Even some designers emphasize that their ideas derive from all possible sources. Therefore, their activities cannot result only from the previous stage and they have to loop through a few times during the whole design process (Baxter, 1995).

A review of the recent literature shows that several types of models describing the engineering design process can be found. It is common to differentiate three classification schemes (Wynn and Clarkson, 2005):

- stage vs activity-based models,
- problem vs solution-oriented literature,
- abstract vs analytical vs procedural approaches.

In the first scheme, also known as morphological and problem-solving approach, a linear, stage-based chronological structure of the project is perceived as the morphological dimension of the design process, whereas the problem-solving dimension results from cyclical, rework characteristic of the designer's daily tasks. Problem vs solution-oriented literature scheme is based on the results of the research study conducted by Lawson (1980) that designers prefer to 'try and see' solution-oriented approach, while the scientifically trained firstly unravel the problem and then they synthesize solutions. Thus, it is necessary to adopt both these strategies at one point or another following the nature of the design problem. It leads to such a curious phenomenon that stage-based models implement a problem-oriented strategy and, activity-based models can be either problem- or solution-oriented in nature. In the last scheme it is affirmed that abstract models have typically activity-based nature and can adopt either a problem- or solution-oriented strategy. On the other hand, procedural models are problem-oriented in nature and encompass a stage-based component (Filippi and Cristofolini, 2010). Analytical models of designing are completely different ones as they are based on mathematical equations which represent the physical characteristics of the product.
The models can be also classified as (Birmingham el al., 1997; Cross, 2000; Dym and Little, 2003; Filippi and Cristofolini, 2010):

- descriptive models,
- prescriptive models,
- integrative models.

Descriptive models, as they are rather not so detailed, only display the sequence of the activities occurring in the design process, whereas prescriptive ones show algorithmic procedures for design methodologies. In the integrative models the attention is concentrated on the iterative understanding of the problem and development of the solution.
Furthermore, some other authors differentiate sequential design models, cyclical models, and hybrid ones. It is also possible to categorize models as process-based, task-based, and parameter-based models (Filippi and Cristofolini, 2010).

ROBUST DESIGN APPROACH

Robust design is a set of engineering methods for managing uncertainties. It relies on such a designing of the system that it becomes robust or insensitive to variations without eliminating or reducing its sources in the system (Singh, 2006). One commonly known mean to achieve greater robustness is through parameter design.

In robust design literature, design parameters are divided into categories (Taguchi, 1986; Phadke, 1989; Mrugalska, 2008):

- control factors,
- noise factors,
- input factors,
- output factors (responses).

Control factors, also known as design variables, are those system parameters that a designer can adjust, and thus they can be controlled and manipulated. Noise factors are parameters that influence the performance of a product or process but are relatively uncontrollable (Hidahl, 2001). They are mainly perceived as too difficult and/or costly to control as they encompass working conditions, manufacturing variability and degradation of the system (Frey and Li, 2004). Therefore, they can be divided into the following subcategories:

- manufacturing disturbances,
- operational disturbances.

As far as manufacturing disturbances are concerned they are object and resource disturbances. For example, object disturbances involve changeability of environment in the technological process, labour division and machines breakdowns whereas resource disturbances concern energetic disturbances, material defects or shortage of raw materials and errors in production planning and control. The operational disturbances are the result of exposure to environmental changes such as humidity, pressure, pollution and temperature (Mrugalska and Kawecka-Endler, 2012) and derive from natural causes or activities of a human as describe conditions under which the product must be operated, and dictate the performance of the product characteristics (Sutherland et al., 1988; Mrugalska, 2013b). They also depend on electrical and mechanical disturbances (i.e. inaccuracy of control system, transient voltage, unbalanced voltage, voltage fluctuations, poor mounting, mechanical over load and pulsating load (Mrugalska and Kawecka-Endler, 2012; EN 60079–0; Singh and Kazzaz, 2003; Mrugalska, 2013a). Therefore, it is necessary for designers to identify where the uncertainties are present in a system model (Figure 2) be able to employ an appropriate uncertainty management method.

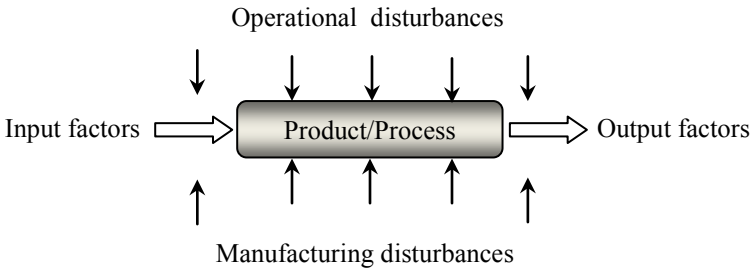

Figure 2. Factors influencing product and its process.

In design parameters methods, for a given system architecture, the designer's task is to choose controllable parameters in such a manner that the target or optimal response with minimal variation in output is assured (Singh, 2006). For this aim, the coordination of two tasks is needed: estimation of sensitivity to noise factors and finding such design variables that reduce sensitivity (Frey and Li, 2004). Presently, different robust design methods have been proposed for a large number of systems. However, the choice of the appropriate design method is still controversial. Some robust design techniques yield good results but at relatively high cost. Therefore, in practice they are only used for the most critical components. Other robust design methods seem to be easier to apply and demand less amount of resources but it may happen that the rsults are not satisfactory(Frey and Li, 2004). Thus, some researches underline advantages of parameter design, however, others claim that it alone does not always lead to satisfactorily high quality (Choi, 2005). Practitioners highly recommend to use Taguchi Methods on the basis of their effectiveness in industrial implications, however, it requires the knowledge about experimental design methodology and it does not eliminate the source of variation by introducing "signal to noise" ratio (Quirante, 2011; Venkataraman and Pinto, 2011). Thus, others and scholars prefer alternative techniques based on statistical theory. Now, it is a Systems Engineer who is responsible for choosing the strategy on the basis of pros and cons of every available technique (Frey and Li, 2004).

DEVELOPING DESIGN PROCESS BY ROBUST AND SAFETY ASPECTS

A few decades ago, safety was an issue virtually ignored in the world. Design field was dominated by engineers, who paid main concern on functionality of products. But now the situation has changed and more companies are employing human factors experts, while others are hiring consultants (Swain, 2007). An integration of a human factor in the design at various stages of design has become not only an engineering issue. Designers have started working with focus groups and/or end users, even before having working on prototypes. It is widely recognizable that understanding of the abilities and limitations of the human may contribute to preventing human error in operations or maintenance (Energy Institute, 2011). Furthermore, more and more often companies refuse to accept customers' claims saying "it was a user error, not a design problem". Such situations result from the fact that clients are more approachable and are getting used to have the right thing for the first time. On the other hand, it is said that companies are interested in industrial design, which encompasses both product development and optimization of production process, and have understood how costly is redesign of products due to use errors (Swain, 2007). However, it is still noticed that the process of safety integration is not always efficient. It is assumed that to be efficient in the applications a regular risk analysis and control procedure must be conducted in practice and they should be integrated into the design process. Such an integration allows to optimize the results achieved in particular design phases.

In order to elaborate a model, which encompasses both safety and robust aspects, it is necessary to develop the procedures that facilitate performing the task and analysis of working environment (Tavares and Silva, 2012). According to Bonsiepe (1984) the following sequence of activities can be established:

- problem definition,
- tasks analysis and operators' opinions,
- project requirements list,
- ergonomics and anthropometrics studies,
- brainstorming and sketches,
- functional mock-ups,
- preliminary tests,

– revisions,
– implementation of new products.

However, it is worth to emphasise that in practice such a design process does not follow a linear path but it is a compound sequence of stages or phases (Wilpert, 2007).

The proposed approach in the paper is based on thirteen steps as it is depicted in Figure 3. As it was mentioned in the previous chapter, the robustness can be achieved via the parameter design. For this aim, mathematical modelling and methods of parameter estimation, in which parameters and acceptable tolerance of manufacturing product parameters are calculated, can be used. For example, such a method as Bounded-Error Approach can be applied (Walter and Pronzato, 1997; Mrugalska and Kawecka-Endler, 2012). It is based on the assumption that the values of disturbances are in a certain limited interval. The information about these limits can derive from legal acts, standards or regulation. Moreover, the potential hazards analyzed in this approach are directly related to machinery as they result from noise factors. They also indirectly influence safety and health of the machinery users what enables to integrate safety and robust approach.

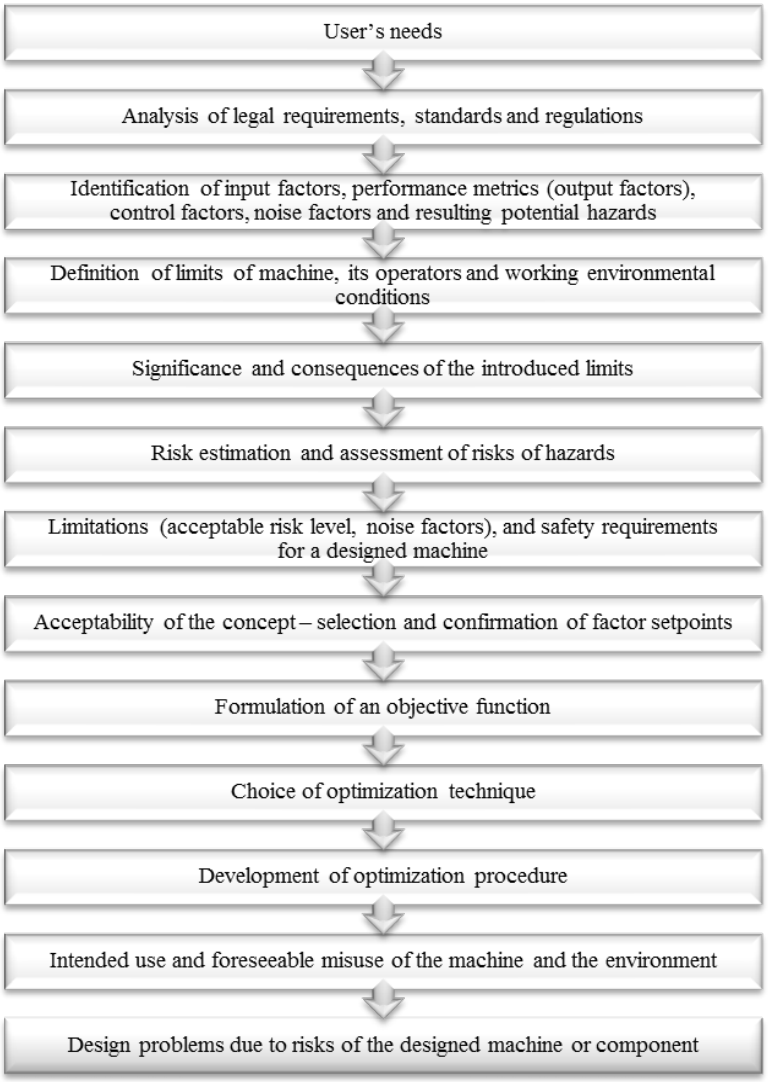

Figure 3. Safety and robust integration in design process.

CONCLUSIONS

Design process is a series of steps that lead to the development of a new product or system. However, it is a challenge to find a good niche and create a successful product as more and more competitors are on the market and customers' requirements become strict and demanding. Thus, a development of a solid foundation for a new product must be done beginning from the early product design stage. In this paper a particular attention was paid to incorporating safety issues in design stage. For this aim a model, which includes activities required in machinery design, was elaborated. It was extended by the knowledge derived from robust design methodology.

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Occupational Risk In Improving The Quality Of Working Conditions

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ABSTRACT

Adherence to the systemic approach to improving working conditions is increasingly becoming a central prerequisite for the successful operation of business organizations. By adopting systemic principles to improve the quality of working conditions, organizations gain access to effective tools for eliminating hazards and strenuousness and consequently acquire the ability to grow and improve themselves. Any measures adopted within that framework are undertaken in recognition of the roles and tasks of employees seen as the internal clients of specific processes.
The article demonstrates that improvements can be achieved by assessing risks. In this context, risk assessment is viewed as a tool for gathering information on irregularities. By assessing risks, businesses can identify any hazardous, deleterious and strenuous factors which require improvement (through corrective and preventive measures) and whose scope and characteristics depend on the level of occupational risk. The use of occupational risk as a criterion for selecting improvement measures helps identify adequate technical means and organizational arrangements to be applied to bring the working environment to the required quality standard. In particular cases, such means and arrangements should be complemented by using personal protection items. An essential consideration in improving working conditions is to incorporate any selected elements of the systemic approach that are critical for shaping the working environment. Only then will the proper improvement measures be effective.

Keywords: Occupational risk, quality of working conditions, occupational safety

INTRODUCTION

As the environment in which business organizations operate evolves, enterprises are constantly forced to improve their work processes. To that end, they increasingly rely on the systemic approach which entails searching for opportunities to improve quality in various areas of operation. One of their common focal areas is the quality of working conditions. The system developed for this purpose can be equated with one based on the principles of quality management. Its central focus is to fulfill criteria for the achievement of customer satisfaction (Górny, 2011).

In view of the way in which such a system operates and the nature of work processes pursued by business organizations, the system's clients are the organization's employees who may well considered internal. If such internal clients are to be recognized as critical for the efficient operation of an enterprise, they must be treated as verifiers of continuous improvement (Arsovski and Arsovski 2012; Thompson and Strickland, 2003). Such clients must evaluate their organization's improvement efforts in terms of their impact on ongoing processes and various aspects of working conditions, some of the most common of which are occupational safety, hygiene, health and ergonomics.

To accomplish such goals, an organization needs to acquire tools to identify areas for improvement, select

improvement measures and define the scope of such efforts and any related prerequisites. As it turns out, the necessary improvement measures may well be identified with the use of tools for assessing the occupational risks involved in performing work. Their application determines the methods adopted to conduct improvement measures.

THE ESSENCE OF IMPROVEMENTS IN QUALITY AND WORKING CONDITIONS

In its essence, the systemic approach involves pursuing all required actions in an orderly fashion in keeping with the expectations of all concerned parties. In the particular case of the quality of working conditions, the systemic approach focuses essentially on ensuring worker safety and protecting their health. Occupational safety may be seen as affecting an enterprise's working efficiency and its ability to grow by means of structured actions undertaken in all areas of its operation (Jasiulewicz-Kaczmarek, 2013; Mrugalska, 2013).

To gain the ability to satisfy client needs and expectations, an enterprise needs to create an environment which will allow and promote work efficiency. To that end, businesses need to recognize their internal clients who see quality, viewed as conditions which allow them to perform work, is a key criterion for assessing compliance with system requirements.

To undertake improvement efforts in the systemic approach, enterprises must revise their procedures and create conditions to support the achievement of the level of safety (worker protection) desired by the stakeholders and ensure that work proceeds appropriately. Systemic procedural documents (working procedures and manuals) affect the outcomes of such efforts and, as a consequence, determine the ultimate quality of working conditions. The effectiveness of such efforts bears on the ability to eliminate any hazards and strains and mitigate the associated risks. In the process, enterprises create conditions for the effective hazard-free performance of work which in turn allows them to build the working environment conditions desired by their internal clients.

The requirements which underlie systemic client-orientation apply to client needs and expectations pertaining to links between the client and the working environment. Some of the crucial factors which allow an organization to achieve the desired status include (Górny, 2011):

- care and responsibility for worker health and safety displayed by the management and all other concerned parties,
- identifying any applicable legal requirements and standards,
- identifying and assessing the potential impact of processes and actions on worker health and safety.

Organizations which shape their working conditions in the above manner may well be considered innovative. Although the method is based partly on well-tested guidelines for the systemic approach to working conditions, it goes well beyond the traditional systemic arrangements for managing sole areas of companies' activity in line with integrated system guidelines (ILO-OSH 2001; Górny, 2011).

To ensure a modern approach to the quality of the working environment, organizations need to engage in efforts which drive such quality. Specifically, they should:

- formulate a corporate strategy designed to achieve the desired quality of the working environment and, consequently, meet the expectations of the labor force and other stakeholders, as the organization's top priority,
- secure any means necessary to achieve the desired state of the working environment,
- translate their strategy for achieving the desired quality of working conditions into technical and organizational specifications with a view to satisfying the needs of all individuals involved in work processes,
- recognize that responsibility for ensuring the desired quality of working conditions rests with all workers regardless of their function and responsibilities,
- assign responsibility for shaping the quality of the working environment to all individuals all across the board

from decision-makers down to rank and file employees, rather than exclusively services and persons nominally responsible for ensuring proper working conditions,

- have all responsible individuals accept their assigned duties,
- ensure that employees are motivated to make a continuous effort to improve the working environment and secure ever better working conditions,
- recognize that the responsibility for satisfying requirements rests with all member of the organization.

The effort to ensure working conditions may be associated with the concept of total quality management whereby success in an organization's business depends mainly on the coordination of its human and physical resources (Górny and Grzybowski, 2007). To make this happen, businesses should build mechanisms for the development of structures and identify tools to effectively assess the current state. A primary role in all such efforts is played by factors in the working environment (Gołaś and Mazur, 2008). A secondary job is to secure instruments for improving the existing status by identifying areas for improvement and areas which can potentially be modified.

OCCUPATIONAL RISK IN IMPROVING THE QUALITY OF WORKING CONDITIONS

Occupational risk as indicator of irregularities

Occupational risk may be described in various ways depending on the specific characteristics of the field in which it has been identified (Górny and Lech, 2003; Górny and Jasiak, 2006). However, such risk is always associated with the occurrence of hazards and strenuousness in the working environment and with prospective losses. Owing to its nature, occupational risk is linked inextricably with the human factor. When making improvements, due care needs to be taken to consider the workers (the human factor) and the possibility of hazards and/or strenuousness occurring as a result of the state of the working environment.

A study of factors behind occupational risks has identified two key considerations which are (Guidance…, 1996; 89/391/EEC, PN-N-18002):

- losses, i.e. possible consequences defined as the severity of injuries caused by hazard-related factors and their extent expressed as the number of affected employees who may suffer health issues precipitated by the event,
- the probability of losses, which is a function of the probability of occurrence of a loss-triggering event, the frequency of exposures to hazards, the capacity to eliminate hazards, the ability to reduce losses by applying available loss-mitigation means, the way in which an organization becomes aware of the risks, the knowledge and experience of employees, etc.

Defined as above, risk may be described by means of the following formula (Guidance…, 1996; 89/391/EEC, PN-N-18002):

$$\text{RISK} = \text{function (LOSS; PROBABILITY OF LOSS)}$$

Occupational risk may be viewed as an indicator of irregularities which combines assessments of the degree of losses (disease, injuries or strenuousness) and the probability of occurrence of a given effect. Once identified in this manner, risk serves as an indicator of the impact of hazards as well as a consideration taken into account in decisions to undertake specific improvement measures. Descriptions of desired improvements to be made in response to specific risk levels have been provided in Table 1.

Table 1: Risk levels and recommended measures designed to improve the working environment (BS 8800).

Risk level	Description of risk and recommended improvements
very low	Hazards described as very low risk are considered acceptable. Measures are recommended to keep risks at this level.
Low	Requires no additional checks unless such checks take very little resources (time, effort, money). Although risk-mitigating measures are given a low priority, arrangements need to be made to ensure that any adopted solutions get implemented.
Medium	Ways to mitigate risks should be considered with proper attention paid to implementation time and cost. It is essential to adopt checks to ensure that risks to not escalate beyond medium, especially where the implications might be grave.
High	A risk-mitigation effort is necessary. Measures to reduce risks and, in particular, to ensure additional means of control, need to be taken within specified time. The option of temporarily interrupting work should be considered. If the possible worker health risks are very serious, arrangements must be made to ensure risk reduction.
very high	Very high risk is unacceptable. Work can only be performed if arrangements to reduce it are put in place. Where risk reduction is impossible, any further work must be prohibited.

An essential consideration in adopting improvement measures is to recognize that occupational risk assessments reveal irregularities and suggest the need to take action to eliminate them. Using occupational risk solely for insights into the existing status adds no value to the company and will not contribute to improving the quality of working conditions. This would reduce occupational risk assessment to a tool for merely describing the status quo rather than a driver of growth.

Occupational risk in hazard elimination

To take proper systemic action to improve the quality of working conditions, an organization needs to account for all significant legal and normative criteria which affect the decisions of its top management (Guidance…, 1996). This principle should be seen as equivalent to actions taken in any other area in which the systemic approach has been adopted. As part of the systemic approach, organizations need to employ any resources needed to achieve the desired improvement.

Based on the quality requirements which account for selected requirement areas, businesses may identify the need to have their top managements adhere to principles concerning the working environment, infrastructure, cooperation with suppliers and other business partners as well as care for natural resources (Górny, 2011).

An assessment of occupational risks arising in specific working environment provides information on the need to (Górny and Grzybowski, 2007):

- satisfy workstation design requirements,
- ensure that principles governing technical and organizational changes adopted to minimize hazards are used effectively,
- arrange employee recruitment processes with proper account taken of occupational risk assessment results,
- arrange occupational risk assessment processes by adopting related mandatory procedures or manuals to be followed within the organization,
- take advantage of worker dedication to assessing occupational risk and properly apply the findings of such

assessments,

- ensure that occupational risk assessments account for work methods and outcomes,
- ensure that occupational safety considerations are incorporated into the purchasing specifications stipulated in trade agreements,
- ensure that any corrective and preventive measures rely on the results of occupational risk assessments and on analyses of their impact on risk levels.

Legislative acts and legislation-derived systemic criteria call for measures designed to mitigate risks and improve occupational safety. In the systemic approach, such duties entail an obligation to ensure continuous improvement. The pivotal measures in this field include (Mazur, 2009; Górny, 2011):

- training in occupational health and safety and ergonomic requirements pertaining to specific workstations and the overall working environment,
- the acquisition, through proper training, of any required professional qualifications, competencies and knowledge on work organization at specific workstations with adequate account taken of technical and organizational requirements recognizing the needs of human operators,
- ensuring efficient and effective flows of information on safety requirements in the working environment,
- ensuring the use of effective employee health checkup methods to assess fitness for work so as to screen out individuals whose health condition may pose risks and/or contribute to aggravating hazards,
- ensuring safety in the performance of dangerous jobs, i.e. jobs where risks approach unacceptable levels,
- ensuring effective supervision over the working environment and the technical equipment in the place of employment, particularly equipment which may cause hazards, injuries and accidents leading to absences from work,
- defining rules of procedure to be followed in circumstances which may lead to accidents, occupational diseases and near misses.

The specific activities and tasks performed by organizations correspond to actions designed to improve the working environment. The scope of actions and the relationships they cover result from occupational risk assessments. Among the key efforts to improve the quality of the working environment is risk avoidance by applying technical solutions, technical machinery and equipment, materials and organizational work arrangements which pose no threat to employees and other persons who might enter the work area and the impact range of technical equipment (Gołaś and Mazur, 2008; Górny, 2011; Guidance…, 1996, Mrugalska, 2013). The need for such actions follows from their significance for the level of occupational safety, for ensuring proper supervision over the operation of technical equipment and for the extent of damage caused by improper operation of technical machinery and equipment.

The results of occupational risk assessments provide the information necessary to take (plan and carry out) appropriate corrective and preventive measures. Based on evaluations of the effects of actions and the extent to which actions contribute to working environment improvements, organizations choose the most fitting workstation equipment and work organization arrangements. By employing state-of-the-art solutions in their work systems, businesses mitigate the adverse impacts of hazards on safety levels and, as a consequence, improve working conditions. Working environment improvements must be achieved in all areas considered to be priority for business operations and all areas which affect improvements in the quality of the working environment.

Impact of occupational risk on the improvement of working conditions

The level of occupational risk should be seen as a criterion for defining the requirements which best ensure effective performance of work. Any incompliance would then signal a need for improvement. The development of optimal working environments by adopting solutions on the basis of risk assessment findings covers both the human as well as physical factors which are associated with creative work methods and which allow organizations to utilize their

full potential (Arsovski and Arsovski, 2012).

The goal behind eliminating hazards by means of occupational risk assessments is to rule out or reduce the impact of factors which are:

- dangerous and lead to injuries,
- deleterious and constitute a cause of work-related health conditions,
- strenuous and cause working discomfort.

Regardless of the specific nature of individual hazards, their elimination is fundamental for improving the working environment.

A company's growth vision may rest on the commitment of its management to adopt and deploy measures aimed at achieving the organization's safety goals so as to ensure occupational safety and hygiene for workers and protect their health. Associated closely with guidelines derived from the assessment of risks, such measures should allow companies to (Guidance…, 1996, 89/391/EEC):

- design their actions on the precept that the top management carries ultimate responsibility for the end result – the scope of such actions should be designed to help ensure improvement in worker safety,
- develop a strategy and internal-client orientation aimed at satisfying the needs of internal clients with respect of working conditions,
- adopt a process management system combined with elements of the continuous improvement approach to ensure sustainable success in efforts aimed at improving working conditions and the quality of the working environment,
- employ advanced managerial improvement tools and techniques suited to the organization's needs to identify and eliminate irregularities in occupational safety arrangements,
- improve employee competencies,
- build a safety culture to boost occupational safety.

When introducing control measures and reflecting on the need to modify any existing protections, it is critical to consider the option of applying technical solutions. Only after such solutions are found to be ineffective (or rather inapplicable), is it justified to resort to other types of protections (89/391/EEC). These include procedural solutions and individual protection items.

Improvement measures pursued in the systemic approach are shown in Figure 1.

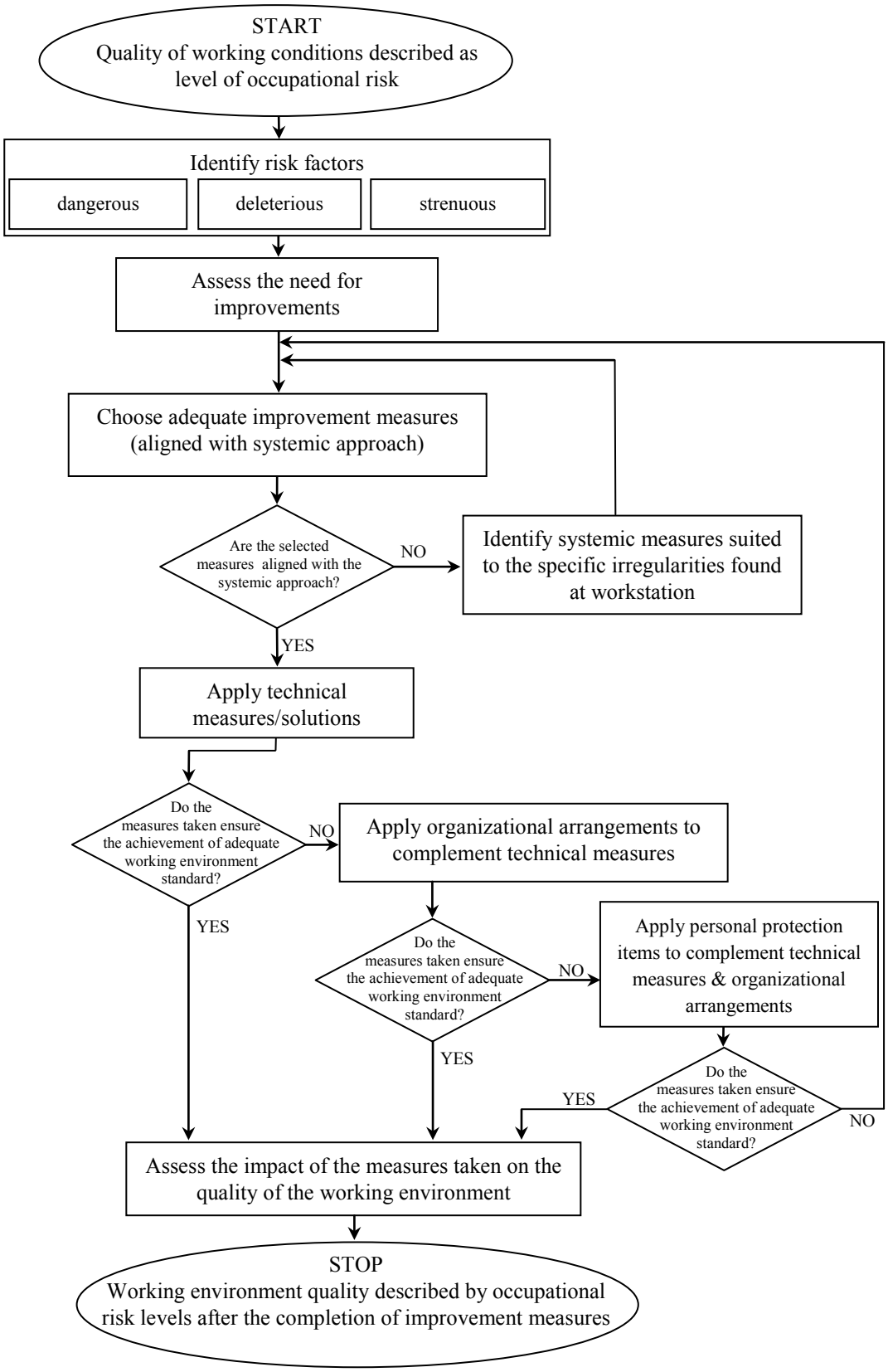

Figure 1. Flowchart depicting measures designed to improve the quality of the working environment. (Author's work)

IMPROVEMENT IN THE QUALITY OF WORKING CONDITIONS BASED ON OCCUPATIONAL RISK

In order to successfully improve the working environment in all of its quality aspects, it is crucial to rely on continuous improvement measures and arrangements. This applies in particular to systemic solutions designed for areas which are pivotal for ensuring the safe and effective performance of work. Such areas comprise, in particular, any criteria pertaining to the working environment which need to be incorporated into safety guidelines. The criteria include (ISO 9001, ISO 9004):

- the use of protective items to satisfy significant hazard protection criteria and allow workers to perform work,
- compliance with ergonomic requirements at workstations – this includes facilitating comfort and safety for all worker groups,
- proper choice of workstation location with account taken of social implications,
- recognition of conclusions from hygienic inspections concerning temperature, humidity, lighting, noise, vibration and air pollution in the working space.

Other requirements of equal significance for workers' ability to perform work in a given organization include the necessary production infrastructure comprised of working space, tools, machinery and equipment, support services, ITC and moving equipment (ISO 9001, ISO 9004). Assessments of worker's ability to work efficiently and of the quality of working conditions resulting from infrastructure improvements should be focused primarily on technical measures.

When assessing the technical solutions an organization has put in place, attention needs to be paid to their usefulness and availability and specifically to the scope of functionalities, specifications, cost of deployment, operation and disposal, environmental impact and conformity with safety requirements. To improve working conditions, an enterprise needs to undertake actions which will allow it to effectively carry out tasks and shape as well as oversee its working environment with proper account taken of safety requirements while mitigating hazard levels.

To respect working environment requirements which form part of their systemic enterprise management approach, organizations need to incorporate them into their existing enterprise management system. Such incorporation may serve as a starting point for developing an integrated management system. Occupational risk management would then become a part of the system and, as such, require that enterprises take action in various fields of their operation.

When seeking to improve the quality of the working environment in a systemic manner, it is vital to take preemptive actions to achieve absolute safety by adopting the required safety standards (Górny, 2011; Górny, 2012). Such actions require a prior detailed formulation of an action plan and identifying an adequate scope for such actions. The effort should allow enterprises to (89/391/EEC; Górny, 2011):

- prevent on-the-job accidents and occupational diseases,
- seek to continuously improve their working conditions,
- comply with legal requirements and worker expectations with respect of working conditions,
- ensure the resources and means needed to allow the organizations to achieve the required safety level,
- improve the professional/vocational qualifications of the workers with respect to safety to allow for the safe performance of work,
- recognize the significance of worker contributions to efforts to raise safety levels,
- reduce accident rates and, in effect, improve the organization's financial standing.

Organizations need to realize that a proper recognition of such outcomes in evaluating the benefits of solutions adopted in keeping with occupational risk assessment findings is necessary for shaping working environment quality in a systemic manner.

CONCLUSIONS

Occupational risk assessments should be seen as an integral part of the working conditions improvement system. By incorporating occupational risk assessment findings into the working conditions improvement scheme, enterprises can identify key issues for the specific jobs performed in their organizations.

By adopting and effectively deploying adequate solutions suggested on the basis of an occupational risk assessment, businesses gain the ability to:

- improve their occupational safety and, as a consequence, improve their accident standings (measured as the total number of accidents and cases of occupational disease relative to the total headcount or man-hours),
- gain an ability to make continuous improvements, particularly in occupational safety levels defined as continuous steady reductions of occupational risk,
- satisfy legislative requirements and meet any unwritten rules formulated by workers as an expression of their desires,
- improve worker qualifications, in particular with respect to occupational safety and worker's ability to perform work efficiently,
- boost the dedication of the management to efforts aimed at improving occupational safety.

The above actions should be seen as a starting point for further improvement efforts made with an eye to increasing the social engagement of organizations in the community in which they operate. Such a role is associated with responsibility towards all stakeholders. By identifying and overseeing the actual impact of their efforts on man (the workers they employ), organizations can evaluate workers' ability to perform work and accept the existing level of hazardousness as well as the risks associated therewith.

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Analysis of Psychosocial Risk in the Context of the Objectives of Macroergonomics

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ABSTRACT

The psychosocial risks in working environment can and must be coped with just like it would if they were physical, chemical or biological hazards. Yet the employer awareness in this field seems relatively small. One should recognize this as a fault because a working environment free of stress overload favors not only the workers' health but also may generate reasonable profit as enhanced productivity and increased quality of work may be noticed (Merecz, Potocka, Wężyk and Waszkowska, 2012). Ergonomic quality in contrast to previous does not depend on few strictly identified factors that may be influenced by user, but is a result of a number of elements of macro environment (Butlewski and Tytyk, 2012). It becomes necessary to better one's understanding of the concept of psychosocial hazard and risk connected with it to be able to evaluate and lessen the risks. In subject literature one can find many titles that suggest usage of risk managing paradigm to successfully manage psychosocial risk. According to this paradigm the correct identification of danger is most important and must be legible, simple and easy to apply. It seems so that the described in this paper checklists proposed by International Labor Office (ILO) meet these requirements.

Keywords: occupational safety, work environment, psychosocial risk, participatory ergonomics, checklists, stress prevention at work

INTRODUCTION

The basic requirement in designing work is its safety. Creating safe working conditions requires knowledge concerning operation reliability of not only the technical systems but also man – his physical and mental abilities. Analysis of causes of work-related accidents and occupational diseases indicates a high number of risks emerging from human behavior and improper organization of work. Research concerning causes in the human factor shows that neglecting hazards and insufficient concentration on work, are among others, reasons for accidents. In Polish workplaces that underwent inspection through the National Labor Inspectorate abnormalities connected with breaching in the range of schooling in work safety regulations as well as workers obeying them were noted. In the context of striving for increase safety at work in Poland (also to decrease the index of accidents) job inspectors especially look at the assessment of occupational risk associated with workplace and its quality – a wrongful assessment is fostering the arising of work-related accidents as well as a opportunity fostering occupational diseases. It must be emphasized that nowadays the physical chemistry part of work is not in contrast to the psychosocial one the main source of occupational risk (Widerszal-Bazyl, 2009). And although there is no one generally accepted definition of the term *psychosocial risk* experts agree about the problematic aspects generated by the term.

PSYCHOSOCIAL RISKS AT WORK

New risk factors

Over the years not only the types of risk occurring in the human environment have changed but also attitude towards safety. Work-related accidents as well as occupational diseases and pathological symptoms of behavior in a work place are the greatest factor suppressing market growth.

In the last decade huge changes occurred in organization and management of the work process. As a result, new risk factors arose as well as new challenges in the field of work safety regulations. Psychosocial risks are labeled as essential new coming risk factors (EU-OSHA, 2007; NIOSH, 2002). Changes in structure of the job market and the character of human activity have an impact on societies mental condition.

A decreasing number of employees is hired in sectors like heavy industry or agriculture, where the job in general is performed in difficult environment conditions and present many physical and chemistry hazards (noise, pollination, high temperature and so on) while employment in sector of services, performed often in big companies ; in foreign too, demanding closer than ever interpersonal contact It does matter that in the process globalization and related with it increase in competition. This forces employers to a more elastic approach to forms of employment. It also causes an increase in job intensity and a continuous willingness for change.

The feeling of overwork, too much responsibilities, falling behind on novelty, resistance to everlasting change, uncertainty of employment – all this is a more frequent with a worker today. As a result the physical chemical aspect of work is not the greatest source of occupational risk, but its psychosocial aspect is. Problems such as work-related stress or violence at a workplace that are related with psychosocial hazards are generally considered the main challenges for work safety (EU-OSHA, 2007).

International Labor Office defines psychosocial risk factors as the interaction between job content, management and organization of work process and other organizational or environmental factors on one hand and workers' needs and expertise on the other. In this aspect they correlate to the types of interaction that were proved that through workers' perceptions and experience are a threat to health (ILO, 1986). Psychosocial risks may also be defined in a simpler matter as such aspects of designing and managing work process along with the social-organizational which have the potential to cause mental or physical harm (Cox and Griffiths, 2005).

When saying hazard, one should have in mind every factor that may cause harm (http://psychostreswpracy.pl). A general division to physical risks (biological, biochemical, chemical and radiological) and psychosocial risk is accepted. When we consider the psychosocial factors as hazards we greatly widen the definition of work environment. Looking at the dynamic change in work conditions and the examined scale of exposure to psychosocial factors it becomes more often acknowledged that work environment consists of all material environment conditions (physical, chemical and biological factors) as well as non-material factors (psychosocial factors) within which work process takes place (Warchał, 2010). In contrast do classic hazards that are present in a work environment, ex. Chemical or physical hazards, one may not establish sanitary standards for psychosocial risks such as a TLV indicator (Threshold Limit Value) because the effects depend on both worker's trait (also hereditary) and specified configuration of the work environment (Merecz, Potocka, Wężyk and Waszkowska, 2012). Due to this one may not create a universal list of psychosocial hazards or in other words indicate the ones which cause stress to everybody and in every circumstances. In subject literature one meet with a listing of potential psychosocial occupational risks and many attempts to categorize them.

In the sphere of subject literature and based on performed research a safe set of psychosocial work environment factors that are experienced by workers and indicated stressful or potentially harmful was put together. This method reflected in creation of 10 separate categories concerning job characteristics, organization and management of work as well as other environmental and organizational factors that are potentially hazardous towards health. In specific conditions every one of the 10. aspects of work is causing stress and/or is directly hazardous towards health (WHO, 2010).

Figure 1. Psychosocial risks related to work (based on WHO, 2008)

Is stress a worker's personal matter?

Work-related situations are recognized as stressful when they are perceived as demanding significant requirements connected to work which not too well respond to the workers' knowledge and skills (competence) or their needs, especially if they have little influence on performed work and receive little social support in the workplace (Cox, Griffiths and Rial-Gonzalez, 2000). Work as a factor determining the wellbeing was a subject of extensive research that allowed to demonstrate relation between negative work conditions and health breakdown (ex. Floderous et al., 2009; Karasek et al., 1981; Wang et al., 2008). Wilkins and Beaudet (1998) examined work-related stress affecting the Canadian population of workers (n=9023).They found that among men work-related stress was accompanied by migraines and the sense of mental distress while among women – with work-related accidents. Employment insecurity was related to women' migraines. Large physical exertion was associated with work-related accidents regardless the gender. Little support from coworkers was related with men' migraines, and work-related accidents and sense of mental distress for women (WHO, 2010).

Work-related stress is a common effect that in a bigger or smaller way affects every employee. For most people a moderate stress level is beneficial – it energizes and motivates to action and increases effectiveness (Merecz, Potocka, Wężyk and Waszkowska, 2012). However when stress becomes too big and/or long-lasting and exceeds the efficient way of coping with it there might occur problems which one may observe not only on the individual

level but also the organizational level. Burden of the mind resulting from stress in some jobs has consequence not only for employee's results, his health and safety but also may be a critical factor for safety and health of others.

The mentioned earlier results documented diverse results of stress starting from changes in the emotional area and mental functioning, going through behavior and various somatic reactions. In the past it has been also proven that stress may be a risk factor for the development of infective processes, however it must be emphasized that a pathological stress influence arises when it is severe and/or long-lasting (Merecz, Potocka, Wężyk and Waszkowska, 2012). Somatic health disorders as well as mental health disorders (depression, anxiety disorder) are classified as chronic long term work-related stress product. It was shown among others that stress is a risk factor for disease development in the circulatory system, ailment of muscular-skeletal system (ex. lower back pain), escalates allergies, and is the reason for a decrease in body immunity (Merecz, Potocka, Wężyk and Waszkowska, 2012).

One must emphasize that results of work-related stress arising from the presence of psychosocial occupational risks in the work environment effect also employers. It was proven that workers who undergo stress show a negative reflection on team work, communication process in the company, decreases morale and commitment to work. Workers that are afflicted by work-related stress are less loyal to their employer, more often generate conflicts, are less productive (Tucker et al., 2009; Chen and Cunradi, 2008). Then absence due to illness caused by work-related stress usually takes longer than absence due to other reasons, and this also has a negative impact on a worker's productivity index (Merecz, Potocka, Wężyk and Waszkowska, 2012). Occupational stress due to its specificity is related to greater accident risk in during work; it is a deciding argument supporting the statement that attention to safety in work should also involve the elimination of psychosocial risks.

Psychosocial risk analysis – key elements

Labor code obligates employers to evaluate occupational risk on job positions. Whereas the aim for evaluating occupational risks is to establish the correlation between harmful factors and their results as and also establishing the risk arising from exposure to these factors. Every evaluation of occupational risk should be previously analyzed for occupational risk. This kind of analysis consists of:

1. gathering information about stress causing factors
2. identifying stress causing risks
3. evaluating occupational risk considering stress causing factors (Warchał, 2010).

The next step is appointing admissibility of occupational risk where one may encounter barriers of a mental nature concerning measurable stress causing factors. Appointing the acceptance level for stress risk is another problem. Going back to the psychosocial risk one must notice that the process of gathering information about stress causing factors is most crucial. The method of obtaining information about exposure to such factors is at will, but not negligible. One can use ready-to-use questionnaire and checklists or work on own ones. It is emphasized in subject literature (Warchał, 2010; Zawieska, 2007), to keep the interview just it is better to use such a questionnaire that carries out the psycho-metrical characteristics, both questions and their answers reflect the status of organization and workers against the results in group (of a population) of other organizations and workers (we speak of a standardized questionnaire). It is worth emphasizing the undeniable quality of tools that are constructed individually – at the time there exists a possibility to take into account non-typical and at the same time characteristic for every individual workplace psychosocial risk factors. Such a tool should feature a sure level of generality thanks to which when creating a new job position it will not be necessary to make changes in the questionnaire. It is good to remember that the form should be simple and easy to understand as well as accepted by workers. The most common monitoring instruments and evaluation of stress causing factors in an organization are:

- checklists (consisting of "YES/NO" type of question)
- surveys (ex. NIOSH survey)
- data analysis (ex. Productivity, diseases and accidents, fluctuation and so on).

STRESS – RECOGNITION, CONTROL, MODERATION

Prevention approach to stress in a workplace

Practice shows that too extensive objective data analysis, ex .of absence level may by nearly effective during the analysis of stress causing factors stage. This type of data shows the effects and not the reason for stress. However usability of checklists during the stage of analyzing data has been confirmed – it is a effective instrument used for collecting basic information about the quantity manner, this means the exposure of a defined number of workers to stress causing factors. Alongside checklists questionnaires are used to estimate work-related stress in a job position. In Nofer Institute of Occupational Medicine two questionnaires were developed:

- to evaluate job characteristics (for experts)
- for subjective evaluation of work (for workers).

They include questions concerning specific job characteristics that may be the origin of occupational stress. Basing on this one can tell the results of general work inconvenience in a specific job position and also evaluate the redundant inconvenient job characteristics. Evaluation is completed by experts – independent workers of an institution hired on different job positions.

In the Central Institute for Labor Protection – National Research Institute (CIOP-PIB) developed a questionnaire for monitoring psychosocial work conditions. It examines firstly the demands that are required by work, the range of control over performed work, type and level of support that is given to a worker as well as the worker's state of being.

Carrying out the evaluation of occupational risk in the aspects of stress it is worth to familiarize with International Hazard Datasheet on Occupations that was developed by specialist from International Labor Office, Israel Institute for Occupational Safety and Hygiene (IIOSH) and International Occupational Safety and Health Information Center (CIS). However taking into account the characteristics of stress causing factors checklists that are oriented on analyzing respective job positions are most effective. Moreover in the case of examining nuisance stress causing factors a subjective evaluation of work conditions of specific workers is essential. An individual perception of work conditions decides about its acceptance among workers and influences creation of psychosocial workplace climate (Kucharska, 2011).

Checklists in the field of ergonomics are a common instrument for analyzing deciding factors when it comes to work conditions. Next to NIOSH checklist used to identify ergonomic risk factors and Ergonomics Checkpoints (ILO) one should especially notice that checklists included in International Labor Office report: *Stress Prevention at Work Checkpoints* (ILO, 2012). It includes experts opinion stating that there are methods allowing to reduce stress level at work – most importantly identifying stressors, then take control over them and moderation. It is suggested to take a prevention approach to stress in a workplace and easy-to-implement checklists were introduced. The presented solutions are grouped in 10. categories:

1. Leadership and justice at work
2. Job demands
3. Job control
4. Social support
5. Physical environment
6. Work–life balance and working time
7. Recognition at work
8. Protection from offensive behaviour
9. Job security
10. Information and communication.

Identifying stressors

The report *Stress Prevention at Work Checkpoints* is a sort of textbook that includes not only outlines the

problematics of occupational stress and characteristics of the instrument but also detailed principles how to use checklists and practical pointers for those who perform such research. The list contains 50. checkpoints comprising 10 problematic issues. Authors suggest to develop your own list by choosing only the checkpoints that relate to the specific workplace. As a rule a list consisting of 20-30. is at its optimum. What rises particular interest are pointers from the authors concerning the initial process that predates usage of the list.

So in the report the necessity of a being well familiarized with the workplace is emphasized – gathering information about offered products or services, number of workers, working hours and so on. It is also important to design appropriately the field for research (company's department or organizational unit) – it is vitally important from the organizational point of view and especially when we have to do with a large workplace. Authors evidently and more than once encourage to spend time with workers (ex. during a break) and have a casual talk about stress before application of the checklist. It is very important to initiate discussion concerning difficult topics, prompt thought and reflection. Such behavior prepares grounds for careful filling out checklist by the workers and in a big matter guarantees the topic being treated serious.

The authors of the report also emphasize the importance and meaning of post-control meetings – discussions about the choices made in checklist (YES/NO/PRIORITY) is a excellent way for sharing own opinions, remarks and also point out the organizational area of work that are correct and positively received by workers. The scope of content of problems covered in the checklist (Checklist No.1) can be presented with a scheme:

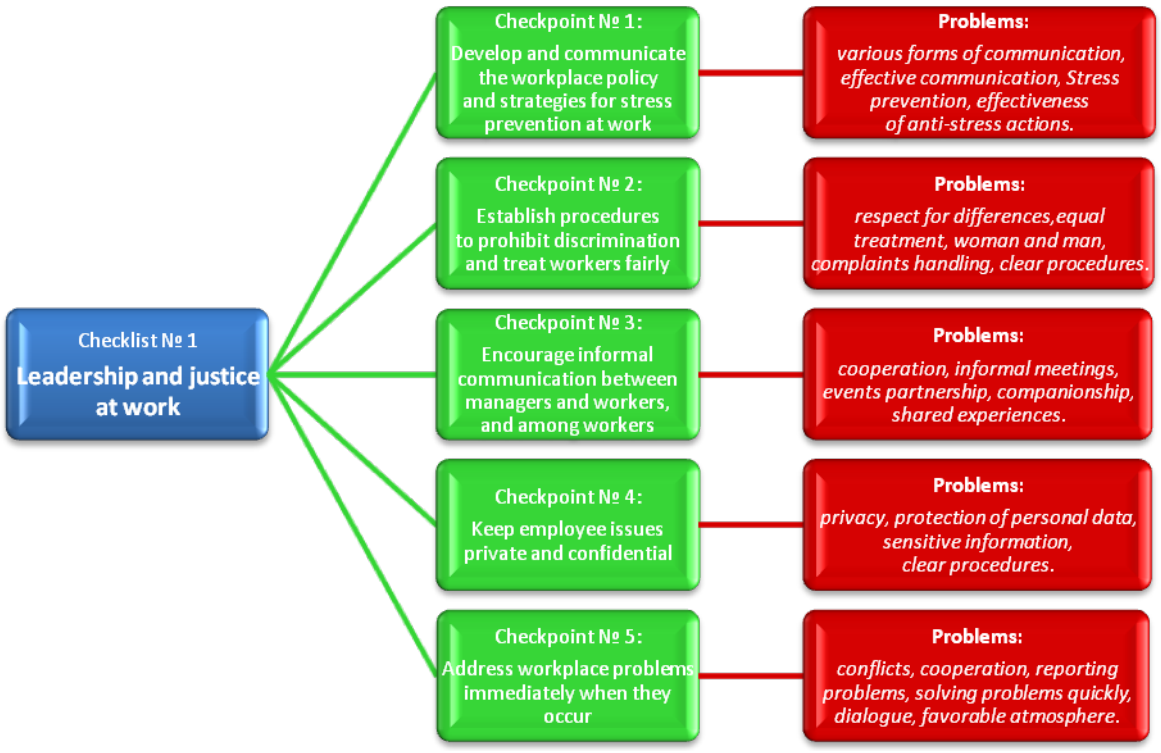

Figure 2. Checklist No.1: Leadership and justice at work (based on ILO, 2012)

Checklists proposed by the ILO are very detailed – the covered issues are explained in different contexts, overall they include pointers what to do next, many problems are illustrated. This instrument cannot require expertise knowledge – it should enable the employer to implement procedures or a group of company's workers (ex. work

safety service) – being workers they know best the characteristics of their working environment. Carrying out the analysis of occupational risk in the aspect of dangerous stress causing factors it is good to cooperate with the ones it affects, the workers themselves. Practically in the past years it turned out that in workplaces in highly developed countries benefit from participatory ergonomics (Kucharska, 2011), which with the workers participating in forming their working environment enables the connection of continuous optimization of working conditions alongside with increasing efficiency.

Problems identified – what next?

Stress in a workplace is strictly connected with working conditions and the way work is organized. Preventing stress in a workplace should be based on clear policy and a strategy to assure worthy work. It is significant that these goals are clear to all workers and managers because a common effort is essential to continuously better working conditions and the way it is organized. In the report *Stress Prevention at Work Checkpoints* it is emphasized that a close cooperation between the board and workers is required on a regular basis.

Preventing stress should be a part of occupational safety and a health managing system at a workplace. Currently it is acknowledged that the participatory approach – participation of managers, directors, workers and their organizations – is the best method for stress reduction in a workplace. This stress involves many factors – work schedule, work methods, working environment, balance between professional and private life and others. Such numerous and differentiated factors require a multi-aspect intervention, thus the need for participatory approach.

Solutions regarding workers' health protection against exposure to psychosocial risks in working environment were developed in developed countries. W Poland this area of prevention action is still marginal, and this is a consequence of relatively liberal regulations in this area, no guidelines for realization such programs, no sufficient qualifications for conducting such actions, and also because of no knowledge among the managerial staff in companies regarding the relation between exposure to psychosocial factors in a workplace and efficiency.

A systemic approach to the issue of safety which participation of both workers and managerial staff is a part of is a trusted way of creating a culture of safety and including the matter of safe work in everyday practice (Jasiulewicz-Kaczmarek and Drożyner, 2011). It is not easy but possible. It requires however effort and an individual approach as well as cooperation with the companies' workers. In this context one must recognize that limiting psychosocial risk and promotion of well-being in a workplace is in the area of interest in macroergonomics. Man and his sense of well-being are supreme, and at the same time the engine for civilization development (Złowodzki, 2003).

Unfortunately, health is rarely viewed as a main area of interest in business. However workers' health in a great manner influences the financial state of a company and next the company's development. While the managerial staff is interested mainly in the influence of workers' state of being on the company's business efficiency the workers are interested in the managerial and and working processes that influence their health. Both aspects must be considered parallel. It is worth noticing that managing psychosocial risk a secure support from the top managerial staff and convincing that strategical management of psychosocial risks, so showing the health and business benefits, both in the context of saving costs as well as value added seem to be most important. This can be illustrated in a perfect way with the example of flexible working hours, possibility of working at home, actions eliminating discrimination and mobbing behavior – these actions have a direct influence on the workplace atmosphere satisfying both workers and the managerial staff (Pęciłło, 2011; Misztal and Butlewski, 2012).

CONCLUSION

Civilization generates many problems related with human work that cannot be solved by one branch of expertise treating issues in a fragmentary way only from one point of view. A synthetic knowledge concerning work, which ergonomic is (Stachowski, 2003), allows solving these dilemmas by connecting problematics of many fields, ex. physiology, psychology, technical sciences, economics. *Organizational ergonomics* concentrates on issues like systems optimization called macroergonomics (Pacholski and Jasiak, 2011). The most important issues here concern communication in human resource management, workplace design, organizational culture and so on. Assuming that

the goal of ergonomics is to develop organizational and material framework for ensuring well-being of man kind – both physical and mental, the macroergonomic aspects will embrace even more areas concerning management, organizing work time, relation on the edge of axiology, sociology, psychology and pedagogy.

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Humanization of Work in Project Management

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ABSTRACT

The experience gathered in the course of many IT projects ranging from the simplest to the very complex, shows that the key adverse factors affecting the productivity of project teams are: the stress that accompanies designers in the development and implementation of IT projects, poor use of the intellectual capacities of individual project team members, excessive focus on design support tools at the expense of project quality, excessive adherence to a specific method of IT project management, the pressures of time and budget restraints on projects where labor intensity has been underestimated. According to many IT project managers, the treating of people as "spare parts" often jeopardizes project outcome. Managers commonly forget the simple fact that the intellect and personalities of every employee are different and that often neglected in accomplishing project goals by not helping individual staff members to achieve personal satisfaction. My practice shows that the choice of a design method has little effect on design productivity and often reduces it where the system needs continuous customization to ever new client requirements and restrict the operating freedom on individual projects contributing to less innovative outcomes.

Keywords: Project Management, Software Engineering, Requirement Engineering

INTRODUCTION

A study of the effectiveness displayed by our team[1] on software development projects performed between 2000 and 2013 shows that, in project management practice, excessive emphasis is commonly placed on the technical aspects of project management while neglecting the innovation side. We have observed that the use of standard software development procedures does not make a project more cost efficient nor speed up the design process. What it often does, however, is keep project team members from devoting their time to forging friendly relationships with one another. Practice has shown that mutual relations among designers are pivotal for creating an environment which will unlock the intellectual potential of individual project team members and inspire the team's innovative spirit. Software design managers need to recognize the influence of non-environmental factors on designer productivity and select management methods and techniques which will minimize the arduousness of intellectual work and bring out the innovation potential of the design team (Cushman and Rosenberg, 1991). Our observations show also that, regrettably, the present design practice is geared towards getting designers to become as "efficient" as possible and to making entire projects highly effective. This makes design work extremely strenuous and often described as "the dark side of intellectual work". The reason for this lies in underestimating the importance in the design process of the human factor and, in particular, people's intellectual and psychological dimensions. In searching for ways to make project teams more productive, the majority of project managers choose to use various CASE support

[1] Since 1990, during his employment in PPH Softmar, the author has led numerous deployments of management information systems. Between 1990 and 2001, he and his team developed and unrolled dozens of proprietary applications in logistics and finance.

techniques in design work and project management. Such tools are viewed as facilitators for the efficient development of complex IT systems which are more functional, reliable and efficient and allow for easier maintenance and system transferability.

The majority of CASE functionalities are designed to help gather knowledge on the project at hand, create a knowledge-base for future reference, build a project management model and develop a knowledge and team management strategy. Despite their widespread application, such tools do little to keep developers from exceeding deadlines or overspending budgets. . Such problems are particularly pronounced in innovative projects where designing is non-linear and involves a sequence of fixed steps performed up to a certain point in the process after which the developers go into feedback loops not envisioned in the initial project model. In non-linear design, the structure of a software development project may be unknown at the outset. The knowledge which has been acquired tends to be used to unify software development procedures rather than create the kinds of ergonomic conditions for software development that are certain to bring out innovation.

Stress - new challenges for humanizing the work of software designers

Uncertainty in project management

Many project managers lack the means needed to protect projects from failure caused by unforeseeable random circumstances. This applies in particular to innovative projects. In specific project circumstances, decision-making depends on one's knowledge of the possible developments. Each decision boils down to the choice of one of a range of possible solutions. That is why, before reaching a specific decision, one needs to assess the impacts of all the possible options. . IT project management allows for defining four situations in which solutions need to be selected which is similar to decision-making theory (Buslenko,1967):

1. Well-defined situations where the impacts of actions result clearly from specific parameters. Such circumstances occur where specific individuals are to be assigned to a project – the project costs will then be calculated on the basis of the base pay and overtime rates of such individuals and using a specific cost allocation method (proportionately, at the start or completion of a project task). In such a case, decisions are said to be made in well-defined situations (spaces).
2. Random situations in which the consequences of decisions depend on parameters which may offer some degree of foreseeability and can be defined by means of probability distribution. Such circumstances may occur in repeated projects when the knowledge repository provides an idea of the time needed to produce specific repetitive project parts – the estimates are based on the time taken by other programmers to develop the same program part in other projects. Experience shows that programmers tend to differ widely in how efficiently they can design the same program segment. In such circumstances, decisions are said to be made in random situations (spaces).
3. Uncertain situations are circumstances occurring commonly in managing innovative projects where the impact of decisions is affected by factors which are uncertain, i.e. factors which may be subject to change and offer no indications as to what specific changes could be expected. In the case of actual IT projects, the choice of resource types and its use is made at the stage of project definition which is when one is not aware of the time to be allocated to the performance of individual tasks. On many innovative projects, decisions on how to order tasks and associate interdependent tasks with one another tend to be postponed. Innovative IT projects certainly meet the definition of projects on which decisions are made in uncertain situations (spaces).
4. Conflict situations in which certain parameters which affect the consequences of decisions made in the course of design work result from progress made on competing simultaneous projects. Circumstances in which designers are simultaneously engaged on multiple projects are common in companies which pursue entire IT project complexes – such circumstances produce conflict space. Under such circumstances, the impacts of decisions differ widely and depend on the circumstances at hand and the responses of parties to conflicts. Decision-making in the conflict space may be described with the language of the game theory which investigates conflict models in which project managers are given a choice from one of many possible strategies.

The consequences of choosing specific design options are often assessed by common sense and precisely this is a common source of trouble. Typically, the selection of impact assessment criteria is followed by a quantitative evaluation of the consequences of choosing a specific project approach.

Information stress

Information stress results from the inability of employees to process excessive input data supplied to them in the course of software development or from not having enough information to complete their work. At the start of the design process, it is difficult to tell which information will be of use and value. Information stress results from the discord between the volume of information provided during software development and the individual processing capabilities of the designers. Such stress can be seen to affect developers with varying intensity at all stages of software design and deployment – it affects all persons involved in creating software as well as its would-be users (who are also involved in the design process). Experience with a great number of IT projects which varied in the degree of their innovation and complexity points to the following key factors which undermine the productivity of designer teams is to stress experienced by designers in developing and implementing IT projects results from:

- their post-go-live accountability for software defects;
- their inability to process a flood of input data supplied during software development or having to complete their assignments based on incomplete information;
- having to cope with gaps in knowledge, especially technological, needed to complete their project,
- changes to software requirements made in mid-project, especially by the prospective user.

Figure 1 shows three key non-environmental factors which affect the ergonomics of software development and which can be influenced by team manager.

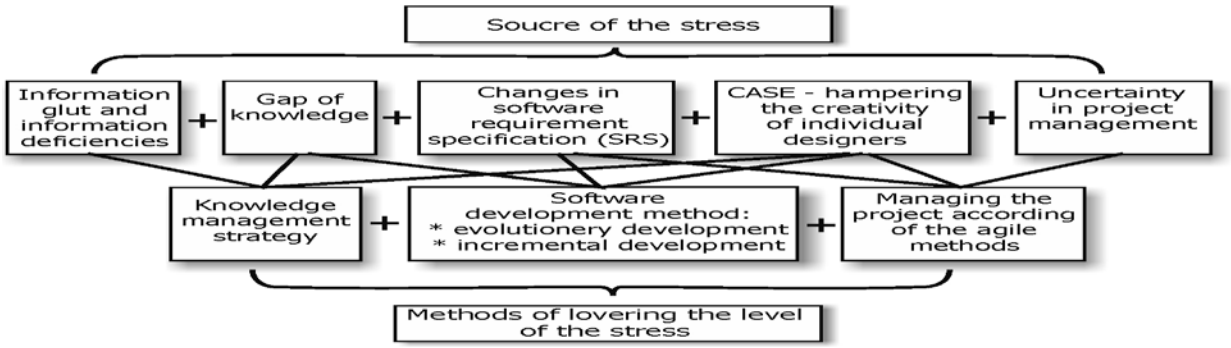

Figure 1. Non-environmental factors affecting key ergonomic conditions for software development.

A number of factors determine an individual's sensitivity to information stress. Such factors include inquisitiveness manifesting itself as hunger for knowledge, temperament, personality and rational intelligence. Information stress may be experienced at various stages of information processing (Ledzińska, 2009), (Hankała, 2009). Excessive or insufficient information at various design stages may affect the severity of the stress experienced by designers. Stress may also harm the working efficiency of developers who are bombarded daily with aggressive information. The resulting information glut may impair their ability to process and select information causing them to make misguided judgments. Information stress may distort cognition and result in delivering products based on false or incomplete assumptions. In extreme cases, it may contribute to project failures. Our observations of dozens of software development projects suggests that designers experience the most severe information stress while identifying and examining functional software requirements. At this stage, conflicts abound due to excessive functional demands made by various groups of would-be users as well as functions left out by designers and the system functionalities unnoticed by future software users.

In designing large systems in projects which go on for months on end, requirements concerning specific functionalities may change considerably over time. This may be due to the persons responsible for selecting software functionalities changing their minds, changes in the effectiveness factors applied on the business parts of IT architecture for which a given software package is being developed and changes in the legal environment of a given enterprise. The practice of software design is a complex process of compiling documentation to support specific ideas for designing a model of the finished system. Software design documentation usually contains specifications of requirements as well as contextual, behavioral and data models and the documentation necessary for software rollouts and testing. The design documentation should indicate the purpose for which specific software is being developed, its structure and functionality. It should also recommend configurations to ensure proper software installation and offer operating guidance for software users. Software documentation should come in either a simplified or a full format. A good example are web-based applications operated in a dispersed processing environment which require full documentation. In their case, the logical model developed in, for instance, the UML technology, should be captured in five different system model perspectives, i.e.:

- the perspective of sample uses expressed in diagrams of applications and activities (used for system behavior modeling),
- the process perspective developed by means of class and object diagrams (depicting system structure models) and activity diagrams designed to present a model of the states of a given process and the transitions across such states as well as a control flow model,
- the implementation perspective presented by means of component diagrams,
- the implementation perspective presented by means of implementation diagrams,
- the design perspective expressed by means of class, interaction and state diagrams used to model system behavior**.**

For each of the perspectives, developing project documentation requires gathering a huge amount of information in the repositories of various CASE tools. In practice, even where unlimited and equal access to data has been ensured for all designers assigned to a specific project area, it may still be impossible to properly select and classify such data by relevance. It may therefore happen that the available information on functional requirements for the software in development may be mutually complementary but also mutually exclusive, overly general or overly detailed at a given stage of system design. A common problem associated with the use of CASE tools in designing IT systems is to ascribe information to a specific design stage at which it is to be used, which results in data overloads at specific stages. While leading several software design teams in the last two years, I have noticed that demand for access to project knowledge varies from one designer to another. Many have shown a great desire to learn all details of every issue. Others showed more restraint in seeking to obtain a wide range of information, which did not at all mean their performance was in any way inferior. While leading several software design teams in the last two years, I have noticed that demand for access to project knowledge varies from one designer to another. Many have shown a great desire to learn all details of every issue. Others showed more restraint in seeking to obtain a wide range of information, which did not at all mean their performance was in any way inferior.

Methods of lowering the level of the stress

Knowledge management strategy

A key role in developing software is played by the intellectual resources of project teams, i.e. their knowledge. The knowledge used to produce software may be either open or hidden. As knowledge grows, it is placed in repositories available to designers and ready for use on a wide range of projects. Multiple use of the knowledge stored in CASE tool repositories is believed to be critical for rapid software development and expected to streamline the design process. The knowledge held in such repositories concerns software design, implementation and testing. The options for its use are numerous and depend on the knowledge management strategy adopted for a given design project. Three distinctive knowledge management strategies are available for managing software development. These are the knowledge codification strategy , the knowledge personalization strategy and strategy mixt (Jashapara A., 2004), (Borucki, 2011).

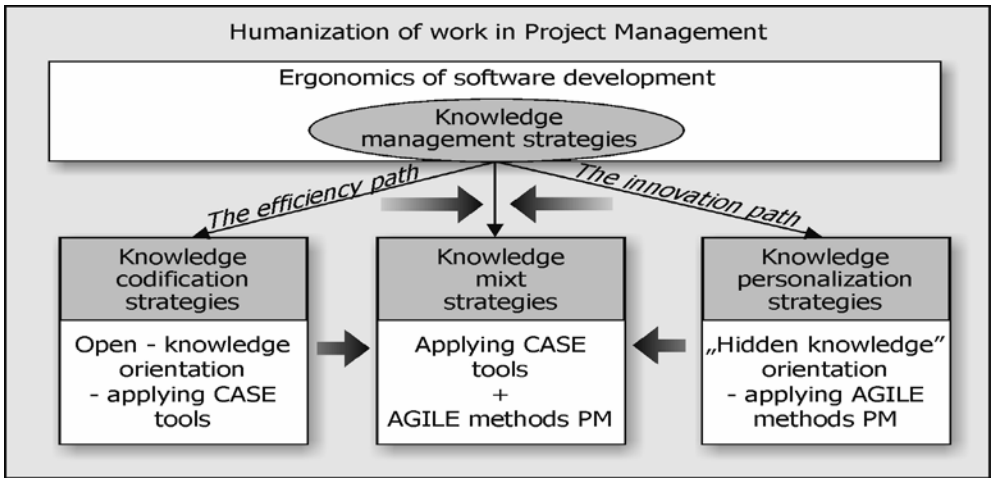

Figure 2. Alternative approaches to the knowledge management strategy.

As proposed by the knowledge codification strategy, project management involves rational gathering of knowledge on technical issues encountered in the design process and inserting it into databases, procedures and the documentation of logical and physical models developed during a project. The use of a knowledge codification strategy in IT project management resembles approaches to repetitive production where the technological process of producing a product follows a prescribed structure and comprises such individual components as operations, measures and items. Each component of the technological process employed to produce a machine part is described in great detail in a database (of standards) in terms of the depletion of physical and financial resources, machine and equipment uptime and labor intensity. Similarly in software development, the primary purpose of the information held in CASE tool databases is to build logical and physical software models suited for repeated use on various projects. The knowledge codification strategy is intended to make the software development process repeatable and base it on well-tested components and development methods. The knowledge codification strategy requires the use of expensive technology to apply CASE tools. It entails high costs of strict compliance with the design and documentation principles stipulated in CASE manuals. The knowledge codification strategy makes it necessary to use CASE tools. Based on two decades of experience in managing IT projects, we have grown somewhat critical of the use of CASE tools (Borucki, 2012).

On the down side, CASE tools undermine designer productivity by contributing to:

- limiting the creativity of software designers;
- preventing osmotic communication among members of the same design team and across multiple design teams assigned to a single project;
- making the design process more rigid by strict adherence to the design methodology imposed by CASE tools;
- compounding project management problems wherever the design process becomes non-linear and random;
- imposing limits on the roles assigned to design team members;
-"thoughtless" work resulting from strict reliance on knowledge provided in the CASE tools database;

An overview of successful IT projects in recent years, particularly those relying on internet technologies, shows that a key to their success is to employ a proper knowledge management strategy which helps bring out and effectively utilize the intellectual potential of individual design team members.

Another approach to project management is to apply the knowledge personalization strategy. In the context of project management, such a strategy places emphasis not as much on design supporting technology but rather on personnel improvement by mutual interaction intended to share knowledge and employ designer creativity in problem solving. Such a mutual exchange of information on problem issues encountered in implementing various project components promotes innovation and mitigates failure risk. Managing projects in keeping with the knowledge personalization strategy does not entail any additional expense.

Ergonomic software development methods

The requirements put to designers are ever more demanding in terms of the time allowed to deliver new software services. Requirement changes are managed in the four stages of change identification, change analysis, change monitoring and change planning. All requirement modifications need to be examined not only for implementation issues but also in terms of the time and cost of their adoption. In a rapidly changing environment, requirements management becomes an essential skill of software engineers (Berenbach et al.,2009). Due to highly changeable business models and shorter software modification time, application developers are forced to resort to adaptive rather than predictive and non-linear methods which allow for the structure of a given project to be partially unknown at project launch as the design project includes feedback loops decisive for the definitions and solutions adopted further into the design process. Such an approach to software development is only possible when knowledge management in the project team follows the knowledge personalization strategy. The strategy aims at osmotic communication which allows exchanges of information among project team members on the basis of equal access. Project team members are granted access to all project information regardless of whether such information is of direct relevance for the design tasks they perform or concerns another set of responsibilities. The assumption is that one can never be sure if a given piece of information will not be needed further in the project and turn out to be helpful in solving a problem which cannot yet be foreseen. If the knowledge codification strategy is applied in software design management resulting in extensive use of CASE tools, volatile requirements will wreak havoc with painstakingly composed project schedules and prevent clients, i.e. future software users, from intervening on an ongoing basis. This is because to intervene in such a manner, the clients would first have to learn the language and detailed rules of using specific CASE tools. The benefits of replacing CASE tools with the knowledge

personalization strategy become obvious on very unique and challenging projects conducted to highly changeable software design requirements.

In the practice of IT systems design, two of the many available software development methods are considered to be ergonomically sound in terms of knowledge personalization strategies and incremental development . In both of these methods, project success depends chiefly on the effective use of all creative potentials of individual designers working together and on the creative collaboration with the future software user. Such an approach to working with the prospective system user allows the client to accept the proposed designs much easier as the client is involved in design development by providing its business expertise to contribute to defining requirements and testing individual design components.

Evolutionary development

One method of software development is the evolutionary approach in which a preliminary (working) software version is created and submitted to the user for preliminary approval of the system requirements referring to the basic functional specifications (Sommervile, 2003). At this stage of software development, designers collect feedback from the future user which they subsequently incorporate into the successive intermediate prototypes. The evolutionary development method requires that software specifications, software development and software approval proceed in parallel. A diagram illustrating evolutionary development is provided in Figure 3.

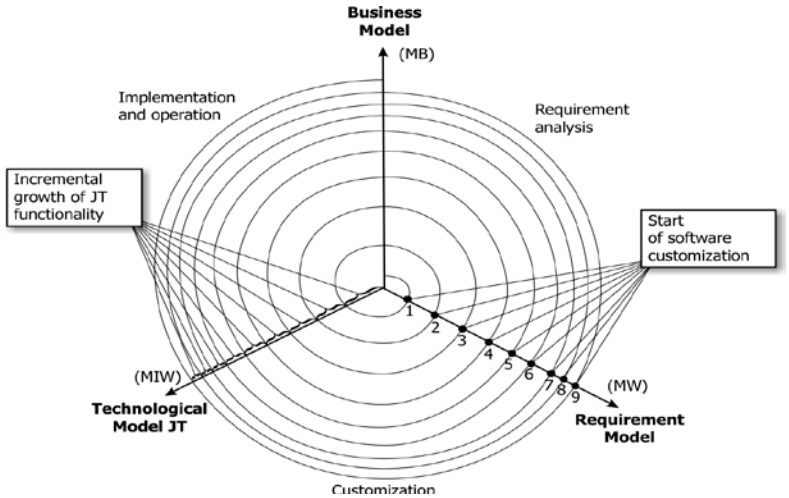

Figure 3. Evolutionary development.(Adopted from Borucki and Pacholski ,2010)

Evolutionary development allows one to accept requirement changes in the course of software development. By providing the software user with intermediate versions, one makes gradual adjustments of the software to meet individual requirements. As the experience of many software projects demonstrates, evolutionary development is well suited for small as well as large programming projects.

Two evolutionary development models have emerged in business practice (Sommervile, 2003):
- in one such model, software development begins with the requirements which are best known to designers as they have been applied on other projects or constitute core functional requirements of vital importance for satisfying the business needs of future software users. The literature describes this sort of evolutionary development as “research-based”,
- the other type of evolutionary development, known as “throwaway prototyping”, entails developing and providing the client with a software prototype to be tested to arrive at the ultimate version of functional requirements. In practice, the client is provided with multiple successive prototypes, some of which are discarded after preliminary assessment. This software development method is used commonly in designing the modules of large software systems.

In both types of evolutionary development, software specifications are developed incrementally to allow the future user to gradually gain insights into designer intentions and respond on whether the functional solutions in the software meet its expectations and comply with the company's business model.

Our vast practical experience proves that the evolutionary software development method reduces the negative implications of asymmetries in development knowledge between system designers and users. Such asymmetries are one of the main causes of failures of business management software projects.

Incremental development

Another ergonomic approach known as incremental development**,** clearly helps create an atmosphere of cooperation which reduces the overall adverse effects of stress resulting from information gaps and the variability of requirements seen on most software development projects (Sommervile, 2003).

A distinctive feature of incremental methods used for software development is that they allow clients to:

- take part in each stage of design,
- defer certain decisions on the functionality of software (or at least selected modules) until they are fully familiar with issues and experienced with previous software increments.

The incremental software development method provides clients with successive "increments", each of which may well be seen as a project in its own right. A diagram of the incremental development process is provided in Figure 4.

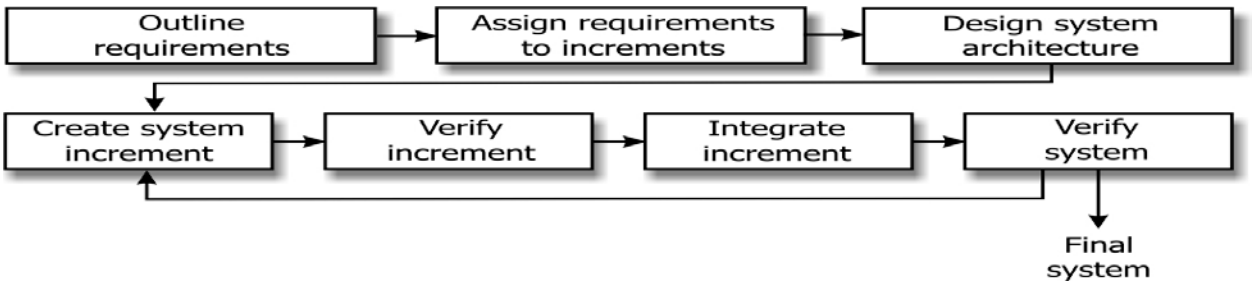

Figure 4. Incremental software development.(Adapted from Borucki and Pacholski,2010).

At the initial stages of software development, the client is expected to show the designers which functional requirements need to be satisfied first with the successive increments. An increment should satisfy a certain orderly version of functional requirements. Every increment is built around a full cascade structure made up of definitions of requirements, the design, implementation, testing, integration and the testing of the complete sum of individual increments which the would-be user has identified as its top priority. The key functional requirements should be delivered in early increments. The designers' job is to work closely with the client to identify such increments.

The incremental method of software development makes it possible to deliver the parts of the system the client cares most about at very early stages. The client gets to experiment with such system parts to learn more about the system. Clients may also provide their feedback on how satisfied they are with system functionality and how the increments help them perform the requested services and define further increments, i.e. draw up a list of system functions to be delivered in the next increment. To ensure the mutual consistency and integration of individual increments, it is necessary to develop a preliminary system architecture model comprised of three components: a business model, a requirements model and an implementation model. The preliminary system architecture model should reflect a specific level (view) of system abstraction to allow the future user and designer to define individual increments, specify functional requirements and estimate project costs, including the costs of building the technical infrastructure required for software implementation.

Agile software development methods

The best software development method is selected by a number of criteria, the most critical ones being project size, project complexity and the degree of involvement of the future user in software design. The term agile software

development describes the ability to produce software quickly in response to fast-changing requirements (Martin and Martin, 2009). Project team leaders prefer the so-called light customization methods:

- whose design is human-factor-oriented as they allow for software engineer creativity ,which are more adaptive then predictive meaning that IT designers go through a *system life-spiral* in the iteration process as they develop successive prototypes and then verify them against updated requirements,
- which are non-linear meaning that the ultimate structure of a programming project may be defined only partially at project launch and fine-tuned through the feedback loops at successive stages of development.

Most IT projects are one-off ventures. The choice of a particular tactic is seen as vital for running them in a structured and consistent manner. . Such documentation helps to document progress (and prepare bills of quantities) as well as to develop designs at the maintenance phase of the software lifecycle. Another anticipated advantage of completing full design documentation was the added capacity to manage human resources, especially at times when unforeseen events arise. Unfortunately, the practice of applying rigid software development rules has killed creativity as processes and tools take precedence over technical solutions and client satisfaction. An Agile Software Development Manifesto was announced on February 11-13, 2001 in Snowbird, Utah, USA. The authors of the Manifesto sought to change the existing rigid rules of forcing software developers to apply a prescribed method for drawing up design documentation in software design practice. The authors of the Agile Software Development Manifesto devised 12 principles in an attempt to define a paradigm for developing software whose distinguishing feature is the so called agile programming used in its development which differs significantly from the common variety of software development (Martin and Martin,2008) , (Highsmith, 2007). The approach focuses on:

1. **Client satisfaction.** The software designer's top priority is to satisfy the client by delivering, as soon as possible, software that meets the current requirements imposed by the company's business model.
2. **Changeable needs.** One must accept that needs will change even if defined late in the design process. Software designers should not shy away from clients ordering software modifications who then change their minds and redefine previously agreed requirements. The design team should strive to develop a flexibly structured product in anticipation of new demands. The ability to build software in an environment of frequently changing needs is a powerful asset of programming firms that will definitely set them apart from other providers of such IT services. A design team that is open to change will be more likely to recognize the problems and expectations of future software users. Agile software development prolongs software lifecycle. Combined with customization, the approach offers programming firms a substantial revenue potential as software is a product that generates customer loyalty. The longer customers use a given product, the stronger their attachment.
3. **Frequent delivery.** In keeping with the above rule, software developers should divide the product delivered to their clients into increments (by the iterative software development method) which represent successive software versions. Each such version builds on its predecessors. Early versions should focus on the most challenging and controversial functionalities. Frequent delivery of software increments allows designers to verify the extent to which their product meets client needs. This mitigates the risk of project failure and helps tighten the relationship with future software users.
4. **Closer to business users.** The key prerequisite for the success of IT projects is to work closely with future users at each stage of software development. By recognizing business problems and learning about a client's business model early on, designers can define software increments in response to client needs. What is more, business and programmer jargons are "tribal languages", as it were, imbued with technical terminology that stands in the way of communication between the two parties. Close cooperation between programmers and business clients alleviates the problem.
5. **Reliance on talented and well motivated members of the design team**. IT project managers often believe that designer effectiveness depends primarily on their technical skills and working time management. To increase designer effectiveness, managers seek to standardize design procedures and processes by using CASE tools and pressurizing their people to work longer and more efficiently even at the expense of product quality. Such an approach to designer work stems from the fact that many managers graft their human resource leadership practices from production floor. The common claim is that a well-managed design team can be changed in mid-project without compromising project completion (Marco and Lister, 2002).
6. **Talking and "osmotic" communication is the best way to exchange information among design team members.** The authors of the agile software development approach believe that one-to-one conversation is the best way to exchange information within the design team. Documents and other written matter may only supplement oral messages. One should therefore arrange shared space in the workplace for team members to meet and freely exchange information (Marco and Lister, 2002).
7. **The key measure of design work progress is properly working software.** The software delivered to client should come in well thought out increments that contain functionalities needed to support business processes. Such an approach will help assess progress in satisfying the needs of future software users. Hence, design project

progress is measured by the number of functions that meet client expectations rather than the size of documentation or the number of source code lines.

8. **Continuous and sustained software development at a steady pace.** Agile designs are suited for frequently changing requirements – their development methodology is adaptive rather than anticipatory meaning that product development is iterative (and follows e.g. the spiral pattern). Each iteration ends with the production of a prototype to be verified against an updated requirements model. The work should continue at a steady pace over a long term to ensure the resulting software meets high quality standards.
9. **Technical perfection.** Agile projects are not linear meaning that early on in design development some of their components are not sufficiently recognized. As a consequence, care for technical details will help develop a source code to the highest quality standards.
10. **Simplicity.** Agile software development is suited for small and simple projects by the rule of "tailor-making" to meet current needs. One should develop customized designs in response to the clients current business needs while remaining open to change and retaining scalability to allow for easy modifications of both the software as well as the system's logic model documentation (e.g. in UML).
11. **Self-organizing design teams.** Successful agile design must allow for the creative working style of each designer and creative client relations. Agile development designers should themselves assign tasks to individual team members and decide how to approach them in the best way. The team members should rely on mutual osmotic communication. This will ensure equal access to project knowledge for each team member. Each designer should be allowed freely to comment on the work-in-progress while taking responsibility for the total team work.
12. **Continuous improvement of organization, operating procedures and team communications.** Agile design requires continuous adjustments of teams to changing client demands. A team's ability to adapt to new working conditions is pivotal for project success.

The authors of the Agile Software Development Manifesto suggesting that the way to effectively manage personnel is to allow designers to adopt an individual working style. Bear in mind the basic fact that each employee has its own unique personality which needs to be recognized in project implementation by ensuring the designers are personally satisfied.

CONCLUSION

Our research has revealed the following leading causes of difficulties in managing innovative IT projects to support management:

1.The non-linear nature of management software design,
2.Inadequate scheduling methods failing to recognize the random nature of certain schedule inputs and uncertainties
3.Asymmetrical access to all project information by project developers,
4.Project managers keeping team members from showing initiative and limiting their roles,
5. Rigid adherence in the design process to the regime of a specific design methodology
6.Applying CASE tools without adopting measures to assess the quality of designers' performance,
7.Hampering the creativity of individual designers.

In order to manage software development effectively, advantage needs to be taken of the knowledge held by each design team member. This is to ensure that the resulting software meets the requirements defined by its future user and arrives on time and on budget.

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From ICT-Machine Determinism to a Socio-ICT Organic Design of Knowledge Sharing Systems

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ABSTRACT

The transfer of knowledge between individuals, groups, practices, communities or systems is regarded as Knowledge Sharing (KS) in organizations. Research suggests that understanding social interaction between different interest groups within an organization is a critical component of effective KS. The relevance of social interaction approach has been debated in areas such as systems design, organizational process redesign, process improvement and artificial intelligence. Organizational science literature also highlights that information and communications technology (ICT) network structures provide insight about the communication patterns of individuals working in an organization. Therefore, an understanding of the ICT networks at play needs to be viewed as an essential element of the design of KS systems in organizations. We posit *Mechorganics* in terms of 'the synergistic combination of civil mechanical systems engineering, social network dynamics, ICT and the management of interconnected knowledge, information (and data) infrastructures in the designing and composing of adaptive (resilient and sustainable) organizations'. It is further suggested that organization structures have both a formal and informal structure that may be considered to be a coalition of individuals, with implications for methods of communication and collective decision-making and taking, In this paper, we provide a background to organization as a network of people.

Keywords: Techno Determinism, Socio Design, Knowledge Sharing, Strengths of Ties, Structural Holes, Mechorganics.

INTRODUCTION

The transfer of knowledge between individuals, groups, communities or systems is regarded as Knowledge Sharing (KS) in organizations (Davenport and Prusak, 1998; Hansen and Von, 2001; Alavi and Leidner, 2001). Research suggests that understanding social interaction between different interest groups within an organization is a critical component of effective KS (Pickering and King, 1995; Ivari and Linger, 1999; Tuomi, 1999). The relevance of a social interaction approach has been debated in areas such as systems design, organizational process redesign, process improvement and artificial intelligence per se (Wigand, 1988; Nonaka and Takeuchi, 1995; Pan and Scarbrough, 1999; Davenport, 1999, 2000; Earl, 2001). The social approach for designing KS is based on the argument that communication between individuals, teams, groups, and communities is critical to the development and sustainability of a knowledge-creating organization (Argyris and Schon, 1978; Kogut and Zander, 1992; Watson, 1999; Levine, 2001). It is also suggested in studies that an appropriate structure of KS is essential for facilitating effective sharing in organizations (Davenport et al., 1998). Specifically, we suggest that KS is dependent

on the structure of the social communication network at play in an organization (D'Eredita, Hossain, and Wigand, 2002; Hossain, D'Eredita, and Wigand, 2002).

We posit *Mechorganics* in terms of 'the synergistic combination of *civil* mechanical systems engineering, social network dynamics, ICT and the management of interconnected knowledge, information (and data) infrastructures in the designing and composing of adaptive (resilient and sustainable) organizations' (Hossain, et al. 2013). Mintzberg (1979) recognizes that organization structures have both a formal and informal structure. Meanwhile, organizational science literature suggests that every organization is a network of people (Cyert and March, 1963; Mueller, 1986; Charan, 1991; Nohria and Eccles, 1992; and Stacey, 1996). Consequently, an analysis of the ICT network can help us in understanding the information exchange, patterns, coalition and power of the individual members in an organization (Wigand, 1988; Bonacich and Bienenstock, 2000). In the legitimate network, interactions or links are either (i) formally and intentionally established by the powerful members of the organization or (ii) established well-understood, implicit guiding principles, which is accepted by the members of the organization (Stacey, 1996). On the other hand, the shadow network consists of links that are spontaneously and informally established by the individuals among themselves during the interaction process in the legitimate system (Stacey, 1996).

Organizational science literature also highlights that communication network structure provides insight about the communication patterns of individuals working in an organization (Wigand, 1988). An understanding of the communication network at play needs to be viewed as an essential part of the design of KS systems in organizations. There is also a tension in the organizational structure, strategy and process literature when applied to KS in organizations. Studies suggest that organizations should not start with structure but with a task-and-person based foundation that incorporates both authority and responsibility (Drucker, 1974). Consequently, the design of the KS structure should be based on the study of the existing communication structure. Communication networks may suggest how individuals, groups, communities or systems interact in an organization and can be used as a basis for KS process of an organization (Davenport and Prusak, 1998; Hansen and Von, 2001; Alavi and Leidner, 2001).

It is further suggested by Mintzberg (1979) that organization structure have both a formal and informal structure. Formal organizational structure is usually represented by the organization chart and widely accessible by the internal and external members. It is also suggested in the organizational science literature that every organization is a network of people (Cyert and March, 1963; Mueller, 1986; Charan, 1991; Nohria and Eccles, 1992; and Stacey, 1996). An analysis of the communication network can help us in understanding the information exchange, patterns, coalition and power of the individual members in an organization (Wigand, 1988; Bonacich and Bienenstock, 2000). The distinction between formal and informal organization structure can be drawn by looking at the types of interactions, or links, between individuals or agents in an organization. For example, the legitimate network refers to formal structure and the shadow network refers to the informal structure of an organization (Stacey, 1996). In the legitimate network, interactions or links are either (i) formally and intentionally established by the powerful members of the organization or (ii) established well-understood, implicit guiding principles, which is accepted by the members of the organization (Stacey, 1996). On the other hand, the shadow network consists of links that are spontaneously and informally established by the individuals among themselves during the interaction process in the legitimate system (Stacey, 1996). It is also evident that the shadow system does not coincide with the rigid boundaries of the legitimate system. Shadow systems are classified to have porous boundaries and are considered to be the principal route for interaction between individual agents in an organization or in an inter-organizational network (Stacey, 1996). We argue that the KS system needs to be designed by conducting a thorough requirement analysis of both the legitimate and shadow network (see D'Eredita, Hossain, and Wigand, 2002). This is important as the legitimate network may provide a normative view of how individuals should share knowledge while the communication network analysis of shadow network will assist KS system designers in understanding the descriptive view of individual agents' communication patterns. This information could later be used to directly address issues of *structural holes* that may or may not exist in an organization or in a department (Burt, 1992).

In this paper, we first provide a background to organization as a network of people. A person or a group of people united for some purpose is considered to be a form of organization (Cyert and March, 1963; Arrow, 1974). Cyert and March (1963) suggest that organization needs to be viewed as a form of coalition. That is, an organization is considered to be a coalition of individuals, some of them organized into sub-coalitions. Arrow (1974) highlights that formal organizations, firms, labor unions, universities, or government, are not the only types of entities that represent the term 'organization'. For example, the market system has elaborated methods for communication and collective decision-making and can be interpreted as an organization (Arrow, 1974). We first highlight that successful KS initiatives require (1) attention to communication patterns of individuals or groups working in different divisions of an organization and (2) the development of ICT systems that support both strong and weak ties between participants. In particular, we provide a distinction between different network structures as they relate to the concept of *structural holes*. We also highlight how types of network structures effect sharing of explicit and tacit

knowledge. Additionally, strong and weak tie theories are applied to develop a framework for potential ICT-based initiatives aimed at addressing *structural holes* of communication. A set of propositions is proposed with their implication for designing KS systems in organizations.

DESIGNING KNOWLEDGE SHARING SYSTEMS

KS systems design evolved from the traditional structured systems design literature. Scientists, engineers, technicians, and programmers initially performed the design of technology-based systems in the 1950s and 1960s (Yourdon, 1989; Kling et. al. 1998). Kling highlights that design flaws were the major impeding factor for ensuring the optimal use of computer-based information systems in organizations (Kling, 1991; Kling, 1993; Kling and Jewett, 1994; Kling et. al., 1998). The design of computer systems for supporting collaborative work requires careful attention in five key areas--planning, analysis, design, implementation and support (Avison and Shah, 1997; Whitten and Bentley, 1998). The importance of careful examination of these phases for ensuring the success of systems implementation has been addressed in organizational design literature as well (see Schon, 1967; Mintzberg, 1979; Mintzberg, 1989; and Mintzberg, 1994). Previous studies suggest that systems design is essentially a social process (see Kling, 1991; Kling, 1993; Kling and Jewett, 1994; Kling et. al. 1998). The social role of systems analyst is one of the critical success factors for the successful design and implementation of the system (see Forsythe, 1992, 1994; Suchman, 1996; Davenport, 1996). This social role is essential for the collection of relevant information from different disciplines and people during the requirements analysis phase of the systems development (Kling et. al. 1998). Hence, the design of technology-based products has to be in line with social and organizational dynamics (Kling et. al 1998). In fact, there is a danger of systems failure or not receiving high rate of user acceptance if systems design issues are considered separately from the organizational issues. This is a common problem for the implementation of multi-module software systems such as enterprise resource planning (Kling, et al. 1996).

A study by Wyatt (1997) suggests that the social systems design approach by Mauro Mauro Design Inc. improved the performance of the New York Stock Exchange trading systems. The systems analyst from Mauro Mauro Design Inc observed the traders at the Stock Exchange for six moths prior to start coding new software together with 30 iterations in testing their new systems (see Kling et. al., 1998). Kling and Star (1998) highlights that analyses that cover the complexity of social organization and the technical state of the art is critical to the design or use of human-centered computing. This analysis can provide the systems designers with insights both the technological characteristics of a computerized system and the social arrangements under which the system will be used (Kling, 1987). For example, it is highlighted in studies that understanding the distinction between the legitimate and shadow network structure is an important first step towards the design of the KS in organizations (D'Eredita, Hossain, and Wigand, 2002). Understanding the shadow network structure requires a communication network analysis so that the patterns of exchange between agents in a network can be understood. It is highlighted in previous studies that a successful knowledge creation process requires an established communication network (Hossain, D'Eredita, and Wigand, 2002). Communications network structure deals with individuals communication pattern in an organization or in a unit of work. KS design can be viewed as a social process because it requires interaction between all parties moving through developmental phases together in order to produce a system that is efficient and effective. It creates ownership in a system, which alleviates many of the problems traditionally associated with implementing a new system, resistance to change, resistance to imposed authority, training, etc. This serves as a basis for the development of a conceptual model of KS in organizations (Armbrecth, et. al., 2001).

Nonaka (1994) and Brown and Duguid (1998) also support that knowledge creation is essentially a social process. It is suggested in case studies such as Nucor Steel (Gupta and Govindarajan, 2000) and Buckman Labrotaries (Pan and Scarbrough, 1999) that understanding the interaction of individuals, groups, teams and communities in knowledge networks leads to a successful KS in organizations. Thus, it can be seen that there is a growing interest among social scientists to view KS as socially constructed and embedded in social networks and communities of practice (Pan and Scarbrough, 1999; Kogut and Zander, 1992). These findings clearly highlight that the dichotomy of KS systems design can be seen from three perspectives—technological determinism, systems rationalism, and socio design. In the following section, we provide a brief overview of the systems design literature as it relates to the design of KS in organization.

TECHNO DETERMINISM, SYSTEMS RATIONALISM AND SOCIO DESIGN

Systems design literature can be divided into three distinct categories: *ICT-machine determinism*, *systems rationalism* and *socio-organic design*.

Here, *ICT-machine determinism* refers to the view that treats information and communication technologies as information processing systems whose technical characteristics cause specific social changes when they are adopted and used (Kling et. al. 1998). Kling et al (1998) further argued that this paradigm is applicable and useful when there is a high degree of control and short time frames. The value of technological deterministic approach to systems design is limited to a dynamic and complex situation. For example, technology for supporting KS is the most common form of KS systems existing in organizations. It is seen in studies that the introduction of KS has resulted in substantial bottom-line impact by companies such as Texas Instrument ($1.5 billion over 3 years), Chevron ($2 billion annually), and BP ($30 million in the first year) (Payne and Elliott, 1997; O'Dell et al. 2000). As a result, technology for supporting KS activities in organizations is becoming critical in search of near-term efficiency, productivity, and service quality improvements through knowledge reuse (Smith and Farquhar, 2000). However, this approach cannot adequately account for the interactions between technologies, people who design, implement, and use them, and the social and organizational contexts in which the technologies and people are embedded (Kling et. al. 1998).

Systems rationalism is seen as a useful starting point to develop an understanding of the value of technologies in organizational practices, social activities and work life per se (Kling, 1980; Kling et. al. 1998). Conceptualization of technologies as rule-bound and carefully structured process and then generalization of these characteristics to people, groups, and organizations is central to this approach. It further provides a simplification of the nature of technologies, the nature of people and their relationships, and the way in which people interact with technologies (Kling et. al. 1998). The backdrop of this approach is the simplification that tends to emphasize formalities by representing only the formal defined tasks and ignoring the process involves in performing the actual tasks (Kling et. al. 1998). This approach may be primarily useful in designing and implementing systems that have a narrow set of well-understood organizational problems and a high level of consensus about problems and solutions by the participants. For example, ERP automates the tasks involved in performing a business process—such as order fulfillment, which involves taking an order from a customer, shipping it and billing for it (Koch and Slater, 1999). With the use of ERP, a customer service representative can take an order from a customer about information necessary to complete the order (e.g. the customer's credit rating and order history, the company's inventory levels and the shipping dock's trucking schedule). Other employees in the company with a similar technology platform may access this through a single database that holds the customer's new order. When one department finishes with the order it is automatically routed via the ERP system to the next department; so providing easy access to client's information.

Additionally, the changing technology landscape offers increasing integration across systems, knowledge bases and self-service for knowledge workers. It also provides opportunity to embed increasing amounts of knowledge in the systems themselves. These KS *mechorganics* can ensure that important background information is identified and captured. Once organizations recognize knowledge as a critical factor in their success, they can apply the planning, analysis, and process techniques needed to manage this valuable enterprise resource (Clark, 2001). For example, customer relationship management or CRM deals with collecting and sharing knowledge about the customer that flows into the organization via a wide variety of channels and personal and electronic exchanges. But achieving this seamless continuum of sales and support channels presents a significant systems integration challenge. Call center systems and electronic commerce servers must be linked to a company's enterprise resource planning (ERP) backbone, allowing sharing of information on a global scale and ensuring a professional and coordinated approach to dealing with each customer (Phillips, 1999). Sharing information is what transforms an ERP system into the backbone of a supply chain, and not just the backbone for a company. ERP installations need to provide a common and consistent foundation for capturing information internally. As most strategically significant information comes from external sources, ERP has to be well integrated into the wider inter-enterprise infrastructure (Phillips, 1999; Clark, 2001). One of the challenges of managing an ERP implementation is understanding that not all entities within the organization will instinctively see the value of knowledge capture and management. Consequently, a social design perspective of the systems must be well integrated for ensuing the optimal use of ERP in organizations.

Socio-organic design or social design refers to joint design of both the technological characteristics of an organisational system and the social arrangements under which it will be used (Kling, 1987; Bijker, 1997; Bijker and Law, 1992). Bijker (1997) argued that the development of technological systems should be viewed as a social process, not an autonomous occurrence where relevant social groups will be the carriers of that process. Kling et al (1998) further highlights that these social choices are considered to be an integral part of computerization, even though they are not formally decided or completely within the control of any one person. For example, company A is adopting portable computers so that they can improve the flexibility of people's work situations and relationships. However, company A still insists that their employees report to work daily during the regular working hours. As a result, employees of company A have very little flexibility to work from a remote location even though they have access to the technology infrastructure provided by the company. In contrast, the underlying operational philosophy of company B is to allow its employees to work from remote location so that it provides maximum flexibility and optimal use of portable computing. This example illustrate that it is not only the technology that guide successful operation, but the guiding principles or social design of work practices that organizations decides to pursue.

Managers need to address the cultural side of change when implementing software systems such as ERP as it increases fear among managers that the availability of company wide information may challenge their authority (Wah, 2000). A study by Bock (1998) suggests that the biggest impediment to knowledge transfer is corporate culture and the biggest difficulty in managing KS is changing people's behavior. Thus organizations need IT infrastructure to make progress or to provide the facilitation of knowledge networks, but the use of ICT for managing KS activities should be supported by introducing proper organizational processes, people and content (Pan and Scarbrough, 1999; Smith and Farquhar, 2000). There is also a growing interest in considering a social network approach to understand the KS design in organizations (Hossain, D'Eredita and Wigand, 2002). Social network analysis refers to the method of analyzing social structures and relational aspects of structures that exist in a communication network (Scott, 2000). It is highlighted in the previous section that communication network structure can be viewed as a legitimate or shadow network. That is, an organization's structure may suggest how the legitimate communications network should work and the shadow network structure may suggests how the communication flow occurs at an organization. Therefore, social network analysis is continuing to play a significant role in developing a deeper understanding of the actual process of communication flow between individuals (Charan, 1991). Additionally, one can conclude from all of the above that social network analysis has the potential to play a significant role in the design and implementation of knowledge management systems (Cross and Prusak, 2002).

HSI experts work within the framework, consisting of processes and methodologies, provided by systems engineering to ensure successful human systems integration. Methodologies include the familiar, carefully structured approach to meeting the functional and nonfunctional requirements. The systems engineering team relies on each branch to assist in analyzing customer requirements (see Figure 1). Research has shown that HSI aspects and components remained, until today, with no established methodologies or integration tools to link various human aspects to systems engineering models due to two reasons (Meilich, 2008): lack of relevant taxonomy linkage to SE needs and poor domain languages.

BUILDING INFO-CULTURE FOR KNOWLEDGE SHARING

Socialization, externalization, internalization, and combination can be seen as a *mechorganic* creation of knowledge in organizations (Nonoka, 1994). Here, the socialization in organization refers to the conversion of tacit knowledge to new tacit knowledge through social interaction and shared experiences (Alavi and Leidner, 2001). The combination mode deals with the creation of new explicit knowledge by merging, categorizing, reclassifying and synthesizing existing explicit knowledge. Both the externalization and internalization mode refers to interactions and conversation between tacit and explicit knowledge where externalization deals with the conversion of tacit knowledge to new explicit knowledge and internalization deals with the creation of new tacit knowledge from explicit knowledge. Table 1 provides an overview of four modes of knowledge creation.

Table 1. An Overview of Four Modes of Knowledge Creation

Modes of Knowledge Creation	Characteristics	Examples
Socialization	Conversion of tacit to new tacit knowledge	Apprenticeship, user training
Combination	Creation of new explicit knowledge	Survey reports
Externalization	Conversion of tacit to new explicit knowledge	Lessons learned
Internalization	Creation of new tacit from explicit knowledge	Learning and understanding from reading and discussion

It can be seen from table 1 that knowledge sharing and creation is dependent on the modes of knowledge creation. Here, socialization is seen as an important aspect for the conversion of tacit knowledge into new tacit knowledge. For example, the development of an "*infoculture*" is the first essential step for creating knowledge-based organizations (Gupta and Govindarajan, 2000). The study of Nucor Steel highlights that three essential elements—superior human capital, high-powered incentives and a high degree of empowerment guide the knowledge creation process (see Gupta and Govindarajan, 2000). Nucor Steel used a *group-based incentive* mechanism to encourage people to start sharing knowledge that in fact lead to the development of an *inforcultute* in their organization. This *mechorganic* incentive was introduced at all levels of the organization so that Nucor could only reward group-based performance.

Social network analysis is increasingly used to develop a better understanding of the shadow system network that is considered to be a true representation of the communication patterns that exist in an organization (D'Eredita, Hossain and Wigand, 2002). Social networks can be defined as an individual's relations and contacts with others (Burt 1992; BarNir and Smith, 2002). Social network analysis can be seen as a method that allows us to analyze social structures and relational aspects of the structures that exists in a communication network between individuals, teams, groups and communities (Scott, 2000). The argument advanced in this paper is that once the ICT-based KS systems are put into practice or implemented in organization, it becomes a social network. Consequently, the social design of this ICT-based KS should be established through a thorough analysis of both the formal and informal social networks that may exist in an organization. It is argued here that the design of ICT-based KS should be able to accommodate the facilitation of the communication patterns or flow process that exists in a department or in an organization. Therefore, the social dimensions of KS can be described from two perspectives—the first is the role of socialization and community building as a backbone social infrastructure for KS, and the second is the ICT-based KS systems. ICT-based KS systems are also considered as social systems as this KS systems link people as well as machines.

Wellman (1996) suggests that computer supported social networks help sustain strong, intermediate and weak ties which provide information and social support in both a specialized and broad-based relationships. It is also important to note that there are direct and indirect ties exist between agents or the participating agents engaged in KS. It is clear that these ties are embedded in both the legitimate and shadow network of an organization. This, when combined with what is known about computer supported social networks mentioned above, may provide valuable insights for the effective design of ICT-based knowledge management systems. This is discussed further in the following two sections.

KNOWLEDGE SHARING THROUGH STRENGHTS OF TIES

It is indicated earlier that organizations can be viewed as a network of people. In particular, we discussed two types of networks—legitimate and shadow and its implications for the design and sustainability of KS provided. These networks consist of individuals working in an organization and can be seen as redundant or nonredundant. A structural hole is referred to as a relationship of nonredundancy between two or more contacts (Burt, 1992). Nonredundant contact between individuals can be seen as disconnected either directly or indirectly. Here, the

disconnected direct nonredundant contacts suggest that there is no direct contact with one another and the indirect contacts suggest that one has contacts that exclude the others. Burt (1992) further suggests that the two contacts provide network benefits as a result of the structural holes. Here, we discuss the concept of structural holes together with the strong and weak ties metaphor as it relates to KS systems design in organizations. Burt (1992) suggests that two criterion—cohesion and structural equivalence can be used as an indicator for detecting structural holes. Cohesion criterion refers to direct connection between the contacts. For example, two contacts A and B are redundant to the extent that a strong tie connects both A and B. Here, this strong tie between contacts A and B indicates the absence of a structural hole (e.g. the relationship between father and son, or people who frequently connects with each other for social occasions). However, structural equivalence concerns indirect connection by mutual contact. For example, both A and B are structurally equivalent to the extent if they both have same contacts.

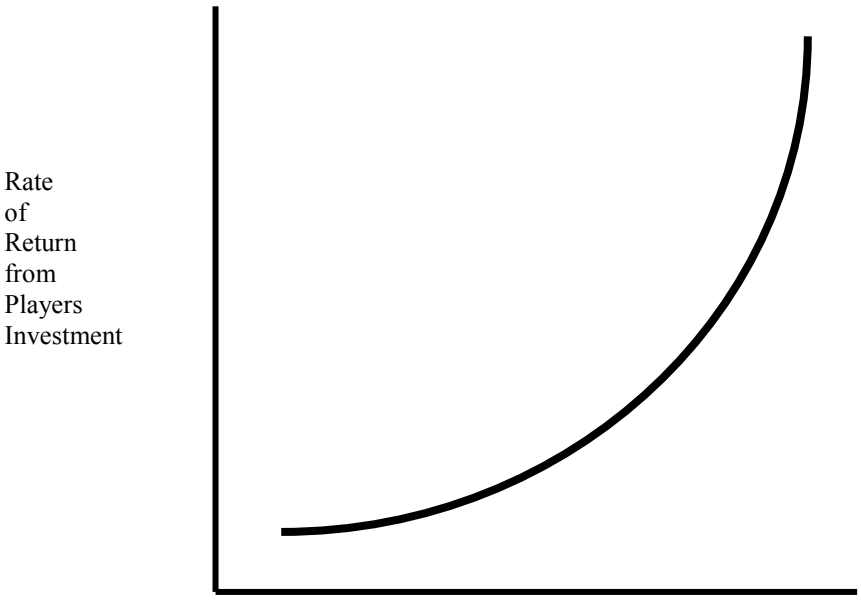


Figure 1 Relationship between Rate of Return and Structural Holes (Burt, 1992)

This nature of the contacts between the executives and persons in their network is referred to as strength of ties (Granovetter, 1973). Intense, emotion-laden, and reciprocal relationships that require time and energy to create and maintain can be a reflection of strong ties. Weak ties on the other hand, reflect loose networks and are best explained by the concept of a bridge (Granovetter 1973). The strength of the tie has traditionally been viewed as bearing on the overall amount and content of information associated with the contact. It is however suggested in previous studies that novel and nonredundant information is available through weak ties more than through strong ties (Granovetter 1973; Granovetter, 1974). Strong ties can be seen as advantageous because they allow for quick flow of information and social support. Furthermore, strong ties are reliable, easily available, and important when dealing with conflicts, crises, and uncertainty (Granovetter 1982; Krackhardt 1992; Nelson 1989). Granovetter's (1973) theory of strong and weak ties highlights the importance of weak ties in providing information. A weak tie is defined as a "casual acquaintance" and a strong tie is a formal relationship defined by a high-shared knowledge base and multiple interactions (Granovetter, 1973, 1974; Hansen, 1991). Burt (1992) further suggests that weak ties provide a useful mechanism for understanding the strength of structural holes in a communications network. We believe that both these types of ties offer unique opportunities for developing a theoretical base for the design of KS systems in organizations from both a theoretical and an applied perspective.

We considers that there are two predominant, coupled systems at play within contemporary organizations, one to do with collaborative social influence (CSI) in which the social drives the IT (S-IT) and the other to do with coordination, rule and control (CRC) in which the IT drives the social (IT-S) (Walker et al, 2012; Harmaakorpi et al, 2003). These two systems have different and at times conflicting or antithetical characteristics, one to do with

weaker social signals and influencing / responding, *over time* (CSI / S-IT); the other relating to *stronger* communication signals necessary for controlling / reacting, *in time* (CRC / IT-S) (Ansoff, 1975; Coffman, 1997; Hiltunen, 2010; Hiltunen, 2008). The two systems also have different *signatures*, where CRC / IT-S systems are considered as strong-signal systems, in which: 'System control (through switching) of Information, Data and Communication are the key variables', (Hence also ICT) after, Castells (1996) and Sokol (2003) and *weak-signal* CSI / S-IT systems, in which: 'System Influence (through shared awareness) of Information and *abstracted* social Knowledge are the key variables', after Castells (1996) and Bunge (2010).

Studies suggest that weak relationships such as casual acquaintances, do not take as much time and effort to cultivate as friendships or community of practice (Hossain, D'Eredita and Wigand, 2002; D'Eredita, Hossain and Wigand, 2002). Thus, it is easy to have more acquaintances than friends. A larger number of acquaintances can provide access to information about more out-groups. Most importantly, acquaintances offer the potential for (1) a relationship that takes limited time and effort and (2) offers the most potential for non-redundant and, thus, valuable information and knowledge. Specifically, Burt (1992) proposed a direct relationship between the number of structural holes and the rate of return on player's investment in terms of time and energy and social capital (Figure 3). Here, the shape of the curve is to indicate the general relationship between structural holes and human capital as opposed to any validated and specific function.

SUPPORTING KNOWLEDGE SHARING THROUGH SOCIAL CAPITAL

We propose above that the value of social interaction and social exchanges needs to be taken into consideration by a designer of an ICT-based KS system. We further propose here that the design of an effective ICT-based KS system should allow for an economic use of time and energy in the growth of social capital.

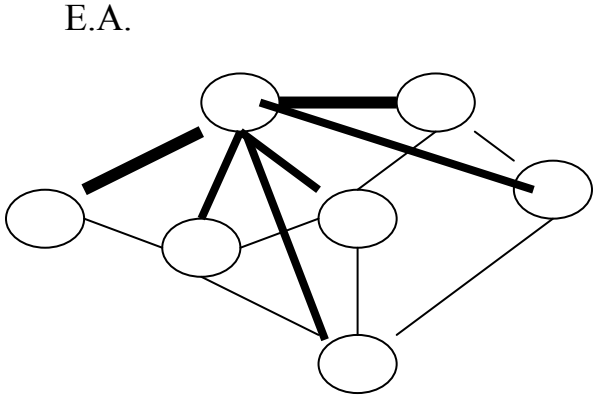


Figure 2. Example of Social Network with proximal, strong ties (bold lines)

To discuss the specific effects of an ICT-based KS system on social capital we will illustrate how one can increase capital by acting on the following eight propositions:

1. Maximizing weak ties in one's network increases the potential for innovation and/or market penetration (Granovetter, 1973).

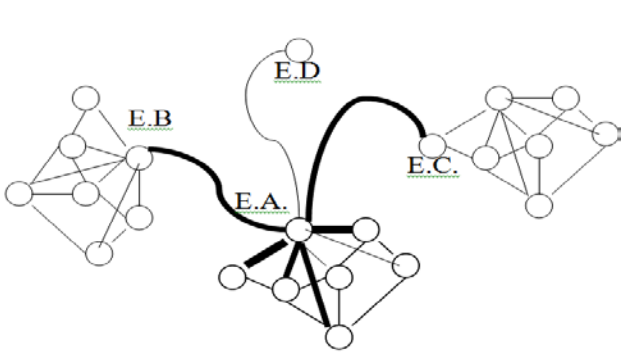
2. ICT-based KS systems are an effective means for establishing and maintaining weak ties (Wellman, 1996).

3. Maximizing the number of structural holes in one's network increases the potential for innovation and/or penetration (Burt, 1992).

4. A finite number of strong ties can be maintained (Burt, 1992).

5. Minimizing the number of strong ties allows for more allocation of resources to the application and creation of new knowledge.

Assume "Entrepreneur A" (E.A.) has lived and worked in city "Home" for a number of years. During this time, E.A. has established a number of strong ties due numerous in-person exchanges (Figure 2.) E.A. soon realizes that both new ideas and/or potential markets for his product have become too redundant and that a larger network is required for further growth. E.A. decides to explore some potential new contacts via various forms of IT (Figure 3). After establishing a number of loose contacts, E.A. decides to strategically strengthen ties with those who offer the greatest number of resources. The inherent communication barriers associated with numerous forms of IT (for further discussion see Hossain, D'Eredita and Wigand, 2002) motivate E.A. to invest time and energy into more face-to-face interactions with one of the selected new contacts. E.A. spends weeks (or, perhaps, longer) on-site with new contact E.B. who resides in Home2 and begins to strengthen their tie. E.A. also spends times with some of E.B.'s contacts and establishes a number of new relationships. During this time, E.A. maintains his ties back home by using IT channels. The maintenance of these ties requires (1) relatively little effort given the established shared knowledge base and (2) a strategic approach as to which contacts from Home make the most "economic" sense to maintain. E.A. maintains other new contacts by using the same methods used while at home. E.A. takes special care to maintain a weak tie, or no tie, between E.B. and other new contacts (Figure 4). This process continues until E.A. reaches a maximum number of strong ties that can be maintained without having to "fill" in, or bridge, important structural holes due to a limited number of strong ties that can be maintained. E.A. eventually shows a significant amount of growth in social capital (see figure 3 below) and invests more time in managing the flow of knowledge and information rather than actively searching for more capital (Figure 6).



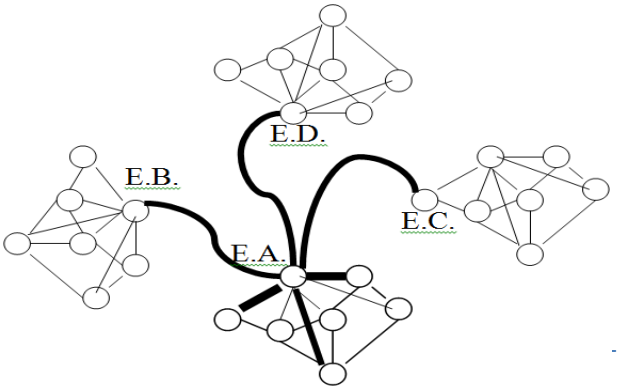
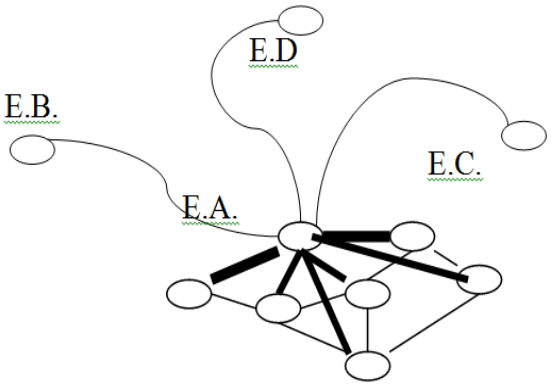


Figure 3. (LHS) Example of Social Network with proximal, strong ties, and new "distal", weak ties
Figure 4. (RHS) Example of Social Network with proximal, strong ties, distal weak ties, and a new distal strong tie



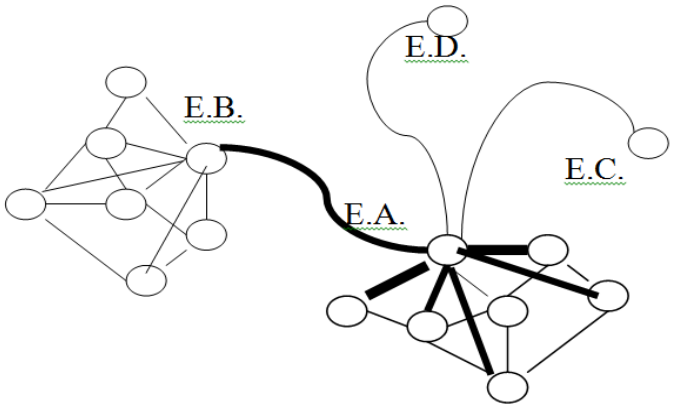


Figure 5. (LHS) Example of Social Network with proximal strong ties, new distal weak ties and strong ties
Figure 6. (RHS) Example of Social Network with the same number of strong ties as shown in Figure 4, but with a significant increase in the amount of social capital.

Once the required shared knowledge base is established, E.A decides to move to Home3 to establish a stronger tie with E.C. E.A. maintains strong ties with Home and E.B. through efficient use of IT. Most importantly, E.A. maintains the structural holes between Home, E.B., E.C., and E.D. (Figure 5). One can better understand the

demands of a system designer by combining an understanding of cognitive demands and limitations with the social behaviors and needs of end users like E.A. That is, for example, E.A. potentially realizes his cognitive capacity with the development and maintenance of 6 strong ties and the knowledge and information flow resulting from the increase in social capital. With every developed strong tie the demand imposed by the maintenance and utilization of a growing—and, thus, more complex—social network increases. The ultimate requirement of an ICT-based KS system becomes one of minimizing cognitive demand in the maximization and utilization of social capital. From this perspective, the ICT-based KS system complements the individual and increases the potential for innovation and knowledge creation.

CONCLUSIONS

We provided a discussion of the systems design approaches from a ICT-machine determinism, systems rationalism and socio-organic (suggested also as *mechorganic*) design in this paper. It is concluded that complex systems design such as knowledge sharing systems requires careful attention to the social context for which is systems is developed. Therefore, we suggest here that the designer of KS systems is required to develop the systems based on observations of the social interaction and social exchange needs of the individuals working in an organization. We further highlight that the design of KS should be based on an understanding of both the legitimate and shadow network structure of an organization. We recommend that social network analysis is a useful methodological paradigm for the purpose of eliciting the communication patterns for understanding the shadow network structure. It is suggested here that structural holes provide network benefits for developing social capital among participating members in knowledge sharing and conclude that strong and weak tie is a useful metaphor for fitting the structural holes. We further proposed number of propositions, which can be used to develop a better understanding about how to effectively and efficient leverage information technology for the development of social capital.

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A Day-in-the Life of a Systems/Software Engineer 3-5 Years Ahead

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ABSTRACT

Key technology shifts such as big data, social technologies, internet-of-things, and mobile are reshaping the landscape in which engineers operate. This paper will present a vision of software and systems engineering of the future, specifically considering development of complex large-scale real-time embedded systems. We will discuss the future of software/systems craftsmanship, and how this impacts the day-in-the-life of an engineer. In order to address challenges related to speed, quality, and cost we see organizations responding by driving initiatives in the following areas:

- Agile – deliver more often with focus on business outcome
- Lean – take out non-value adding tasks
- Collaboration – a culture of open information sharing
- Innovation – create room for risk-taking
- DevOps – breaking down organizational silos

We also see development practices evolving to respond to the changing landscape in the areas of architecture, steering/governance, people/teams as well as how to manage development platforms.

Keywords: Systems Engineering, Agile, Lean, DevOps, Innovation

INTRODUCTION

The world of systems engineering has traditionally been one shaped by well-defined and predictable processes and methods to ensure high-quality outcomes. In development organizations consisting of hundreds and sometimes thousands of people this has been a necessity in order to put clearly defined roles and quality toll-gates in place to ensure order in creative chaos. Tools play a key part to manage dependencies and traceability between a complex web of project deliverables as well as automate work-intensive tasks such as testing.

Technology and culture shifts are driving towards a more open and collaborative way of working, where the traditional governance principles can be perceived as standing in the way of making progress. In this paper we

explore how the tools infrastructure of the future can help break down silos, not only within the development team, but also between the development team and its suppliers and customers, where some of the largest productivity barriers remain due to governance and supply chain practices that have grown and calcified over decades.

In a sense, systems engineering historically is about creating a development factory where people are imagined to act as cogs and wheels in the machinery that produces complex systems or products.

The systems engineering industry is moving towards a significant culture change driven by external factors – the next generation engineers will expect a different level of empowerment to make decisions based on information and people available through e.g. social media and analytics. The pace of change in the market place is increasing rapidly, and being able to quickly react to change in market needs is essential. Where before a new function could take months or years to make available we are now down to expectations of days and weeks. We are also evolving our understanding of how people are incentivized to excel and how in this context the style of management is evolving (Denning, 2010).

Technology advances are now enabling computer-assisted engineering in ways that were not practical only a few years ago. In many areas of engineering, advanced computer-assisted tools help practitioners analyze vast amounts of data and run sophisticated "what if" analyses to help make technical decisions. However, these techniques have largely not been applied to complex software development projects. Decision-making in large-scale software development is still primarily ruled by trial and error, intuition and "SWAGs"[1]. We strongly believe that the next few years will see the application of Big Data and analytics on large scale systems engineering and software development, and practitioners will begin to trust and even depend on machine-driven analyses to cut through large amounts of data to help them make better decisions. Through this paper we explore the potential impact that these techniques may have on the productivity of individuals and teams when they are seamlessly integrated in to our development environment. Our intention is to stimulate dialog on the anticipated impacts these technologies may have, and to get development organizations to start thinking about and planning for the next wave of change in process and ways of working that will be enabled by such advances.

The key technology shifts considered are:

- Cloud,
- Mobile,
- Big data,
- Analytics

The context in which we have been considering the topic is of that of organizations developing complex large-scale real-time embedded systems with long life expectancy.

RESHAPING THE LANDSCAPE IN WHICH ENGINEERS OPERATE

Industry Direction

In order to change the way organizations operate to be more flexible and faster, the industry is looking to strengthen operations through:

Agility: In essence to deliver more often with a relentless focus on business outcome. There is a very strong community formed, an agile movement considering the formulation of the Agile Manifesto (http://www.agilealliance.org/the-alliance/) as its defining moment in time. Its foundation is in software development, but has grown to be applied across engineering organizations (Denning, 2012).

Lean: Grown out of manufacturing, lean is focused on taking out non-value adding tasks while preserving value. A set of principles is applied to move waste out of the production line. The term was coined in the 80s, but ideas around waste reduction were applied already in the early days of the industrial revolution (Womack, Jones, Roos

[1] Software Wild-Assed Guess

1990). An evolution of this thinking are the principles are the ideas on Lean Startup techniques (Ries, 2011)

Collaboration: The idea of collaborative leadership has been discussed since the 1990, what we now also see with the evolution of social techniques as an evolving culture of more open information sharing.

Innovation: Traditional techniques for managing predictable results and driving down risk has a side effect of discouraging doing things you haven't done before. Organizations have and increasing focus on making sure resources are carved out to focus on innovation, in essence create room for risk-taking.

DevOps: This is in essence about breaking down organizational silos. Originating from issues in a traditional IT organization where development hands off and application to operations. The concept has evolved to cover what it means to instrument a lean and agile organization, creating an environment that help overcome organizational barriers and support transparency of information across the organizations.

The Software and Systems Engineer's View

The key technology shifts that support this operational change are found mainly in how information is available and shared – as concepts like big data, analytics, internet of things are becoming reality and a natural part of how people engage with one another and how we look to solve problems, this will enhance our ability to work anywhere, access our work space from anywhere, and ask anyone for help.

We can say that engineers are moving from being 'in the box' in terms of ways of working, a box defined by managers and method& tools people, to being expected to act also outside of the box. Rather than following strict process, governance and metrics, and using a standardized environment they are acting in empowered teams that are focused on the outcome. We still expect the teams to be disciplined, but constantly evolving their ways of working t improve performance and use whatever they need to get the work done.

The Development Manager's View

The opportunities a manager sees in these technology shifts are typically around resource flexibility and ability to more effectively use external resources, and better tools to make predictions about cost and delivery schedules.

In terms of management style we see a shift from a command and control style with strict governance and process, to more of a collaborative leadership style where management teams are considered self-optimizing and the focus is on outcome rather than the more classic key-performance indicators, as exemplified by movement towards more agile/lean methods.

EVOLVING PRACTICE AREAS

As a consequence of changes in the engineering landscape, we see key practice areas evolving. Not necessarily revamping the way we think of these practices, but as a consequence of changes in technology and ways of working they are changing their shape. Here we are considering four areas: architecture, steering, people, and development environments.

Architecture: Model-Driven/SOA evolving to API Focused

In the past 10 years, the industry has been moving towards model-based architectures based on principles of loosely coupled systems such as service-oriented architecture (SOA). With the emergence of web and cloud-centric systems, we see a move to add the dimension of making the architectures focused on clearly defined APIs. This is reflected in a change in the way we want to do business. We want to build solutions or products that are easy to add to through well defined APIs We call this architectural style API-driven. It is interesting to note that this evolution from SOA to API-driven is not purely a technically driven change but is also one driven by the emergence of the "API economy" and an awareness that providing access to data and services represents new opportunities to monetize existing capabilities.

As part of this trend, we see movement from monolithic models and internally focused documentation to increased awareness of external "consumers" of the interfaces and focus on improving their ability to discover and use the services of our systems. In many cases, this is accompanied by the move to a more open source style of collaboration and transparency, where we design and code with the expectation that our artifacts are published and shared by a community that will include consumers outside of our organizational boundaries. We will see an increased focus on reuse of existing components open source style, vs new implementation.

Steering: Requirements Driven evolving to Outcome Focused

The classic way of steering programs and projects is through specifying and validating the implementation of requirements. There will always be requirements (regulations, standards, etc) but with the introduction of agile practices the classic requirements definition process breaks down. The focus is instead on solving the problem in more consumable chunks (i.e., "iterations") – with clear focus on achieving a business outcome vs. detailed requirements. Information access is the key to identifying and prioritizing problems. This shift is accompanied by a desire for more fluid and continuous collaboration between consumer and provider.

People: Role Based Responsibilities evolving to Team Collaboration

There will still be a need for specialized roles (technical architect, domain specialist) but the focus is on creating self-organizing cross-functional teams extended to business stakeholders and even customers and suppliers. Teams can be better equipped to self-optimize how they work by having better access to information, supported by computer-driven analytics to help interpret the vast amount of information available. We will see a higher emphasis on people and open access to information, and less on strict process or hierarchical control of information (the democratization of information).

Development and Target Environments: Integrated Standard Development Environment moving to Development & Target Environment as a Service

There is still a lot to do to better integrate tools that originally were written for specialized roles and stove-piped organizations rather than cross-functional teams. Teams expect environments to require less overhead and just work without extensive manual intervention. Development environment should transparently help teams go faster, and help remove barriers in the organization. They should not be something you need to take several days of training to understand how to use, and not something a team needs to spend man weeks to configure before they can get productive.

Considering the history of development environments, it is interesting to note that much of the more widely adopted tools are those that address communication issues appearing at organizational boundaries – think of change request management tools and requirements management tools.

There will always be a need for tools that help us organize and track engineering assets, maintain traceability, and abstract complex problems. We see a new class of tooling emerging which we call expert advisors, which help practitioners make better-informed decisions more quickly. The organization's ability to derive value from this new class of tools *depends* heavily on the quality of data available from the other lifecycle tools, and on the ability to see and extract relationships between the artifacts.

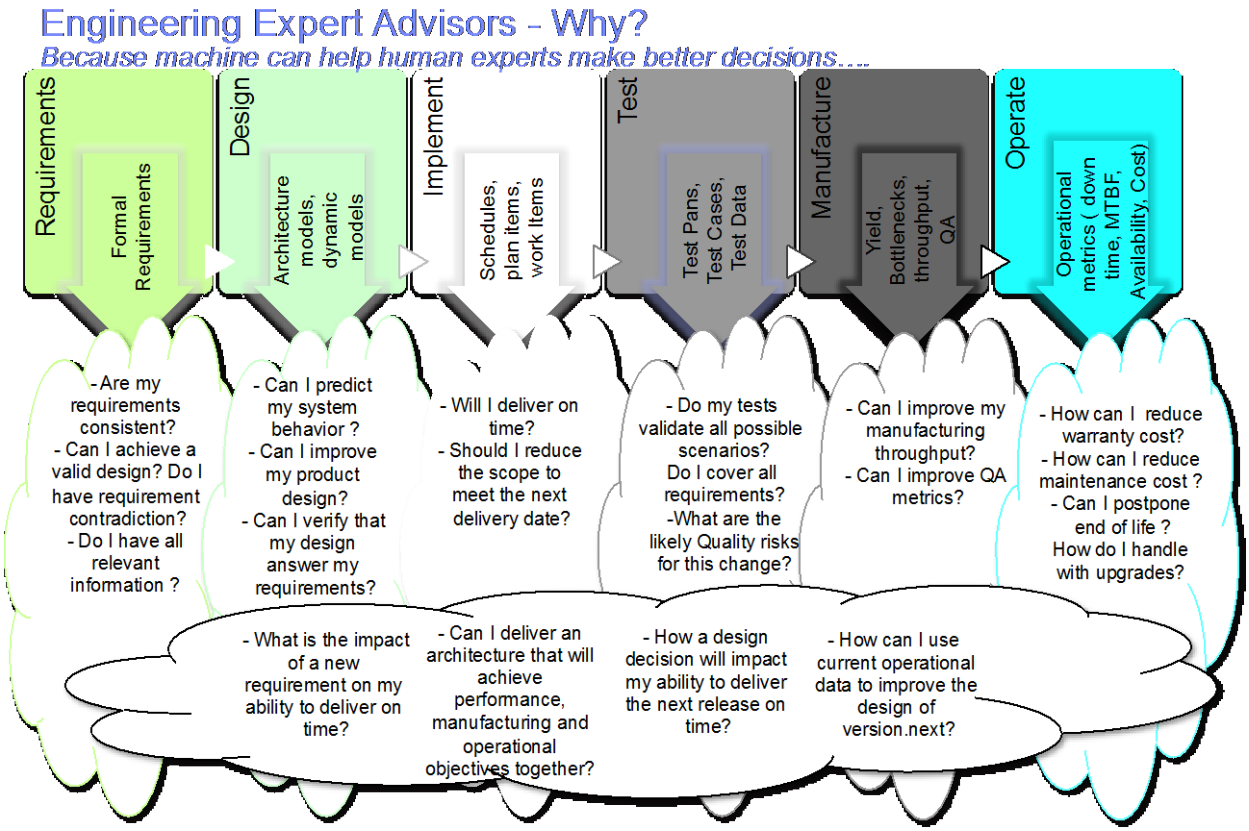

Figure 1. Expert Advisors

It is our belief that this concept of expert advisors represents the "next evolution" of Agile/Lean methods. The heart of the lean/agile methodologies is the desire for continuous learning and improvement, and the obvious frontier for improving the speed of learning is to enlist the tools to help us learn faster. Computer automation will accelerate team's ability to continuously improve and learn, but will require that sufficient attention is paid to the instrumentation of the development process to allow analytics tools to learn from the data.

A DAY IN THE LIFE 3-5 YEARS AHEAD

Let us introduce our development team from the future. They are at work at 5GMaker Inc (a fictional mobile network service provider). 5GMaker Inc is a fictitious company name representing a manufacturer of mobile telecommunications infrastructure equipment. The development team in our scenario works for 5GMaker Inc.

Elsa is new to the development team hired just 4 weeks ago. She is 23 years old (born in 1994 – the year Netscape and WWW launched). She is brought on to a feature team for China MSP 5G customization. China MSP is a fictitious company name representing a Mobile Service Provider (MSP), deploying and operating the mobile 5G network. They are a customer of 5GMaker Inc.

Hannah is the Scrum master for the team.

Adam is the most senior architect. Unfortunately, Adam is on 2 months leave on Safari in Africa.

The development environment's deep "trouble detection" analytics (which run continuously) have flagged an emerging problem trend in the network equipment provider's problem reports DB and correlated with China MSP equipment logs (automatically collected with China MSP's agreement during the early 5G rollout phase)

The development environment has correlated the problem with the deployment of the new build to a 5G base station, and identified the likely component based on cross-reference against the new features added in the most recent build and has flagged the most likely suspect components.

This information along with the links to the problem reports and the logs are included in a work item[2] created in the team collaboration function of the development environment.

Getting Started

During the daily scrum, Hannah opens the new high priority work items to review with the team and decide on how to assign. During the review they follow the data linked in the work item and see that the problem is growing in frequency, though China MSP has not escalated it yet. Hannah wants to know if they have time to investigate without disrupting the next milestone in 2 weeks time.

Looks like the only one who can work on investigating without affecting the next milestone is Elsa. Although the team is reluctant to leave this investigation to the new developer, they have no choice but to see how she handles it.

Hannah assigns the work item to Elsa. Back at her desk, Elsa opens the work item and immediately starts to investigate.

Understanding Architecture

From the work item, Elsa navigates to the feature that the Deep Analytics tool flagged as the likely origination of the problem. Elsa opens the visual Navigator and drags the feature on to it. This populates the navigator with a visual display of all the immediately related artifacts. She selects 'Build' as the target filter. The result shows the indirect traceability graph from the source (a feature) to the target (builds).

Right away, Elsa can see that this feature was first deployed in a build to US MSP[3] the previous year. She does a search for unresolved defects against Build US MSP 5G 2016 and finds none, suggesting there's something unique about the configuration of the feature in the China MSP build, OR an inadequately tested area.

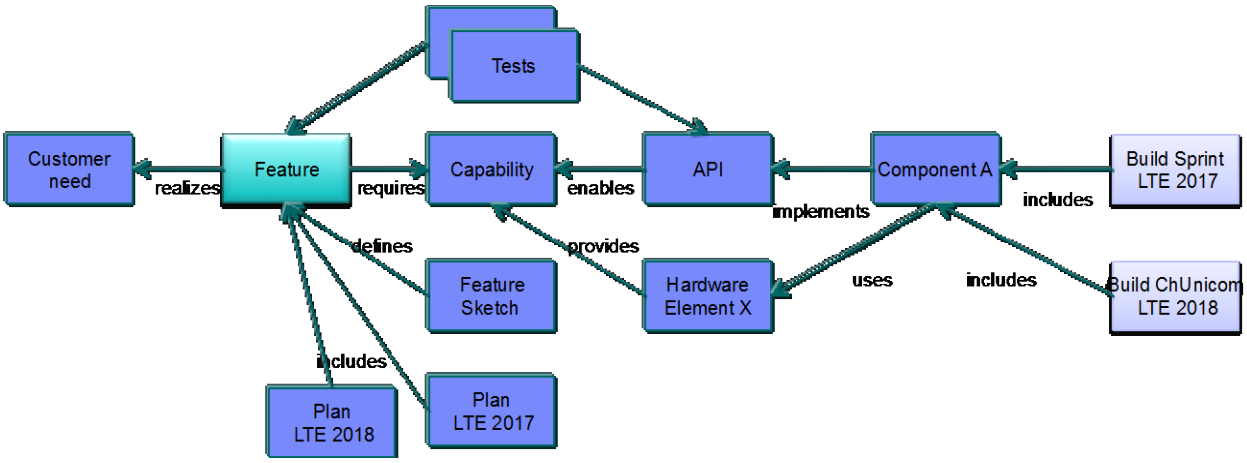

Figure 2. Understanding Architecture

Elsa can use the configuration-awareness of the visualization to see differences between these. She selects Build US MSP 5G 2016 to filter the view to see the specific versions of these artifacts as used in that build.

She saves a snapshot of this view.

She then generates a view for China MSP 2017 build and does a comparison to see what is different. It appears that newer version of a Hardware chip was used and Elsa identifies this as the possible root cause.

[2] a "work item" is a task that needs to be done by a team as part of a larger project. The work item is the electronic record of that task, the people who worked on it, the states or stages of process that it must go through in order to conform (and prove conformance) to the development process for the organization, and links to artifacts required or modified to accomplish the task.

[3] Another fictitious company name representing a US Mobile Service Provider.

Elsa checks the Quality 'Expert Advisor' for 'ChMSP2018' and sees that the advisor warns that defects are 78% likely in this feature due to this change. Perhaps the Quality Advisor feature was not available when they did this build.

Show versions: filter configuration "US MSP 5G 2016"

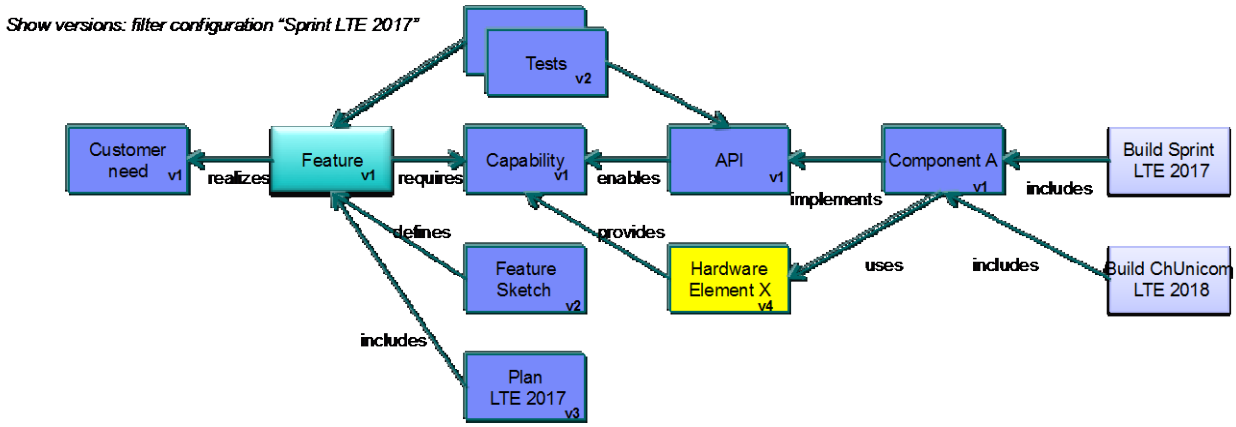

Figure 3. Analyzing Architecture

Social Discovery

She wants to review the problem logs with someone who understands how the feature tests were written. If they can reproduce the problem in their lab they should be able to isolate it quickly. She goes back to the navigation window and selects the test cases then selects a 'related experts' button that examines the relationships to the users who most frequently updated this artifact or immediately related artifacts such as work items.

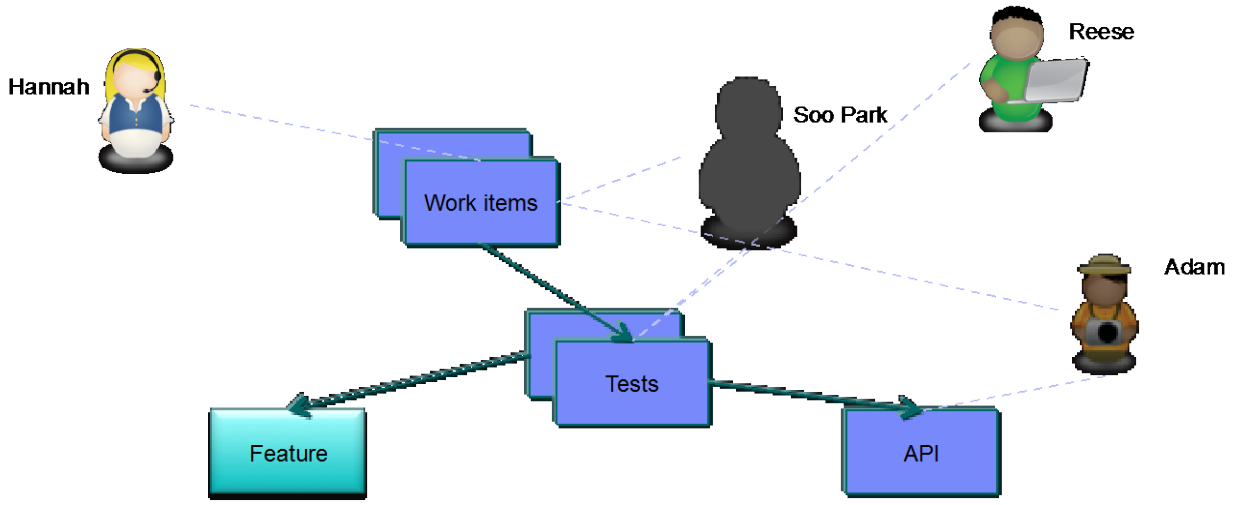

Figure 4. Social Discovery

This view combines social awareness and topic knowledge. The size of the team member icon shows how frequently and recently they worked on the topic. The coloration shows their availability. Soo Park was the most knowledgeable about the tests, but is no longer with the company. Reese is the next most knowledgeable. She talks to Reese about the tests. Reese guides her on which tests will be necessary and how to set up the test run.

Elsa does a quick search on the test lab environment looking for any nodes equipped with v4 of the Element.X chip. She finds one node in one of the test racks.

She schedules a test run of the existing tests for this feature through the integrated test generation equipment on Test Rack 1/Node 3 using the ChMSP2018 build.

The tests pass but analysis of the logs shows the same anomaly. The logs seem to show that a timeout is occurring in one of the message responses expected from Node 3.

She writes a new test case variant but changes one of the timing parameters to change expected response timing, and then schedules another test run. This time the test fails exactly as expected. Something about the hardware change has subtly changed the timing.

She looks up the part in the part tree and initiates a discussion thread on the chip. Since the chip comes from a supplier, the question and any follow-ons are automatically emailed to the supplier. The supplier does have limited access just to this part's data, its requirements and associated tests.

Mobile Access

This supplier is based in the US. Elsa is hopeful she gets some response prior to the next day's daily scrum.

Later in the day in the US, the supplier confirms in the thread that the on-chip buffer design was changed and it is possible that could introduce delay in software receiving the response signal.

Elsa gets an immediate notification on her iPhone client that the thread has new responses. Her iPhone securely connects to her corp. system once she verifies with her thumbprint.

She looks up the unit tests associated with the Hardware Element to see if she can run a test that would isolate or prove the timing problem

Elsa finds the hardware element using a simple keyword search. The element contains links to the unit tests. Sarah loads the unit tests to her workspace. The workspace wizard identifies likely dependent components to load, Sarah accepts recommended dependencies and loads them to workspace.

She explores the unit tests but does not find one that tests for a longer latency message. She uses one of the existing tests to write up a new test that will test for the latency issue using the mobile version of the IDE.

On her mobile she finds the test lab equipment that has the right Hardware Element configured. She uses the test scheduler to set up the test run for later that night.

Work Fix into Sprint Plan

The next morning Elsa's test run results appear at the top of her main page. The result does show that there is a timing window that can cause some messages to exceed the specified latency. Elsa links the chip design discussion thread, and her new unit test and the test result back in the work item and closes the work item with a recommendation to try updating the component to do an additional hardware check on the buffer when the timeout occurs per the chip supplier's recommendation.

During the team's daily scrum the next day, Elsa reports her findings.

Hannah immediately tries to check the impact to project plan if they squeeze the fix in the next sprint with Elsa as the lead developer.

The Planning Expert Advisor provides an indication that this plan has low probability of success. The reason is the changes to Component A have historically taken longer than estimated by a large margin. AND, historically changes made by someone who has never worked on a Component before result in higher % of defects and more time on test and defect fixing.

Hannah tries a 'what if' scenario assuming she can get help from another developer on a different feature team who worked on Component in the past. Elsa tells her that Reese has experience in this area. With that person assigned to help Hannah with the change, the plan has a reasonably high probability of success. She also creates a plan

dependency on ‘Reese’.

Hannah assigns the work item for the next iteration to Elsa, and sends a high priority request for some of Reese’s time to his manager.

CONCLUSIONS

Key technology shifts in cloud, analytics, mobile and social are all impacting the way engineering organizations operate. They have a fundamental impact on our ability to comprehend and analyze engineering data. An observation is that engineering and software organizations seem to be one of the last bastions not adopting and taking advantage of analytics technology – there are significant opportunities for productivity and quality improvements from the use of analytics. Also, the democratization of information and the expectation of young engineers is that you can get a first approximation of answers to your problems from 'the environment' (applying analytics and social techniques) and be less dependent on interaction with your local 'guru', and to be able to do it 'anywhere' not only in the confines of the your cubicle.

From an engineers perspective, the key words in this transformation are empowerment and flexibility. Managers will look for improved productivity, more resource flexibility and better predictions.

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Management with Ergonomic Indicators: A Conception of Indicators System for Performance to the Industry of Construction from the Workers Perception

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ABSTRACT

The main systems available for evaluating the performance of organizations, including the construction industry, leave out many aspects regarding the scope of Ergonomics and Environmental Sustainability. This gap imposes a partial understanding by organizations on their actual performance, compromising their strategies, efficiency, longevity and survival. This article aims at proposing a System of Performance Indicators for the Construction Industry, from the perception that professionals in this industry have on the indicators. This System, built from the Ergonomics approach, integrates the production, health, safety and sustainability criteria, aiming at assisting managers in making decisions. From a bibliographical research 62 (sixty two) indicators were identified. These indicators were classified into 9 (nine) categories, forming a system of indicators. All indicators composing this system underwent validation of 13 (thirteen) groups of professionals working in the construction industry. The proposed system of indicators aims at meeting the attention demand for workers, including indicators of occupational health and safety, and environmental management. It is expected that, consequently, this system can contribute to the development of maturity and organizational culture in construction, as the system expands and integrates the elements of productive efficiency to be measured and improved.

Keywords: Management; Indicators; Performance; Ergonomics; Construction.

INTRODUCTION

The area of Construction, according to Brazilian curricular references (2000) covers all activities of work production. The activities included in this area are related to planning and design, implementation, maintenance and restoration of works on different segments such as buildings, roads, ports, airports, navigation canals, tunnels, building facilities, sanitation works, foundations and land in general, leaving out activities related to operations such as the operation and management of transportation systems, the operation of water treatment plants, dams etc.

Construction is a sector of the economy that has its own characteristics and needs tools adapted to its reality. Ergonomics uses methods and instruments that allow clarification and demonstration of the actual acting of the organization for performance, health, safety and comfort.

Indicators and systems of indicators are used by organizations to monitor organizational performance and assist managers in decision making in order to improve organizational efficiency. Kaplan and Norton (1997) state that a "measurement system strongly affects the behavior of people within and outside the company." For these authors, the survival and prosperity of companies in the information era requires the use of systems of management and performance measurement derived from their strategies and capabilities (KAPLAN and NORTON, 1997).

CONSTRUCTION INDUSTRY

The construction sector was in the center of the American crisis that erupted in late 2008, but the global economic recession has had little impact on infrastructure plans in developing countries like Brazil. (MONTEIRO FILHA et al, 2010).

In Brazil investments in the construction industry are still urgent and necessary, because of the deficit in habitation. Although in recent years there have been signs of reducing the housing deficit, Brazil still has a lag of more than 5 million homes, according to information released by the Institute for Applied Economic Research-IPEA (2013).

The performance of the construction sector in Brazil in 2010 followed the national trend, with growth rate of 11.6%, the best performance in 24 years, according to the Gross Domestic Product - GDP - by sector. Until 2003, the scenario of Brazilian construction experienced a period of instability, characterized by a lack of incentive, by the timid availability of resources and a negligible presence of real estate financing. Since 2004, the industry began to show signs of growth, with increased investments in infrastructure and housing units (DIEESE, 2011).

In 2009 the country adopted several measures for the construction sector that contributed to the recovery of the economy, among them the tax exemption of some building materials, the expansion of credit for housing, notably the "Minha Casa, Minha Vida" program, and increased resources for the Growth Acceleration Program-PAC (MONTEIRO FILHA et al, 2010).

In Europe the awareness about sustainability on the part of public and private clients has required construction companies some regulations in this area. Health and safety factors have also exerted pressure on the productive processes of the European construction companies, as well as the search for greater efficiency. As stated Monteiro Filha et al (2009), "in general, it can be said that quality improvement is possible thanks to the use of planning in the construction stages, considering the availability of materials, equipment and manpower."

The Brazilian labor market of the construction industry still admits unskilled workers. Hauagge (2010) states that it was expected that the heating in construction until the year 2016 developed along with the qualification of manpower, but what occurs in Brazilian reality is "a huge gap between the growth of supply and demand."

The Construction industry is one of the fastest growing in Brazil. This is mainly due to government-funded projects. The works of the Growth Acceleration Program (PAC), the 2014 FIFA World Cup and the 2016 Olympics will be responsible for this growth in the coming years. (PORTAL BRASIL, 2011).

DESIGN METHODOLOGY OF THE SYSTEM OF PERFORMANCE INDICATORS

The technical and scientific literature lacks specific Ergonomics indicators and there isn’t a system of Ergonomics indicators to evaluate the performance of construction organizations. "Ergonomics appears as a prominent factor, however we can see that the conceptual barrier to the practical has not yet been transposed" (NOGUEIRA, 2002). Companies still do not know exactly how to act when it comes to ergonomics. "For ergonomic practices to find shelter in organizations, in the form of systematic practice, it is fundamentally necessary to identify and define 'ergonomic indicators'" (NOGUEIRA, 2002).

The ergonomic study permeates all stages of production and acts in accordance with all of them, seeking above all health, safety and satisfaction of workers, resulting in process efficiency (IIDA, 2005).

Vidal (2008) summarizes the definitions of Ergonomics as follows: the various definitions of Ergonomics established by several authors swarm around its object, work activity, and towards its goal, the positive transformation of the work situation; the components of its scope are influent - technical factors (hardware, software, maintenance), human factors (ability and physical and mental limits of the individual), environmental factors (lighting, acoustics, ventilation, air quality) and social factors (work organization, communications, pauses and stops) - and considered as determining or intervening of work activity.

Ergonomics professionals should have the competence to "plan, design and evaluate tasks, jobs, products, organizations, environments and systems in order to make them compatible with the needs, abilities and limitations of people" (IEA, 2000).

Ergonomics or Human Factors aims at performance and well-being jointly, in terms of results to be achieved (DUL et al, 2012). "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods in the development of projects that aim at optimizing human well-being and overall system performance" (IEA, 2012).

Stage 1: Bibliographical Research

The development of this system of indicators began with a literature review on the topic. We intended at this stage to meet the performance indicators cited in bibliographies, to clearly define the scenario in which performance indicators are included, who are the main authors dealing with the subject and which are the best known and used systems in Construction. Furthermore, we sought to identify, among the set of indicators found, indicators of Ergonomics and, specifically, to identify systems of indicators to evaluate the ergonomic performance in Construction companies. No indicators or system of indicators of this nature were found.

The initial idea was to develop a system of indicators which combined the practical objectives of Ergonomics in order that the indicators be fully useful, practical and applicable to the construction industry.

We searched for bibliographies that presented indicators or system of indicators which aimed at measuring the quality of work life, health and work safety, productivity, quality production, and environmental sustainability which were accessible and validated in real situations.

We also researched bibliographies that addressed the conceptual and theoretical aspects of performance indicators and also presented methods of developing indicators or system of indicators that would help develop the system of indicators proposed here.

The present system of Ergonomics indicators was developed from the following bibliography:

- The System of Indicators of Quality and Productivity in Civil Construction – SISIND (COSTA, 2003);
- The System of Performance Indicators for the Management of Production in Residential Buildings Enterprises (NAVARRO, 2005);
- The Regulatory Standard from Ministry of Labor n. 18 - NR-18 (Conditions and Work Environment in Construction Industry) (MTE, 2012);
- The Regulatory Standard from Ministry of Labor n. 17 - NR-17 (Ergonomics) (MTE, 2012);
- Ergonomic Costs established by studies in Macroergonomics (HENDRICK and KLEINER, 2006);
- Ergonomic Indicators proposed by Nogueira (2002);
- Scales of Measurements for Organizational Behavior (SIQUEIRA, 2008);
- Indicators of Competence Management (CARDOSO, 2002);
- Gross National Happiness (FIB, 1972);
- Indicators of Life Quality at Work (LIMONGI-FRANÇA, 1996);

- Brazilian Standard n. 14280:2000: Registration of accident at work - Procedure and classification, from the Brazilian Association of Technical Norms (ABNT, 2001);
- OHSAS 18001 (2007) - Occupational Health and Safety Management Systems;
- Indicators of Safety at Work (BARKOKÉBAS JÚNIOR et al, 2006);
- Global Reporting Initiative (GRI, 2010);
- Balanced Scorecard (KAPLAN and NORTON, 1997).
- Brazilian Program for Habitat Quality and Productivity - PBQP-H (BRASIL, 2005).

Stage 2: Research on Perception along professionals of the Construction Industry

All indicators that composed this system were submitted to the validation of 13 (thirteen) professional groups acting in the Construction Industry, as follows: Work Managements; Tax Auditors of the Ministry of Labor and Employment; Professors in Civil Engineering; Civil Engineers; Entrepreneurs; Consultants; Representatives of the Regional Council of Engineering and Architecture of Rio Grande do Norte; Ergonomists; Professionals of Specialized Service in Safety Engineering and Medicine at Work-SESMT; Workers in Construction; Representative of the Union of Construction Industry of Rio Grande do Norte-SINDUCON/RN; Representative of the Intermunicipal Union of Workers in the Construction Industry, Loads, Assembly, Equipment and Related of Rio Grande do Norte-SINTRACOMP/RN; Other professionals in Construction.

The following questions were asked to these professionals: a) whether they were using these indicators, b) if they would use them, and c) what degree of importance (Very Important, Important, Undecided, Not very important or Unimportant) they attributed to the information these indicators offered. From the responses, the indicators that would be part of the proposed system, the ones in need of some modification and those that would be excluded from the proposed system of indicators were defined.

RESULTS

The Bibliographical Research the identification of 62 (sixty two) indicators, which were classified into nine (9) categories (column 1), outlining a system of indicators to measure Ergonomics organizational performance, as shown in Table 1 (Bezerra, 2010). As you can see, each of the 9 categories of indicators is associated with a set of indicators (column 2) correlates. Each indicator is given a name (column 3), has a specific tool for collecting data (column 4) and characterized as to their type, in proactive and reactive (column 5).The literature allowed the identification of 62 (sixty two) indicators, which were classified into nine (9) categories (column 1), outlining a system of indicators to measure Ergonomics organizational performance, as shown in Table 1 (Bezerra, 2010). As you can see, each of the 9 categories of indicators is associated with a set of indicators (column 2) correlates. Each indicator is given a name (column 3), has a specific tool for collecting data (column 4) and characterized as to their type, in proactive and reactive (column 5).

Table 1: Indicators arising from stage Bibliographical Research (Bezerra, 2010).

Category of Indicators	Total Indicators by Category	Indicators	Form or instrument of Data Collection	Classification (Proactive or reactive)
1.External environment or context	04	• Evaluation of suppliers and contractors	Form	Proactive
		• Degrading Impacts of production to the environment	Form	Proactive

		• Indicator of external pressures over the company	Form	Proactive
		• Index of customer satisfaction	Formula	Proactive
2.Environmental work conditions	03	• Good practices in logistics and worksite layout	Form	Proactive
		• Volume of generated waste	Formula	Proactive
		• NR-17 indicator of adequacy to environmental conditions on worksites	Checklist	Proactive
3.Work efficiency	06	• Efficiency in autonomous units sales	Formula	Proactive
		• Average productivity of each employee	Formula	Proactive
		• Rate of production errors	Formula	Reactive
		• Rate of activities that do not add value to the product	Formula	Reactive
		• Overall work productivity	Formula	Proactive
		• Rework index	Formula	Reactive
4.Worksite machines and tools	03	• Total maintenance cost	Formula	Proactive
		• NR-17 Indicator of machinery and tools adequacy on worksites	Checklist	Proactive
		• NR-18 Indicator of machinery and tools adequacy on worksites	Checklist	Proactive
5.Worksite furniture	02	• NR-17 indicator of furniture adequacy	Checklist	Proactive
		• Number of departures due to ergonomically inappropriate furniture	Formula	Reactive
6.Work organization	19	• Repair and replacement of material cost	Formula	Reactive
		• Cost on assistance to the insured	Formula	Reactive
		• Total cost	Formula	Reactive
		• Costs for the period of removal	Formula	Reactive
		• Compensation received by the company	Formula	Reactive
		• NR-17 indicator of adequacy to work organization	Checklist	Proactive
		• OHSAS 18001 indication of adequacy to work organization	Checklist	Proactive

		• Indicator of employee satisfaction with coworkers	Scale	Proactive
		• Indicator of employee satisfaction with supervisors	Scale	Proactive
		• Indicator of psychological overload	Form	Proactive
		• Indicator of organizational performance according to their collaborators	Scale	Proactive
		• Improvements in work process and technology	Form	Proactive
		• Number of conditions of insecure environment by sector/workplace	Formula	Reactive
		• Absenteeism rate	Formula	Reactive
		• Turnover rate	Formula	Reactive
		• Training rate	Formula	Proactive
		• Total of investments in ergonomics actions	Formula	Proactive
		• Total workforce by employment type, employment contract and region	Formula	Proactive
		• Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with laws and regulations	Formula	Reactive
7.Workers Satisfaction	03	• Actions that enable the contributor a good quality of life	Form	Proactive
		• Indicator of employee's trust towards the organization	Scale	Proactive
		• OHSAS 18001 indicator of adequacy to work safety	Checklist	Proactive
8.Workers Health and Safety	19	• Statistics of occupational diseases to occupational activities	Formula	Reactive
		• Statistics of occupational diseases by occupational activity	Formula	Reactive
		• Incidence of unsafe acts by man/hours worked	Formula	Reactive
		• OHSAS 18001 indicator of adequacy to work satisfaction	Checklist	Proactive
		• NR-18 indicator of adequacy to workers' health and safety	Checklist	Proactive

		• PCMAT indicator of adequacy to workers' health and safety	Form	Proactive
		• Rate of personal factors of insecurity	Formula	Reactive
		• Number of medical care by workers	Formula	Reactive
		• Average number of days charged due to permanent disability	Formula	Reactive
		• Average number of days lost due to total temporary disability	Formula	Reactive
		• Percentage of impersonal species accidents with higher incidence	Formula	Reactive
		• Percentage of impersonal accidents	Formula	Reactive
		• Percentages of injury sources with higher incidence	Formula	Reactive
		• Percentage of personal accidents	Formula	Reactive
		• Percentage of types of personal accidents with higher incidence	Formula	Reactive
		• Frequency rate of accidents with removal injuries	Formula	Reactive
		• Frequency rate of accidents with injuries without removal	Formula	Reactive
		• Average time computed	Formula	Reactive
		• Accident severity rate	Formula	Reactive
9.Transportation of Materials	03	• Material circulation index	Formula	Proactive
		• NR-18 indicator of adequacy to loading, transportation and unloading of materials	Checklist	Proactive
		• NR-17 indicator of adequacy to loading, transportation and unloading of materials	Checklist	Proactive

The system of Ergonomics indicators developed from the literary review was predominantly constituted by 33 proactive indicators (53.23%) and 29 reactive indicators (46.77%).

Among the 62 indicators generated, we found in the responses of the professionals surveyed that most systematized indicators (35 or 56.4%) needed modification, 9 indicators (14.5%) had no interest to these professionals and hence were excluded from the system developed, and 18 indicators (29%) were accepted and considered relevant and should remain in the system, as can be seen in Figure 1.

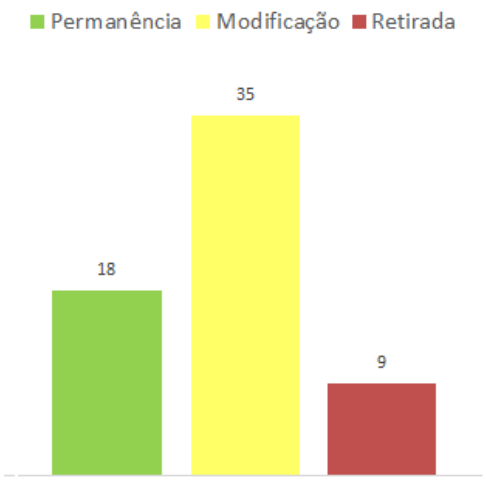

Figure 1: Quantity of indicators according to the judgment of Professional Groups (Group of Extension and Research in Ergonomics-GREPE/UFRN).

Table 2 below shows the indicators used by most professionals surveyed and the number of professional groups that use them.

Table 2: Indicators used by more professional group surveyed

Indicators		**Number of Groups Professionals who use**
1	Evaluation of suppliers and contractors	9
4	Index of customer satisfaction	9
34	Training rate	8
36	Total workforce by employment type, employment contract and region	7
2	Degrading Impacts of production to the environment	6
9	Average productivity of each employee	6
14	Total maintenance cost	6
45	NR-18 indicator of adequacy to workers' health and safety	6
46	PCMAT indicator of adequacy to workers' health and safety	6

All indicators from the system of Ergonomics indicators arising from the literature, shown in table 1, are used by at least 1 (one) group of professionals surveyed. The least used indicators are the indicator #35 (Total investments in Ergonomics actions) and indicator #43 (Incidence of unsafe acts by man hour worked). Among the 62 (sixty-two) indicators identified in the literature, only 18 (eighteen) indicators had the approval of the professionals surveyed and are divided into 8 (eight) categories and not the 9 (nine) categories of the initial research, because the category "Furniture of work sites" was the only one that had no representation in this selection.

Table 3, below, shows the category of indicators, with eighteen (18) indicators selected by professional groups surveyed.

Table 3: Selected by professional groups surveyed indicators

Category of Indicators	**Indicators**
1.External environment or context	• Evaluation of suppliers and contractors
	• Degrading Impacts of production to the environment
	• Index of customer satisfaction
2.Environmental work conditions	• Good practices in logistics and worksite layout
3.Work efficiency	• Average productivity of each employee
	• Rate of production errors
	• Rate of activities that do not add value to the product
	• Overall work productivity
4.Worksite machines and tools	• NR-18 Indicator of machinery and tools adequacy on worksites
5.Worksite furniture	• Indicator of employee satisfaction with supervisors
	• Improvements in work process and technology
	• Number of conditions of insecure environment by sector/workplace
	• Absenteeism rate
	• Training rate
6.Work organization	• Actions that enable the contributor a good quality of life
7.Workers Satisfaction	• NR-18 indicator of adequacy to workers' health and safety
8.Workers Health and Safety	• NR-18 indicator of adequacy to loading, transportation and unloading of materials
	• NR-17 indicator of adequacy to loading, transportation and unloading of materials

We observed that only 1 indicator (5%) of the “Health and Safety of Workers” category was selected by the professionals surveyed.

CONCLUSIONS

The most accepted indicators are in the category "External environment or context", suggesting that professionals who relate to the construction industry privilege the analysis of the environment and context in which they operate, business competitors, customers, market scenarios, their weaknesses, their strengths and potential growth or weakening before the market.

The category containing the largest amount of less approved indicators by the industry professionals was "health and safety of workers", even though this is the category with the highest number of indicators (19), as shown in table 1, referring to the stage of literature review. The higher rejection of these indicators occurred, according to the people surveyed, due to the apparent difficulty of performing data collection to feed the indicators.

Many professionals stated that the information generated by these indicators was dispensable for the company management and that the information provided by these indicators would not help them in any important decision making.

We conclude, therefore: a) there is a preference and overvaluation of productivity indicators by most professionals; b) the safety and health of workers are not sufficiently considered in the principles and management tools and in the organizational culture; c) there is a notion that people are not part of the productive system; d) that accidents and occupational diseases are not considered production and performance factors, nor their reduction constitutes a real factor of production and strategic value.

As a corollary, the preference of the professionals surveyed by the indicators of productivity suggests a kind of culture focused on performance evaluation, which often favors the stimulus to activities with a high work rate, increasing the risk and the probability of accidents, diseases, fatigue, rework, paradoxically becoming factors of productive inefficiency.

We defend the idea that a system of indicators for organizational performance should integrate social and technical factors, integrally, i.e., performance and human factors.

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Section 5

Safety and Occupational Health Care

sEMG Studies of Milking Activities in Two Different Working Conditions

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ABSTRACT

The increasing degree of specialization of the work involved in milk production due to the growing size of herds often leads to upper limb repetitive movements. Despite the adoption of automation processes, milk production is still an occupation that is susceptible to biomechanical overload. Muscle activity of the extensor pollicis brevis (EXT), flexor carpi radialis (FLEX), biceps brachii (BB) and deltoideus anterior (DA) was studied in five workers while they performed udder cleaning and tapping tasks both before and after an ergonomic intervention consisting in 1) reducing the working plane height by means of a 5 cm-thick carpet; 2) changing the plastic bottles used in tapping tasks regularly to prevent them from hardening. The mean activation and the time percentage over 10% of the maximal voluntary contraction were calculated. Both tasks induced a marked effort from the EXT and DA muscles, and a milder effort from the BB and FLEX muscles. The ergonomic intervention was followed by a downward trend in both parameters. Further data are currently being acquired on a larger sample of workers to verify whether these preliminary findings are supported more robust statistical analyses.

Keywords: sEMG, ergonomic, dairy parlor, upper limb repetitive movement

INTRODUCTION

The increasing degree of specialization of the work involved in milk production due to the growing size of herds often leads to upper limb repetitive movements. The activity of dairy parlor workers in recent years has changed radically. Milking activities, which require no more than a few minutes per cow, may in large herds last the entire working shift. Despite the adoption of automated processes, milk production remains an occupational problem, as reported in many studies in the literature, with milkers often experiencing pain in different parts of their musculoskeletal system. Vostrikov (Vostrikov, 1995) demonstrated that the efficiency of skilled workers after two hours of continuous milking activities tended to decrease, resulting in an increased number of errors and disruptions as well as a loss of productivity.

Lundqvist (Lundqvist et al., 1997) reported a high risk of repetitive movements of the upper limbs for parlor milkers, as did Stal (Stal, 2001), who found high flexo-extension and radial deviation values in both wrists. More recently, Pinzke (Pinzke, 2003) and Stal (Stal et al., 2000) applied surface electromyography to assess milkers' muscle activity. Pinzke, who recorded the biceps brachii and forearm flexors bilaterally in three main tasks, i.e. "drying (the cow's udder)", "pre-milking (the first milk)" and "attaching (the milking unit to the udder)", found high muscle load values and a lack of time for rest. Stal recorded the biceps muscle and the flexor and extensor muscles of the forearm bilaterally in both a traditional and a more modern milk production system. She found that the peak

loads for the flexor and extensor muscles were close to their maximum capacity. Both studies concluded that the combination of high muscle activity values and extreme wrist and hand postures might contribute to the development of musculoskeletal disorders.

The afore-mentioned studies highlight the risk of upper limb musculoskeletal disorders associated with milking activities. However, it should be borne in mind that these studies were conducted with wired sEMG equipment that restricted the workers' movement during the recordings. For the purposes of our study, we instead adopted totally wireless equipment that allowed us to record muscles involved in fine motor skills, such as the extensor brevis pollicis, without affecting the real working conditions and, consequently, to record milking activities not in laboratory simulation conditions but in a real working environment.

MATERIALS AND METHODS

Five skilled male workers were enrolled in the study. The tasks of udder cleaning and tapping were studied in two different work stations before and after ergonomic interventions consisting in 1) reducing the working plane height by means of a 5 cm-thick carpet; 2) changing the plastic bottles used in tapping tasks regularly to prevent them from hardening. Each task was based on the milking of six cows; the workers' mean age (SD) was 37 years (4.2) and their mean height was 170 cm (3.8). None of the participants had a history of either musculoskeletal disorders or neurological diseases. No information regarding the expected results was provided in order to avoid the results being biased, whether consciously or unconsciously. Electrical muscle activity was recorded using a 16 channel Wi-Fi surface electromyography system (FreeEMG, BTS SpA, Milan, Italy) at a sampling frequency of 1 kHz.

After skin preparation, surface electromyographic signals were detected from each muscle by means of two Ag/AgCl pre-gelled disposable surface electrodes (H124SG, Kendall ARBO, Donau, Germany), which had a detection surface of 10 mm (gelled). Electrodes were placed in the direction of the muscle fibers, according to the European Recommendations for Surface Electromyography (SENIAM) (Hermes et al., 2000), with a centre-to-centre distance of 20 mm. We investigated the following muscles on the right side of the body: extensor pollicis brevis (EXT), flexor carpi radialis (FLEX), deltoideus anterior (DA) and biceps brachii (BB). In order to elicit the maximal voluntary isometric contraction (MVCi) from each muscle, six isometric exertions were performed, according to SENIAM recommendations. The sEMG signals were rectified, integrated with a mobile window of 0.125 s, filtered with a 5 Hz Hamming low-pass filter and normalized to the maximum value of the MVCi. The mean activation and the time percentage exceeding 10% of the MVCi were measured.

Figure 1 shows the probe placement. The probes were protected by means of gloves used specifically for milking activities (Figure 2).

Figure 1: probe placement

Figure 2: dairy parlor worker executing MVC, wearing specific glove

RESULTS

Figure 3 contains a sample of the data we recorded. The recordings clearly illustrate the activity of each of the four muscles studied while the six cows were being milked. Figure 4 shown the tie stall before (above) and after (below) the ergonomic intervention performed by adding a 5 cm high plate.

Figure 3: a sample of the four sEMG signals recorded. The image shows (from top to bottom): the extensor pollicis brevis, flexor carpi radialis, deltoideus anterior and biceps brachii

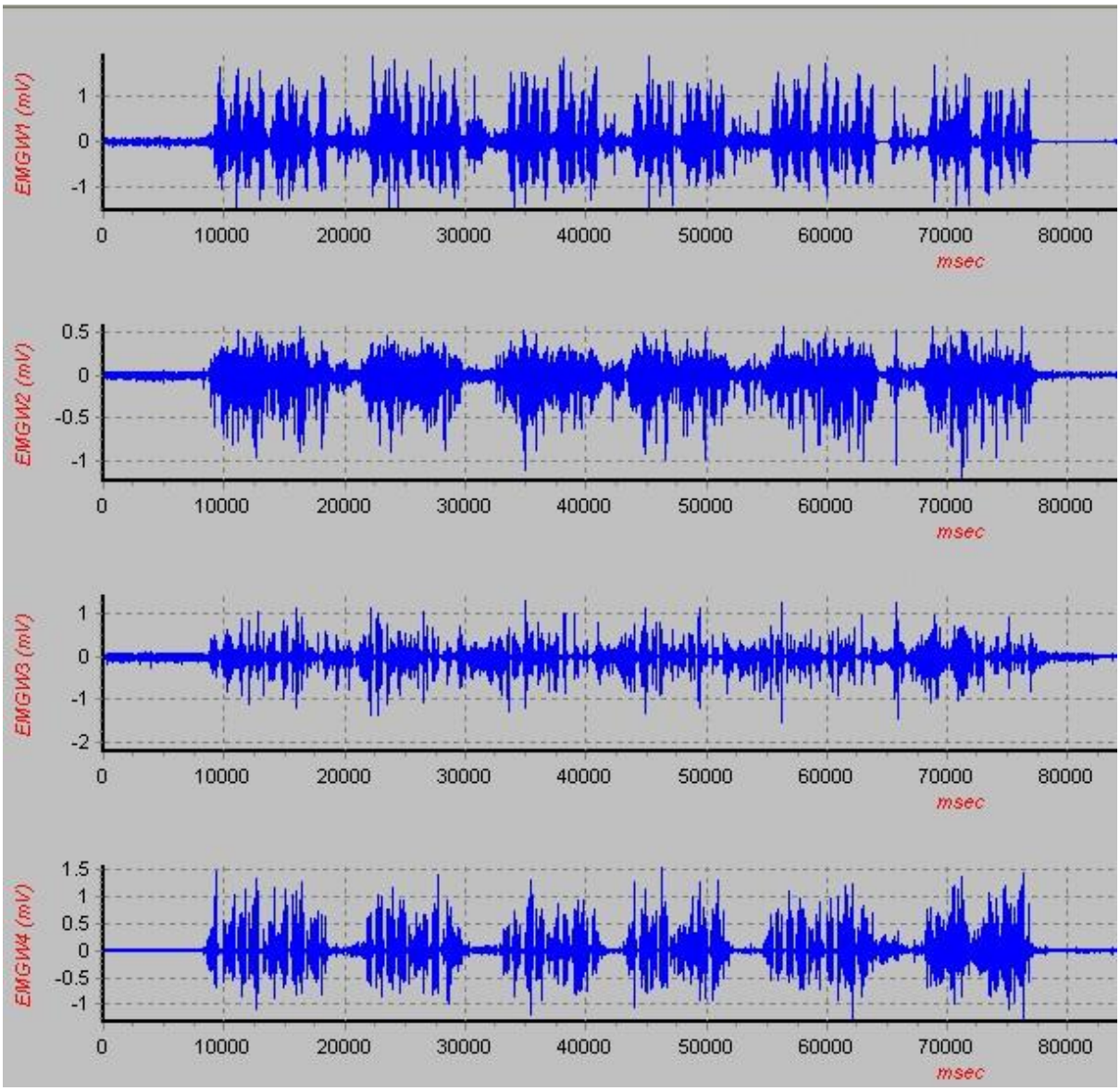


Figure 4: tie stall before (above) and after (below) the ergonomic intervention. Below the 5 cm high carpet and an aiding cradle containing dirty and clean wipes are shown

The results show that both tasks induced a marked effort from the EXT and DA muscles, and a milder effort from the BB and FLEX activities.

Tables 1 and 2 show the mean values in both tasks before and after the ergonomic intervention. Figures 5 and 6 schematize the values shown in Tables 1 and 2. Tables 3 and 4 and Figures 7 and 8 instead illustrate the time percentage over the 10% threshold of the MVC.

Table 1: mean activities before and after the ergonomic intervention in the tapping task

Muscle	Tapping Pre (mean)	Tapping Post (mean)
EXT	29.3	22.2
FLEX	8.1	8.5
BB	8.2	7.1
DA	13.1	12.1

Table 2: mean activities before and after the ergonomic intervention in the udder cleaning task.

Muscle	Udder Cleaning Pre (mean)	Udder Cleaning. Post (mean)
EXT	32.2	29.2
FLEX	8.5	7.2
BB	8.8	7.7
DA	24.8	21.3

Figure 5: comparison of mean muscle activities in the tapping task pre- (dark gray) and post- (light gray) ergonomic intervention.

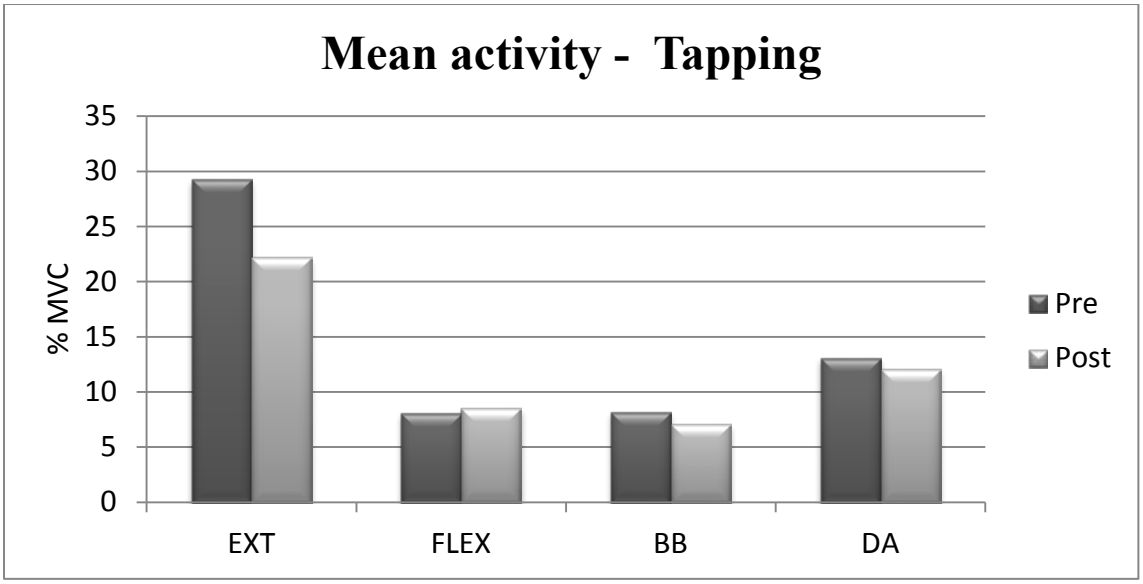


Figure 6: comparison of mean muscle activities in the udder cleaning task pre- (dark gray) and post- (light gray) ergonomic intervention.

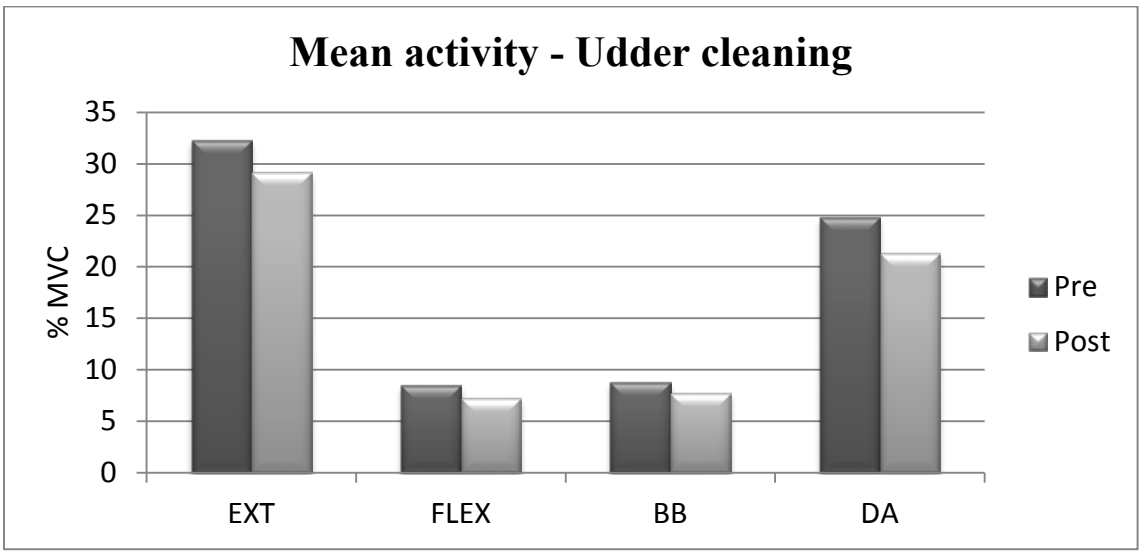


Table 3: time percentage activity over the 10% threshold of the MCV for each muscle in the tapping task before and after the ergonomic intervention.

Muscle	Tapping Pre (Time % over threshold)	Tapping Post (Time % over threshold)
EXT	71.3	64.7
FLEX	38.6	35.9
BB	33.7	22.4
DA	51.5	48.8

Table 4: time percentage activity over the 10% threshold of the MCV for each muscle in the tapping task before and after the ergonomic intervention.

Muscle	Udder cleaning Pre (Time % over threshold)	Udder cleaning Post (Time % over threshold)
EXT	91.1	83.2
FLEX	29.7	20.4
BB	30.7	25.3
DA	86.1	77.9

Figure 7: comparison of time percentage activation over the 10% threshold of the MCV in the tapping task pre- (dark gray) and post- (light gray) the ergonomic intervention.

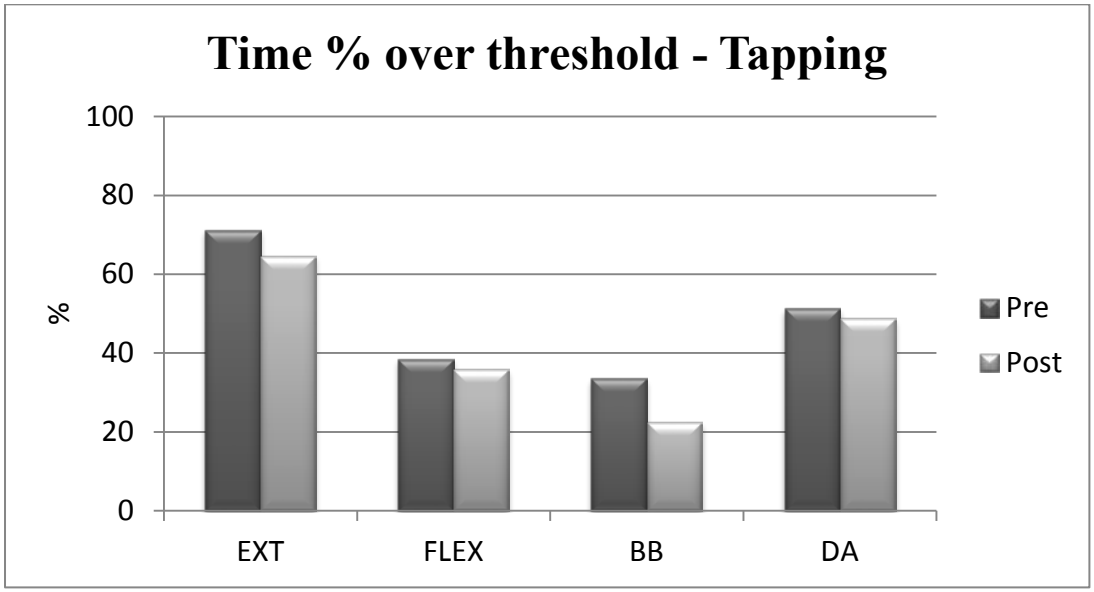
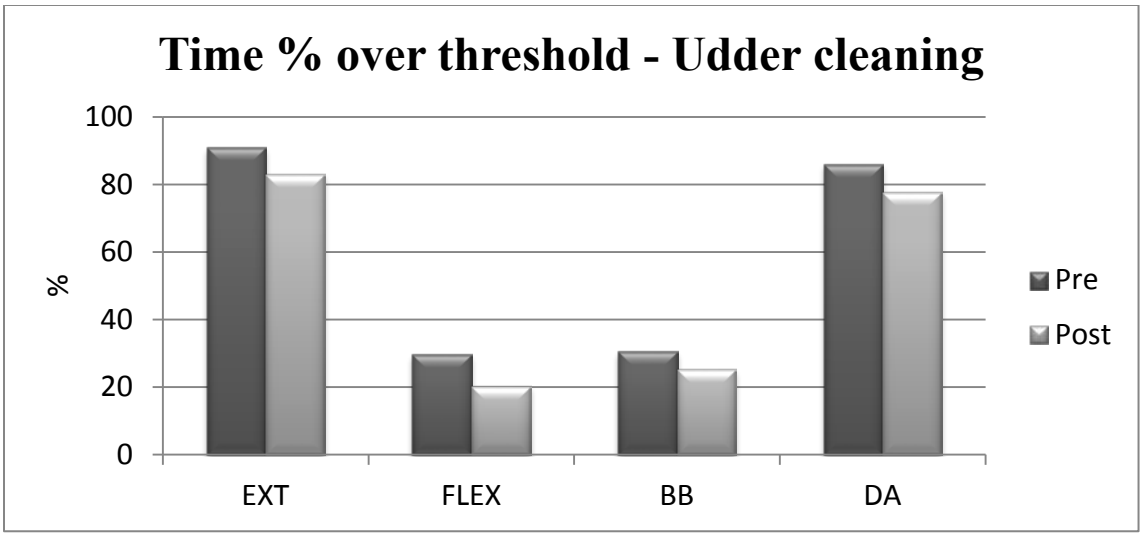


Figure 8: comparison of time percentage activation over the 10% threshold of the MCV in the udder cleaning task pre- (dark gray) and post- (light gray) the ergonomic intervention.



DISCUSSION

In contrast to the papers cited in the introduction, our study was not conducted in laboratory simulation conditions but directly in the stall thanks to the non-invasiveness of the sEMG recording technologies available nowadays. Indeed, the equipment we used allowed us to investigate not only the muscles normally studied, such as the biceps brachii, flexor and extensor of the forearm, but also the extensor pollicis brevis muscle, which played a major role in the two sub-tasks investigated.

After the ergonomic intervention, we observed a downward trend in both parameters (mean activity and time percentage over threshold) in both tasks (tapping and udder cleaning) in the muscles involved most, i.e. extensor pollicis brevis and deltoideus anterior. There were, instead, no substantial differences in the muscle activity of the flexor carpi radialis or biceps brachii in either task between the pre- and post-ergonomic intervention values.
We thus observed, albeit in a small sample of workers, that the measures we adopted (i.e. reducing the working plane height by means of a 5 cm-thick carpet and changing the plastic bottles used in tapping tasks regularly to prevent them from hardening) may be considered as two simple and cheap solutions to reduce the risk of biomechanical overload in milking activities.

Further data are currently being acquired on a larger sample of workers to verify whether these preliminary findings are supported more robust statistical analyses.

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Relationship among Movement Trajectory of Body Parts, Center of Gravity Movement and Standing Postures while Chucking of an Expert and Non-Expert

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ABSTRACT

The participants are an expert is 85 years has been working 70 years in lathe and the non-expert is 16 years that only 1 year of experience. The standing posture aligned with the chuck had the rotation pattern movement. It had a most distance movement of wrists, shoulders, elbows and hands. The standing on the right of the chuck was not a rotation pattern but trend line movement was a straight line. The standing posture of right side of the chuck always used his waist as like the base of movement. The standing postures did not influence the balance movement between left and right side of body. The standing postures affect the body movement on XZ plane. The expert always bent his elbow both left and right side and stretched it out of the body not only the standing aligned with the chuck but also the standing on the right of the chuck. The difference of hand holding position does not affect the standing posture on the right side of the chuck. The expert always sidle away from the machine around 45 degrees. The differences of hand holding position affect the distance and pattern movement.

Keywords: Center of gravity, Standing posture, Hand holding, Chucking movement,

INTRODUCTION

Lathe processing

Turning is a cutting operation that the part is rotated as the tool and hold around a horizontal axis while being formed to size and shape by cutting tool on a machine which called a lathe. Lathe is one of the machine tools most well used that is a machine tool used principally for shaping pieces of metal, wood, or other materials. The shapes of part on the lathe processing usually are cylindrical, radial, or irregularly shaped. Principal capabilities of the lathe are forming straight, tapered, profile cut, groove, or irregularly outlined cylinders, facing or radial turning cylindrical sections, cutting screw threads, and boring or enlarging internal diameters (Kalpakjian, 2006). Generally, workpieces are clamped and are held to the headstock spindle of the lathe with chuck. The independent chuck includes four jaws which are adjusted individually on the chuck face by means of adjusting screws. The jaws of the independent chuck may be reversed so that the steps face in the opposite direction; thus, workpieces can be gripped either externally or internally. The independent chuck can he used to hold square, round, octagonal, or irregular shaped workpieces in either a concentric or eccentric position due to the independent

operation of each jaw. Because of its versatility and capacity for fine adjustment, the independent chuck is commonly used for mounting workpieces that require extreme accuracy. The universal scroll chuck usually has three jaws which move in unison as an adjusting pinion is rotated. The advantage of the universal scroll chuck is its ease of operation in centering the work for concentric turning. This chuck is not as accurate as the independent chuck but, when in good condition, it will centre the work automatically within 0.003 of an inch of complete accuracy. In addition, the universal scroll chuck can be used to hold and automatically center round or hexagonal workpieces. However, this chuck unable used effectively to hold square, octagonal, or irregular shapes (Army Institute, 1988). The worker always uses the chuck key as the t-shaped wrench when the worker wants to loosen or tighten the work-piece gripping in the chuck jaw.

Figure 1. Characteristic to chuck key, universal scroll chuck and independent chuck

Skills were of vast importance to the industrial work. All part of the production efficiently depended on the professional's skills. Without their expertise in the making of goods merchandise, most of the industrial factory would not have survived. Because of advanced technology, the professional and the precision machine have been necessary to operate in many areas of industrial complex to become an important asset in developing simultaneous.

Quality has become one of the most important consumer decision factors in the selection among competing products. The product quality can be assessed in several methods. The quality engineering parameters are often called quality characteristics such as diameter, length, surface roughness, taste, appearance, color, reliability and durability. Moreover, they are often evaluated relative to specification. For a manufactured product, the specifications are the desired measurements for the quality characteristics on the components and subassemblies that make up the final product (Douglas, 1997).

The external factor of the appropriate condition for product quality includes machine, method, material, measurement, milieu and man-power. There is some researches show the several behaviors of workers whose difference experience how to affect the product quality. The research of stance of chucking by the takumi on lathe working found that there are the faults surfaces of work piece on non-expert more than expert. Because the non - expert quite tight lock the chuck jaws, this fault surface occurred (Yoshikawa, 2011). The research of using the elbow had shown the acceleration of the elbow while the worker was being chucking exertion to lock the chuck jaws. Then the expert began to change an elbow movement for chucking he increased the speed of the force action than the non-expert (Ito, 2013). And then the time-use data show the measuring time spent of worker while he directly measured the workpiece dimension by vernier caliper and micrometer. The expert took time to measure and had carefully measurement more than non-expert (Yoshikawa, 2012). Furthermore, the expert gave precedence in the measurement and to measure repeatedly with precision in work pieces. He has focused on the task only (Koshino, 2011).

The last experiment of study the difference among an expert and a non-expert in the behavior for chucking in the lathe found that the characteristic of standing posture and the hand holding position on chuck key of expert worker did not influenced on movement pattern of body along Y value. However, only the standing posture influenced the movement pattern of XZ plane. Before chucking, the expert exerted the forearm force to push the body backward after that he move the body forward and he start twisting. Moreover, the distance movements of shoulder right, waist left and waist right are quite similar. However, the distance movement of shoulder left is smaller. In addition, Expert worker always bent the body down forward while he was chucking whereas the non-expert always kept upright standing along the movement of chucking. His body did not move forward. Expert worker have a quite steady

balance movement between left and right side of body until he twisted the body for chucking. The body leaning did not rather appearance. While he was chucking he did not blend his knee and have not up and down movement. The expert has a few position movements in Y axis. The distance movement of expert both the X and Z axis have a less distance movement along each axis than non expert**.**

Conversely, the non-expert could not keep the balance movement. He often leaned the left side of body. It is determinant of inclining the body to the left while he was beginning chucking. The non-expert kept standing upright along movement of chucking. The position of waist and shoulder of each side was quite concentric. It showed that the non-expert did not move the shoulder forward. Beside he rotated both shoulder right and waist right to backward for exert force to twist chuck key. At the same time, both shoulder left and waist left move to left side as a rotation pattern. The difference in acceleration of vertical movement between expert and non-expert is a much more significant. The vertical motion of the expert that quite smooth and constantly. The certain intervals the acceleration is approximately constant and not over other intervals. The acceleration data of non-expert is interesting. The maximum acceleration is about 2.5 G (gravitation). The acceleration increasing occurred in the end of time. As expected, the Y values of expert hover around zero point while the Y values of non-expert shows the up or down acceleration of the chucking behavior.

METHOD AND INSTRUMENTS

Aim

This study focused the relationship among the pattern direction of body movement such as the torso, waist, shoulder, hand, elbow and forearm with the center of gravity movement and the stand postures that there are difference between an expert and the non-expert.

Participants and tool

The experiment participants were 2 Japanese-men experienced for the lathe processing. The expert worker (85 years) has worked in the company for 70 years and the non-expert (16 years) has worked 1 year of experience for the lathe operation. This experiment investigates by used universal scroll chuck. Both of them operates on the lathe machine without the controlling speeds, feed and tooling instructions. In Figure 2 is the workpiece drawing on lathe operation used tool steel (S45C) as the work pieces material.

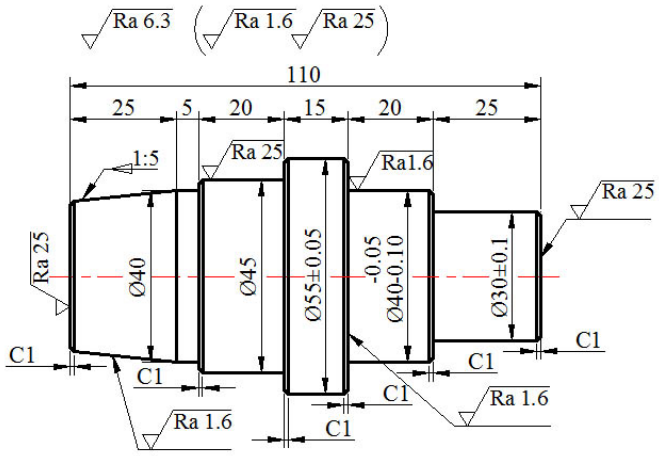


Figure 2. Working drawing

An expert and the non-expert workers were conducted with 16 reflective markers only on the top of their body. All reflective markers position data which the synchronization was taken by a motion analysis system (sampling rate: 100Hz). As equipments for chucking movement analysis in lathe processing are three-dimensional motion capture system (Mac3D Motion analysis) consisted of 6 infrared cameras and 2 video cameras captured the position of each subject (Figure 3).

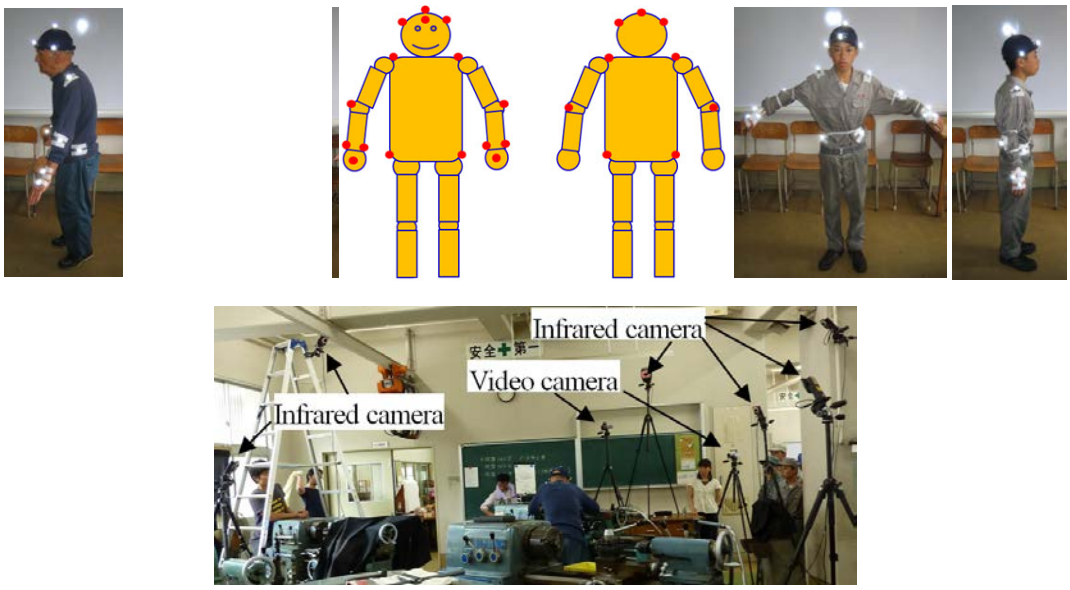
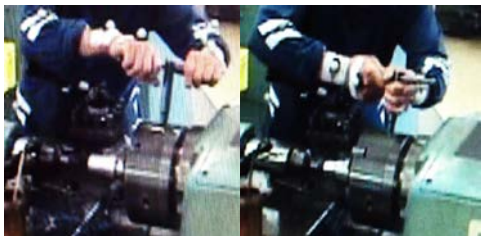


Figure 3. Position of reflex markers on the top body of participants, location of infrared and video cameras.

RESULTS & DISCUSSION

(a) **(b)** **(c)**

Figure 4. The standing posture of the expert and the non-expert worker



(a) **(b)**

Figure 5. The characteristic of hand holding position.

The observation thoroughly work of time found that the expert worker have using the chuck key for lock the work piece into the chuck jaw in 10 times. The 6 times are the first probably quite tight of jaws with workpiece (1, 2, 3, 4, 5, 6) and the 4 times are the repetition tighten chucking (1', 2', 5', 6'). The non-expert worker has 6 times for the tight only. The standing character of expert worker can divided in 2 groups and the non-expert is only 1 group (Figure 4). The first standing of expert on Figure 5(a), the body of expert such as waists, shoulders and trunk aligned with the chuck (AC). The second standing posture on Figure 5(b), He stood at the right side of the chuck and quite near the tailstock (RC). Besides, Figure 5(c) showed the non-expert worker had the left standing of the chuck (LC).The hands holding position on the key chuck in Figure 5 consisted of 2 characteristics. Firstly, both the left

hand and the right hand held on the handle of chuck key (LR). Secondary, only the right hand was holding on the handle and the left hand held on the shank of chuck key (SR). The hand characteristic of the expert worker was both the former and the latter hand position. However, the hand holding position of non-expert was the former only. These data were categorized the behavior of the expert and non-expert in 4 groups such as type I, II, III and IV. The details are as below in table 1

Table 1**:** The subdivision group of the expert and non-expert worker were separated by the characteristic of hand position and standing posture.

Type	Time	Standing posture	Hand position	Group	Type	Time	Standing posture	Hand position	Group
Expert	1	AC	LR	I	Non-expert	1	LC	LR	IV
	1’					2			
	2					3			
	2’	RC		II		4			
	3					5			
	4		SR	III		6			
	5		LR	II					
	5’								
	6		SR	III					
	6’								

For understanding clearly, Figure 6 showed the X, Y and Z axis construction for help the conception of movement on each plane for example XY plane, YZ plane and XZ plane. The legend used for understanding the purpose and the content of the chart.

Figure 6**.** Tooling for comprehension analysis

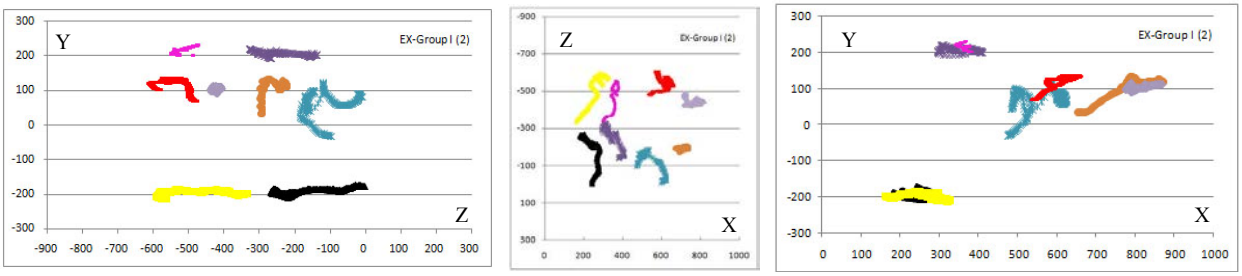


Figure 7**.** Group I of Expert worker, Stand alignment with the chuck (AC), both left and right hand hold on the handle of chuck key (LR)

The consideration on YZ plane should be image at behind of worker. On Figure 7, It shown the movement data of an expert worker in group I that included the movement of bilateral on shoulder, elbow, hand and waist. The group I, the standing posture of expert worker was alignment with the chuck (AC) by turning the face of expert to the chuck beside his hands both left and right side held on the handle of chuck key (LR). On above mention in last my research that the line graph of shoulders and waists had a fairly stable movement along the Z axis that easy detection on YZ plane. The line graph on Figure 7 can also explained the movement of torso and forearms. In case of elbows and hands, the expert worker always bent his elbow both left and right side and stretched it out of the body. He can control the line balance of forearm for parallel movement of hand and elbow position along the XZ plane. The

position reflex marker of YZ and XY plane found both hand and elbow position pretty similar on the Y axis. On XZ plane, the line graphs movement of elbow left and right had a similar pattern of waists and shoulders that the line graphs of them as a curve. But the truth of their direction movement have difference. When he began twisting the chuck both the waist and the shoulder turned to the left side but the elbows were swing to the right side. His hands had a least movement distance. It can observe by comparison of movement distance on each line graphs. The curves line graphs movement of waists, shoulder and elbow on plane of XZ can confirm that during the expert was chucking he used the center of body as the line of backbone for center of rotational movement.

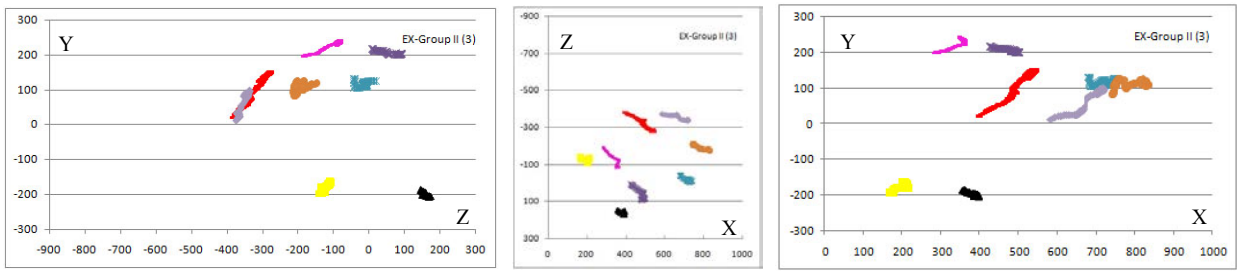


Figure 8**.** Group II of Expert worker, Stand on the right side of the chuck (RC), both left and right hand hold on the handle of chuck key (LR)

In Figure 8, all though this figure has difference the standing posture with the previous figure but the expert still keep steady straight between the position of hands and elbows. The positions of them are as alike the Y position along the X axis. In this case, the expert stood on the right side of the chuck (RC) and sidle away from the machine around 45 degrees. The jaws tighten up by this procedure often used his waists for center of twisting. The expert worker still bent his elbow both left and right side and stretched it out of his body. When he get start, he will fix the waist and jerk the elbow for pulling the shoulder to the left side together. Therefore, when the elbow moved both shoulder and hand will follow up. On XZ plane, the parts of right side were used less than the left side.

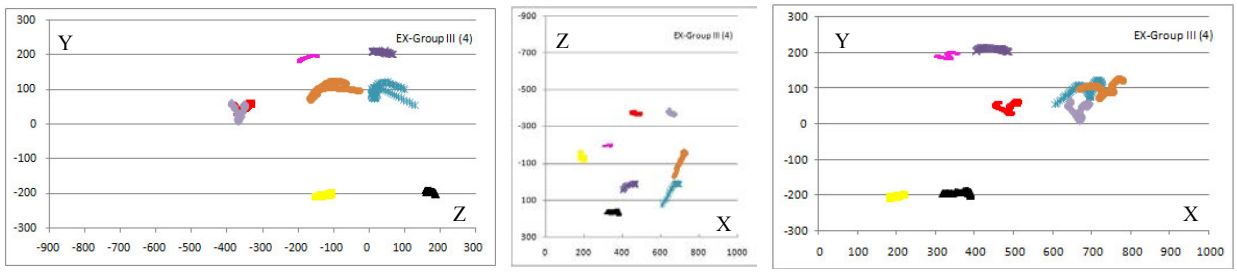


Figure 9**.** Group III of Expert worker, Stand on the right side of the chuck (RC), left hand hold on the shank but right hand hold on the handle of chuck key(SR)

Even if, most characteristic important of group II and group III such as the keeping steady straight between the position of hands and elbows, the standing posture, the bending his elbow both left and right side and stretched it out of his body, the sticking of his waist for as the center of twisting while chucking were similar. Nevertheless, the movement characteristic of his waists, shoulders and hands had difference. In case of group III, the bodies movement of left side were hardly moved when compared with the movement of right body and compared with the left side movement of group II. The trend line graphs both YZ plane, XZ plane and XY plane shown that the maximum distance movement of group III was belonged to the hand and the elbow of right side. At the moment of an expert chucking, he had a few movement of his waists, shoulders and forearm of left side. The jaws tighten on group III, the expert used only the forearm of right side by the right handle of chuck pulled.

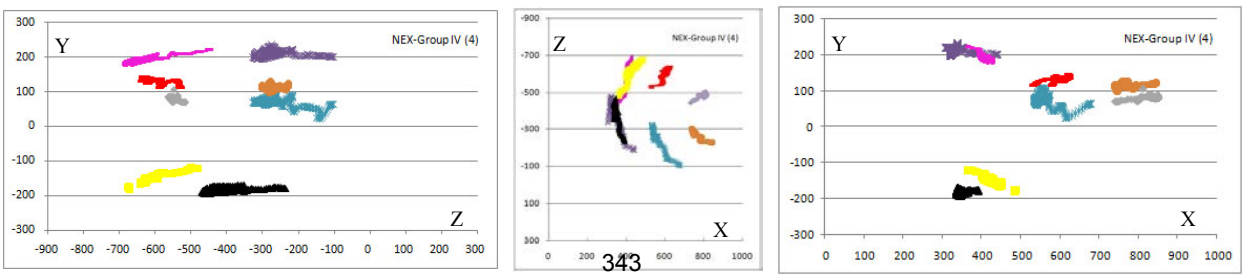


Figure 10**.** Group IV of Non-expert worker, Stand on the left side of the chuck (LC), both left and right hand hold on the handle of chuck key (LR)

This graphs indicated the uncommon movement of the non-expert worker. Firstly, the position line on XY plane of his left hand and elbow were aligned by inclining towards with his shoulder meanwhile the right elbow was bent lower than his right hand. During chucking, his arms both left and right side had not a changed appearance. Secondary, the line graphs of body movement on XZ plane shown that the non-expert always had rotated the body movement together with swung the body to the left side by used the left hand as a center of rotation. Therefore, the distance movement of left side will be less than the right side. Lastly, the YZ plane indicated the non-expert inclined the body left down all the time.

CONCLUSION

This results mention can summarize the relationship among the movement trajectory of body, the center of gravity movement and the standing posture of an expert and non-expert meanwhile chuck jaws was tighten for lock the workpiece on lathe processing as below;

1. The pattern movement of the standing posture which alignment with the chuck on group I had the rotation pattern movement. The line of backbone is also a center of body between left and right side has been the center of this rotation.

2. The characteristic movement of an expert both group II and III which stand on the right of the chuck are not a rotation pattern but their trend line movement are a straight line.

3. The standing posture of right side of the chuck (group II and III) always use his waist as like the base of movement.

4. The standing postures do not influence the balance movement between left and right side of body. Both waists and shoulder still keep parallel steady among wrist line, shoulder line and XZ plane. On the contrary, the standing postures affect the body movement on XZ plane

5. Not only the standing posture which alignment with the chuck on group I but also group II and III which stand on the right of the chuck, the expert always bent his elbow both left and right side and stretched it out of the body.

6. The difference of hand holding position does not affect the standing posture on the right side of the chuck. The expert always sidle away from the machine around 45 degrees. However, the differences of hand holding position affect the distance and pattern movement.

7. There are a most distance movement of wrists, shoulders, elbows and hands on the standing posture which align with the chuck on group I.

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Work-Related Accident on Petroleum Industry: Beyond Human Errors and Immediate Causes

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ABSTRACT

In 2005, there was an explosion during a repair at Barrancabermeja refinery in Colombia. The fire that followed caused the death of two people, left seven wounded and caused losses estimated at nine million dollars. The company presented a video with the description of this accident, pointing as immediate causes of the explosion a dripping of propane-butane mixture from a heat exchanger and a spark generated when a man lift was switched off. The analysis done by the company identified unsafe acts (the use of an inadequate tool to correct the dripping), unsafe conditions (inadequate cap installed on the heat exchanger) and also included in the assigned causes disregarding of rules (not using Safe Isolation System). The objectives of this paper are: to approach this accident analysis from a different perspective, discussing new hypothesis based on organizational factors; to formulate new recommendations in order to contribute to accidents prevention; to encourage an organizational approach for analyzing work-related accidents that goes beyond human errors, technical causes or standards perspectives. This paper used an Analysis and Prevention of Accidents Model (MAPA) based on ergonomics of activity and other concepts used in accident analysis. Info sources were taken from the video, the presentation that summarizes the research done by the company, some press articles and interviews.

Keywords: Work-related accident, Ergonomics, Petroleum industry, Accident analysis methodology.

INTRODUCTION

Throughout history, the analysis of accidents and disasters has blamed the victims or their colleagues. This has been the classical approach for analyzing industrial accidents in industrial safety departments, with support of a structure for practice in accordance with Health and Safety Management Systems. Nevertheless, the structure of the process with these steps does not represent a break in the essence of the traditional paradigm, as it maintains its features. The approach of Health and Safety Management System is anticipatory as if all risk factors were known, especially if the analysis can reveal, in a systemic view, the contradictions that lie at the root of these factors alone.

Reason (1993) described three periods of those approaches regarding their focus of safety. Wilpert and Fahlbruch (1998) added a fourth one. Dien et al (2012) mark these periods into recent decades according to the most important industry events:

a) Technical period: up to the seventies, the source of safety problems was placed mainly upon technical reliability. During this period, the most used model to analyze and predict accidents was the so-called domino model (Heinrich, 1931). Hollnagel (2003) proposed to call it Sequential Accident Model. It describes accident as result of a string of clearly distinguishable events that occur in a specific order and illustrate it as a set of dominoes falling because of a single triggering event.

b) ‘‘Human error’’ period: during the eighties, the source of problem was/were the person/people and the Sequential Accident Model was still used. According to the domino theory of Heinrich, investigation should identify unsafe acts and conditions to analyze accidents. It is an approach that studies human actions through the analysis of the

workers' behavior from the perspective of human error, seeking to identify the types of errors that occurred and focusing on the removal of these errors – a behaviorist approach. There are some important limitations related to some of the assumptions adopted (Almeida, 2006).

Even today, human errors are identified as causes of accidents. However, errors are the consequences of a situation that did not allow operators to mobilize their skills in a relevant way (Daniellou et al., 2010). Based on the recognition of the inevitability of error, Llory (1999) advocates the need for changing the approaches proposed for human error. According to him, we have to assume that that to err is human.

c) Socio-technical period: during the nineties, the concept of ''Safety Culture'' emerged. In it, the source of problem is the interaction between social and technical subsystems. In behaviorism, still used in this decade, safety programs promote the implementation of observation practices that census unsafe or non-compliant behavior at work. Individual approaches are usually stimulated by practices that seek to obtain confession of the fault committed by the observed worker. Furthermore, this approach does not explore the history of the system, and possible contributions of aspects incubated in the origins of that behavior (Almeida, 2006).

For Llory (1999), the behaviorist approach does not clarify, but rather obscures the understanding of how the accident occurred. Although explained by the need for exploring the origin of human behaviors identified as immediate causes of an accident, these studies show that the interpretation of these findings continues to be based on the conception of the human being in the traditional paradigm. They begin with the assumption that there is one proper way of executing work, based on industrial safety procedures; workers are expected to take conscious decisions and consider several alternatives in complete control of the situation in progress. It disregards the context, the nature of the task demands, variability and history of the usual forms of work execution, the adequacy of standards in term of variability and associated psychic processes. Thus, this practice exacerbates the blaming of the victim and inhibits effective prevention practices (Almeida et al. 2006).

In that decade, new models to analyze and predict accidents start to be used. Hollnagel (2003) refers to them as Epidemiological Model, because of its analogy to a disease, that is, the result of a combination of factors. The classic example is the description of latent conditions (Reason, 1990). Another example is the model that considers barriers and carriers and pathological models of systems (organizations, states).

Hollnagel (2008) have discussed the features of different barrier systems and their relative advantages and disadvantages. Barriers are used as a reaction or as a response, but safety cannot be guaranteed only by reacting. Barriers are an effective mean against known risks, a way to prevent unwanted events from taking place and to protect against their consequences.

d) Inter-organizational relationship period: this decade is moving towards taking account of ''Organizational Factors''; the source of problem is a dysfunctional relationship between organizations.

According to Reason (1999) occupational accidents are organizational phenomena. Llory (1999) prefers to call psycho-organizational accidents. They use contributions of ergonomics, of psychology, of systems engineering and other sources of knowledge about cognitive aspects - individual and collective -, and about human reliability in open socio-technical systems; also contributions of the study of some aspects of production methods and of safety management in these systems.

Daniellou et al (2010), proposed an approach of Human and Organizational Factors of Safety (HOFS) to identify and implement the conditions that favor a positive contribution from the operators individual and collective work in the construction of industrial safety. The knowledge given by this approach would allow understanding what determines human activity and act on the design of work situations and the organization. This approach helps to develop the dimension of "safety on action" based on the skills of people, on organizations objectives and functioning and helps to promote compatibility with "normatized safety" within a culture of integrated safety.

Hollnagel (2003) describe a Systemic Model that attempts to describe the performance characteristics at the system level as a whole, rather than at the specific level of "cause and effect" mechanism. The symbol for the latter type is the analogy of swiss cheese (Reason, 1997).

In many industrial companies, the numbers of accidents do not decrease anymore and similar events seem to recur. Dien et al. (2012) shows some limits since current operating feedback and argue that weaknesses come mainly from analysis methodology.

In recent years there has been an increasing number of studies that criticize the limits of accident investigations conducted by professional teams of companies. One of the outstanding features is the high frequency of findings in which the event is not understood as socio-technical and systemic phenomenon, entailing accurate prevention recommendations: this limits organizational learning. This study is an example of such a situation in a company that clearly would benefit from using analysis practices supported by systemic conceptions.

OBJECTIVES

- To approach the accident analysis with a different perspective to the one used by the company in its initial investigation
- To discuss new hypothesis for the accident based on Human and Organizational Factors of Safety (HOFS)
- To formulate recommendations that would help to accidents prevention
- To encourage work-related accidents analysis to use an organizational approach going beyond human errors, technical causes or standards perspectives

METHOD

To make the description and analysis of the accident, we have used several sources of information: a video presented by the company, the presentation that summarizes the research done by the company, some press articles and some interviews with union members. The case was also sought for in the databases of the judiciary, without success.

To re-analyze this accident, we have used the Model of Analysis and Prevention of Accidents (MAPA). This model was developed, tested and perfected by Almeida and Vilela since 2008, and applied in various companies from different segments and in accidents of more or less gravity. MAPA's major objective is to understand the work related accident as a result of a network of multiple interacting factors, overcoming the dichotomy of unsafe acts and conditions and thus, identifying factors related to organizational aspects.

The MAPA begins by describing the accident with the basic elements, who, where, when, how the accident did happen, and then, describe the usual work. This description does not take account only of the work's established procedures, but also of how it is actually done, taking account of its variability and the worker's know-how.

After this description, MAPA analyzes the changes that occurred in the usual work, at the level of individual, task, equipment and environment which could contribute to the occurrence of the accident. The third part of MAPA analyses the prevention or protection barriers, existing or not, for each energy, condition or event with hazard potential. If existing, it analyses the efficiency or the flaws on that barrier. This analysis must reach the origins of the eventual fault, the reasons for the absence of eventually prescribed barriers and why they were not implanted.

To analyze the Safety Management and the Production Management is the next step on the model. Here the focus is placed on organizational factors that came previous to the accident, trying to identify not only absences or failed elements, but latent causes like project and management decisions, rules, norms or procedures which by its nature could have hindered the usual way of executing work and have gotten the opposite result they were created for.

The last part of MAPA proposes an auto evaluation, through a series of questions that help identify if it is necessary to expand the concepts from analysis.

RESULTS

Description of the accident

On December 18th, 2005, during a repair of the plant DEMEX at Refinery of Barrancabermeja in Colombia, there was an explosion and subsequent fire that caused the death of two people, left seven wounded and losses estimated at nine million dollars. The company presented a video with a detailed description of this accident. For this analysis, a translation to English was taken from the video report (see Table 1).

Table 1. Translation from the accident video report

This is the DEMEX plant, responsible for processing funds from empty units toping. Here, on December 18th, 2005, a fire that left two dead and seven wounded took place. On Friday, December 16th, at 3:40 pm, the coordinator commissioning of the plant detected a drop of water attached to the cap of this heat exchanger. The function of this equipment was to cool the mixture of propane-butane required in the extraction process. After the discovery, the coordinator asked a maintenance worker assigned to the plant to eliminate the dripping. However, the worker told him he could not do anything because the plug threads were all in the hull of the heat exchanger and the cap was slightly tilted. Two days later on December 18th, at 8:30 am, the supervisor of the work done to the heat exchanger detected a steady drip at the cap and called the coordinator to define what to do around the exhaust. The two decided to apply a sealant and the *work controller* undertook. He made contact with the supervisor of the outsourcing company to correct the anomaly, and they went together to the equipment. The supervisor of the outsourcing company told the *work controller* that that tightening the cap would fix the dripping, so he decided to process a work permit. Operations issued the permit without moving to the area or verifying the location and risks for the job. The permit was signed by the supervisor of the outsourcing company, who in turn asked a subordinate to take a pipe wrench and go with him and the *work controller* to the heat exchanger, in order to tighten the cap. The contractor worker hit the cap twice with the socket wrench. Immediately an increased dripping was generated. However, both withdrew from the area for lunch. Between 1:00 p.m. and 2:00 p.m. that day, another company's contractor performed radiation work, so all work was suspended in an area of 45 meters around it, including the exchanger with the exhaust. Around two in the afternoon the entry of personnel to the area was enabled again. Another worker in the contractor firm, more experienced, was sent by the supervisor to tighten the cap that was still leaking. By the time he got to the area to do the work, the expulsion of the body exchanger plug occurred. Immediately, solvent escaped, forcing the evacuation of the area. In parallel to this, various tasks were being developed in the area, including the installation of heat shield pipe in an absorption tower, 12 meters high. Three workers were using a man lift or lift people. The cloud of the solvent from the exhaust exchanger shifted to the tower where the lifting equipment was and wrapped it. The elevator operator was ordered to evacuate, but before doing so he pressed the remote control to switch to the workers who were in height. At that moment, a spark was triggered inside the fuel cloud and caused an explosion that left two people dead, seven injured and nine million dollars in losses for the company.

Description of usual work

During repair and maintenance, leaks detected are reported to the operations department through the *work controller*[1], who requests the repair to outsourced company. This presents a diagnosis of the problem and one or more alternative solutions. *Work controller* and operators analyze these alternatives taking into account the need of electric, mechanical, process or other kind of isolation, among other factors. Many requests and presentation of these alternatives are made informally, as working conversations. After choosing an alternative, the outsourced company's responsible makes an assessment and risk analysis, using a systematic description of the task and the list of tools to be used. The result of the risk assessment (very high, high, medium, low, very low) will define who reviews and approves the execution of the task. The higher the risk, the higher the hierarchic level within the organizations is necessary to approve it. It is a normal practice in the company to try and underestimate the risks during this evaluation exercise, for quicker agreements among the lowest levels of operation, thus preventing retardation of work. Sometimes, this analysis undergoes a review by the *work controller*, sometimes it doesn't. The outsourced company processes a work permit to operations department. According to a member of the union, at that time an operator on projects like this could have up to 200 work permits in one day. It is also usual that the operator only makes a measurement of explosive gases in the process area at the beginning of their shift and then sign the work permit that start later without repeating this measurement. According to union, the operators repeat the measurement just when strange odors are detected.

Analysis of Changes

Changes at Individual level

The hypotheses can be made that workers without much experience / knowledge did the repair work. According to the research done by the company, the higher the risk, the higher the level organizations approving the execution of work to operations department since December 11th (a week before the accident). This version corresponds to the statement given by the outsourcing representative to the press, which clarifies that maintenance hired by the company had already expired, and that on the day of the accident they were 'following orders of the company' (El Tiempo, 2005). Even so, the outsourced company, after accepting the job, designates a person to make the task before lunch, and then designates another employee to complete it after lunch. This research is unaware of the availability of experienced workers in the outsourced company during that weekend and when maintenance work had already finished. In the same newspaper article, a union worker points out that several weeks before, they had warned the company about the risks involved in employing people without knowledge and experience required for this maintenance. The 'lack of experience / knowledge' factor is analyzed as a change at individual level, and as an organizational factor, as it will be explained later. A second factor to consider at the level of individual changes is the Christmas season, which begins in Colombia in December 16th; on it, it is common that workers have many sources of distraction, for example, increased phone calls from family, logistics coordination for the activities that will be performed in the *novena*[2] and conversations with coworkers about travel destinations, holiday's family plans, etc.

Changes at Task level

The task was unusual, because, as mentioned, the heat exchanger had been delivered. According to the information of the video, the first decision was to put a sealant, although it finished using a tool to tap directly the cap. Issues leading to changing the plan were not explored: Did they have sealant available? Was this sealant resistant to the type of product that was leaking? Neither were explored issues such as why an isolation process was not made to intervene at the heat exchanger: would it need a higher risk assessment, causing the need for the outsourcing company to wait until Monday to get the approval from the refinery manager? On the other hand, national standards for working at height were still not well-implemented that year: it requires, among other procedures, the preparation of a rescue procedure. The hypothesis here is that the company that performed the coating work had not foreseen the

[1] The word *interventor* is translated from Spanish as *work controller* in this paper. He/she is a person independent from outsourced company who audits the works.

[2] Traditional catholic gathering during nine nights before Christmas.

risk of a gas leak and therefore the evacuation procedures for workers who were on the man lift without having to activate the electric switch.

Changes at Equipment level

The research done by the company showed that the cap installed was not suitable for the heat exchanger. The video presentation does not clarify when the cap was installed and why they decided to put it on. Nor it is asked how they came to the decision of using a pipe wrench to repair it and what they had specifically planned to make with it, for instance first removing the cap and then putting a new one.

Changes at Physical work environment

The company does not report conditions such as heat and noise in the workplace as factors that could increase fatigue of workers, and this in turn, influence on decision-making. The temperature in the city of Barrancabermeja on that time of year can exceed 40°C (IDEAM, 2013) not counting that the wind chill can be increased because of the relative humidity and the heat radiation from the refinery machines. The noise level is unknown, even more because it is not known exactly which were the machines that were working and which were shut down inside the plant.

Changes at Organizational work environment

It is reported that after hitting the cap and incrementing the product leakage, workers retreated to lunch. One can build the hypotheses that they had underestimated the risk by not knowing the contents of the product that was leaking, but also fatigue, hunger, and rushing to catch a bus to go out from refinery to lunch, could be added to this decision. Each company offers a bus to transport workers, as the refinery offers transport only to direct workers and controllers, not to outsourced people. The issue of overtime is not addressed in the presentation of the company, but according to the version of a union worker, the injured were doing rounds of 16 and 24 hours, and over the past 48 hours had only rested 2 hours (El Tiempo, 2005). Other factors such as time pressure to deliver the plant will be discussed in the analysis of production management.

Analysis of Barriers

In this analysis, two conditions with potential danger were identified as more proximal to the accident: a) the presence of combustible material classified as stored potential energy, since a highly flammable mixture was under high temperature and pressure within the heat exchanger and b) an electrical spark created when operating the man lift to descend workers who were in high. Prevention barriers analyzed for these two conditions are: a safe isolation system, the use of another type of man lift and previous monitoring of gases in the atmosphere. It is possible that the failure of those barriers are associated with the fact that the plant was very old – projects were made without as much care with safety as today – and also due to failures of safety management that, in their analysis, did not record the existence of these dangers and did not recommended corrections due.

Another distal condition of the accident is the potential of falls by working at height; prevention barrier analyzed is the rescue procedure, which could have been used to evacuate workers without operating the man lift. Other environmental conditions such as noise and heat are unknown, but an approximation of how they might have influenced the accident occurs.

Information on protective barriers in the consequences of this accident, as the fire control or rescue of wounded by the brigades are unknown and therefore are not discussed in this paper. The summary of the barrier analysis is presented in Table 2.

Analysis of Safety Management

Safety Management in the company takes into account the occurrence of previous accidents for risk assessment. At the background, there is a record of a fire in the same plant in 1993 (because of a stolen pressure indicator). It would have been decisive to give a review of the high-risk intervention work on the heat exchanger. In the video it is mentioned that the operator did not go to the heat exchanger to analyze the risks, but it is unknown how many work

permits (WP) he would have signed that day. However, as mentioned before, in this kind of projects inside this company and at that time, an operator could become responsible for signing 200 WP in one day. The high number of work permits granted to one employee not only suggests the existence of imbalance between the usual demands of the service and available workers of the plant: it suggests as well that the management is clearly favoring responses to short-term problems disregarding possible contributions of this situation for the continuous degradation of working conditions and safety in the plant.

There is no physical or temporal space for subcontractors to exchange information about simultaneous jobs. Finally, according to the press reports, the workers would have alerted their bosses on the exhaust and the union had warned about the risks to the company of employing people without experience and knowledge (El Tiempo, 2005).

Table 2. Analysis of barriers

CONDITION	INDICATED BARRIERS			OBSERVATIONS
	PRESENT		ABSENT	
	WITHOUT FAIL	WITH FAIL		
Stored potential energy: propane-butane at high temperatures and high pressures within the heat exchanger			Safe Isolation System (aka *SAS* into the company)	The company provides and requires the *SAS* procedure before the intervention to equipment with stored potential energy. Reasons leading to the decision of not applying this procedure are unknown. Were they unaware of the risk? Alternatively, did they give a lower risk rating in order to do the job faster? Did the company not want to stop the plant?
Electric: Presence of man lift with electric activation		Previous explosive gases test	Man lift with pneumatic activation	Was it considered within the project the use of a non-electric man lift? The company requires the use of gas detector whenever the equipment with electric actuation enters a process area (from cameras to cars). Operators also have the gas detector to measure before approving the work permit. On that day was there a gas detector available? If so, why was it not used before the man lift entering? Was it usual to make the measurement just at the beginning of the shift?
Kinetic: fall from height			Rescue plan for workers' descent without using the man lift	Did workers wear harnesses? Could they go down the tower structure without using the man lift?
Acoustics: Noise level machines unknown				Conditions that could indirectly lead to accident by increased mental fatigue of workers. Noise level and ambient temperature that day are not known, and if some sort of barrier was being used.
Ambient temperature: unknown				

Analysis of Production Management

According to press articles, the company hired 14 subcontractors to do the maintenance work of the plant that started in November (El Tiempo, 2005). Probably it hired just an outsourced responsible for all plant repair and this, in turn,

hired the others for implementing specific jobs. *Work controlling* company is also outsourced. The company has a scoring system for procurement where aspects of the project's cost and delivery time have higher values than other aspects such as experience in the petrochemical sector and implementing projects previously with successful safety results. The projects presented by the competitors do not take into account factors such as rain and strikes that delay the work. Even though this is a region with a high rainfall level (up to 300 mm) and strong presence of groups of legal left (unions) and illegal left (guerrilla) that organize strikes which could delay, for example, the arrival or the input of materials or workers to the refinery. The contractor for this work was foreign, with much experience abroad, but apparently new within this refinery and therefore, within the safety management of the contracting company and the socio-political conditions of the country. No one knows the appraisal system that this outsourced company used to outsource some of contracted services, but here one can highlight again that unionists would have warned the company about hiring inexperienced people for the implementation of this project.

It is necessary to mention, in order to have a dimension of time pressure on the completion of these jobs, that 30% of the country's largest refinery was stopped because of this repair. The delivery of the plant was due to December 20th. This analysis argues that if the leak was detected on Friday, December 16th and involved people knew that a review of high risk would request implementing a safe isolation system, it would entail more time to the adoption of risk analysis and work procedure. Finally, it would lead to postponement of the refinery delivery for operations; besides, it would have been necessary to rehire workers, who were only expected to stay on the plant until December 20th. Probably there was also a conflict of interests because the outsourced company was no longer responsible for this equipment, but could have understood this work seemingly simple to please those in charge of receiving the plant (operations) and facilitating the closing of the project. Finally, it would be necessary to explore how the materials management led to the use of an inadequate cap. Was it known that the piece was not suitable for the equipment? Was its installation temporary? Would there be a delay if one waited for the arrival of a definitive cap?

DISCUSSION. EXPANDING THE CONCEPT FROM ANALYSIS

In summary, retelling the events description and adding data collected from workers can show that the analysis presented by the company did not explored aspects that contributed decisively to the accident. This is visible both regarding the absence of barriers for the prevention of hazards identified easily in the plant and also with respect to the origin of the leakage that occurred in the plant: they were hardly explored for possible failures in the period immediately preceding the event. And that in a company that seems to accumulate problems in the management of materials, maintenance, safety and human resources, which could boost slow and progressive deterioration of working conditions in a process equivalent to what Rasmussen (1997) described as system migration to the accident.

The analysis of the accident made by the company assigns as causes the disregard of rules and procedures. Also the prevention recommendations were instructed to 'continue demanding tracking procedures' prescribed, although after the accident the company took more 'organizational' measures, such as including accident indicators in project directors' evaluations, promoting safety audits made by project managers and adopting successful safety practices from other companies in the sector (Ecopetrol, 2007). Besides the new manual of work permits allows one operator be responsible just for 20 WP per day.

A bow tie model is presented below, marking a difference between the facts that have some evidence and those who are just hypothetical (red in the figure). The emergence of these assumptions would lead to a conceptual expansion of the analysis done by the company.

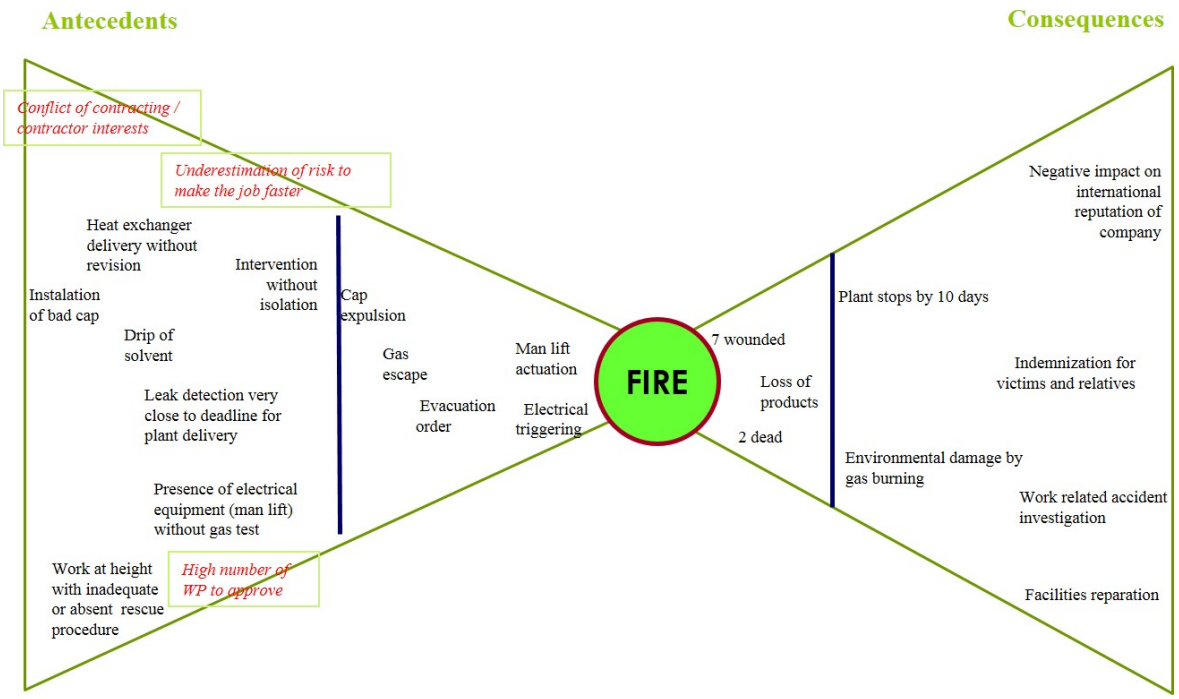

Figure 1. Bow tie model (From MAPA, 2010)

CONCLUSIONS AND RECOMMENDATIONS

This study argues that searching for immediate causes actually is not enough to result in accident prevention. Investigation and analysis made by the company show some limits and that is probably why accidents do not decrease more. We focus on an organizational analysis of events and, even though there is lack of information, we try to construct hypothesis to point out not technical factors or human failures. It is necessary to explore aspects related to outsourcing, like the priority of the cost and time factors and the impact of this safety management on projects. Material management, delivery of equipment and the existence and content of the rescue procedure to work at heights should also be explored further.

Human factors such as the workload of plant operators, outsourced labor experience available at the end of projects and excessive overtime cannot be left out of the analysis of an accident such as this one. Safety barriers, such as work permits and risk analysis, should be discussed from its management point of view and if they actually are used as is expected or became just bureaucratic paperwork to fill out.

We would recommend not only to this company, but also to others that use *learned lessons*[3] practice, to include the issue of shifts and overtime in all disclosures of accidents, so that other projects are able to appreciate the weight of this organizational factor in the accident analysis, and take effective prevention measures to reduce fatigue. Finally, this company could create a periodical meeting of risk analysis with representatives of all subcontractors that will run concurrent jobs, as it is already done in other companies from the same segment.

[3] In Colombia's oil sector also known as '*lecciones aprendidas*'.

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Analysis of Temperature on the Surface of theWrist in Individuals Emulating an Operation with Highly Repetitive Movements Using Sensory Thermography

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ABSTRACT

This study focuses on the application of sensory thermography, as a non-invasive method to evaluate the musculoskeletal injuries that industry operators performing Highly Repetitive Movements (HRM) may acquire, which could enhance the pathological understanding of the Cumulative Trauma Disorder (CTD). Changes in wrist temperature throughout the test will be monitored and analysed, with the aim to show the feasibility of the sensory thermography method for wrists. To undertake the experiments, we had three individuals which had common physical conditions, to which the test was applied in a University, following a pre-defined set of conditions; four samples were taken for eachindividual.The maximum temperature was recorder during the 1st test of individual 1, in the left wrist, reaching a temperature of 34.16ºC after 2:06:47 hours, simultaneously at this time lower back pain surged. Analysed data showed that trends do not follow a normal distribution, but a Weibull distribution, with a correlation coefficient in the range of 0.86 and 0.91. It was concluded that it is possible to analyse patterns of temperature in the musculoskeletal areas of an individual performing HRM, which could lead to CTD. By using the sensory thermography CTD's could be prevented, below an acceptable cost/benefit threshold.

Keywords: Temperature, Sensory thermography, Highly repetitive movement (HRM), Carpal tunnel syndrome (CTS), Cumulative Trauma Disorder (CTD), Wrist, Musculoskeletal disorder (MSD)

INTRODUCTION

The World Health Organization defined a work-related disorder as one that results from a number of factors, and where the work environment and the performance of the work contribute significantly, but in varying magnitude, to the causation of the disease (World Health Organization, 2003; Buckle P. et al., 2000). The term musculoskeletal disorder (MSDs) signifies health problems of the locomotor apparatus, for example: muscles, tendons, the skeleton, cartilage, the vascular system, ligaments and nerves. Work-related MSD's include all disorders that are induced or provoked by work and the circumstances of its performance (Schneider, 2010).

The importance of MSDs in terms of their impact on the working population is well established. According to the Health and Safety Executive (HSE), MSDs are the most common work-related illness in Great Britain, affecting 1.1 million people per year. An estimated 11.8 million working days per year are lost to work-related MSDs in Great Britain, with each sufferer having taken around 19.4 days off in that 12 month period (Melrose, A.S. et al., 2007). In the United State in 2005, MSDs accounted for 375,540 cases, or 30% of the injuries and illnesses with days away from work (BLS, 2006), whilst across Europe as a whole MSDs are the most common work-related problem, with

almost 24% of the EU's workers reporting backache and 22% reporting muscular pains (European Foundation for the Improvement of Living and Working Conditions, 2007).

It is widely acknowledged that ergonomics has an important role to play in the prevention of MSDs (Buckle, 1994; David, 2005; Dempsey, 2007). MSDs, including those localized to the upper extremity such as carpal tunnel syndrome (CTS) and forearm tendinitis, are common and disabling. They comprised 29% of the approximately 1.2 million total workplace illnesses and injuries resulting in lost days from work in 2007 in the United States (BLS, 2008). In a general European working population (Andersen et al., 2007), found neck/shoulder pain prevalence of approximately 30–50% and arm pain prevalence of 11–28%. In service sector workers, slightly lower prevalence's prevailed. 51% of workers in the European Union used a computer at work in 2005, with an annual growth rate ranging from 3% to 4% (Demunter, 2006).

Recent European studies provide ample evidence that MSDs such as back, neck and upper limb disorders are a significant ill health and cost problem and are becoming more common. Every year millions of European workers in all types of jobs and employment sectors are affected by MSDs through their work. MSDs cover a broad range of health problems. The main groups are back pain/injuries and work-related upper limb disorders, commonly known as "repetitive strain injuries" (RSI). Lower limbs can also be affected. Lifting, poor posture and repetitive movements are among the causes and some types of disorders are associated with particular tasks or occupations. Treatment and recovery are often unsatisfactory especially for more chronic causes. The end result can even be permanent disability, with the loss of employment (Schneider, 2010).

Subsequently, work-related MSDs include all musculoskeletal disorders that are induced or aggravated by work and the circumstances of its performance. MSDs cover a wide range of inflammatory and degenerative diseases of the locomotor system. They include: Inflammations of tendons (tendinitis and tenosynovitis), especially in the forearm wrist, elbow and shoulder, evident in occupations involving prolonged periods of repetitive and static work; Myalgias, as pain and functional impairments of muscles, occurring predominantly in the shoulder-neck region, that occur in occupations with large static work demands; Compression of nerves, occurring especially in the wrist and forearm; Degenerative disorders occurring in the spine, usually in the neck or lower back, especially in those performing manual handling or heavy physical work. However, they may also occur in the hip or knee joints. These disorders are chronic, and symptoms usually occur only after exposure to work related risk factors for a period of time (World Health Organization, 2003).

Carpal tunnel syndrome is a manifestation of median nerve compression within the carpal tunnel of the wristdue to increased intra-tunnel pressure from a variety of sources (Gelberman RH et al., 1981). It has been reported that CTS is associated with certain diseases and conditions such as diabetes, hypothyroidism, pregnancy, rheumatoid arthritis, and work-relatedfactors. In some cases, two or more of these risk factors may coexist; placing the individual at a higher risk of developing CTS (Spinner RJ et al., 1987). The Carpal tunnel syndrome is one of the most common causes of occupational disabilities. Even though less than halfof all cases of CTS are identified as work related in medical claims, a definitive role of work activities as the central cause of CTS is unclear (Department of Labor,1999). In addition, the role of common lifestyle and personal characteristics as predictors of CTS has received substantially less scrutiny (Atcheson SG, 1988).

Thermography is a non-invasive technique without biologic threat. It detects, measures, and converts invisible, surface body heat into a visible display, which is then photographed or videotaped as a permanent record (Feldman, 1991). Infrared thermography detects skin temperature, which is a function of subcutaneous perfusion (Anbar, 1998; Anbar, 2002). Digital images coupled with computer processing and storage allow for dynamic realtime analysis. Thermography for distinguishing between normal subjects and those with various UEMSDs has proved to be positive(Tchou et al., 1992; Coughlin et al., 1999; Schuhfried et al., 2000; E. Gold et al.,2004).

Previous research by (E. Gold et al., 2004) shows that a reduced blood flow could contribute to the development of UEMSD, like tendinitis and the CTS. The low temperature in the extremities could be caused by the low blow flow, however, cold hands are generally no accompanied by UEMSD's.

The infrared thermography detects the cutaneous temperature, which is a function of the subcutaneous perfusion. Previous comparison of thermograph results of individuals with UEMSD and individuals without UEMSD has shown promising results, as it was possible to detect trending differences(E. Gold et al., 2004).These authorsundertook a study, in which 12 individuals were used as the controlling individuals out of 17 individuals. The selection process of the individuals was based on previous studies, within the 12 individuals selected to perform the experiment, some had symptoms and cold hands, and others had symptoms but no cold hands, and also some that

presented no symptoms and no cold hands.

In order to execute the comparative examination to the 3 different groups the sensors were places in the desk (which could be adjusted to the comfort of each patient preceding the examination), the markers were places underneath a manila folder, and the individuals sat down 20 min prior to the exam, aiming to obtain a more detailed recording. The first thermography was taken 1 minute before the examination, at the start, during and at the end, lastly a final recording was captured a few minutes after ending the examination. During the test, various questions were inquired to the individuals, especially related to temperature, cramps, pain and numbness of extremities. The dorsal metacarpal region of the right hand was identified as a strategic spot to detect the vascular response. It was demonstrated that the difference in temperature among the different groups (with and without UEMSD) is significantly different.

It was also stated in this study, that the differences in temperature after typing for 9 minutes were detected by using the infrared thermograph in all 3 groups. Individuals with UEMSD syndromes showed abnormalities in the cutaneous temperature. As mentioned in the study, it is likely that the temperature derived from the use of the keyboard arises due a low blood flow, nevertheless, definitive conclusion were not reached (E. Gold et al., 2004).

MATERIALS

The equipment and material used in this research study were the following:

Digital Sköll thermograph with 2 sensors with a temperature range of 0˚C to 40˚C, precision ±0.3˚C, and a resolution of 0.1˚C (López, 1992); micropore tape; adhesive tape; stop watch; laptop. On top of these, the Akela software is used for the programming of the Sköll thermograph. Lastly, Minitab®15 and Microsoft® Office Excel 2007 statistical packages were utilized.

METHODS

The testing was applied to 3 students of the faculty of Engineering, Architecture and Design of the Autonomous University of Baja California, of a sample of 6 students, one of the pre-requisites for the testing was that the individuals did not perform any physical activity during the 20 minutes prior to the start of the test (Gold et al., 2004; Gold et al., 2009), this interval was derived based on previous research,in which it was stated that the required time to stabilize the body temperature after undertaking physical activity was approximately 20 minutes (E.Y.K NG et al., 2001). In the other hand, it was also asked to the individuals to avoid the consumption of alcohol or tobacco (Gold et al., 2009), due to the fact that smoking induces a reduction in body temperature (Puig, 1993), in contrast, alcohol rises the body temperature (K.S. Kim, 2006; A. A. Puig, 1993).

Furthermore, a questionnaire was applied to the individuals, aiming to gather some general information related to the age, height, weight, previous injuries and/or traumas. The following step consisted of keeping the room temperature between 20ºC and 25ºC (E.Y.K NG et al., 2001), controlled by the air-condition in the testing room. After the stabilization period, the individual sat in the ergonomic chair and the thermographs were placed in both wrists (in the mid nerve region). Once the thermographs were in position, both arms were laid down on an entirely horizontal table, in line with the height of the ribs (Kroemer et al., 2001), this position was adopted for the 20 minutes prior to the test and after the test.

Subsequently, the individual emulated a highly repetitive movement for a period or 3:30 hours, given the fact that this corresponds to the maximum time a HRM is performed in the textile industry. The HRM's consisted of movements of long and short reach, as well as grabbing and releasing HRM's. During the test anomalies were identified, discomfort and pain was also registered.

Lastly, the after completing the cycle of 3:30 hours and resting for 20 minutes (Gold et al., 2009), the thermographs were detached, the data was downloaded in Microsoft® Office Excel 2007 for post processing, and finally the analysis and validation of data was done with Minitab®.

The individuals that participated in this research were 3 healthy men. The main anthropometric characteristics of the individuals are summarized in Table 1. It is important to point out, that none of the individuals presented lumbar problems, arterial pressure (high or low) problems; moreover, none reported to have any type of alcohol/tobacco

addiction. Furthermore, it is highlighted that none of the individuals had previous experience performing HRM's at work.

Table 1: Anthropometric Characteristics of Individuals

Individual	Age	Gender	Weight(Kg)	Height(m)	Handedness	Fractures
1	22	M	54	1.69	Left	N
2	23	M	78	1.63	Right	N
3	25	M	64	1.63	Left	Y

RESULTS

For the development of the intermittent tests, as the name indicates, a considerable buffer time between tests was always respected; lapses of 1 week were set, aiming to verify trends or to detect changes in the behaviour from test to test.

After carrying out the examinations, the results shown in Table 2 were obtained. For the experimental analysis of the results individual 1 was selected, in the 1st day using the 1st test, given the fact that this individual presented the maximum temperature of the whole testing sequence, important to mention that the highest temperature was recorder in the left wrist.

Table 2 shows the results of the Anderson Darling analysis, which indicates the type of distribution followed by the data, in this case it was detected that a normal distribution was not trailed by any of the tests applied. Table 2 also shows the determination coefficient that indicates the percentage of variation of the data.

Table 2: Temperature Patterns

Individual / Test Day	Max Temperature in right wrist	Max Temperature in left wrist	Anderson Darling in right wrist	Anderson Darling in left wrist	R Adjusted in right wrist	R Adjusted in left wrist
1/1	33.810	34.160	1617.320	2274.080	0.993	0.941
1/2	33.021	32.870	416.902	609.855	0.566	0.833
1/3	32.400	32.710	12.228	41.418	0.089	0.210
1/4	33.840	33.900	1592.548	497.736	0.771	0.683
2/1	32.647	33.366	657.405	346.944	0.804	0.913
2/2	33.860	33.593	214.710	443.132	0.364	0.408
2/3	33.464	33.259	304.003	174.847	0.833	0.651
2/4	33.505	33.491	190.965	136.037	0.857	0.690
3/1	33.543	33.065	331.800	79.098	0.918	0.777
3/2	33.130	33.363	52.892	677.498	0.717	0.818
3/3	33.488	33.592	205.391	37.281	0.874	0.772
3/4	33.592	33.928	24.016	29.017	0.559	0.287

The results of this test case can be observed in Figure 1 and Figure 2, for both wrists it was possible to apply a 3rd order polynomial adjustment curve to represent the behaviour of the temperatures during the experiment, bearing in mind that the corresponding coefficient R Square shows this as a results of the test. For the left wrist, (Figure 1, temperature versus time) a coefficient R Square of 94.1% was obtained. Successively, it is possible to indicate that the maximum temperature was 34.160º C, and it occurred after 3:06:47 hours.

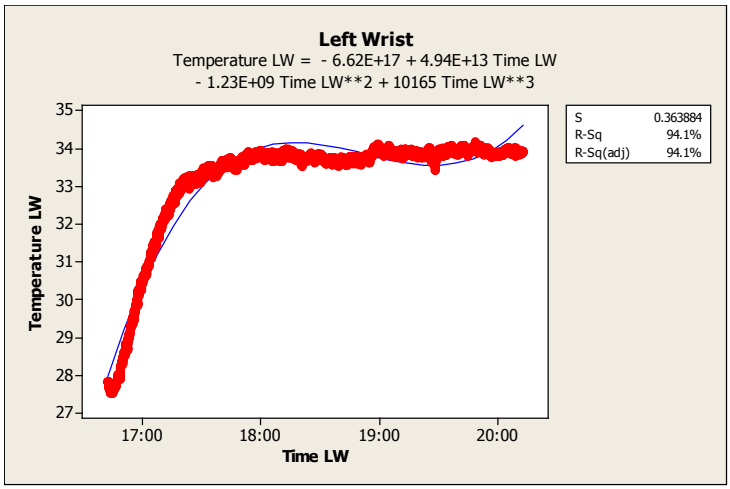

Figure 1.Individual 1 test day 1left wrist Polynomial Adjustment.

For the right wrist (Figure 2, temperature versus time), a coefficient R Square of 99.3% was derived. In comparison with the left wrist, it can be observed that the patterns of temperature are very similar. A comparable behaviour was also detected in the results of the other individual, where it is clear that during the first hour there is a constant rise of temperature. Moreover, the maximum temperature reached during the test for the right wrist was of 33.810 ºC, after 2:17:00 hours of testing, very similar temperatures as the ones recorder in the other wrist. It is relevant to point out that during the final part of the test; the individual mentioned that he had lower back discomfort, which prevailed throughout the last part of the test in a moderate to low level of discomfort. Additionally, after 1 hour of testing the individual felt some type of swelling and numbness in the fingers; which faded away later in the test.

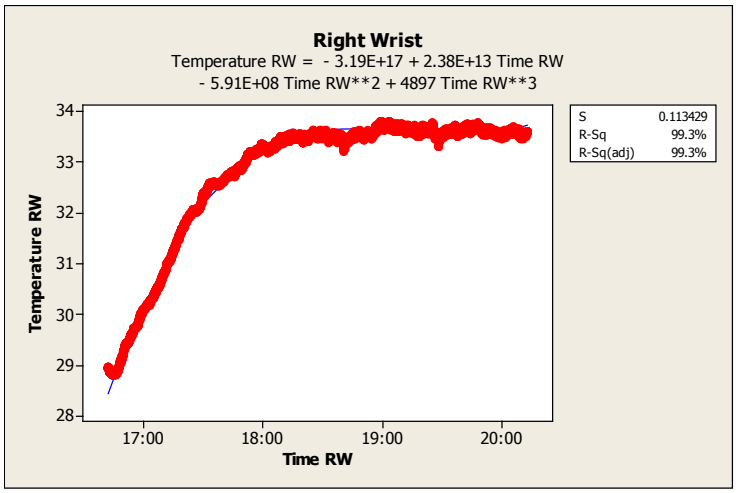

Figure 2.Individual 1 test day 1 right wrist Polynomial Adjustment.

Another part of the analysis that served as evidence to prove that a normal distribution is not followed by the data is shown in Figure 3; the histogram shows the spread of the data that was recorded for the left wrist during the 1st test of individual 1.It is possible to visualize that the temperatures with the highest frequencies oscillate between 33.5 and 34ºC.

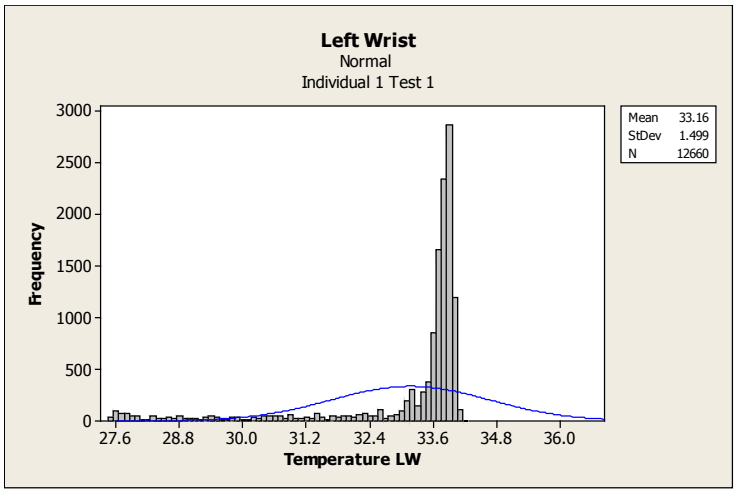

Figure 3.Individual1 test day 1left wrist Histogram.

Figure 4, shows a histogram of the right wrist temperature versus frequency behavior. Once again it is visible that a normal distribution if not followed by the data. Data utilized to create the following figure corresponds to the 1st test of individual 1. On the same table it can be observed that the temperatures with highest frequencies range between 33 and 34ºC.

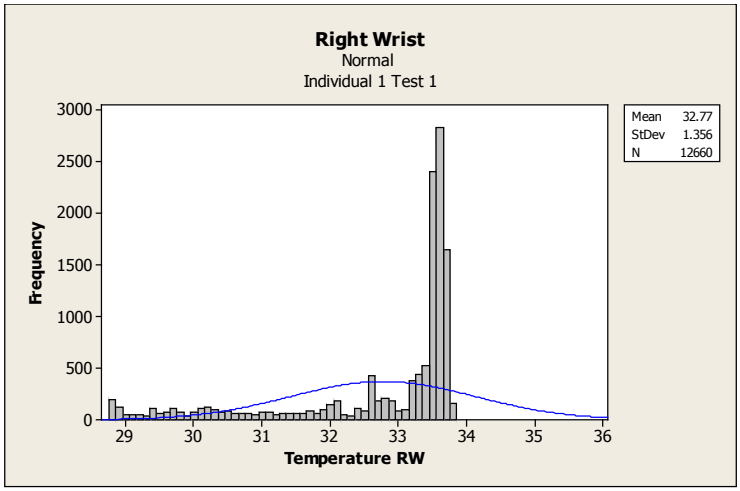

Figure 4.Individual 1 test day 1 right wrist Histogram.

Figure 5 and Figure 6 show the normality test. For every output dataset from the test the next hypothesis was followed:
Null Hypothesis *(H_0) = the dataset follows a normal distribution.*
Alternative Hypothesis *(H_1) = the dataset does not follow a normal distribution.*

Figure 5 shows the results of the Anderson Darling (AD) assessment, a value of 2274.08 is obtained, meaning that the distribution is not normal; it is also visible that the resulting p-value is clearly lower when compared to the significant level that was previously established at 0.05, therefore we must reject the null hypothesis that indicates that the data follows a normal distribution, and follow the same procedure as before to find a distribution that more accurately fits the spread of the dataset showing temperature on the left wrist.

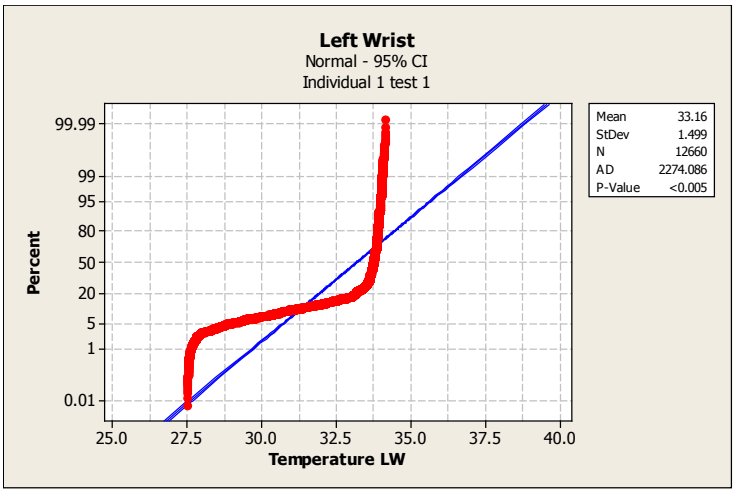

Figure 5.Individual 1 test day 1 left wrist Normality test.

Figure 6 it can be visualized that for the right wrist the AD analysis produces a value of 1617.32, which indicates that a normal distribution is not followed by the dataset, in this case we can confirm that a normal distribution is not followed by checking the p-value, which in fact is also lower than the significant level (set to 0.05, same as for the left wrist), furthermore, the null hypothesis is also rejected for the right wrist. Moreover, it can be concluded that in both AD analysis the statistical values are significantly large, 2274.08(left) and 1617.32(right).

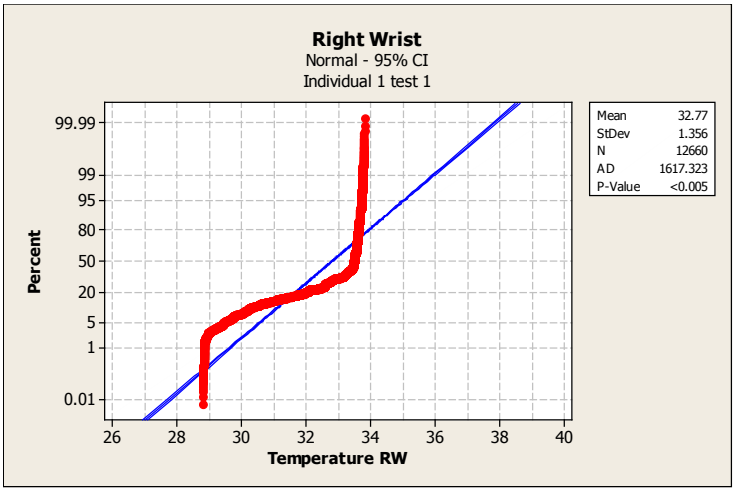

Figure 6.Individual test da1 test day 1 right wrist Normality test.

Table 3 shows a summary of the different fits/probabilistic distributions that were used for the analysis of the data of both wrists. Since the distribution of the data was not normal, other known distribution were used, the best fits of the data were obtained by using Weibull, 3 parameters Weibull and Smallest Extreme Value. Also, the results of the AD analysis are added to the table together with the correlation coefficient. Very similar results were obtained using the different methods, which in fact serves as a validation tool.

Table 3: Probability Distributions of the Individual 1 test day 1

Distribution	Anderson-Darling right wrist	Correlation-Coefficient right wrist	Anderson-Darling left wrist	Correlation-Coefficient left wrist
Weibull	1260.703	0.913	1808.616	0.860
3 parameters Weibull	1226.004	0.915	1738.011	0.865
Smallest Extreme Value	1225.962	0.915	1737.867	0.865

It can be summarized that the most representative distributions of the 3 individuals during the 4 testing phases, show whether or not a similitude in temperature patterns was found, furthermore, they datasets can determine if the distribution of the data follows one or more probabilistic distribution for the left or right wrist. Based on the results,we were able to conclude that the dataset shows large resemblances in the patterns of temperature for all three distributions (Weibull, 3 parameters Weibull and Smallest Extreme Value) for both wrists.

CONCLUSIONS

This research allowed us to answer the following question: What is the maximum temperature reached while performing a HRM for 3:30 hours? It was determined that the maximum temperature was 34.160ºC, and it was reached by the 1st individual, during his first test, after 3:06:47 hours. For the same individual the maximum temperature of the right wrist was 33.810ºC, and it was recorded after 2:17:00 of test. By the end of the test the individual mentioned that he felt some discomfort in the lower back, which was described a low to moderate pain. After 1 hour of test, some swelling and numbness of the fingers appeared, but constantly faded away during the test. Temperature in both wrists was similar. The maximum temperatures for the 2nd individual were reached during the 2nd test after 3:19:10 hours of starting the test corresponding to the left wrist, and 3:30:59 hours for the right wrist. The maximum temperatures for this individual were 33.593ºC and 33.860ºC respectively, and can be considered very similar in temperature and time when they occurred. Furthermore, the individual mentioned that he had some discomfort in the lower back after 3 hours of test. Lastly, the results of the 3rd individual show maximum temperatures of 33.928ºC for the left wrist and 33.592ºC for the right wrists, and were obtained in a much shorter period, 1:10:00 and 00:51:20 hours respectively, similar to the other cases the temperatures are in the same order or magnitude and do not vary significantly from one wrist to the other.

It was concluded the best fit for the temperature datasets was the Weibull distribution for all 3 individuals that undertook the testing (results can be observed in Table 3). Therefore it was concluded that while working with the sensory thermography we obtained reliable results within confidence intervals that are satisfactory for analysis, and furthermore they provide a good understanding of the wrist temperature as a triggering value to predict and diagnose cumulative trauma disorders. It was also determined that the datasets of temperature do not fit a normal distribution, neither for the left of the right wrist, this was determined based on the AD analysis that was completed for the datasets of each individual participating on the testing. The sensory thermography offers the early detection of cumulative trauma disorders and with it, it would be possible to prevent further injuries, and perhaps prevent CTD's from occurring. Disorders like the Carpal tunnel disorder or tendinitis could be avoided by using an early monitoring system like the sensory thermography, which in fact provides a cost benefit acceptable relation.

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Risk Assessment of Forging Workers in Unorganized Sector of Uttrakhand, India

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ABSTRACT

A blacksmith is a person who forges, or shapes, metal by first heating it until it is red-hot, then uses tools like chisels and hammers to force the metal into the shape he desires. Blacksmiths usually work standing up and have to bend over to work on pieces of metal. The work can involve heavy lifting, use of power tools such as power hammers, drills, air chisels and hydraulic presses. However, use of such power tools and poor body posture lead to MSDs. Musculoskeletal disorders (MSDs) are common health problem throughout the world and a major cause of disability in the workplace. MSDs are found due to Inappropriate and poor working postures, lack of task variation, poor ergonomic design of work places, and poor design of plant layout, long working hours, low salaries and awkward schedules are all areas where relatively simple intervention can significantly reduce the rate of exposure to MSDs. They also deal with extremely hot objects and face a constant worry about fire and heat. The blacksmiths perform repetitive hammering jobs that give shape to the instruments. This type of job not only requires skill but is also time consuming. Hammering jobs are responsible for most of the incidents. In Iron & Steel and other manufacturing industries, foundries and forges produce a lots of pollutants in the environment – both working and ambient environment. In these processes, metals are extracted and produced from ores by various metallurgical processes and processes for moulding, melting and castings etc. are accompanied by evolution of heat, noise, dust fines, fly-ash, oxides of Nitrogen, Sulphur and metals. Particulate matters are generated in large quantities when preparing mould core sands and moulds melting metals, pouring metal, knocking out poured moulds and loading and unloading raw materials. Here metals are given a specific shape by metal castings for various engineering purposes. Gaseous matters like gases, vapours, fumes and smoke are produced during melting and pouring operations. The major pollutants are emitted from various work areas in Foundry i.e. Pattern shop, Sand preparation, moulding and core making, mould drying and ladle heating, cupola, electric arc furnace, pouring and mould cooling, knockout, fettling, heat treatment etc. In addition, various air pollutants and noise pollutants (Davis, 2002) are produced from forge shops and other manufacturing industrial units. So keeping all these factors in mind, a study was conducted to assess the risks involved among forging workers of Uttrakhand state of India. For this purpose 120 workers were taken through snowball technique. The data revealed that the most common problem faced by the workers was improper working posture and inappropriate working environment. Due to poorly designed work place, working environment, and working tools, workers physiological and psychological cost of work was high they reported to have health problems like back ache, shoulder ache and difficulty in movement of hands while in operation. Workers were also observed to be found irritated and restless.

Keywords: Blacksmith, MSDs, Ergonomics, awkward schedules

INTRODUCTION

A blacksmith is a person who forges, or shapes, metal by first heating it until it is red-hot, then uses tools like chisels and hammers to force the metal into the shape he desires. Blacksmiths usually work standing up and have to bend over to work on pieces of metal. The work can involve heavy lifting, use of power tools such as power hammers, drills, air chisels and hydraulic presses. However, use of such power tools and poor body posture lead to MSDs. Musculoskeletal disorders (MSDs) are common health problem throughout the world and a major cause of disability in the workplace. WMSDs are one of the biggest occupational health problems in industrialized countries (Hagberg et al., 1995). MSDs are found due to Inappropriate and poor working postures, lack of task variation, poor ergonomic design of work places, and poor design of plant layout, long working hours, low salaries and awkward

schedules are all areas where relatively simple intervention can significantly reduce the rate of exposure to MSDs.

The casting and forging sectors of the country constitute a considerable proportion of employment (Singh. et.al, 2010.However, health protection is still ignored. Here metals are given a specific shape by metal castings for various engineering purposes. Gaseous matters like gases, vapors, fumes and smoke are produced during melting and pouring operations. The major pollutants are emitted from various work areas in Foundry i.e. Pattern shop, Sand preparation, molding and core making, mould drying and ladle heating, cupola, electric arc furnace, pouring and mould cooling, knockout, fettling, heat treatment etc. In addition, various air pollutants and noise pollutants (Davis, 2002) are produced from forge shops and other manufacturing industrial units.

So keeping all these factors in mind, a study was conducted to assess the risks involved among forging workers of Uttrakhand state of India. For this purpose 120 workers were taken through snowball technique from Uttrakhand state. Descriptive data was done to access the risk faced by forging workers. Most of the workers were illiterate and were working as a forger for more than 5 years. The preceded interview schedule was used to gather information from the respondents pertaining to research work.

RESULT AND DISCUSSION

Occupational hazards, accidents, risks or injury at work place

Hazards, accidents, risks or injuries are common incidence at forging work. The data revealed (Table 1) that more than 80 percent of workers were experiencing hazards or accident in their work places. The reasons for these hazards or accidents include awkward posture, allergies, rashes, itching, poor environmental condition etc.

Table 1: Occupational hazards, accidents, risks or injury at work place

Occurrence of accidents/ hazards		No. of respondents	
Yes		98(81.66)	
No		22(18.33)	
S.No	**Type of hazards**	**Reasons of hazard**	**No of respondent (N=120)**
1	**Mechanical/ ergonomically**	Repetitive task	95(79.16)
		Awkward posture	98(81.66)
		Sharpe edges	37(30.83)
		Forceful motion	43(35.83)
		Awkward grip	32(26.66)
2	**Biological**	Rashes/ allergy	59(49.16)
		Skin infection	36(30.00)
		Itching	78(65.00)
3	**Chemical**	Dust	84(70.00)
		Smoke/fumes/gas	93(77.50)
		Oil and solvents	53(44.16)
4	**Physical**	Lifting	64(53.33)
		Heat	77(64.16)
		Tiring position	90(75.00)
5	**Environmental**	Temperature	89(74.16)
		Humidity	53(44.16)
		Noise	45(37.50)
		Light	31(25.83)
		Crowded area	31(25.83)

Mechanical hazards

The results regarding mechanical hazards as experienced by workers revealed that majority of the workers were encountering with the problem of awkward posture and repetitive motion during work schedule followed by 35.83 percent and 30.83 percent workers who reported hazard with forceful motion and injuries with Sharpe edges respectively. A small proportion i.e 26.66 percent of nurses reported hazards with awkward grip.

Biological hazards

Hazards may occur through contact with still water during cooling of iron product and ashes etc which may be infectious to the workers who continuously work in such condition. In the summative responses, biological hazards like itching were reported by majority of workers (65 percent) followed by approximate 50 percent of workers who reported rashes/ allergy. A small no of workers ie 30 percent were suffering from skin infection.

Chemical hazards

Chemical hazards may happen while using oil and solvents, exhaustion of waste aesthetic gases, dust, fumes etc. It can be envisaged from table that more than 75 percent of the workers got injured with smoke/fumes/ gases followed by 70 percent who were having infection with dust. Only a small proportion of workers were having infection with oil/ solvents.

Physical hazards

Physical hazards are a combination of hazards from lifting, tiring position, heat. It is evident from the table that majority of workers ie 70 percent were suffering from physical hazards due to tiring position for longer period of time followed by nearly 65 percent who were suffering from heat. More than 50 percent of the workers had reported physical hazards due to lifting of heavy instruments while working.

Environmental hazards

There are many reasons for environmental hazards which includes noise, temperature (cold as well as hot), light, humidity and crowded area. Majority of the workers had reported that temperature is the most hazardous environmental hazards. As they had to perform their work near heat which might be beneficial in winters but during summer season it is very difficult to work in that situation. Nearly 45 percent of worker had reported humidity as hazardous factor followed by 37 percent of workers who were having problem with noise. Some of the workers nearly 30 percent had reported poor light and crowed working environment as an environmental hazards.

Table 1: Environmental parameter at work place

Activity area	**Temperature (^{o} C)**		**Humidity (Percentage)**		**Noise (dB)**	**Light (lux)**
	Max	Min	Max	Min	86	596
Workshop	48.7	35.9	62	44		

As weather has a profound effect on human health and some of such factors include temperature, humidity, illumination, noise etc. The magnitude of activity is greatly influenced by such environmental factors. Table depicts the environmental condition during the experimental phase. Environmental parameters were recorded in work area where all work are performed. The maximum and minimum temperature was 48.7oC and 35.9oC respectively. The humidity in working area ranged from 62 to 44 percent. However noise level in working area was 86 dB. It was further found that illumination was 596 lux. The noise is known to distract, confuse and make mental concentration more difficult. Depending on the individual, the noise intensity and the length of exposure, may affect hearing in long run. It is recommended as per ISI 2207(1999) that maximum ambient noise at operator's ear level should not exceed 90 dB for 8 hour duration. But it was further conceded that 40 hour of exposure per week of noise of 90 dB or greater will result in hearing loss. It can be concluded that all the measured environmental variables were more in working area as hot temperature, humidity, increased noise level (nearly upper limit of exposure) and adequate illumination.

CONCLUSIONS

The data revealed that the most common problem faced by the workers was improper working posture and inappropriate working environment. Due to poorly designed work place, working environment, and working tools, workers physiological and psychological cost of work was high they reported to have health problems like back ache, shoulder ache and difficulty in movement of hands while in operation. Workers were also observed to be found irritated and restless due to poor working environment.

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Influence of Footwear on Fall Risk in Older Persons

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ABSTRACT

It has been shown that several gait parameters are predictive for fall risk in older persons. There is evidence that footwear can influence foot position and gait patterns, especially in older persons. We carried out experiments to study the effects of type of footwear on gait patterns in persons aged 60+. We found an association between the type of footwear and certain gait parameters that are predictive for falls. In conclusion footwear can increase fall risk. Footwear for older people should be designed in such a way that risk of falls is minimized.

Keywords: Older persons, gait, footwear, shoe design, home safety, anthropometry, inclusive design

INTRODUCTION

Falls are a major problem in the older population. One third of community dwelling older persons experience a fall at least once a year, of those fallers 50% fall more than one time per year (Campbell, et al., 1990; Tinetti & Williams, 1997; Tromp, et al., 2001). Most falls occur in and around the house (VeiligheidNL, n.d.). In a pilot study at the Geriatrics Outpatients Clinic in the Erasmus University Medical Center we found that older people prefer to wear open heel slippers in and around the house (Oei, 2005; VeiligheidNL, n.d.).

The association between footwear and falls has been demonstrated (Boelens, Hekman, & Verkerke, 2013). Inappropriate footwear has been identified as a contributor of up to 45% of falls (Gabell, Simons, & Nayak, 1985). It has been found that walking barefoot or in socks elevates fall risk (Koepsell, et al., 2004; Menz, Morris, & Lord, 2006). Also wearing shoes with a low collar or a high heel may increase fall risk. These features of shoe design have been implicated as having an impact on balance (Lord & Bashford, 1996; Lord, Bashford, Howland, & Munroe, 1999).

Several investigators have reported effects of footwear on gait characteristics (Arnadottir & Mercer, 2000; Stephen,

et al., 2012). Wearing walking shoes increased gait speed compared to wearing dress shoes (Arnadottir & Mercer, 2000). The application of insoles with a mechanical stimulation to the soles of the feet decreased stride-to-stride variability in step width and stride length (Stephen, et al., 2012).

Gait parameters as measured with an electronic walkway system have been shown to be associated with increased fall risk in several studies (Camicioli & Licis, 2004; Hausdorff, Rios, & Edelberg, 2001; Maki, 1997; McGough, Logsdon, Kelly, & Teri, 2013; Nakamura, Meguro, & Sasaki, 1996; Sterke, van Beeck, Looman, Kressig, & van der Cammen, 2012; Verghese, Holtzer, Lipton, & Wang, 2009).

Literature on the use of open heel slippers and fall risk is lacking. We were interested in the possible relationship between use of open heel slippers and fall risk. In this study we used gait parameters as a derivative of fall risk. We therefore investigated the influence of footwear, including an open heel slipper, on gait parameters which are associated with fall risk in older persons.

Project GERON in Delft

Before starting an experimental study on this topic, we first did an explorative study into the variation of characteristics of healthy older people that could be relevant to designers. This study was first described in Steenbekkers and Beijsterveldt (1998) and later the data are also included on the DINED platform (dined, n.d.) and are shown under DINED2004. Is daily-life equipment sufficiently adapted to use by the older persons? Or are product developers biased towards voting, healthy males with technical skills and insight? When designing products to he handled at home or in a professional situation or in the public domain, designers ought to base their choices of technical properties on the capacities, habits and preferences of the user group. Although there is a continuing increase in the grey sector of society, design-relevant data on older persons users are almost nonexistent. This project attempts to narrow this gap in gerontechnology: product design for the older persons. This name is closely related to Inclusive Design, which focuses on design for older persons and handicapped.

In this study 750 subjects, who lived independently, were assessed. In total about 80 variables, all more or less important for product use, were measured. The sample consisted of four age groups ranging from 50 to over 80 years of age: a group of young people (20 - 30 years) was also studied for the purpose of comparison. Women and men participated in about equal numbers. The variables covered a variety of human characteristics, such as body and limb measurements, maximum forces exerted, speed of movements, eye-hand co-ordination, etc., as well as their seeing, hearing and feeling capacities and certain aspects of memory. In addition, a questionnaire was used to probe the problems experienced with various products.

This study consisted of a survey of how characteristics differ between the age groups or generations. Some variables proved to deteriorate earlier and some later in life, and some hardly at all. The theory that the ageing process means a slow increase in the differences between people, i.e. individualization, is confirmed. The ageing process also implies a decrease in the level of capacities: older people exhibit a growing tendency to resemble weaker young people. In most respects, however, differences between people are influenced more by sex than by age. These general rules can provide inspiration for product innovators. Inclusive Designers can use these results in their innovations to include older persons and handicapped when designing products and or services.

About Feet and Walking

A selection of the above 80 project variables concerned feet and walking and are described for this paper. In daily life walking is an integral part of many activities, such as shopping, visiting friends, moving around. In literature, information can be found about the influence of step length and walking velocity on the pattern of the effects of age and balance (Berg & Norman, 1996; Judge, Ounpuu, & Davis, 1996). The influence of age on the pattern of walking can probably be explained by such factors as deterioration of visual capacities, resulting in diminished visual contrast sensitivity. This together with reduced sense of balance and slower reflexes results in fear of falling, which is compensated for by a different pattern of walking whereby the feet remain in contact with the floor for a longer period of time. The steps of the older persons are 12 to 18 % shorter compared to younger individuals. The velocity of walking also decreases with age. After the age of 70 the walking velocity decreases by 12 to 16 % per decade (Judge, et al., 1996).

METHOD OF MEASUREMENT

Choice of variables

Step length and walking velocity are the variables chosen to be measured. The relevance of step length to product design is the fact that the space for walking has to be known when designing, for example, push cars, trolleys and other products which precede a walking individual. Knowledge of walking velocity at a fast pace is required to assess the period of time needed to cross a street. For the sake of comparison, walking velocity at normal pace was measured too. Step length was assessed by asking the subjects to walk at normal pace. They were told to stand still at the tenth step and not to change the placement of their feet. The distance from the starting point to the heel of the foot that made the tenth step was measured and divided by ten to obtain an estimation of step length. The number of steps was more or less arbitrary. It had to be enough to achieve a normal walking pattern and to counteract the effect of mass inertness on balance and gait. Walking velocity was measured with a stopwatch, clocking the time the subjects needed to walk a distance of 10 meter. First they had to walk at their normal pace, defined as the pace which they 'usually adopt when walking outside'. After that they had to walk the same distance at fast pace, defined as the pace adopted if they 'had to catch a bus or train, but without running'.

RESULTS

The results of the (Spps-function) Scheffé post hoc show that, generally speaking, people above 75 years of age differ significantly from younger subjects. Individuals between 70 and 74 years of age are slower than those below 65. The age group 65 to 69 years differs from the younger group.

The differences between men and women were statistically significant. Men walk faster and take larger steps than women, as could be expected. This difference might be explained by differences in leg length between men and women.

Stepwise regression analysis was applied to assess the relative influence of leg length, age and sex on step length. The results indicate that all three variables have a significant effect on step length. The size of beta shows that sex is the most important factor, followed by leg length and age.

The formula describing this relationship is:

step length = 42.2 + 0.61 * leg length - 0.18*age - 7.2 *sex
(sex: male = 1 and woman = 2)

Some other results: our step length is significantly decreasing with our age (Table 1) as does our pace (Table 2).

Table 1 The breakdown of step length with age groups

age group	mean step length [cm]	difference [%]
20 - 30	75.0	
		7.2
50 - 69	69.6	
		8.8
70+	63.5	

Table 2 The breakdown of the pace with age groups

age group	n	mean normal pace [m/s]	difference [%]	mean fast pace [m/s]	difference [%]
60 - 69	198	1.33		1.86	
			13.5		11.8
70 - 79	195	1.15		1.64	
			5.2		9.8
80 - 89	64	1.09		1.48	

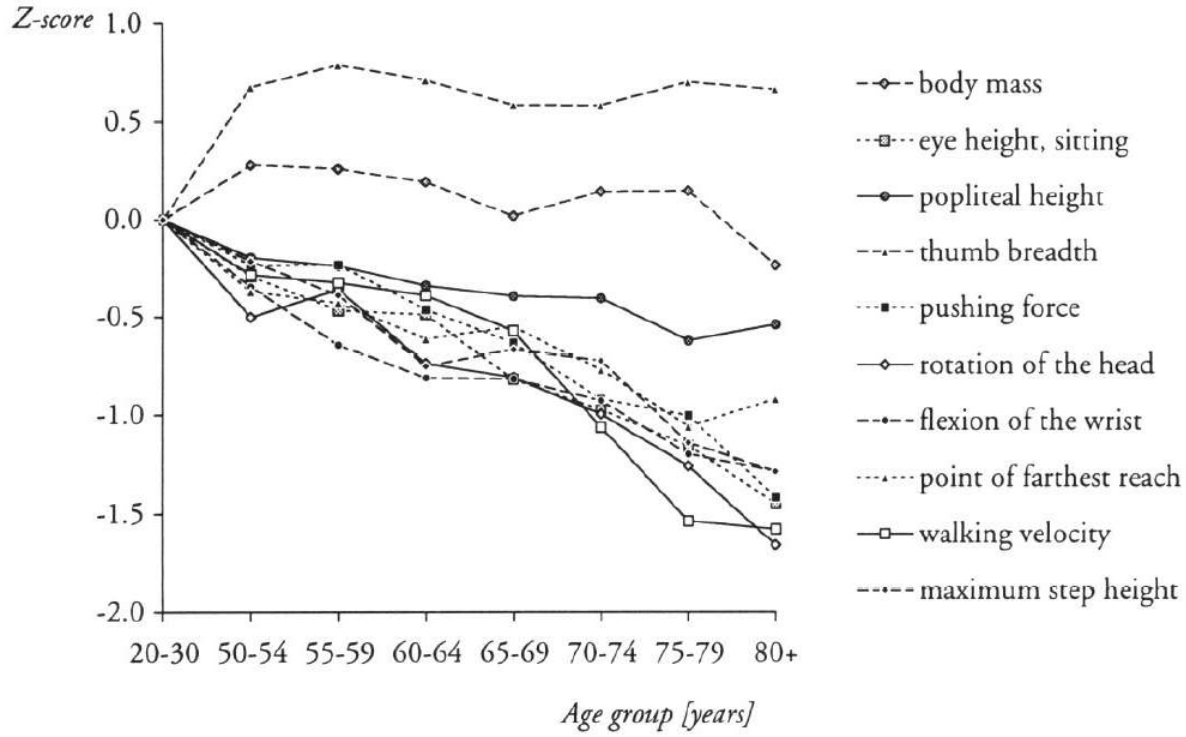

Figure 1. Influence of age on walking velocity and other variables

DESIGN OF FOOTWEAR

Most of the design students of our school use our DINED information system (dined, n.d.) when they need ergonomics or anthropometric information because they are taught from the first year on how to use these data. One of the master students, Bianca Oei (Oei, 2005), designed a pair of shoes which could contribute to a decrease in fall risk in older persons. After observational research she saw that older persons want to wear safe shoes but tend to wear ill-fitting and hazardous footwear. This because they have problems getting in and out their shoes.. She decided to design a shoe that offers a good fixation around the ankles as with shoelaces but without the hassle of bending over to fasten it. For easy stepping in and out her design contains a moveable heel counter

Her principle solutions (figure 2 and 3) were done together with the supervisory team. The chosen ideas were all

rated as good. An important thing is that the actual user of the footwear should also be attracted to the concept and the way it should be used. It might be that their perspective on the principle solutions and concepts are very different, which could lead to an unsuccessful product.

This means the design proposal (figure 4) provides in the following needs:

A. to reduce risk of falls:

Good fixation around the ankles and easy to fasten.
A gradual toe lift to prevent stumbling.
A flat heel with maximum inclination of 14˚ (Snijders 2005).
A sole with high mid-sole hardness, low mid-sole thickness for sufficient feedback.
Large heel surface for stability.
A light weighted sole to prevent tiring out the user.

B. to adapt to older persons needs:

Enough space in the toe box (10 and 15 mm (Snijders 2005))
Variability in width to be compatible for people with oedema
A low shaft perceived as more convenient and appreciated as ‘ their’ style.
Space for personal foot bed.
Soft leather upper material perceived as best quality material together .

The characteristic features of the design

1. **The combination of properties which all lead to an ideal shoe for seniors.** Comfortable and supporting shoes: The design offers the ease and comfort of a slipper but at the same time the stability and support of a sturdy shoe.
2. **Putting on and taking off footwear without the need to bend over.** A moveable heel counter in the shoe, which has the form of a shoe horn, makes it possible to easily put on and take off shoes without the need for the consumer to bend over. While entering the shoe with the foot, the heel counter is leaning backward and is making room for the foot. When the foot is in the shoe the heel counter bends back in its original position. With this application, people with hip problems and/or stiff fingers will be able to stay more independent putting their shoes on and taking them off, while wearing good fixated in-house shoes.
3. **The use of memory foam in the filling of the upper material of the shoe which offers extra comfort to changeable measurements of the foot.** It offers enough space for foot problems like a hallux valgus, hammertoes and wide feet. The upper material has memory foam in its lining. This way the shoe can adapt itself to changing volumes of the feet caused by oedema, without putting pressure on the (sometimes sensitive) feet.

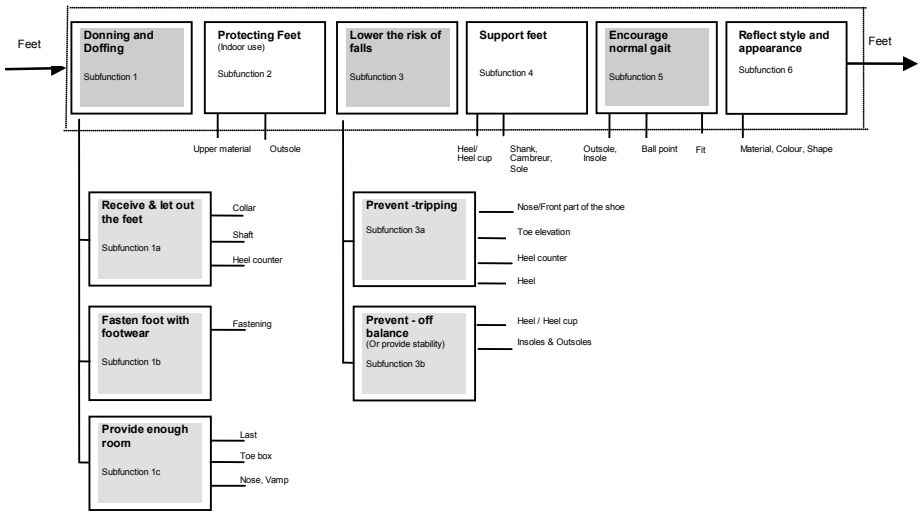

Figure 2. Function Structure of a shoe as a means to walk and not slip away.

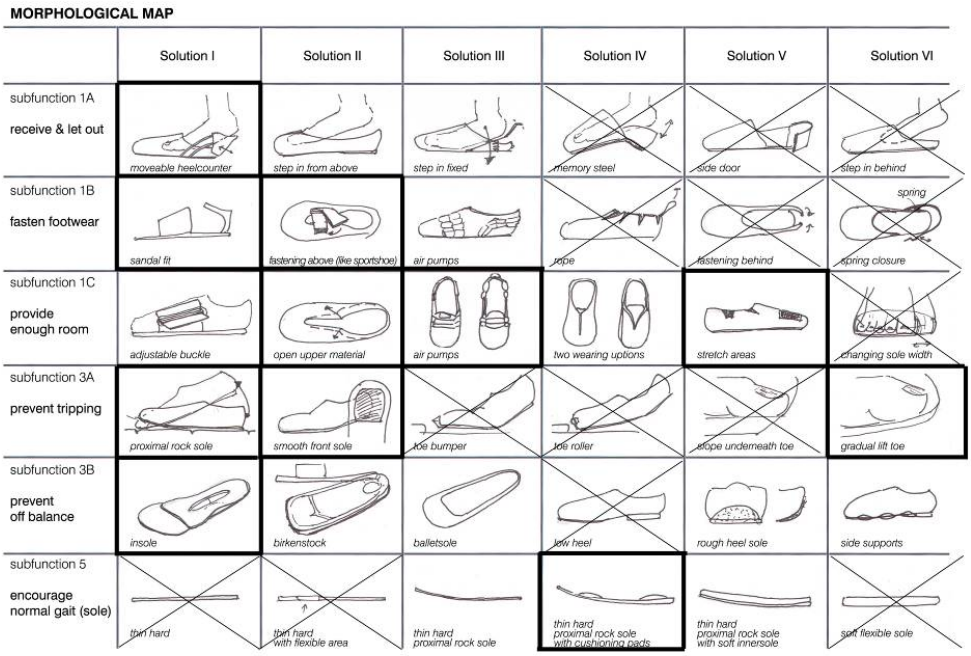

Figure 3. Morphological map

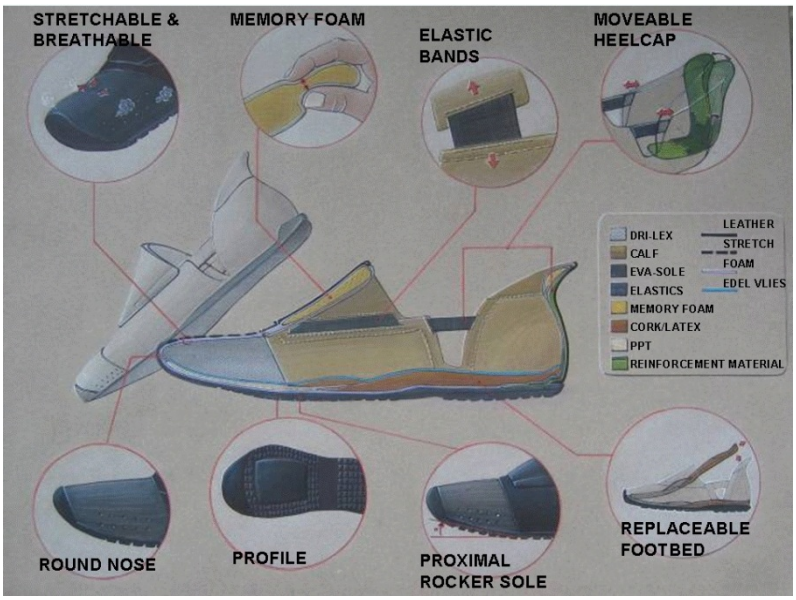

Figure 4. Characteristics of the design proposal

Figure 5. Final rendering of the design

CONCLUSIONS

After the research of design relevant characteristics we did get more insight in the influence of walking related variables of senior citizens and their change with age. These results were used in the design of footwear which should contribute to the prevention of falls in older persons. This design was manufactured by a company and is tested with a sample of older persons. The results will be described in a following paper.

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Ergonomic Problems in Japan's Medical Air Transportation Services

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ABSTRACT

Special considerations must be given in medical air transportation to medical professionals, medical equipment, and flight crews due to the conditions of the critically ill patients transported, the intra-aircraft environment, and the need to make emergency flights. However, few studies have investigated the ergonomic problems faced by the medical air transportation services provided in Japan. Therefore, here we investigated ergonomic problems, including those related to medical device use, faced by medical personnel and the aviation community in Japan. Results indicated that basic education and training on aerospace physiology, intra-aircraft use of medical equipment, flight operation systems, and crew resource management are currently insufficient in standard medical education. In fact, most medical devices used during flights are conventional devices with no ergonomic considerations made for vibration or low cabin pressure. In particular, problems relating to human-machine interfaces, power supplies, electromagnetic compatibility, and the ergonomic and technical compatibilities of electronic medical equipment used during the flights must be improved. Improvements are also needed in relation to safety during emergency flights such as those made at night or in bad weather, crew training, and air traffic control systems during large-scale disasters. Interdisciplinary collaboration is required to further investigate and resolve these problems.

Keywords: Medical air transportation services, Medical education, Medical Equipment

INTRODUCTION

The aviation industry has successfully applied human factors engineering to achieve a highly integrated human-machine system. Over the past decade, emergency medical service helicopters in Japan have been dispatched more than 60,000 times, and many critically ill patients with artificial hearts for severe heart failure have been transported to and from Japan on international flights. However, few ergonomic considerations have been given to various aspects of medical air transportation services, which often must be delivered on emergency flights and under less than ideal medical treatment conditions. Here we investigated the ergonomic problems, including those related to medical device use, encountered by medical personnel and the aviation community in Japan.

MATERIAL AND METHODS

Medical air transportation services are classified according to their purpose: emergency medical transportation of patients to hospital due to illness or disaster, patient transfer between hospitals, medical personnel transfer from hospital to disaster site, organ harvesting, and humanitarian aid. We investigated the ergonomic problems encountered by medical personnel and the aviation community during the transportation by helicopter, personal medical transfer plane, and commercial airplanes.

Figure 1. A helicopter for emergency medical transportation (Kawasaki Medical School Hospital)

RESULTS AND DISCUSSION

Problems encountered by medical personnel

Medical personnel involved in providing medical air transportation services require specific knowledge of aerospace medicine and aircraft conditions such as hypoxia, low pressure, and humidity. For example, although the cabin of a commercial jetliner cruising at 30,000 feet is pressurized, cabin pressure is equivalent to that at an altitude of 8,000 feet. Such a condition can cause hypoxia and expansion of gases in the body, which can be harmful or even fatal to critically ill patients such as those with cardiopulmonary disease, pneumothorax, or intestinal obstruction. Most commercial aircraft have no humidifying system in the cabin, so cabin humidity decreases to less than 10% on long-haul international flights. Medical education on the aircraft conditions and physiological changes encountered during high-altitude flight is currently insufficient in both undergraduate and postgraduate medical schools in Japan, with the exception of a few military and aerospace institutes. Clinical education on changes that occur in circadian rhythm is also very limited among general physicians in Japan.

The medical air transportation service has been designed to treat critical patients in emergency situations, but medical practice within the aircraft is limited by various aspects of the intra-aircraft environment such as capacity, vibration, noise, and power supply. In addition, the use of electronic medical devices and medical gas is limited due to safety and technical reasons such as electromagnetic compatibility and aviation regulations. In-flight medical procedures such as endotracheal intubation, central venous catheterization, and minor surgery under turbulence together with problems of vibration and noise can make work difficult; yet no training system or support devices have been developed specifically for in-flight medical procedures in Japan. As the severity of a patient's condition should not jeopardize flight safety, medical personnel need a certain basic knowledge of aviation systems so that they can communicate situation awareness and discuss flight plans and safety with the aircrew. In addition, basic aviation knowledge is also important for efficiently managing pre-flight to post-flight medical care. Therefore, basic aviation education and crew resource management should be provided to both aircrew and medical personnel to ensure safe and efficient medical air transportation services.

Problems affecting medical devices

Changes in the intra-aircraft environment during flight also affect the operation of medical equipment. For example, changes in cabin pressure affect drip infusion speed, the respirator ventilation ratio, and the cuff pressure of a balloon catheter and medical anti-shock trousers. In fact, as most electronic medical devices are designed for use on the ground, their use under low pressure or vibration should be accounted for in the regulations and design process to improve their ergonomic issues. (see Figure 2, Figure 3) Optimal techniques for loading, stowing, and unloading of medical equipment to and from commercial aircraft should also be devised. Problems relating to the power supply and medical gas supply for electronic medical devices, as well as their electromagnetic compatibility with avionics and other medical devices, should be addressed for each type of device and aircraft. A simple problem such as the stowage of medical equipment during flights must be performed in line with the regulations for medical devices and aviation. Such problems are troublesome issues in medical air transportation services; therefore, technical and ergonomic improvements in line with the regulations for medical devices and aviation are required.

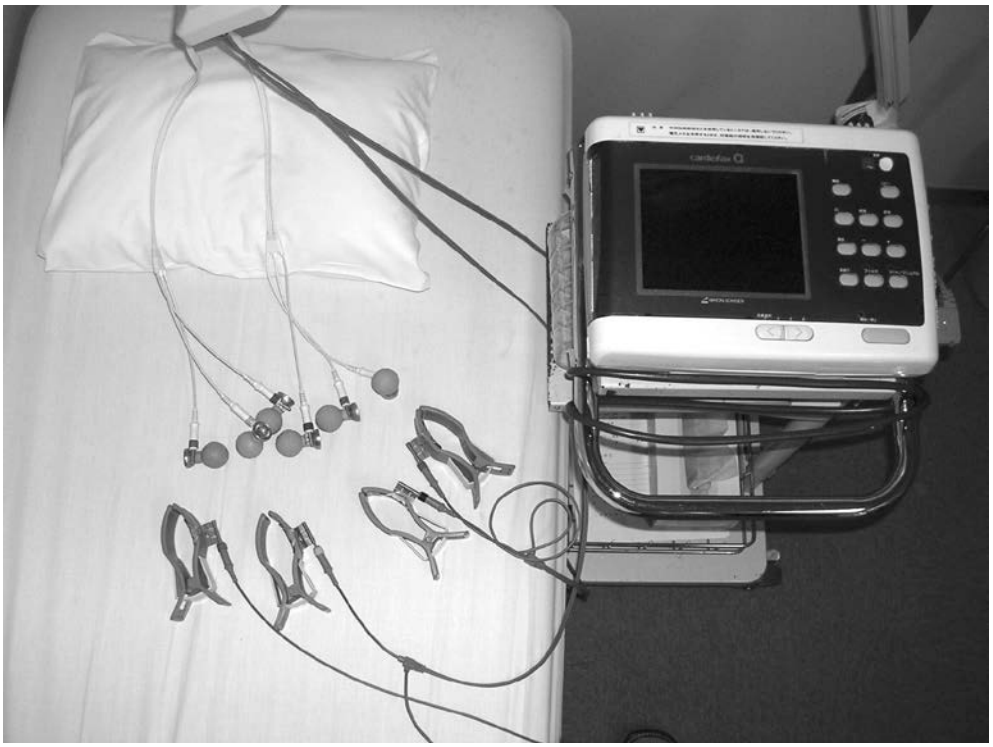

Figure 2. A typical electrocardiograph used in a emergency ward.

Problems encountered by the aviation community

Heart attacks, traffic accidents, and industrial accidents often occur at night and at dawn. However, night flights of civilian helicopters for medical transfer are prohibited in Japan under the aviation law, even if the avionics comply with the Instrumental Flight Rules standards. Therefore, emergency patients are transported by military and/or government service helicopters such as those operated by the police and Fire and Disaster Management Agency. These restrictions are partially due to the lack of ground support facilities for general aviation. In emergency medical transportation, helicopters in particular are required to land and takeoff at different sites for every case, even at night and in bad weather; thus, a flight support system specific to emergency medical transport that includes night-vision goggles and a terrain warning system should be developed and fitted to aircraft. Moreover, an improved navigation infrastructure to support flight dispatch, automatic dependent surveillance broadcast, global positioning systems, satellite-based navigation systems, and air traffic control systems in large-scale disasters should be developed to ensure the safety of emergency medical transportation at night and in bad weather. Medical air transportation services are essentially provided as non-scheduled flight services operated by small- to medium-sized airlines, so sufficient education and regular training of flight crews are important. Moreover, training medical personnel in crew resource management will help to ensure flight safety while maintaining clinical urgency.

Figure 3.Typical Infusion pumps used in a hospital

CONCLUSIONS

The medical air transportation service is steadily growing and currently includes emergency transfer by helicopter and transoceanic transfer of patients with an artificial heart by commercial and chartered jets. However, ergonomic investigations of this system have only just started in the areas of medical education and medical devices, and in the aviation industry. Among the measures needed, ergonomic and interdisciplinary collaboration are important to ensure efficient medical workflow and cooperation with aircrew.

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Environmental Problems Among Rural Women and Management of Occupational Health and Safety

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ABSTRACT

Women have long occupied a central place in agriculture production in developing countries, ensuring food security for their household and communities, but this role is not performed without adverse consequences for health. The major consequences include health risks owing due to women's use and exposure to hazardous agro-chemicals/pesticides, farm-related accidents or physical injuries and exposure to hazardous solid fuel in the interior house. Developing countries like India have many polluting sources that produce high level of human exposure. Indoor air pollution in developing countries from biomass smoke is considered to be a significant source of public health hazard, particularly to the poor and vulnerable women and children. Women and children face the greatest exposure to the harmful health effects of pollution. Women traditionally carry out most household chores and spend a considerable part of their time indoors. The pollution also affects young children under their mothers' care. Another source of high risk of ill health in rural India is exposure to spray of pesticides in the fields. In India, 70% of the population is farmers and they are the target group to be affected by the hazards of pesticide applications. In India, 70% of the population is farmers and they are the target group to be affected by the hazards of pesticide applications. Moreover, in developing countries the users are rather careless in handling pesticides. The high risk groups exposed to pesticides include the production workers, formulators, sprayers, mixers, loaders and agricultural farm workers. During manufacture and formulation, the possibility of hazards may be more because the processes involved are not risk free. In India, 70% of the population is farmers and they are the target group to be affected by the hazards of pesticide applications. Moreover, in developing countries the users are rather careless in handling pesticides. All pesticides in a given chemical group generally affect the human body in the same way; however, severity of the effects varies depending on the formulation, concentration, toxicity and route of exposure of the pesticide. Descriptive cum experimental research design was chosen for the study. The study was carried out in two districts Udham Singh Nagar and Nainital. Purposive cum Random sampling design was used to select the study area. Total sample size was comprised of 240 women from rural areas of Uttarakhand state in India. Experimental data was recorded through various scientific instruments and descriptive data was collected through interview schedule, awareness scales, and observation sheet. On the basis of anthropometric measurements the 5th, 50th and 95th percentile was calculated for the designing of personal protective equipments (gloves and coverall) through CAD for reducing the hazards of pesticide spraying and designing of chimney for minimizing the hazards of smoke originated by traditional cooking source. It was found from investigation that indoor air pollution and pesticide hazards were almost same for the families of hill region but sufferings related to indoor air pollution and pesticide hazards were more in the plain region as compare to hill region. The healthy and natural environmental conditions in the hill region and less dense housing of this region were the cause of less suffering from cooking smoke and pesticide spraying conditions. Taking the above fact into account the chances of diseases, risks and hazards were less for families of hill region.

Keywords: Rural Women, Occupational Health Hazards, Ergonomics

INTRODUCTION

Women have long occupied a central place in agriculture production in developing countries, ensuring food security for their household and communities, but this role is not performed without adverse consequences for health. The major consequences include health risks owing due to women's use and exposure to hazardous agro-

chemicals/pesticides, farm-related accidents or physical injuries and exposure to hazardous solid fuel in the interior house. Developing countries like India have many polluting sources that produce high level of human exposure. Indoor air pollution in developing countries from biomass smoke is considered to be a significant source of public health hazard, particularly to the poor and vulnerable women and children. Women and children face the greatest exposure to the harmful health effects of pollution. Women traditionally carry out most household chores and spend a considerable part of their time indoors. The pollution also affects young children under their mothers' care. Another source of high risk of ill health in rural India is exposure to spray of pesticides in the fields. In India, 70% of the population is farmers and they are the target group to be affected by the hazards of pesticide applications. In India, 70% of the population is farmers and they are the target group to be affected by the hazards of pesticide applications. Moreover, in developing countries the users are rather careless in handling pesticides. The high risk groups exposed to pesticides include the production workers, formulators, sprayers, mixers, loaders and agricultural farm workers. Mayer and Korhonen (1999) found in their investigation that the lack of scientific and technical knowledge in certain complex fields, together with schedule constraints, have led to adopt others standards insufficiently validated tests, relying sometimes on an empirical approach. Brantingham *et al.* (1970) reported that the primary occupational symptoms and diseases related to prolonged constrained standing are pain, discomfort, fatigue, swelling of the lower extremities and foot, due to blood pooling and varicosities of the lower extremities. There is pronounced effect of posture of an individual on the energy expenditure (Gross and Crandall, 1973). Agriculture is the central to developing countries and rural women contribute substantial share to labor that goes into this sector as food producer in household sector and agriculture workers in agriculture sector. Developing countries have been the focus for several investigations of health outcomes in household-generated biomass smoke exposures, primarily from the use of solid fuels for cooking. It cook with solids fuels, approximately 95% of which consists of wood fuel or burning of agricultural residues (Smith *et al.,*2004). Incomplete combustion and poor ventilation in biomass burning devices used for cooking or heating can result in extremely high PM exposures in these households(Naeher *et al.,* 2007; Smith *et al.,* 2000). In many homes in developing countries, however, a major source of exposure to indoor air pollutants is cooking smoke, when people rely on unprocessed biomass fuels such as wood, crop residues, and dung cakes for cooking and space heating. According to some estimates, more than half of the world's population still relies on unprocessed biomass fuels for cooking and heating(Bruce *et al*.,2000).

Chaffin (1977) reported that the muscle fatigue starts with a feeling of discomfort, which is successively increased to a dull, burning pain that at least makes all further muscle activity impossible. A decreased muscle force characterizes the localized muscle fatigue on one hand and by discomfort pain on the other hand. Chaffin (1977) also reported the character of localized muscle fatigue as given below:

Grade I: A study of tightening or slight cramp in the muscle.

Grade II: A sustained feeling of cramp, with a deep, intermittent burning pain.

Grade III: A continuous burning pain with a wish to cease the muscle work.

Grade IV: Impossibility to go on with the muscle activity.

Grandjean (1988) pointed out that static load is associated with a high risk of arthritis of joints, inflammation of the tendon and symptoms of chronic degeneration of the joints, painful muscle spasms and inter-vertebral disc troubles. Further Aaras and West Gaurd (1988), Keyserling *et al.* (1988), Ryan (1989) and Burdorf *et al.* (1991) supported the above said facts by stating that poor body posture was the major cause of musculoskeletal disorders. A good working posture reduces the physiological cost of work and fatigue to the minimum, whereas static muscular efforts and incorrect postures for long periods during performance of work can damage the inter-vertebral discs (Varghese *et al.,* 1989). Genaidy and Karwowski (1993) investigated the discomfort associated with postures at joint, which deviated from the natural position. It was revealed that in standing position, lumber extension was perceived to be more uncomfortable than lateral lumber bending or rotation. In both standing and sitting posture, flexion of the back was least uncomfortable of the extreme postures. Boocock *et al.* (1994) reported that tasks involving lumber extended postures (overhead work) are relatively common, may incure moderately high compressive loads on the lumber spine and are a potential source of occupationally related back pain. It has been demonstrated that simple ergonomic intervention at the work place can result in a reduction of lumber extension required for overhead work. The values of such intervention, in terms of reducing load, remains to be determined.

Occurrence of accidents/ hazards due to indoor air pollution and pesticides spraying

The women facing following problems in the hill areas while occupational safety should be a major concern. The occurrence and magnitude of hazards presented in table 1, Which shows difference in hill and plain region.

Table 1: Occurrence of accidents/ hazards due to indoor air pollution and pesticides spraying N=240

Occurrence of accidents/hazards	**Plain region**	**Hill region**	**Total population**
Yes	74(61.6)	40(33.3)	114(47.5)
No	46(38.3)	80(66.6)	126(52.5)
Reasons of occurrence of accidents/hazards			
Poor lighting	67(55.8)	24(20)	91(37.9)
Poor air circulation	79(65.8)	39(32.5)	118(49.1)
Poor ventilation	74(61.6)	27(22.5)	101(42.0)
High temperature	81(67.5)	8(6.66)	89(37.0)
High humidity	17(14.1)	7(5.83)	24(10)
Faulty construction	77(64.1)	45(37.5)	122(50.8)
Poor building material	72(60)	42(35)	114(47.5)
Dust	3(2.5)	0(0.00)	3(1.25)
Chlorine	2(1.66)	1(0.83)	3(1.25)

Overall analysis of the study reported that more than 45 percent sample women were experiencing hazards in house. It was reported that in plain region 50.8 percent sample women were feeling that hazards or accidents occurred due to faulty construction and high humidity and 1.25 per cent were thinking that dust and chlorine created farm hazards and accidents.

When comparison was made of families of both regions, it was found that in plain region 61 percent sample women were experiencing hazards or accidents in house because of high temperature(67,5 percent) and 1.66 percent due to chlorine respectively. It was observed that in hill region 38.3 percent were experiencing hazards or accidents. About 37.5 percent were feeling that hazards or accidents occurred due to faulty construction and 0.83 percent were thinking that dust created farm hazards and accidents.

As data depicted earlier, people were having small and poorly ventilated house, so there was high chances of hazards or accidents in the house.

Precautionary measures and personal protective equipment used in cooking and spraying

The data envisaged (Table 2) that nobody were using precautionary measures or personal protective equipments such as coverall, gloves, eye protector goggles, apron and other in cooking and spraying activity.

Table 2. Precautionary measures and personal protective equipment used in cooking and spraying N=240

Precautionary measure	**Plain region**	**Hill region**	**Total population**
Yes	0(0.00)	0(0.00)	0(0.00)
No	120(100)	120(100)	240(100)
Use of personal protective equipment			
Coveralls	0(0.00)	0(0.00)	0(0.00)
Gloves	0(0.00)	0(0.00)	0(0.00)
Eye protective goggles	0(0.00)	0(0.00)	0(0.00)
Aprons	0(0.00)	0(0.00)	0(0.00)
Respiratory protective equipments	0(0.00)	0(0.00)	0(0.00)

Table 3. Treatment of pesticide users N=240

Treatment	**Plain region**	**Hill region**	**Total population**
Drinking water	21(17.5)	4(3.33)	25(10.4)
Rest	67(55.8)	25(20.8)	92(38.3)
First-aid	7(5.83)	33(27.5)	40(16.6)
Medical treatment	25(20.8)	58(48.3)	83(34.5)
Other	0(0.00)	0(0.00)	0(0.00)

The data pertaining to treatment of pesticide users revealed that 38.3 percent people were taking rest for minimizing the hazards of pesticides and only 10.4 percent were preferring drinking water. Comparative analysis stated that in plain region 55.8 percent were taking rest for reducing the pesticide hazards and only 5.83 percent were preferring firs aid. Contrary to this, in hill region 48.3 percent were taking medical treatment and only 3.33 percent preferred drinking water. As stated earlier that in hill region people were having more educational status and more monthly income. So, these people were more aware regarding the preventive measures of pesticide spraying.

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Risk Among Hill Families of Mountain Region of Uttarakahnd, India

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ABSTRACT

The present study was conducted in mountain region of Uttarakhand, a hilly state of India. The objective of the study was to find the injury and accidents data due to poor lighting. It was assumed that injuries and accidents among hill people occur due to poor lighting. For this purpose descriptive research design was used. In Uttarakhand state, districts i.e Almora and Nainital were selected purposively from which purposive selection of 4 villages was done. From each village, 30 families were selected by simple random sampling technique without replacement to make a total sample of 120 families. The data was collected through interview schedule and observation. Descriptive and statistical analysis of data was done with the help of frequency, per cent and chi-square test respectively. The records focused that main accidents and injuries in last 10 years due to poor lighting were fall and slip outside the house, catching of fire during cooking and burning of finger while lighting kerosene lamp and cutting finger during vegetable cutting, animal/snake bite, attack of wild animate, catching fire to the cattle and burning of cattle with the use of kerosene lamp. The results were found to be significant at $p<0.05$, indicating that accidents like fall/slip during fetching fodder, fuel and water, accidents in kitchen, cases of wild animals/snake bite and other accidents dependent on availability of light. It was concluded that injuries and accidents among hill people occur due to poor lighting.

Key words: Poor lighting, injuries, accidents, lower income group, middle income group and upper income group

INTRODUCTION

Uttarakhand is a hilly state of India comprised of 13 districts. Out of these 13 districts, nine districts comprise the hill region of the state. Here villages are so remote those basic services such as lighting which is available either in minimum quantity or not at all. In such harsh situation people are really sufferer and prone to many accidents and injuries like fall and slip on the way in the absence of sufficient light.

Generally families use kerosene lamp and poke some firewood into a fuming *chulha* to cook dinner. Both the lamp and the *chulha* fill up the house with hazardous smoke, putting at risk the health of the woman and also her children whom she tries to attend to while cooking. Burning *chilka*, or pinewood, is the traditional source of light in remote villages, yet the health effects of indoor smoke pollution are alleviated with clean energy, smoke affected children's eyes, nose and mouth. These types of light are expensive, dangerous, and harmful to the environment. They also have a negative impact upon people's health, education, and security. Kerosene is costly, a fire hazard, and the fumes from the lanterns are highly toxic, especially for women and children who spend more time in enclosed spaces where the fumes are concentrated. In addition these sources do not provide enough light for a child to study. Children spend a majority of their day at school. By the time they return home, in the night, they are unable to study without light and can never do their homework at home because of the absence of a light source. This makes it very difficult for these children to have proper education. This lack of education is what can have the largest long term effect on a country.

Some people also light dry sticks as a torch for checking on the animals at night. The flammable hay can easily catch on fire. Studies have shown that there are links between biomass combustion and respiratory illness in women and children. There are also numbers of accidents and injuries and problem associated with poor lighting system but limited data are available with respect to injuries and accidents and health problem occurred due to poor lighting in hill region especially in Uttarakhand. Present study filled this research gap. Considering the above facts in the mind, the investigation entitled "Effect of poor light on the hill families of Uttakahand" was proposed with the objective to find out the injuries, accidents and related problems due to poor lighting system.

MATERIALS AND METHODS

To achieve the above objective descriptive research design was selected to see the effect of poor light on the hill families. The multi-stage, Purposive cum random sampling techniques was used to select the study area i.e. state, districts, blocks, villages, families. The Uttarakhand state was selected purposively. Districts like Almora and Nainital were selected purposively from the state Hawalbag and Bhimtal block from district Amora and Nanital respectively were selected purposively. The unit of enquiry was family and the key informant was head of the family. Total sample size comprised of 120 families selected randomly from the four villages which were selected purposively from the above blocks. Pre-coded interview schedule which include three point rating scale to assess the level of injury, accident and related problems due to poor lighting in terms of rarely, occasionally and frequently was used as an instrument for collecting data. Collected data was coded into the coding sheets and was then transferred into tabular form and analyzed using descriptive statistics.

RECULTS AND DISCUSSION

Injuries and accidents due to poor lighting

Fall and slip out side

About 14 per cent families reported that the occurrence of fall and slip was frequent due to poor lighting. While comparing different income group it was found that among 25.85 per cent families from the lower income group fall and slip occurred frequently. The fall and slip might occur due to poor lighting as well as combination with countless terraces outside.

Catch fire/ burn

It was found that 10.38 per cent respondents reported that catching of fire during cooking and burning of finger while lighting kerosene lamp in the absence of lighting was frequent in their family. It was found that in lower income group and middle income group this occurred frequently among 23.25 per cent and 5.45 per cent families respectively. Whereas in upper income group all the families said that it occurred rarely.

Cutting finger

It was found that in the absence of lighting cutting finger during vegetable cutting was frequent among about 18 per cent families While comparing among different income group it was observed that in lower income group and middle income group cutting figure during vegetable cutting was frequent in approximately 19 per cent families while in upper income group among all the families this accident occurred rarely.

Animal/snake bite

It was evident from the Table that in the absence of lighting, the case of animal/snake bite was frequent among about 10 per cent families. When comparison was made it was observed that such cases were frequent in 16.27 percent families from lower income group and 3.63 per cent families from middle income group. While in upper income group it was rare in all the families.

It was found that in mountain region during night wild animal used to attack on the human. From the table it was observed that attack of wild animal was frequent among 0.83 per cent families. While comparing among different income group it was found that this phenomenon was frequent only among 9.3 per cent families in lower income group, 1.81 per cent families in middle income group while in upper income group it was rare.

Psychological fear
Darkness leads to fear among everywhere. This fear is related to slip, fall, wild animal and robber. It is nothing but weaken the person. The data presented in table interpreted that among all about 48.33per cent families frequently had fear of dark. When comparing among different income groups it was seen about 60.46 per cent families among lower income group and 43.63per cent families in middle income group and 27.27 per cent families of upper income group had frequently fear of dark.

Catching fire in cattle shade
Generally it is possible that in the absence of proper lighting, using *chillka* and kerosene lamp leads to chance of catching fire. Data in the table revealed that in the absence of proper lighting catching fire in cattle shade was frequent among 10 per cent families. It was found that this problem was frequent only among 23.85 per cent families and 3.63 per cent families from lower income group and middle income group respectively while among upper income group it was observed rare among all the families.

Burning of animal
Data pertaining to the catching fire to the cattle and burning of cattle due to use of kerosene lamp revealed that it was frequent among 10.0 per cent families. It was clear from the table shows that it was frequent among 30.23 per cent families of low income group and only 9.09 per cent families of middle income group. But it was found to be rare among all the families of upper income group.

Handling cattle at night
It was observed that problem in handling cattle at night was frequent among 19.16 per cent families. While comparing among different income group it was found that difficulty in handling cattle at night was frequent in 37.20 per cent families in lower income group whereas 9.09 per cent families of middle income group and upper income group.

Animal bite to cattle
It was evident from the table that in the absence of lighting the case of animal/snake bite to their cattle was frequent in 11.58 per cent families. When comparison was made it was observed that such cases were frequent in 60.71 percent families from lower income groups and 7.69 per cent families from middle income group. While in upper income group it occurred frequently among only 4.54 per cent families.

Problem in delivering of pregnant animal
Over all analysis showed that 65 percent respondents reported that they frequently faced problem while handling the cattle during delivery due to poor lighting. It was found that about 75 per cent respondents from lower and middle income group frequently faced this problem. While among upper income group only 22.72 per cent families frequently faced this problem.

On the whole it was found that problem in studying was the main frequently occurred problem due to poor lighting system. It might be due to insufficient illumination of kerosene lamp and candle which were used for studying as it was discussed in the study earlier.

Testing of Hypotheses
In order to test the hypotheses statistically the null hypotheses were formulated for each hypothesis. Chi-square test and paired t- test were applied for statistical analysis.

Injuries and accidents among hill people occur due to Poor lighting.
Chi-square test was applied to see the association between occurrence of injuries, accidents and related problems in kitchen, cattle shed, outside and in home and availability and sufficiency of light. The results are presented in the Table 2.

Table 1: Occurrence of accidents/injuries and related problems due to poor lighting

Injuries and accidents	**Income group**									**Total (N=120)**		
	Lower			**Middle**			**Upper**					
	Rarely	Occasionally	Frequently	Rarely	Occasionally	Frequently	Rarely	Occasionally	Frequently	Rarely	Occasionally	Frequently
Fall/ slip outside the house	19(44.18)	13(30.23)	11(25.58)	34(61.81)	16(29.09)	5(9.09)	15(68.18)	6(27.27)	1(4.54)	68(56.66)	35(29.18)	17(14.16)
Catch fire /burn	19(44.18)	14(32.55)	10(23.25)	48(87.27)	4(7.27)	3(5.45)	22(100.0)	0(0)	0(0)	89(74.17)	18(15.00)	13(10.83)
Cutting finger	23(53.43)	12(27.90)	8(18.60)	26(47.27)	19(34.54)	10()18.18	15(68.18)	4(18.18)	3(13.36)	64(53.34)	35(29.16)	21(17.50)
Animal /snake bite	21(48.83)	15(34.88)	7(16.27)	45(81.81)	8(14.54)	2(3.63)	22(100.0)	0(0)	0(0)	88(73.33)	23(19.17)	9(7.50)
Attack of wild animal	38(88.37)	1(2.32)	4(9.30)	54(98.18)	0(0)	1(1.81)	22(100.0)	0(0)	0(0)	113(94.16)	2(1.66)	1(0.83)
Catch fire in cattle shade	24(55.81)	9(20.93)	10(23.85)	46(83.63)	7(12.72)	2(3.63)	22(100.0)	0(0)	0(0)	92(76.66)	16(13.33)	12(10)
Burning of animal	18(41.86)	12(27.90)	13(30.23)	50(90.9)	0(0)	5(9.09)	22(100.0)	0(0)	0(0)	90(75.0)	12(10.0)	18(15.0)
Handling cattle at night	17(39.53)	10(23.25)	16(37.20)	46(83.63)	4(7.25)	5(9.09)	20(90.90)	0(0)	2(9.09)	83(69.16)	14(11.66)	23(19.16)
Animal bite to cattle	14(32.55)	7(16.27)	22(51.16)	45(81.81)	5(9.09)	5(9.09)	21(95.45)	0(0)	1(4.54)	80(66.66)	12(10.0)	28(23.33)
Problem in delivering of pregnant animal	0(0)	11(25.58)	32(74.41)	6(10.90	8(14.54)	41(74.54)a	16(72.72)	1(4.54)	5(22.72)	22(18.33)	20(16.66)	78(65.0)

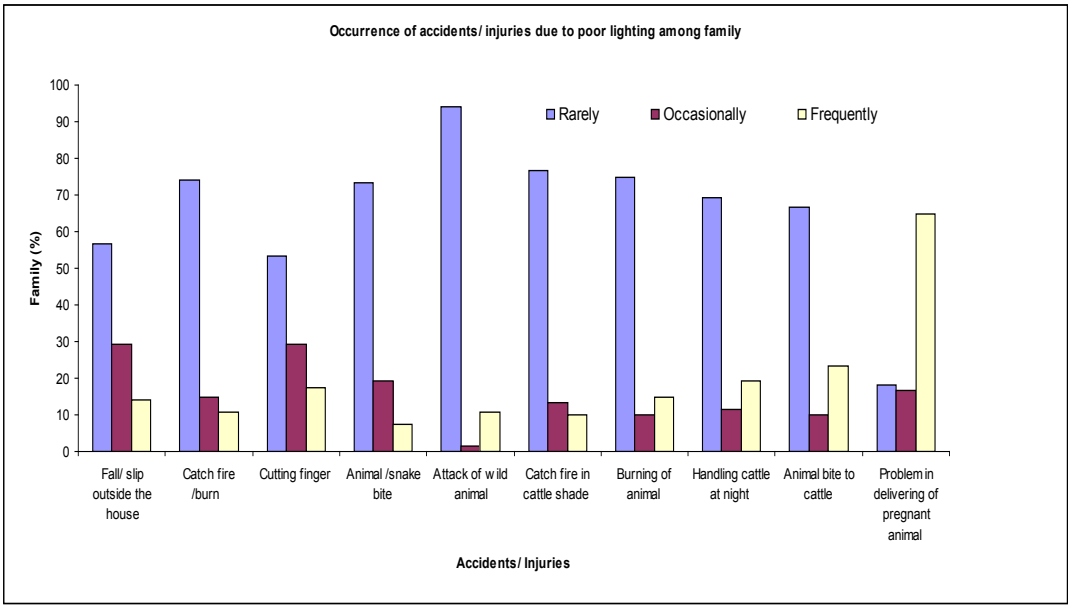

Figure: 1 Occurrence of accidents/ injuries and problem due to poor lighting among family

Table: 2 Injuries and accidents among hill people occur due to Poor lighting

Null hypothesis	p-value
Availability of light and occurrence of accidents in kitchen	0.003381418
Availability of light and occurrence of cases of wild animals/snake bite	1.15394E-05
Availability of light and occurrence of problem while handling cattle	1.29916E-06
Occurrence of problem while handling cattle during delivery at night and availability of light in cattle shed	3.62491E-19
Occurrence of fall/slip during fetching of fuel, fodder and water and availability of light	2.86295E-10

Null hypothesis was formulated to see the association between the availability of light and occurrence of accidents in kitchen, occurrence of cases of wild animals/snake bite, occurrence of problem while handling cattle, Occurrence of problem while handling cattle during delivery at night and Occurrence of fall/slip during fetching of fuel, fodder and water. The results were found to be significant at $p<0.05$ indicated that there was significant association between occurrence of accidents in kitchen, occurrence of cases of wild animals/snake bite, occurrence of problem while handling cattle, Occurrence of problem while handling cattle during delivery at night and Occurrence of fall/slip during fetching of fuel, fodder and water and availability /sufficiency of light.

On the whole it was found that problems were faced by families in every areas of the house including kitchen while cooking, handling cattle in cattle shade and outside the house while fetching fodder, fuel and during late evening and night time in the absence of proper lighting.

It was reported by Barr (2010) that kerosene had adverse effects and it was a barrier to education. Light from Kerosene lamps is poor and inefficient (only 2 to 4 lumens compared to a 60-watt bulb-900 lumens). Poor lighting

affects literacy and education. The light from the lamps is so poor that children can only see their schoolbooks if they are almost on top of the flame, directly inhaling even more of the toxic smoke. He further reported that that kerosene and candles cause countless fire catastrophes every year. There were 282,000 deaths from fire-related burns worldwide in 1998, and 96% of these fatalities were in developing countries. In India alone, 2.5 million people (350,000 of them children) suffer severe burns each year, primarily due to overturned kerosene lamps. Each year, many homes burn to the ground when a lamp is toppled.

According to Mock et al (2008) fire-related burns are responsible for 300,000 deaths every year, 95 percent of which happen in low- and middle-income countries. It was found that that cooking sources as well as lighting sources, including kerosene lamps, were largely responsible for these tragedies. It was common for children to study in bed with a kerosene candle on the edge of their headboards.

From the study it was also reported that poor lighting condition leaded to tiredness and sleepy after short period of time, irritability, difficulty in paying attention, perspiration and sweating and low productivity. This study was in line with Joseph A (2006) who reported that light impacts human health and performance by enabling performance of visual tasks, controlling the body's circadian system, affecting mood and perception, and by enabling critical chemical reactions in the body. Studies show that higher light levels are linked with better performance of complex visual tasks.

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Section 6

Psychosocial Factors, Communication and Teamwork

Adaptive Team Behaviors for Coping with Unexpected and Unknown Situations - An Observational Study

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ABSTRACT

Industries with high risk-potential like nuclear power plants need to manage abnormal potentially critical situations on team level for assuring reliable and safe operating. Safety is looked at as a "dynamic non-event" (Weick & Sutcliffe, 2001) and therefore has to be continually built on by the operating team through adaptive actions in relation to the situational context. The team processes and behaviors used for achieving shared mental models (or common situation awareness) are especially interesting for good problem solving, decision making and adaptation. In our study we collected data from eight four- to seven-person control room teams working in a nuclear power plant in Switzerland during their annual training in the interactive simulator of the plant control room. Simulations of two different scenarios were videotaped. The simulator scenarios generate an unexpected unstandardized situation (situations that were not covered / could not be solved solely by standard operation procedure) the team has to solve in order to stabilize the plant. Additionally, we got individual data by a questionnaire to capture individual characteristics of the team, especially regarding professional experience. The results still have to be considered as explorative in nature, due to the small sample size and time consuming coding of further additional team behaviors.

Keywords: Adaptation, Team Cognition, Safety, Nuclear Power Plant

INTRODUCTION

Industries with high risk-potential like nuclear power plants (NPP) need to manage abnormal potentially critical situations on team level for assuring reliable and safe operating. According to Weick and Sutcliffe (2001), safety is looked at as a "dynamic non-event" and therefore, it has to be continually built on by the operating team through adaptive actions in relation to the situational context. Apart from the strategy to handle unexpected, potentially critical situations by highly standardized procedures, teams have to be capable to switch to flexible team coordination in order to manage situations that are not covered by standardized procedures and to find the right balance between standardization on the one hand and flexibility and openness to changes in unexpected situations on the other (Ritz, 2012; Grote, Kolbe, Zala-Mezö, Bienefeld-Seall and Künzle, 2010). The breaking point between the highly regulated work-process structured by standard operating procedures and the necessity of problem solving in abnormal situations seem especially interesting for assessing adaptive capability in teams. Especially the development of modified situation awareness (or shared mental model) within the team seems to be important for effective adaptive problem-solving and decision-making when unexpected and unknown situations (that means there

are no existing standard procedures for handling these situations) occur. The accurate situation assessment is the basis for further problem-solving activities and should involve intensive phases of information exchange and reflexion within the operating team with possibilities for speaking-up (esp. reactor operators) and updating (esp. foreman / supervisor) (Kolbe, Burtscher, Wacker, Grande, Nohynkova, Manser, Spahn and Grote, 2012). The adaptive process that is necessary for handling changing task requirements, is characterized to a bigger part by "a fundamental activity of groups (that is) … the integration of individual knowledge into collective knowledge." (Okhuysen and Eisenhardt, 2002, p. 370)

The working context in the operating room of a nuclear power plant (NPP) is characterized by the special situation of a complex expert organization (Vidal, Carvalho, Santos and dos Santos, 2009). Such an organization can be looked on as a distributed cognition environment, where nobody has complete information about everything that is happening at a particular moment, so the operators need to share their cognitions to be able to operate the plant in a more resilient way. Especially in this environment the explicit coordination of information sharing seems essential for good team-performance in problem-solving and decision-making. Information collection and exchange in the operating team of a nuclear power plant is mainly dominated by the shift supervisor (team leader). Vidal et al. (2009) described that during problem-solving situations, the strictly centralized control mode is modified and all team members submit hypothesis and participate in a collective decision-making process supplying information. However, all the information is submitted to the shift supervisor who has the ultimate authority to make decisions. Sharing information is the main way, team members use to cooperate in control room environments. The coordination of this information sharing process by the shift supervisor seems to be important for the adaptation of the team.

In our research project TeamSafe we had the opportunity to observe operating teams in a training simulator when they managed scenarios with unexpected and unknown situations - that means they had to cope with a task situation where they did not have a developed operating procedure to follow. Our aim was two-folded: First, we wanted to explore and better understand the process of regaining control over the situation by the team, that mean adapting as a team for coping with new situational demands - so we wanted to explore the process used by successful teams. Second, we combined these successful activities we had identified into a method for guiding adaptive team process by a "formal intervention" (Okhuysen, 2001; Okhuysen and Eisenhardt, 2002) (see also, Brüngger, Kleindienst, Koch and Ritz, 2014).

The following study was done to a large extent on the basis of research of Waller (1999) as well as Waller, Gupta and Giambatista (2004) with regard to the main assumptions of adaptive behaviours. There also has been an important influence from Kolbe, Strack, Stein and Boos (2011) for the inclusion of coordinative behaviours.

TEAM ADAPTATION IN THE CONTROL ROOM TEAM

Adaptive Team Behaviors

Adaptive behaviours occurring after the recognition of changing situational circumstances by the operating team will serve primarily for orientation within a "new" environment (Waller et al., 2004; Burke, Stagl, Salas, Pierce and Kendall, 2006). That means the main interest within the team has to be to gather relevant information about the actual state of the environment, in the case of the nuclear power plant, the plant and the main systems. Information collection behaviors have been shown to be extremely important to crew performance under high workload conditions (Stanton, 1996) and involve collecting and recognizing information concerning the need for action (Waller, 1999). Behaviours of searching and collecting information are important tasks in situation assessment on the individual level. On the team level, the individually collected information and knowledge about the system status, has to be exchanged, that means processes of horizontal interaction and communication should take place so that the individual knowledge is spreading out in the team and individual information is integrated for becoming common information. The interaction process for information exchange to determine the status quo within the situation is two-folded: on the one hand, there are actions to get information from others (asking/questioning), on the other hand giving information without being asked or in a dialogue. Information collection also plays an integral role in both individual and team performance when looking at the development of situation awareness. Operators of complex systems collect information about system cues in their environments, comprehend that information in terms of the current situation and their past experience, and use that information to project future situation problems and

dynamics (Endsley and Garland, 2000). At the team level of analysis, the collection of information by team members plays a critical role in increasing the team's awareness of the situation (Prince and Salas, 2000).

Besides the above mentioned adaptive communicative behaviours of information collection and exchange, Waller et al. (2004) looked at behaviours of task management as central for the adaptation process on the team level. Task distribution refers to the effective allocation of tasks as a process whereby a team can shift the workload among its team members to achieve balance during high-workload, time-pressured or emergency situations. Waller (1999) also found that high-performing crews are significantly more likely than other crews to engage in task distribution behaviors during nonroutine situations.

Coordinative Team Behaviors

Coordination of team process and collaboration is one of the central activities in teams. Coordination can be defined as "the process by which team resources, activities, and responses are organized to ensure that tasks are integrated, synchronized, and completed within established temporal constraints" (Cannon-Bowers, Tannenbaum, Salas and Volpe, 1995, p. 345). Burtscher, Wacker, Grote and Manser (2010) defined coordination (in medical teams) "… as those activities of team members that aim at organizing the joint task execution …" (p. 283). In professional teams there is often a specialized function or position with regard to coordination of task delegation or distribution and the coordinated moderation of the communication process. Within the operating team this function mainly is hold by the shift supervisor (Schichtchef) who is in charge of decisions.

In unexpected and unknown situations it is thought that coordination activities have to be changed to face the challenges of new and unstructured situational demands. Burtscher et al. (2010) defined adaptation or adaptive coordination as “a team´s ability to change its coordination activities in response to changing situational demands, such as the occurrence of unexpected events and varying task characteristics (e. g. level of task load, degree of standardization, time pressure)" (p. 283). Burke et al. (2006) described as one mode of adaptation the adjusting process, i.e. changes in coordination mechanisms, decision making, and communication patterns in response to unexpected events. For example Zala-Mezö et al. (2009) have shown that teams in healthcare adapt their coordination pattern to changing situational demands. The relationship between adaptation and team-performance has to be investigated more deeply.

When task demands are changing, coordinative activities have to be adapted and adjusted according to these changes. If there is the necessity of more information exchange during a new situation, coordinative behaviors have to encourage this. This could also mean a change of the coordinative strategy. One important basic mechanism for a broad information collection with the participation of all team-members seems to be a high ("optimal") attentional level or mindfulness within the team. That means for example, that the shift supervisor is open (attentive) for input of all team members as well, as the team members are able to promote their informational input, that means, can get attention of the shift supervisor. Coordinative behaviors that can foster these basic processes of attention level could also be non-verbal behaviors, like pointing (gesture for orienting attention; see also pointing and joint attention, Tomasello, 1999). Bangerter (2004) describes the role of pointing for focusing attention in dialogue.

Another explicit coordinative behavior that could have a positive influence on the attentional level within the team, could be "addressing someone by name" (Kolbe et al., 2011). For example this could appear when shift supervisors are distributing tasks to team members or questions are posed to a team member. The attentional influence of hearing subjectively important information like one's own name for example is known as the "Cocktail Party Effect" (Cherry, 1953).

The role of these coordinative behaviors should be explored more in detail with regard to the adaptation in teams.

Development of Shared Mental Model / Shared Situation Awareness

The above mentioned adaptive and coordinative behaviors have essential functions in the adaptation of teams to changing task environments. But as Waller et al. (2004) emphasize: "Engaging in adaptive behaviors might be helpful to crews managing the emergence of nonroutine situations and high workloads in dynamic environments, but research suggests that engaging in adaptive behaviors alone might not always lead to success for control crews. Without a gestalt of the current state of the multiple systems they manage, the plan to implement if problems should arise, and the actual problem or problems at hand, control crews might engage in adaptive behaviors because they have been trained to do so, but still might be unable to coordinate their behaviors and contain system problems quickly and correctly." (p. 1536) This means, that without integrating the coordinated collected information into a

new, resp. modified knowledge structure (mental model) concerning the new task situation and required measures, adaptation will not be effective.

According to Waller et al. (2004) there are numerous definitions and conceptualizations of shared mental models. For a review they refer to Mohammed and Dumville (2001). Rouse and Morris defined shared mental models as "a mechanism whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" (Rouse and Morris, 1986, p. 360). Shared mental models provide team members with a common knowledge structure that helps them predict what other team members will need and will do during excessive-workload conditions and therefore help teams quickly adapt their activities during nonroutine situations (Cannon-Bowers et al. 1993; Waller et al., 2004).

Communication processes used by groups to convey information during problem-solving episodes such as shared mental model development are critical to overall group performance (Weick and Sutcliffe, 2001). During these communication processes the proximity of group members has direct effects on group communication and performance. Groups with members that are located physically near each other are able to engage in face-to-face communication during problem solving and are more able than other groups to communicate nonverbally, as well as verbally. Nonverbal communication includes facial expression, eye contact and movement, and physical gestures and can greatly enhance the amount of information communicated in a group setting (Feldman, 1992 according to Waller et al. 2004, p. 1537).

Uitdewilligen, Waller and Pitariu (2013) in their recent study investigated whether team mental model updating - changing mental models in line with changes in the task situation - is positively related to team performance in a situation requiring adaptation and they emphasize the importance of extending the view from a static perspective to a dynamic view of updating of mental models with regard to adaptation in teams: "Authors have emphasized the importance of the structured knowledge team members have regarding their task or team in the team adaptation process (Burke et al., 2006). In particular, team mental models - team members mental representations of knowledge, relationships, or systems - are considered pivotal for successful team adaptation (Cannon-Bowers et al., 1993). However, previous work, while explicating the role of mental models in team adaptation often take a static perspective on team cognition, focusing on characteristics such as similarity, accuracy, or quality. Yet research from the field of managerial and organizational cognition suggests that under dynamic task circumstances, it may not be the momentary stable characteristics of mental models that impacts performance, but the ability to update mental models in light of changing task situations." (p. 129).

Beside of adaptive behaviors for exchanging information within the team, special interaction activities for ensuring common situation awareness (shared mental model) should be regarded. Okhuysen and Eisenhardt (2002) pointed on the mechanisms of "formal interventions" that focus on the improvement of the group process as a potential way to achieve superior knowledge integration. Formal interventions provide explicit instructions for the group to follow and help guide the discussion among members. "These process interventions are designed to create a more structured group discussion, and enhance the communication of personally held information … These formal interventions are intended to structure the group process so that more knowledge is revealed and effectively combined." (Okhuysen and Eisenhardt, 2002, p. 340, 341)

Conclusion and Research Question

Team adaptation in the control room team is a complex process with a lot of different mechanisms running on the individual and on the team level. Perhaps this complex process in the special configuration of an operating team in a nuclear power plant resembles the process within an orchestra which individual parts are synchronized or harmonized by their score, their expertise and by the conductor.

Only a few team processes resp. behaviors have been theoretically mentioned above, but these are looked at being in the center of team adaptation. Collecting and exchanging information from the environment, coordinating the process in the direction of synchronization of the individual actions and re-building a common cognitive (knowledge) base in form of situational awareness or shared mental model should be the basic activities in coping with unexpected situations.

The empirical study we conducted in a Swiss NPP aimed to explore these basic adaptive processes by means of behavioral observation within a real working context as well as to develop a device for supporting operating teams in coping with unexpected and unknown situations (see also, Brüngger et al., 2014).

EMPIRICAL STUDY IN A NUCLEAR POWER PLANT

The observations for this study were made during the annually scheduled training simulations with eight control room teams (four to six persons per team, 61 persons in total). Simulations were audio- and videotaped. Each team worked on the same two simulation scenarios, which had been developed by instructors of the simulation training unit. The scenarios contended non-routine situations that should be handled under a slight pressure of time. Each team member held a specific role in each scenario (shift supervisor (Schichtchef 1), control room supervisor (Schichtchef 2), primary operator (Primäroperateur), secondary operator (Sekundäroperateur), shift technical advisor (Pikettingenieur) and an additional third reactor operator in some of the groups). Some roles had been switched between the two scenarios. The recordings were coded in the software "Noldus Observer", using a coding scheme in dependence to Waller, Gupta & Giambatista (2004). Adaptive behaviors, coordinative behaviors and group discussion phases were coded for each team and analyzed on individual levels (e.g. shift supervisor) as well as on a collective team level. The group discussion phases were considered as phases, where a shared mental model was developed.

Organizational Context

The study was conducted by the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) in collaboration with a Swiss nuclear power plant over a three-year period.

The aim of this project is to identify successful adaptive team behaviors in critical situations within control room teams and to provide the findings not only as a base for further research but also for the use in actual practice. The recordings for the study were made during the annually scheduled training simulations from 2011 to 2013. In the first phase (2011), successful coping mechanisms in critical and non-standardized situations were identified within the control room teams. On the basis of these findings and theoretically based considerations, a prototype of a structuring tool has been developed. It supports control room teams in the process of problem-solving and decision-making in non-routine and potentially critical situations not covered by standardized procedures (see also, Brüngger et al., 2014). In the second phase (2012), the new tool was introduced during the simulator trainings and adapted afterwards by means of the control room team members' feedback.

The composition of control room teams

Control room teams usually consist of a leading shift supervisor (Schichtchef 1), a control room supervisor (Schichtchef 2), a primary operator (Primäroperateur), a secondary operator (Sekundäroperateur) and a shift technical advisor (Pikettingenieur) who is contacted in emergency situations. An additional third reactor operator optionally complements the team (monitoring of the digital readouts and reserve pool employee (Libero) or carrying out actions outside of the control room (Anlagenoperateur)). The shift supervisor bears responsibility for the decisions reached by the team. In the recorded simulation scenarios, each of the four to six team members held one of the mentioned roles. The roles of the shift supervisor and the control room supervisor as well as of the primary and the secondary operators had been switched between the two scenarios. Defining a team as a certain composition of roles, after switching roles in scenario 2 the teams are considered as different, even though the persons remain the same.

The preliminary results are thus based on the sixteen simulations recorded in 2012. The recordings of the simulations in 2013 are still being coded and will be added to the analysis as soon as possible.

Situational requirements for the control room teams: Simulation scenarios

Whereas routine work follows structured guidelines and processes lead by the shift supervisor, in non-routine situations all team members are equally involved in a collective problem-solving process (Vidal et al., 2009). Following Vidal et al. (2009), the work in the control room of a nuclear power plant is characterized by the fact that none of the team members ever possesses complete information about a present situation. Everybody has to share his cognitions (e. g. perceptions, estimations,…) with the other team members in order to be able to stabilize the plant. Especially in non-standardized situations, it is fundamental that the members share information of their areas of responsibility, which leads to a collective understanding of the actual situation as a basis for successful problem-

solving. The shift supervisor is meant to coordinate this process of information exchange.

The simulation scenarios had been developed by instructors of the simulation training unit and generated a non-routine, unexpected and potentially safety-critical situation which could be handled within 30-60 minutes. The generated problems could lead to a more severe situation if not contained within a certain amount of time. Due to the fact that the simulated scenarios consisted of non-routine events, the known procedures did not lead to a solution of the problem given. It therefore became necessary for the team to identify anomalies and elaborate adequate counteractions in a collaborative problem-solving process. Pressure of time and dimension of workload can both be considered as moderate.

The design of the scenarios' complexity was led by the objective that differences in team performance should be shown. The team performance was assessed by the instructors of the simulator training centre by rating the quality of the technical solution.

Aims and Hypothesis

As already mentioned above, the aim of this research project is the description and explanation of adaptive team behaviors within the control room team that have an impact on safety oriented coping in unexpected and non-standardized situations. In order to handle such situations, teams have to be capable to switch to flexible team coordination and to build collective understanding of the actual situation through an interactive information-exchange process within the team. In dependence on theories and empirical findings in literature (Waller et al., 2004; Kolbe et al., 2011) this study focuses on cognitive structures and behaviors supporting a successful collective problem solving process in non-standardized situations.

Based on the indications of previous research (Waller et al., 2004; Kolbe et al., 2011), it was postulated that successful teams would engage more in adaptive behaviors, coordinative behaviors and group discussion phases (development of shared mental models) and that there would be a positive correlation between these behaviors and team performance.

Data Coding and Team Performance Categorization

The recordings were coded in the software "Noldus Observer", using a coding scheme according to Waller, Gupta & Giambatista (2004). Adaptive behaviors (information collection, information provision, task distribution) were coded for each team member as well as group discussion phases for each team. Group discussions are defined as phases of collective reflection of gathered information, of cause identification in order to build a collective situational understanding as well as of decision making among the team members. Moreover, two additional coordinative behaviors guiding attention were coded, since they had been identified as potentially relevant during the first, rather explorative phase of the project (2012): Pointing and addressing by name.

The coding scheme has been elaborated by the research team in dependence on Waller et al. (2004) in an evolving process of testing, reflecting and adapting. To set the final version of the coding scheme some videos were double coded by two different researchers to allow for assessment of interrater agreement. The final agreement can be described as acceptable to good.

The team performance was assessed by the instructors of the simulator training centre by rating the quality of the technical solution.

A questionnaire has been handed out to all the participants, aiming at a descriptive characterization of the teams, such as age average, level of education, period of employment or degree of familiarity among the team members.

Statistical evaluation

The results have to be considered as preliminary so far, by reason of the small number of cases (sixteen simulations). The simulations of the third phase (2013) are currently being coded and will be integrated into further data analysis.

In order to analyze the correlations between the adaptive behaviors within the teams and the team performance, Spearman’s rho has been calculated. Additionally, differences between groups rated with either specially high or low performance have been explored. Furthermore, correlations between the showed adaptive behaviors on the individual level of the responsible shift supervisor and his group’s performance have been focused. Preliminary results are presented in the following chapter.

Results

In this status of the research process, no significant correlations between adaptive behaviors and team performance were found, neither between coordinative behaviors and team performance. There was also no significant correlation detected between development of mental model (team discussion) and team performance. The results could be influenced by two limitations: Firstly, the actual sample size has to be considered as small (N=16) and secondly, the team performance measure was generally rated high ("ceiling effect"). After the scenarios of the third training simulation in 2013 will have been coded, these data will be integrated into the analysis as well as into further evaluation.

There are some individual results of interest for further exploration. With respect to development of mental model (team discussion) two results can be pointed out: The moment of the beginning of the first team discussion correlates positively with team performance (r = 0.32, Sig. 0.84, N = 16). That means successful teams begin later with the first team discussion than less successful teams.

We could speculate that the beginning of discussion in the team could be relevant for the further evolution of the problem-solving process. The timing of the team discussion sequences should be taken into account as well as the relation of team discussion and adaptive and coordinative behaviors as patterns of interaction (see also Waller, 1999; Stachowski, Kaplan and Waller, 2009). For example it could be relevant if there is a relation between the amount of information collection and the beginning of the first team discussion. Given the fact that the actual sample size is very small and the result is not significant, it should be seen as a tendency setting a basis for further exploration.

Another result of interest is the correlation between the time spent on team discussion and the degree of familiarity within the team (r = 0.409, Sig. 0.058, N = 16). This result indicates that teams with high familiarity between team members spend more time on team discussion than teams with a lower degree of familiarity. We could speculate that mechanisms like psychological safety or trust within the team could be of relevance for the participation of team members in the discussion (the more they are involved, the longer the phases of discussion would last). Psychological safety and trust could also have an influence on the willingness of the shift supervisor to let team members participate in the decision making process. Further data analysis with more focus on detailed interaction processes during team discussion phases are being planned.

Whereas adaptive team behaviours and team discussions only occur during non-standardized phases, when official guidelines cannot any longer be followed to handle the situation, coordinative behavior as "addressing by name" can appear in both standardized (sP) and non-standardized (osP) situations.

The analysis of only one of the two scenarios (N=8) showed two different significant correlations between the number of the behavior "addressing by name" and team performance: "Addressing by name" in non-standardized situations (osP): r=0.676, Sig. 0.0333 (N=8) and "addressing by name" in standardized situations (sP): r=-0.688, Sig. 0.030 (N=8). These results show that successful teams display the coordinative behavior "addressing by name" during unstandardized phases more often than less successful teams (in scenario 2). This correlation is reverse for standardized routine work: In a standardized situation successful teams show the behavior "addressing by name" less often than less successful teams. It could be speculated, that different kinds of cognitive modes are required in standardized and unstandardized working phases. The functionality of the behavior "addressing by name" with regard to attentional influence could therefore change with the actual situation and the cognitive modes required.

Furthermore, a nearly significant positive correlation between the coordinative behavior "addressing by name" displayed by the shift supervisor and team performance was found: r=0.479, Sig. 0.061, N=16. The comparison between groups with a high and groups with a low team performance rating revealed that shift supervisors of the best performing groups showed the behavior "addressing by name" three times more often than shift supervisors of the lowest performing groups.

CONCLUSIONS

Due to the limitations we mentioned before (small sample size, ceiling effect of the performance measure, time consuming analysis) the reported results should be seen as tendencies and as signs we have to check in more detail when the data base and our understanding of the complex process is growing. The conclusions therefore are generally drawn with regard to further needs of analysis.

Two main complexes seem to be of interest for further and more detailed analysis: First, the contribution of team discussion phases (as formal interventions) and second, the role of the shift supervisor for coordination and synchronization of team activity / collaboration.

The results show no clear proof of the significance of team discussion phases for team performance. In further analysis it should be looked in more detail on the interaction processes going on during team discussion. They could differ regarding the participation of team members, the coordination of shift supervisor and also with regard to the topics discussed (e. g. updating/exchanging information, updating by the shift supervisor, reflecting new information, ...).

So far it was looked on team discussion without considering the time-course (sequence) and development of team discussion phases or the sequences of time-discussion phases combined with different adaptive or coordinative behaviors. By doing this, perhaps there could be identified typical development patterns of discussion phases or interaction patterns and processes typical or especially successful for adaptation. In the first step this analysis of sequence should be qualitative and descriptive because of the small sample size and the time consuming procedure of sequence analysis.

Second, the role of the shift supervisor for the coordination of the adaptation process should be analyzed in more detail, especially the use of coordinative behaviors by the shift supervisor in relation with situational demands. It could be looked for different styles of coordination by the shift supervisor and their success by managing the interaction process. The influence of the coordinative actions of the shift supervisor could be especially looked on in phases of team discussion.

In general, focusing the interest on the integration of individual knowledge to common knowledge by team interaction within phases of team discussion seemed theoretically and practically especially important for a better understanding of successful adaptation in the operating team. According to Pavitt (1993, see Okhuysen and Eisenhardt, 2002, p. 371) researchers rarely examine how interventions (like team discussion) actually work to help groups modify their process to more effectively integrate knowledge, but there should be more attention to actual changes in the interaction among individuals. The complexity of the dynamic adaptation process makes it difficult to look only for one behavior or factor as a cause for good performance. Therefore, the identification of (interaction-) patterns should be one aim of further analyses besides the inclusion of the data of the third project phase (2013) in our statistical analyses.

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Analysis and Development of Occupational Competencies of 21st Century Managers of Municipal Sector

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ABSTRACT

In the article the implementation stages of 21st century manager's competency profile in municipal sector were presented. The main managers' occupational competencies were described: communication skills, organizational skills, ethics management skills, team management skills and creative thinking skills. In the practical part of this paper examination of managers' professional competencies in selected enterprises of Wielkopolska municipal sector was performed. At the same time methods of occupational skills development were assessed. Current managers' knowledge and skills level were taken into account during planning of their development.

Keywords: managers' competences, manager's competency profile, development

INTRODUCTION

"Modern organizations find that only the ability, experience, knowledge, skills and other characteristics that employees have, may lead the company to implement its strategy, meet customer needs and the conditions dictated by the competition" (Rostkowski, 2004, s.38). However, to manage the professional competencies of employees, it is necessary to explore them and evaluate what competencies are necessary for the proper functioning of the given organization in the future (Boyatzis, 2008, Czapla, 2011, Filipowicz, 2004, Rakowska, 2007, Walkowiak, 2004). Such task is carried out within the project: "Model of validation of competencies for employees of MSME of Wielkopolska's municipal sector." The project is co-financed by the European Union under the European Social Fund. Implementation timeframe is from September 2011 to August 2013. The main implementers of the project are practitioners - executives and managers of municipal sector companies and a specialist in the field of designing competency profiles.

The purpose of this article is to present the main steps in the designing competencies profile for the 21st century manager of the Wielkopolska's municipal sector and to show the results of research of the managers' professional competencies (Spychała 2012, 2013).

Personal profile based on competencies has been created for managerial positions and concerns the required technical competencies as well as social competencies in the workplace in the future. This profile can be used during the various stages of human resource management (including the selection of managers to project tasks, creating career paths, training and development and evaluation of managers) (Dubois, Rothwell, 2004, Whiddett, Hollyforde, 2003).

Knowledge about the quantity and quality of occupational competencies of municipal sector managers will be gathered during the actual test of professional competencies of managerial personnel in mentioned sector. It will allow to determine the competency gap as well as a surplus of knowledge and skills of managers compared to the competency requirements in the future.

To develop the municipal sector organizations, human resources management should be based on employees' competencies, which can be already developed among future managers. Therefore knowing competencies matrixes, that will be required in the future, the management staff can be improved much earlier.

THE CURRENT KNOWLEDGE IN THE FIELD OF RESEARCH TOPIC

Enterprises of municipal sector do not have designed and implemented catalogue of competencies consistent with Polish and European Qualifications Framework for executive and managerial personnel (Babiak 2012, Krawczykowski 2012). There is also no developed system of validation and certification of competencies acquired in non-formal education (Babiak, 2012, Krawczykowski, 2012). Therefore, a team of experts undertook the task to determine the current status of the competencies of human resources in the municipal sector of Wielkopolska. Examination, identification and assessment of professional competencies of managers (ie, the development of methods and tools) are necessary steps for the strategic management of company's community (Babiak, 2012, Spychała 2012).

Thus for effective management of professional competencies of municipal sector managers it is necessary to acquire the relevant knowledge, and then organize, analyze, disseminate and apply it to achieve the desired result.

IMPLEMENTATION STAGES OF 21ST CENTURY MANAGER'S COMPETENCY PROFILE IN MUNICIPAL SECTOR

"Competency comprises the specification of knowledge and skills. The application of knowledge and skills to the

standard of performance requires completing a task." (Jui-Lan Wu, 2013). Thereforethe first stage of the project was to analyze the tasks performed in the workplace by managers of the municipal sector. The aim of the project team was to develop a detailed list of tasks and activities that they do working on their positions. Brainstorming method was used and the analysis of documentation of municipal companies (Spychała 2012).

The next stage of the project was to design the position description for the municipal sector manager. During position description creation, the methods of interview with managers has been used and directors have made self-assessment about range of the tasks on given positions. Documents of studied municipal enterprises were also examined.

However, the project does not concern the tasks of managers performed at workplace, so the project team developed a twenty-first century manager's position model. Involvement of management staff in the development of managerial competency profile allowed to become familiar with it before realization and a better understanding of the purpose of its implementation (Spychała 2012).

During creation of the position description for the manager of twenty-first century in municipal sector brainstorming method has been used, where a team of experts defined the tasks, which will be implemented by managerial personnel in the future. The results are presented in Table 1. Analyzing these data, as well as interviews with managers of the municipal sector, a list of future tasks of twenty-first century manager was developed.

Table 1. Range the tasks of the twenty-first century manager in the municipal sector - the results of tests on 08.02.2012. (Source: own study based on data from the conducted research)

1.	Strategic management
2.	Supervising activities in organization
3.	Activities planning
4.	Activities organizing
5.	Tasks delegating
6.	Safety management
7.	Documentation management
8.	Quality management
9.	Information management
10.	Team management
11.	Negotiating with contractors
12.	Management of organization development
13.	IT assets management
14.	Management of employees development
15.	Management of communication in organization
16.	Communication with surroundings
17.	Selection of employees to given tasks
18.	Procedures management
19.	Financial management

On the basis of the tasks to be implemented in the future by managers the professional competencies have been identified, which the person performing the task on a given position must have. Based on the position description**, competency model of twenty-first century manager of municipal sector** was developed (Spychała, 2012).

"Competency models offer the possibility of creating an integrated and consistent framework for the selection, appraisal, training and development of HR practitioners, as well as a mechanism for linking HR strategy and business performance (Boyatzis, 1982, 1993; Ulrich et al., 1995; Baill, 1999; Ulrich et al., 2008, Caldwell, 2010).

Having analyzed the literature in the field of managerial competences it turned out communication skills are the most important. Therefore, they have been discussed in detail in the practical part of the article. (Cameron., Whetten, 1983, Dickson, Hargie, 2004, Platonoff, 2001, Rakowska 2008, Smółka 2008).

A set of related examples of behaviors and actions determines the specific competency (Filipowicz 2004, Jurek 2008, Walkowiak 2008). To be sure that those will be understood in the same way by all employees of the municipal sector, it is necessary to describe every occupational competency of manager.

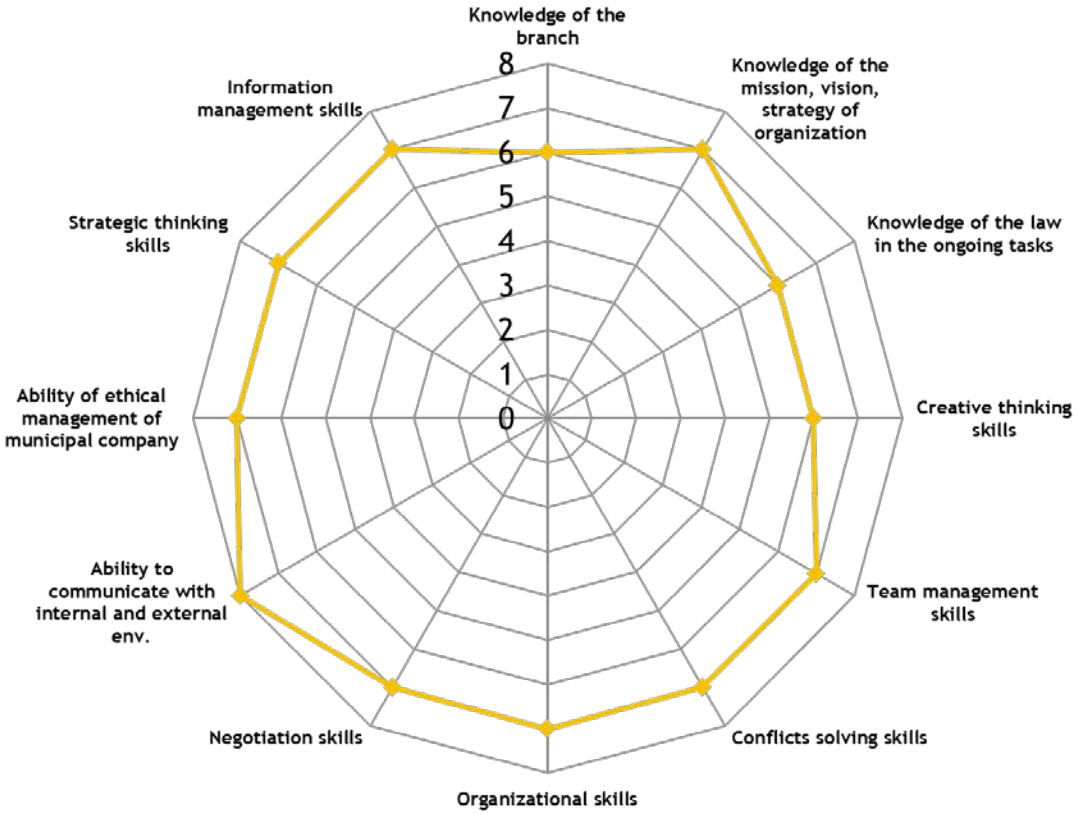

Figure 1 . Competency profile of XXI century manager of municipal sector. (Spychała 2012)

Competency profile is a basic tool for planning of self-development of every manager. Allows for clear definition of the objectives of development, the implementation of which will be the basis for the realization of all pre-planned activities. It is a document that contains 8 levels of professional competencies developed by the project team. Each level has been characterized in table 2.

Table 2. Characteristics of particular levels of professional competencies of the municipal sector managers, (Source: own study within the project: "Model of validation of competencies for employees of MSME of Wielkopolska's municipal sector")

Levels	Characteristics
1	Given competency not absorbed. Lack of behaviors indicating its mastering and use in activities.
2	Acquisition of competency in a basic level. It is used irregularly. Required supervision of more experienced people and giving their support.
3	Competency sufficiently absorbed, it can be used by oneself in practice, but there are situations that require supervision of experienced persons.
4	Competency satisfactorily absorbed, it can be used by oneself in practice, in the performance of professional tasks.
5	Competency absorbed in a good level, which allows better fulfilling tasks in the given field and passing experience to others.
6	Competency absorbed in a very good level, which allows very good fulfilling tasks in the given field.
7	Competency absorbed in a great extent. The ability to creative usage and development of knowledge, skills and desired attitudes in the given range of activities.
8	Expert level, the ability to creatively share their knowledge and skills with other managers and employees.

Presented levels of competencies relate to the requirements for the twenty-first century managers. Therefore during assessment of the actual competencies of the municipal sector managers there will often situation occur where the level of competencies of the manager will be lower than required. The work of the municipal sector organizations will be taking actions to place a person on a particular position in the future, whose level of competencies will be as

close as possible to those specified in the profile. Manager that has insufficient competencies will perform his work poorly, while one whose knowledge and skills far exceed the requirements of the position will not be fully utilized.

Competency profile of twenty-first century manager enables to raise the quality of human resources management (Boyatzis, 2008, Dubois, Rothwell, (2004). However, it will play its role only if it is consistent with the strategy and culture of the organization. Because it must take into account not only the current situation of the organization, but also a vision of the future, it allows to prepare managers for the changes in the organization. (Bratton, Gold, 2007).

EXAMINATION OF PROFESSIONAL COMPETENCIES OF MANAGERS IN SELECTED ENTERPRISES OF WIELKOPOLSKA MUNICIPAL SECTOR

The main objective of the research was to recognize the professional competencies of the municipal sector managers and identify needs to acquire new skills and knowledge useful in performing tasks in the future. The study was conducted in selected small and medium-sized enterprises of municipal sector in the region of Wielkopolska (38% - small enterprises, 62% - medium-sized enterprises). 125 managers were surveyed: 73 men and 49 women (3 persons did not reveal their gender). The research was conducted in the period of March - April 2012.

54% of tested were the middle level managers, who have superiors and are managing subordinates. 30% of respondents are the lowest level managers who are direct superiors of subordinates and are subject to the mid-level manager. Using a 360-degree approach to study professional competencies of managers in these groups one can obtain more reliable and objective results as superior and subordinates will assess the knowledge and skills of the manager. Another group of 14% are executives, who are not subject of supervision and are superiors for other directors. The smallest group is the only-level managers who have no superiors, but subordinates only.

74% of managers are aged 31 - 50 years old, 22% of managers are people over 51 years old, a very small group consists of people younger than 30 years - 3%.

74% of respondents have University level education, 18% high school education, and 5 managers have a vocational education.

The questionnaire addressed to the managers of the municipal sector contained 18 questions: 9 closed and 9 open. Field of research, which managers were subject to, concerned the actual technical and social competencies, used on existing positions as well as an excess of competencies, which they do not use at work. Another question concerned the tasks they have problems with, or lack of competencies, and how to improve and develop skills. The professional competencies of municipal sector managers required currently on given position and competencies necessary for the implementation of future tasks were analyzed.

47% of respondents believe that the position occupied by them corresponds to their qualifications in a good degree. A large part of respondents, as many as 34% think that their competencies are matched to their position in a very good extent. This result is very satisfactory, but attention should be paid to a group of managers who feel that they are not matched to the position in terms of qualifications - 6 managers, and that they are prepared only in sufficient extent. Analysis of the knowledge and skills of those managers should be done and identification of the areas which they have problems with. The nature and level of competency gaps should be examined as soon as possible and be developed and improved.

Next question concerned the tasks that the manager performs better than his colleagues. 69% of respondents answered positively. Table 3 presents the tasks which managers perform better than their colleagues.

Table 3. Tasks which are performed by managers better than by their colleagues.(Source: own study based on data from the conducted research within the project of Polish Chamber of Commerce)

Tasks of managers	Answers of respondents	Number of respondents
Activities organizing	Organization of work, organization of meetings, implementation of several tasks simultaneously; Organizing tasks	11
Team management	Coordination of teamwork, Motivation, Managing subordinates; Leading; Controlling	9
Interpretation of legal provisions	Knowledge of the regulations, Knowledge and interpretation of taxation laws, social security laws, budget accounting, issues related to the acts on local government	5
Documentation management	Databases, Computer use, Keeping personal and personnel documentation; Creating documents, Organization of Document circulation	5
Supervising and delegating tasks	Delegation of tasks, Decision making	5
Information management	Analysis of data and its interpretation; Using various information sources; Giving information; Implementation of programs	4
Communication with environment	Acquisition of services customer, Public procurement; Communicating with customers	4
Communication management in company	Communication in writing; Communication with other employees	4
Negociations with contractors	Negotiating with customers, Quick response to problem atic cases, Solving problems	4
Financial management	Salaries settlement, Finance, International Accounting Standards	3
Strategic management	Strategy development for company	2
Selection of employees to tasks	Staff planning	1
Project management	Coordination of EU projects	1
Change management	Reacting to changes	1
Using knowledge of the branch	Knowledge of the branch	1
	Number of answers	**60**

In table 1, tasks highlighted in blue are the ones which appeared first on the list of tasks carried out by the municipal sector managers as well as on the list of tasks that may be implemented in the future by the managers of the twenty-first century. The color gray marks tasks to be implemented in the future and not included in the list of tasks carried out at present. The research shows that managers handle the best organizing activities -11 respondents.

They feel that they cope better with organizing and executing several tasks at the same time, than their colleagues. The next tasks are related with the team management. 9 respondents believe that they motivate, coordinate and mostly lead a team of employees better than their co-workers. This is a very good result, because it is essential task for the manager's future. 5 respondents believe that they can interpret the law much better than their colleagues. This ability is used in many tasks, for example, during negotiations, managing a team, managing projects and communicating with others.

Another task, with which 5 managers do not find problem with is document management in the organization. It is the task of the future, which will be realized in every company oriented on development. Organization of documentation circulation, creation of databases and personal records facilitate performance of tasks and help in the analysis of enterprises indicators.

Another group of managers surveyed (5 people) think that they can supervise and delegate tasks better than their colleagues. It is the basic responsibility of every manager, which will be carried out in the future.

Although 69% of respondents declared themselves that they can perform tasks better than others in the team, only 48% of managers were able to name the task. This can result from high self-esteem, or lack of ability to name tasks.

Respondents were also asked about the reasons for the development and improvement of their professional competencies. Table 4 shows the results of the research. The criteria represent the levels of needs in Maslow's pyramid, starting with the lowest level (salary) to the highest (self-improvement and development). The main reason respondents indicated was willingness to self-development (17%), followed by meeting the needs of appreciation

(12%) and promotion (7%). In the last place managers positioned salary. For managers surveyed, money is not the main reason for improvement and development of own competencies. Analyzing these reasons it can be concluded that the needs of the respondents are of the highest level of Maslow's pyramid, they are ready for continuous development and improvement of their competencies.

Table 4. Why do employees want to improve and develop their competencies? Source: own study based on data from the conducted research within the project of Polish Chamber of Commerce.

Criteria	Answers of respondents	Number of respondents
Satisfying the needs of higher payment	Salary increase Financials, earnings	4
Satisfying the needs of safety on labor market	Increased mobility on the labor market Position in the labor market Competitiveness on the labor market	6
Satisfying the needs of appreciation	Working better and more efficiently Effective performance the tasks Efficient staff management The pressure of working environment	15
Satisfying the needs of promotion	Promotion Competitiveness against other co-workers Expanding the scope of activities New perspectives More certainty in taking tasks	8
Satisfying the needs of self-development	Personal development Self-fulfillment Improving knowledge related to the industry Improving creativity Familiarizing with the methods of team management Perfecting the competencies of foreign languages;	21
Other	No professional burnout syndrome Possibility to choose Expanding the business opportunities The welfare of company	4

In the testing period (March - April 2012) managers widened their knowledge and skills in the field of tasks (44%). Perfected themselves using the following methods:
a) the professional literature - magazines, internet (7 persons);
b) information and tips acquired from other professionals (2 persons)
c) postgraduate education (1 person);
d) higher education (1 person)
e) e-learning (1person);
f) participation in the conference, (1 person)
g) training, specialized courses (3 persons)
h) branch related meetings (2 persons)

It should be noted that managers primarily use informal methods of improvement (professional literature, the experience of others, industry meetings) and non-formal (e-learning, training, specialist courses). Only two people use formal methods for improving themselves, which are higher and postgraduate education.

Last part of the survey involved future tasks and professional competencies. Responses are shown in Table 6 and 7. Due to the fact that each of the managers could include several sentences, only selected responses will be presented (Table 5).

Table 5. List of future tasks
Source: own study based on data from the conducted research within the project of Polish Chamber of Commerce

Lp.	Future task	Examplary answers of managers	Number of respondents
1.	**Team management**	Building effective teams, based on knowledge, experience and creativity Encouraging others Motivating, stimulating commitment of employee Creative personnel management Increasing the efficiency of employees Teamwork and taking care of the results of work	28
2.	**Change management in organization**	Efficient identification and naming of the changes in environment of enterprise Leading in changes Monitoring the process of change and coordinating the process Flexible adaptation to changes in the company Analysis of changes in the environment	26
3.	**Management of employees' development**	Taking care of staff development Educational programs for professionals experiencing occupational burnout Developing competencies of employees Lifelong learning	18
4.	**Communication with environment**	Acquisition and keeping customers in the company Gaining customer confidence A flexible approach to the customer Developing the right relationship with the environment Meeting the demands of our customers	17
5.	**Communication management in organization**	Tolerance and skillful listening to others Encouraging others to provide feedback Developing interpersonal skills Building relationships Cooperation with labor unions gaining power	15
6.	**Project management**	Implementation of new systems and procedures Designing solutions Introduction of new technologies Acquisition of new solutions in order to commercialize The integration of management process with modern technology	15
7.	**Strategic management**	Building effective development strategies Predicting the direction of energy sector development Predicting future market behavior Anticipation of technical changes strategic thinking Acquisition of new opportunities to develop company	12
8.	**Negotiating with contractors**	Solving difficult tasks Making the right decisions Optimization of conflicts Creative problem-solving	10
9.	**Financial management**	Dealing with rising labor costs Acquiring funds for the development of company Minimizing operating costs Acquisition of EU funding	8
10.	**Information management**	Fast and efficient flow of information	7
11.	**Delegation of tasks**	Delegation of authority-the understanding of subordinates Delegation of authority, duties and responsibilities	6
12.	**IT assets management**	Acquisition and skillful use of information Information management Quick acquisition of information and appropriate usage	6
13.	**Selection of employees to given tasks**	HR problems solving Creating teams to new challenges	5
14.	**Documentation management**	Information technology - the electronic flow of documents The introduction of procedures that will motivate employees to work Adapting (for example) global procedures to real conditions	5

15.	**Organizing activities**	Effective time management The introduction of the new organization of work, which will increase the discipline and efficiency	4
16.	**Supervising activities in organization**	Monitoring of progress and assessment of implementation of tasks Determination of the appropriate objectives	3
17.	**Activities planning**	Creating new structures to achieve expected objectives	3
18.	**Other**	Creating Entrepreneurs Club Skillful combination of interests of the company with the interests of employees Environmental targets (ecology) Self- improvement, implementation of the results of progress Raising the attractiveness of the company The use of the process of globalization	16
		Total	**206**

Managers think that the most important task is to manage a team of employees (28 respondents) and the management of change in organizations (26 answers). Building effective teams, based on knowledge, experience and creativity, as well as creative management of those teams are the tasks of the future, which are challenge for manager of municipal enterprise. Respondents are aware that changes in the test sector are inevitable. Hence it is vital to flexibly adapt to changes taking place in the company, to monitor and coordinate the process. Managers also point out that their main task will be to adapt the professional competencies to changing economical, social and legal conditions. They need to develop own skills but also ensure that employees improve their competencies. Some respondents (5 people) believe that municipal companies should base their actions on the continuous training of human resources across the organization. Which means that enterprises should become learning organizations.

Another future task is to communicate with the external environment (17 managers) and internal environment (15 people). Respondents believe that their main task will be the developing of an appropriate image of the company and establishing appropriate relations with the environment. Thrust of customers and meeting their requirements should be achieved. 8th position is assigned to the task of negotiating with contractors (10 people). Managers think that this is a very important task, which is why they distinguish this task separately from communication with environment, which of course should be included within external communication group. In addition to communicating with customers, managers will also communicate with their employees. Thus they think that interpersonal skills should be developed, such as tolerance and skillful listening to others, to build positive relationships and work together.

15 managers selected project management as a major task in the future in the municipal sector. Tasks will consist not only of standard and repetitive activities, will be largely separate and very complicated: Implementing new systems and procedures, modernization of economical facilities, introduction of new technologies, are just few examples of challenges to be faced by managers of municipal companies in the future.

Another task that is in the top ten, is strategic management. It was listed up by 12 respondents. Managers think that the prediction of future behavior of the market and then building effective development strategy is essential to succeed.

None of the 125 managers chosed quality management and safety management as an important task in the future. Nevertheless these are fundamental tasks for the operation of any organization. Organizations must ensure quality of service, and must meet the demands of customers. In such situation effective quality management is a necessity.

The last point of the study was self-assessment of professional competencies of managers necessary to perform the tasks in the future. The results are presented in Table 6. Managers previously acquainted with the competency levels of 1-8. Each of them has been precisely characterized. Examined competencies were described in details as well. Skills from the first to the seventh line are included as communication competencies. Due to a fact those play an important role on managerial position, they have been examined in detail. Subsequent competencies are a set of future competencies that have been proposed by a group of experts.

Table 6. Self-assessment of occupational competencies required to realize future tasks.
Source: own study based on data from the conducted research within the project of Polish Chamber of Commerce.

Professional competencies	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Ability to cope with impetuous feelings		12	8	22	27	36	12	5
Ability to listen			2	9	20	34	35	18
Ability to sense the needs of others			11	14	21	39	35	4
Ability to gain others		8	8	11	20	37	25	8
Ability to search for understanding			9	15	31	32	27	1
Ability to Foster enthusiasm		8	12	14	31	37	20	2
Presenting skills			4	10	34	42	28	8
Conflicts solving skills			2	18	35	32	28	9
Information management skills				18	26	40	33	6
Ability to communicate with environment			2	15	16	41	40	10
Team management skills			1	9	36	35	33	7
Decision making skills				5	28	34	48	9
Knowledge of the branch				3	14	47	42	18
Knowledge of the law		2	3	10	36	34	31	8
Strategic management skills	1		2	14	42	41	22	2
Creative thinking skills			2	17	23	42	31	7
Organizational skills				1	12	40	53	17
Ethical management skills				7	17	38	49	13

The managers assessed their professional skills very high. As many as 18 people considered to be the perfect listener (level 8 - expert), the same number of people knows the industry excellent and is able to transfer this knowledge, and 17 managers evaluates their organizational skills at the highest level as well. It should also be noted that 13 managers considered to be experts when it comes to ethical management of municipal company, 49 of the respondents are convinced to manage ethically perfectly, and 38 people have rated their competencies in this area very high. This is a very good result. Similar marks are regarding organizational skills and ability to communicate with the environment.

The research shows that the majority of respondents have a problem with strategic management (one manager rated his abilities at level 1, which means no competencies in this area), only 2 people have stated that they are experts. Respondents think that they have the deficiencies when it comes to creative thinking skills, knowledge of the law and the ability of fostering enthusiasm in others.

Only 8% of questioned, responded that they can adequately manage a team of employees, the remaining part, which is 92% rated their skills in this area good (29%), very good (28%), excellent (26%) and at the level of an expert (5%) . Managers said they are ready for management of the project team in the future.

Self-assessment of competencies is an important source of information, but should be verified. Therefore, the next stage of research will be examination of occupational competencies of managers and assessment of their skills and knowledge through Assessment Center and 360 degrees methods. Only after this evaluation objective assessment of the competency level of the respondents can be done.

CONCLUSIONS

The main conclusions of the research include the following statements:

1) 69% of the surveyed managers distinguished group of tasks, which they perform better than co-workers. These are the tasks related with the organization of activities, managing a team of employees, interpretation of regulations and documentation management. According to above list those are the future tasks of managers. This means that some of the respondents already have professional competencies that will be essential to

manage the company in the future.

2) 17% of respondents have difficulty with the current tasks on their positions. These are tasks such as personnel management, document management, supervision and delegation of tasks, management of communication in the organization, financial management and change management.

3) 24% of the examined managers of the municipal sector have competencies not used at work. These are competencies such as the ability to communicate with others, team management skills, knowledge of the law, financial management skills and skills related with their interests. Diagnosis of competencies excess will allow assigning them new tasks and increase the motivation to act.

4) 82% of respondents want to broaden their competencies. As the main reason for improvement, surveyed managers indicate willingness to self-development (17%), followed by meeting the needs of appreciation (12%) and promotion (7%). The least important were answers related to the salary.

5) 44% of managers currently gain additional competencies in the field of performed tasks through training, courses, postgraduate studies, literature, and e-learning. Managers mainly broaden their knowledge and skills in informal and formal manner. Formal way (postgraduate studies) is a small percentage (2%) of the respondents.

6) 77% of managers want to participate in the nearest future in training and courses perfecting their skills. Looking for training they are mostly guided by its topic, quality of training, skills of the coach and the possibility to use gained knowledge on given position.

7) As the main tasks of the future managers, surveyed persons have selected:
   - Creative team management;
   - The management of change in organizations;
   - Management of employees' development
   - Effective communication with internal and external environment;
   - Continuous development and improvement of their skills;

8) Analyzing the self-assessment of professional competencies of municipal sector managers it is concluded that about 70% of respondents rate their competencies at good, very good and excellent level. Most respondents have a problem with the strategic management, creative thinking skills, knowledge of the law, and skills to foster the enthusiasm in others.

Analysis of the knowledge and skills of managers of municipal sector enables to recognize competency gaps and the excess of competencies, and thus affects the rational design of specific development programs for managers. Conducted research of competencies is a first part of study that will cover whole Poland. This action will allow to diagnose real knowledge and skills of managers of the municipal sector, and thus allow to create plans for the development and improvement of their professional competences required in the future.

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Relative age effect in physical and psychological development in young Japanese children and associated problems for kindergarten teachers

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ABSTRACT

In school classroom, a child born soon after the selection period's cut-off date (early born children) may benefit by up to a full year in physical and psychological development compared with a child born just before the cut-off date (late born children). This phenomenon is called the "relative age effect" (RAE). RAE is defined as the consequence of age differences between individuals within the same cohort, either in school or on sports teams (Musch & Grondin, 2001). This study examines the effect size of RAE in physical and psychological development and discusses educational problems faced by kindergarten teachers due to this RAE. Data were collected from 100 five-year-old Japanese children (60 male, 40 female) and their kindergarten teachers. Significant main effects of birth month category on physical development and on psychological development were found (early born children were more developed than late born children). The effect size of RAE in physical development was greater than that in psychological development. We concluded that the RAE existed in physical and psychological development among young children. Further, RAE appeared greatly on physical than on psychological development. Thus, we propose that kindergarten teachers could benefit from an awareness of the RAE.

Keywords: Relative Age Effect, Physical and Psychological development, Young Japanese Children

INTRODUCTION

In most public educational systems, the cut-off date for entrance into kindergarten or first grade is specified; in the Japanese educational system, the school year starts on April 1st and ends on March 31st. Although a primary purpose of this procedure is to avoid large age differences, a child born soon after the selection period's cut-off date (early born children) may benefit by up to a full year in physical and psychological development compared with a child born just before the cut-off date (late born children). This phenomenon is called the "relative age effect" (RAE). RAE is defined as the consequence of age differences between individuals within the same cohort, either in school or on sports teams (Musch & Grondin, 2001) (Figure 1).

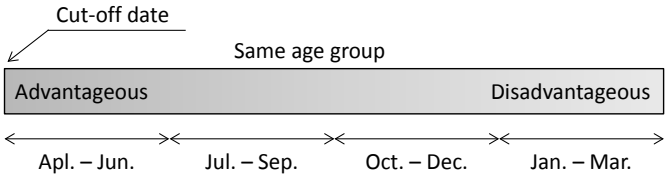

Figure 1. Advantage and disadvantage in the same age group (Japanese school year).

In the sports domain, about 30 years ago, Grondin, Deshaies, and Nault (1984) and Barnsley, Thompson, and Barnsley (1985) discussed a possible relationship between relative age and participation in sport, which is similar to the relationship between relative age and scholastic achievement. They argued that children born early in the competition year have a competitive advantage over their younger peers. Grondin et al. (1984) found that the birthdate distribution of ice hockey players in competitive youth hockey leagues and in the main professional ice hockey league in North America, the National Hockey League (NHL) is highly skewed. That is, the number of players born in the first months of the year is greater than that of players born in the last months of the year. Following these reports, a similar phenomenon has been found in other sports, such as baseball, cricket, tennis, swimming, volleyball, handball, and soccer (for a review, see Musch and Grondin, 2001). Nakata and Sakamoto (2011) also found a similar phenomenon in some sports in Japan. Thus, a late born child may have disadvantage in competitive sports.

In the educational domain, the RAE also exists. A relative age difference of almost one year is related to significant differences in children's cognitive development (Bisanz, Morrison, & Dunn, 1995; Morrison, Smith, & Dow-Ehrensberger, 1995). Late born children have more academic problems than do their early born classmates (Bell & Daniel, 1990; Dickinson & Larson, 1963; Gilly, 1965; Grondin, Proulx, & Zhou, 1993; Hauck & Finch, 1993). Late born children are more likely to be classified as learning disabled (Diamond, 1983; Maddux, 1980), and their academic achievement is significantly lower than that of older classmates' (Davis, 1980). Thus, late born children may have an educational disadvantage, even at a young age. Although, as Musch and Grondin (2001) pointed out, despite the obvious similarity, there seems to be an important difference between the RAE in sports and education: sports participation is voluntary, while attending school is compulsory.

In spite of the growing body of research on the RAE, recent studies of the RAE do not address possible disadvantageous in education. Appropriate support is necessary for children to achieve the maximum benefit from schooling. A lack of knowledge of the RAE in education is serious problem. In Japan, Kawata et al. (2013) founded the existence of RAE on physical development and kindergarten teachers' evaluation of 4–5 year-old Japanese children. Specifically, early born children were more physically developed (height and weight in physical size, running and throwing in motor ability) and received higher ratings from teachers in these skills. Consideration should also be given to psychological variables, such as competence and motivation.

Children differ not only in their physical maturity but also in psychological maturity when the RAE is present. However, the RAE in psychological development among young children has not been well examined. Therefore, this study examined the effect size of RAE in physical and psychological development and examined educational problems faced by kindergarten teachers due to RAE.

METHODS

Participants

Data were collected from 100 five-year-old Japanese children (60 male, 40 female) and their kindergarten teachers from public and private kindergartens in Tokyo, Japan.

Measurements

We collected demographic data (gender, age, and grade), and measures of physical and psychological development.

For physical development, we assessed physical size, actual motor ability, and motor ability as evaluated by kindergarten teachers with the following measurements.

(1) In recognition of circadian variations, we measured physical size (body height and body weight) in the morning after the children had urinated.

(2) Actual motor ability was measured by a 20 m sprint, the standing broad jump, ability to throw a tennis ball, and dexterity of the right and left toes. These were assessed by a skilled measurer using various instruments. For the 20 m sprint, we set up a 25 m straight course with goal lines at 20 m, the actual distance timed, and at 25 m, the line to which the children ran. The experimenter stood at the 25 m goal line and recorded the children's time from the start cue ("set and go") to the 20 m line. For the standing broad jump, we placed a 3 m tape measure on the floor and drew a start line. We instructed the children to jump as far as they could from the start line, pushing off with both feet. To measure throwing ability, we used a tennis ball. We instructed the children to throw the ball as far as possible using their dominant hand. For dexterity of the toes, children were asked to carry marbles as many as they can within 20 seconds using their toes.

(3) Motor ability evaluated by teachers for running, jumping, and throwing was measured the kindergarten teachers' answer to the following questions: "How well does this child run," "How well does this child jump," and "How well does this child throw?" The questions were on a five-point Likert scale from 1 (very poorly) to 5 (very well).

For psychological development, we assessed perceived physical competence, attitude toward physical activity, and zest for living.

(1) To measure perceived physical competence, we used the Pictorial Perceived Physical Competence Scale (Kawata et al., 2013, Figure 2). This scale assesses the children's perspectives of their competence in running, jumping, and throwing, with scores ranging from 1 (low competence) to 5 (high competence). Children are asked to choose one child of five children who do abovementioned physical activities after the following instructions: "How fast can you run," "How far can you jump," "How far can you throw?" Each picture was presented one at a time. Children are asked to point a child with their finger.

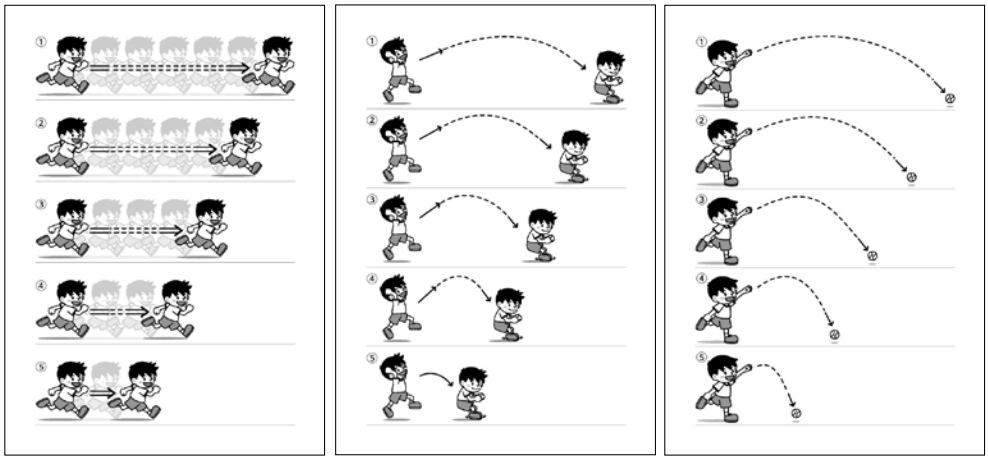

Figure 2. The Pictorial Perceived Physical Competence Scale (Kawata et al., 2013).

(2) To measure attitude toward physical activity, we used the Pictorial Attitude for Physical Activity Scale. This scale assesses enjoyment and liking of physical activity. To measure enjoyment and the liking, we drew a picture of children and playing a sad and smiling child's face (Table 3). Children are asked to provide their level of agreement or disagreement with two questions on a four point Likert scale, ranging from 1 (not enjoyable or dislike) to 4 (enjoyable or like) after the following questions: "Do you enjoy physical activities," "Do you like physical activities?" Each picture was presented one at a time. Children are asked to point a face with their finger.

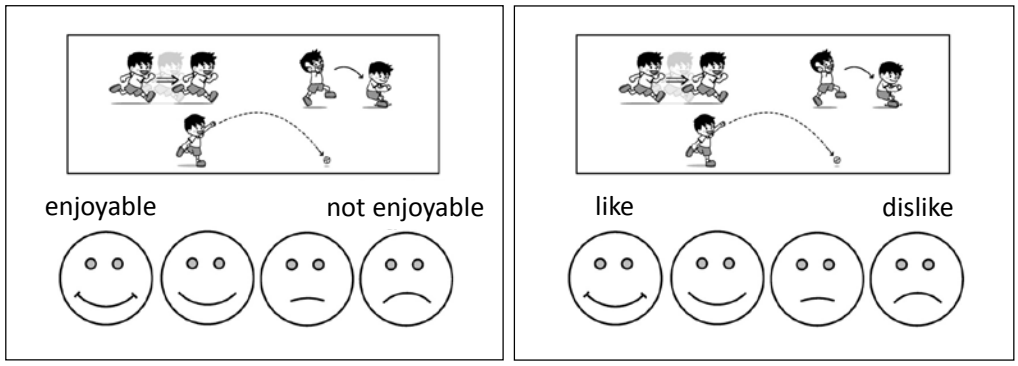

Figure 3. The Pictorial Attitude for Physical Activity Scale.

(3) We used the concept of zest of living (health, human relationships, environment, language, and expression), which is part of the kindergarten educational procedures of Japanese Ministry of Education, Culture, Sports, Science and Technology. We created questionnaire items corresponding to these five aspects. The kindergarten teachers are asked to provide their level of agreement or disagreement with five questions on a five point Likert scale, ranging from 1(completely disagree) to 5 (completely agree). The questions, accompanied by the abovementioned aspects, were as follows: The "Do you think that the child has healthy life rhythm (health)," "Do you think that the child has good relationship with others (human relationships)," "Do you think that the child has feelings of curiosity about the surrounding environment (environment)," "Do you think that the child has ability to express in words what he/she experiences (language)," "Do you think that the child has ability to express in sounds or action what he/she feels (environment)?"

Ethical Consideration

This study was approved by the Research Ethics Committee at the School of Health and Sports Science, Juntendo University. Prior to the study, we obtained permission from the principals of a kindergartens and the board of education. Informed consent was obtained from the parents of the participants. Each participant was made aware of his or her right to decline cooperation at any time, even after consenting to participate, without repercussion.

Statistical analysis

Children were divided into the following four groups according to calendar quarters based on their birth month: Group A (April 2nd through June), Group B (July through September), Group C (October through December), and Group D (January through April 1), which was aligned with the Japanese school year that runs from April 1 to March 31. Children born on April 1 were in the Group D because such children are one grade below according to the Japanese school education law. Group A and B are early bone children, while Group C and D are late bone children. A one-way analysis of variance (ANOVA) was conducted to assess the differences in all variables among the four groups. We calculated the η^2 as an effect size of the each analysis. The effect size is regarded as a statistical measure of the strength of a phenomenon. Thus, we used the effect size to compare the strength of the RAE in this study. The criteria of the effect size of η^2 in one-way ANOVA are regarded as follows: small effect ($\eta^2 = 0.01$), medium effect ($\eta^2 = 0.06$), and large effect ($\eta^2 = 0.14$). Statistical significance was set at $p < .05$.

RESULTS AND DISCUSSION

We examined the existence of the RAE in physical and psychological development through one-way ANOVAs (Table 1). In physical development, there was a significant main effect of birth month category on physical size. Specifically, Group A children were taller and heavier than were Groups C and D children. This result is concordant with the previous study by Kawata et al. (2013). In measured motor ability, the main effect was also significant: Specifically, Group A was better than was Group D in the standing broad jump. In motor ability evaluated by teachers, there were also significant main effects. Specifically, Group A rated higher than were Groups C and D in running and jumping. These results indicated that the RAE exists for physical development (physical size, actual measured motor ability, and motor ability evaluated by teachers).

The analysis of psychological development resulted in no significant main effects of birth month category on perceived physical competence. Kawata et al. (2013) reported that 4 to 5-year-old children gave themselves extremely high scores regardless of their actual measured motor ability. Thus, there were no significant differences between birth month categories. Similarly, there was no significant main effect on attitude toward physical activity. Thus, in this study, most children had a high assessment of their physical competence and they liked and enjoyed physical activities regardless of their relative age. In zest for living, as evaluated by teachers, there were results showed significant main effects. Specifically, Group B had higher language evaluation than did Group D. This is the first evidence of the RAE in the development of language among young children. These results indicated that although the RAE exists in the development of zest for living (language), the RAE does not exist on perceived physical competence or attitude toward physical activity.

Table 1. Comparison of variables by birth month category.

	Birth Month								Total		F-value	Multiple comparison	Effect size (η^2)
	A. Apr.- Jun.		B. Jul.-Sep.		C. Oct.-Dec.		D. Jan.-Mar.						
	n = 25		n = 25		n = 25		n = 25		n = 100				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*			
Physical development													
Physical Size													
Body height	113.5	5.1	111.5	4.7	108.9	4.5	105.8	4.4	110.0	5.3	8.3 ***	A > C, D B > D	0.25
Body weight	19.8	3.2	18.6	1.6	17.9	2.4	16.6	1.7	18.3	2.6	5.2 **	A > C, D	0.17
Motor Ability (measured value)													
20m sprint	5.2	0.6	5.3	0.6	5.5	1.0	5.5	0.6	5.4	0.8	0.7		0.03
Standing broad jump	109.3	20.7	99.1	18.4	96.8	22.1	86.8	35.0	98.6	24.4	2.4 *	A > D	0.09
Tennis ball throwing	7.3	2.7	7.0	2.4	6.0	2.8	5.3	1.9	6.4	2.6	2.1		0.08
Dexterity of the toes (right)	10.1	4.5	8.1	4.5	8.9	4.1	7.2	2.8	8.7	4.2	1.4		0.05
Dexterity of the toes (left)	9.3	4.1	7.7	4.2	8.9	3.9	6.2	5.0	8.3	4.3	1.8		0.07
Motor Ability (teacher's evaluation)													
Evaluation for running	4.2	1.0	4.1	1.0	3.5	1.1	3.4	1.1	3.8	1.1	3.0 *	A > C, D	0.11
Evaluation for jumping	4.1	0.8	3.7	1.0	3.2	0.9	3.5	0.8	3.6	1.0	4.2 *	A > C, D	0.15
Evaluation for throwing	3.6	1.1	3.4	1.1	3.1	1.1	2.8	0.7	3.2	1.1	2.2		0.08
Psychological development													
Perceived Physical Competence													
Competence for running	4.5	1.1	4.3	1.0	4.4	1.0	4.4	0.7	4.4	0.9	0.1		0.01
Competence for jumping	3.9	1.4	3.9	0.7	3.8	0.9	4.2	0.8	3.9	1.0	0.5		0.02
Competence for throwing	4.5	1.0	4.9	0.4	4.5	0.9	4.5	0.7	4.6	0.8	0.7		0.03
Attitude toward Physical Activity													
Enjoyment of physical activity	3.8	0.5	3.7	0.6	3.7	0.7	3.8	0.8	3.7	0.7	0.1		0.01
Liking of physical activity	3.8	0.4	3.9	0.4	3.5	0.9	3.7	0.9	3.7	0.7	1.9		0.08
Zest for Living (teacher's evaluation)													
Health	4.3	0.7	4.1	0.9	4.0	0.9	3.5	1.5	4.0	1.0	1.8		0.07
Human relationships	4.2	1.0	4.3	0.7	4.2	0.9	4.0	1.1	4.2	0.9	0.2		0.01
Environment	4.4	0.8	4.1	0.9	4.2	0.8	3.8	0.8	4.1	0.8	1.4		0.05
Language	4.2	1.3	4.4	0.8	4.0	0.9	3.4	1.3	4.0	1.1	2.4 *	B > D	0.09
Expression	3.4	0.8	3.3	1.0	3.2	0.8	3.3	1.4	3.3	0.9	0.2		0.01

* $p < .05$, ** $p < .01$, *** $p < .001$

The effect size on the physical development indexes was greater than was that on the psychological development indexes. The effect size on physical size was greatest. Therefore, it appears that the RAE is likely to be present in physical development among young children. Within the physical development category, the effect size on motor ability evaluated teachers was greater than was that on actual measured motor ability. This may imply unequal

treatment and expectations in education. For example, if teachers consistently evaluate late born children lower, these children might lose their feelings of competence and motivation. On the other hand, if teachers give early born children higher evaluations, a "Pygmalion effect"—the phenomenon whereby the teacher's expectancy of a student's ability triggers a series of verbal and nonverbal interactions that leads to higher student achievement—may be present in the classroom. Therefore, early born children are profiting from an initial relative age advantage and are likely to be perceived as the most talented in their age group because RAE is not understood, as Musch and Grondin (2001) seggested. Thus, kindergarten teachers' understanding of RAE may lead to appropriate support for all children's healthy development.

CONCLUSIONS

We concluded that the RAE existed in physical and psychological development of young children. Further, the effect size of the RAE was relatively larger in physical than in psychological development. We propose that kindergarten teachers could benefit from an awareness of the RAE.

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Descriptive Evidence of the Work-Family Compensation among Japanese Midwives: Using the Multiple Role Map Program

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ABSTRACT

Working midwives actively perform various roles including midwife, manager, mother, marital partner and friend. From the "compensation" perspective, they try to cope with dissatisfaction caused in one role (e.g. midwife role) by obtaining satisfaction in other roles (e.g. mother role). Although the episodes about compensation were useful information for the practical career support, the previous studies didn't show enough evidence. Hence, this study aimed to collect compensation episodes from Japanese working midwives and to show the descriptive evidence by using Multiple Role Map (MRM) program. The participants were female midwives working in a university hospital in Japan. We conducted the MRM program to all of the midwives working in the hospital and collected eighteen MRM sheets from them (recovery rate = 100%). According to the spreadsheet and descriptive episodes, major contents of compensable dissatisfactions were fatigue, frustration, pressure, distress and job stressors caused in the midwife and manager roles. Meanwhile, these dissatisfactions were compensated by satisfactions received in the friend, marital partner and mother roles and the private time. To obtain more practical findings for the career support, we will develop a statistical scoring method with the MRM data and conduct a validation study comparing the scores and external criterion for standardized health outcomes.

Keywords: Compensation, Multiple Roles, Work-Family Conflict, Midwife, Multiple Role Map

INTRODUCTION

Working midwives actively perform various roles including midwife, manager, mother, marital partner and friend. From the negative spillover perspective (Frone, 2003), engaging in the multiple roles causes role conflict and increases a risk of dropout from their professional career. Moreover, based on the positive spillover perspective (Hanson, et al., 2006, Shein and Chen, 2011), engaging in the multiple roles contributes to their job and career enrichments. Additionally, this study focused on the "compensation" perspective to find measures of practical career support for the Japanese midwives. The compensation (Greenhouse and Singh, 2003, Staines, 1980), which defined as the efforts to offset dissatisfaction in one role (e.g. midwife role) by seeking satisfaction in another role (e.g. family role), was expected to be more useful resource for effective stress coping. However, there were few previous studies on the compensation. The complex process of compensation might be a barrier in showing the evidence of causation between dissatisfaction and satisfaction. Since the compensation process involves both of the positive and

negative conditions, researchers might be confused to select appropriate outcome variables for scientific approach. To solve these issues, we developed the Multiple Role Map (MRM) program (Yamada et al., 2010). The MRM program enables us to collect various episodes with regard to the compensation (e.g. Yamada et al., 2011). Hence, this study aimed to show the descriptive evidence about compensation between work and family roles among Japanese working midwives using the MRM program.

METHODS

Participants

The participants of this study were female midwives working in a university hospital in Japan. We conducted the MRM program to all of the midwives working in the hospital and collected a total of eighteen MRM sheets from them (recovery rate = 100%). Their mean age was 41.1 (SD = ±12.0) yrs and the seniority was 14.3 (SD = ±11.1) yrs.

Procedures of MRM program

In the MRM program, participants described the information about features of multiple roles in the MRM sheet (A3 paper size) based on defined instructions (see Figure 1, Yamada et al., 2010, 2011). Through the MRM program, we could collect descriptive data about the contents of multiple roles, role expectation, role personality, priority and episodes about the spillover, compensation and segmentation. This study especially focused on the compensation caused on the role interfaces between midwife, manager, mother, marital/live-in partner, friend and private time (role-free time).

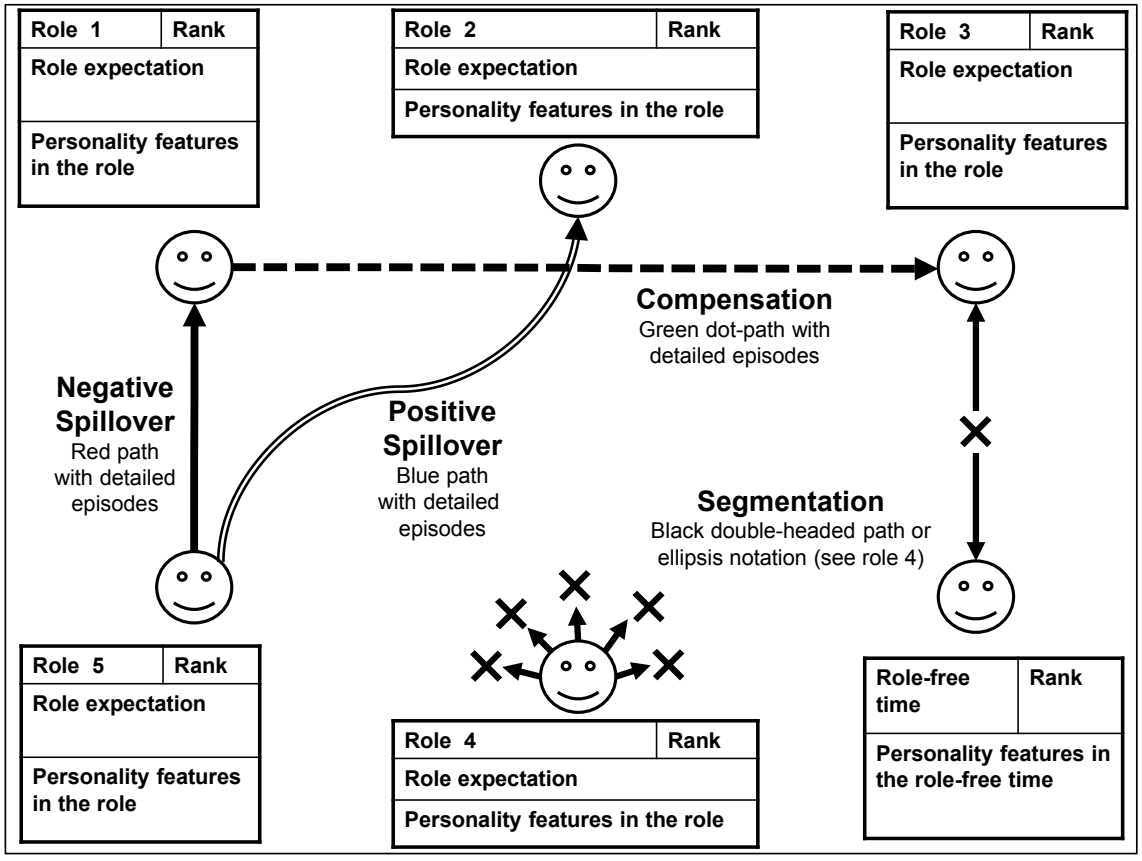

Figure 1. MRM form (A3 size) and guideline for the description. (Yamada et al., 2011)

Ethics

This study was approved by the medical ethical committee of Nagoya City University Graduate School of Medical Sciences.

RESULTS

Participants described five roles and the role-free time in the MRM sheets. All of nurses had role-free time, midwife and friend roles (100%), seven had manager role (39%), eleven had mother role (61%) and thirteen had marital/live-in partner role (72%). We showed frequency rates and representative episodes of compensation in Table 1. Thirty episodes meant that they compensated the dissatisfaction in the midwife role with satisfaction from seeking social supports, taking counsel with the partner, spending time with the children, releasing job stress and enjoying the friendship (Frequency rates: midwife-->mother = 64%, midwife -->role-free time = 61%, midwife-->friend = 44%, midwife-->marital/live-in partner = 23%, midwife-->manager = 14%). Reversely, stress caused in the marital/live-in partner role was buffered by the midwife role (Frequency rates: marital/live-in partner-->midwife = 8%). With regard to the manager role, nine episodes meant that they coped with dissatisfaction in the manager role by gaining a wide perspective, catharsis, social support and enjoyment in the other roles (Frequency rates: manager-->mother = 100%, manager-->friend = 43%, manager-->marital/live-in partner = 33%, manager-->midwife = 14%, manager-->role-free time = 14%). Moreover, four episodes caused on the interface between the role-free time and the other roles (Frequency rates: mother-->role-free time = 27%, role-free time-->marital/live-in partner = 8%).

DISCUSSIONS

Although the compensation effects were complex phenomena, this study succeeded in showing the descriptive evidence by using the MRM program. According to the spreadsheet and descriptive episodes, major contents of compensable dissatisfactions among midwives were fatigue, frustration, pressure, distress and job stressors caused in the midwife and manager roles. These results supported the previous studies reporting their hard work and difficulty in keeping a good work-life balance (Fujimoto,et al., 2008). Meanwhile, this study observed that these dissatisfactions were compensated with satisfactions received in the friend, marital partner and mother roles and the private time. In fact, they tried to receive satisfaction through talking with friends, obtaining advice and positive stroke from marital partner, seeing child's cute sleeping face and enjoying private time. These compensation episodes also emphasized the necessity of receiving social supports from various communities (Ibrahim and Ohtsuka, 2012, Uchiyama et al., 2011), selecting emotion-focused stress coping strategies (Lazarus and Folkman, 1984) and promoting stress management skills. However, this descriptive study has some limitations. While a narrative-based approach such as the MRM program has a great potential to extract midwives' obscure conflicts in their mind, it has to be a small sample size because of episode-based analysis. To formulate evidence-based career support for midwives, we will develop a statistical scoring method with the MRM data and conduct a validation study comparing the scores and external criterion for standardized health outcomes.

Compensation effects			Frequency	Number of samples with both roles	Frequency rates	Representative episodes
Role with dissatisfaction	→	Role with satisfaction				
Midwife	→	Mother	7	11	64%	I could forget job-related fatigue when I saw my child's cute sleeping face.
	→	Role-free time	11	18	61%	Job-related frustration was coped by enjoying enjoying private time.
	→	Friend	8	18	44%	I released the frustration from midwife job to the talk with my friends.
	→	Marital/live-in partner	3	13	23%	To solve a problem at work, I asked for my partner's advice.
	→	Manager	1	7	14%	I could change the negative mood in the midwife job thanks to having managerial position.
	←	Marital/live-in partner	1	13	8%	I could forget conflict with my partner by devoting to the midwife job.
Manager	→	Mother	2	2	100%	I released a managerial stress by watching sport with my child.
	→	Friend	3	7	43%	I released managerial stress by taking counsel with my friends.
	→	Marital/live-in partner	2	6	33%	When I failed in the managerial job, I sought positive stroke from my partner.
	→	Midwife	1	7	14%	Devotion to the midwife job gave me a positive emotion to overcome the pressure from heavy responsibility as a manager.
	→	Role-free time	1	7	14%	I released frustration from managerial stress by enjoying shopping, watching DVD and visiting hairdresser.
Mother	→	Role-free time	3	11	27%	When I felt childcare stress, I went out for a change.
Role-free time	→	Marital/live-in partner	1	13	8%	My boring day off was changed thanks to my hasband's suggestion.

Table 1. Frequency rates and representative episodes of compensation

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A Study of the Organizational Support for Building Resilience of the Fitness Club Employees

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ABSTRACT

The purpose of this study was to clarify the process of building resilience, to obtain the viewpoint of organizational support for building resilience in fitness club. We stand on asserting that was required to build resilience for making best use of human resources from perspective of career management. Interview survey was carried out targeting 32 employees who belong to five major the fitness clubs, 28 (15males, 13females) valid samples were used for this study. KJ-method was adopted throughout analysis to lead the process and the support for building resilience. As a result, the process for building resilience was led. It was found that adversity played an important role in the process, the difference in recognition toward adversities separate the process for building resilience. Additionally, a wide various supports were provided in the process. Especially, following three were shown as significant matters to support building resilience on the process. 1) It was that to construct mistake systems for promoting to challenge adversity positively, 2) It was that to promote creating inter personal relationship of employees and key persons, 3) It was that to structure a frame for collecting and managing feedbacks from the clients.

Keywords: Resilience, Adversity, Career Management, Organizational Support, fitness Club, KJ-method

INTRODUCTION

Recently, fitness club employees are required resilience for overcoming stress in daily operation. They provide a human service constantly. Human service's emotional exhaustion is related to burnout (Kubo, 2007). Moreover, most of them were exposed career stress. Regular employees serve as administrators soon after joining a company at fitness club in Japan. Managerial post involves considerable stress (Tao, 2005), and administrators received excessive pressure to career development (Kanai, 2000). In Japan, about 80% employees are non-regular employment at the fitness club industry (Fitness industry association of Japan, 2009). They have not felt career perspective compare with regular employees (Mizuno, 2007). That is directly connected with career stress (Kanai, 2000). Thus, it is necessary that to build resilience from perspective of career management at fitness club. In other words, the organization is required to management employee's career to make best use of human resource. However,

knowledge about that how fitness clubs support for building resilience has never been revealed. Resilience is constructed by personal-resources and environmental-resources (Ihaya, 2010). Resilience is influenced by environment, so that discussing about how the organization supports for building resilience is important. Especially, it is necessary that to discuss how building resilience for fitness clubs including stressful environment caused human service.

A recent investigation indicates various subordinate concepts of resilience are clarified (Hirano, 2012; Shoji, 2009; Hauser, 2011). It is indicated that the factors constructing resilience are different in each individuals (Grotberg, 2003). Besides, the process of building resilience has never been clarified (Hauser, 2011). The study about building resilience included two streams. One of them is planned training or program like a Master Resilience Training (Seligman, 2011; Reivich & Seligman, et al., 2011) and Pen Resilience Training (Reivich, 2002). Knowledge about the training like them is accumulated sufficiently. Another is the study about transition through experience of adversity. Resilience can be perceived as a dynamic process. That is influenced by life events and challenges (Grotberg, 2003). However, the study about the process for building resilience through the experience has not been accumulated sufficiently.

The purpose of this study was to clarify the process of building resilience, to obtain the viewpoint of organizational support for the process of building resilience in fitness club. In this study, we stand on asserting that was required to build resilience for making best use of human resources. We discussed about essential resilience for career design. Hence, we followed studies about required resilience on work career (Reivich, 2002; Reivich & Seligman, et al., 2011). Resilience is the ability to persist in the face of challenges and to bounce back from adversity (Reivich & Seligman, et al., 2011). Moreover, organizational support is which the organization deliberately conducts to develop the skill and the ability from the perspective of career management.

METHODS

Participants

Interview survey was carried out targeting 32 employees who belong to five major fitness clubs. Because one company was smaller than other four companies in size of the business and the number of employees, four employees belonging to the smallest company were except from the sample. Thus, 28 (15males, 13females) valid samples were used for this study. The average age of the participants was 27.68 years old (SD=±4.96, Range=19-40). Their average years of continuous employment was 4.96 years (SD±=2.96, Range=1-12). They consisted of 16 full-time, 1 contract employee, 11 part-time employees. 6 full-time were administrative workers. They consisted of 3 general clerks, 8 comprehensive workers, and 17 instructors. Participants were collected by snowball sampling through the approval of the manager. The sampling was started from managers, department managers, and job trainers at branches.

Data collection

Interview survey was carried out from October to November in 2012. Participants were required to answer semi-structured interviews, which ranged in duration from 30 to 50 minutes. There was one to one relationship between a participant and the first author. Semi-structured interviews were conducted at a conference room in the office and a classroom in the university campus. This study was carried out in accordance with the ethics committee at the university of the first author. Participants were explained the aim of survey. They could stop with an intention of themselves at any time. We were allowed to record interviews by IC recorder, and to publish in an anonymous. We got consent in writing by participants. When a participant was minor, consent was obtained in writing from both the participant and participant's guardian.

We told the purpose of this study to participants' managers and department managers by sending letters, e-mails, and telephone. Participants were introduced from managers and department managers who had agreed the purpose of this study. After that, we contacted participants to make an appointment to carry out interviews. Furthermore, we obtained participants' consent for investigation in writing before interviews. Interviews were conducted to explore their experience of the process overcoming adversities during their career. Especially, we focused on experience of workplace, because the place mostly lurking adversity is workplace (Reivich, 2002). However, participants' resilience might not be built or promoted by occupational experience. Thus, narrative unrelated workplace was treated like an experience related work. We also asked a question about non-occupational experience. When

participants told about more than one event, they were asked about each experience in detail.

The interview included questions such as “Could you describe me adversities you had faced ever like an event involved great stress and a setback on work career?”, ”How did you overcome the adversity?”, “How did you change before and after the experience?”, “How do you think you had ever obtained ability to overcome adversities?” Structured-questions were above five questions. All of the interviews involved asking a series of open-ended questions and adopted a conversational tone. Main topics included the processes of overcoming the adversity which affected their resilience. "How do you think that looking back at the time?”, “What does that event mean to you?”, “How has that event influenced you?”, “Why could you keep on a challenge for overcoming the adversity at such a difficult situation?” The interview was flexible to allow the participant to describe events that were meaningful to them. About data collection, when interviews were looked like a stays off the subject, interviews were not pulled back to the subject. The interviews were continued with the flow (Kawakita,1996). We avoided questions which were just questions of “Yes” or “No” to except influence of cognitive bias. It did not include questions to confirm on facts. Structured-questions were conducted in reference to previous studies (Tamminen, 2013; Fletcher, 2012; Hauser, 2011) and an opinion of faculty researching about resilience. Interviews were conducted by the first author, and they were recorded and transcribed verbatim.

Data Analysis

We used KJ-method for analysis. KJ-Method was a tool for abduction. In this study, the process of overcoming adversity was subject for analysis. The process included complex phenomena. KJ-method was used as a method for analyzing the process included complex phenomena.

Only qualitative data described spontaneously by participants were analyzable subjects in verbatim. Verbatim like a “Yes” or “No” to confirm the facts were expected from data of analysis. In qualitative data analyzed with KJ-method, one sentence in data description was treated as one data. However, when the sentence did not have a meaning and meant by only combining above and follow sentence, a few sentences were treated as one data. Additionally, a sentence showed two or three incoherent and extraneous meanings was treated as separated one data in every meaning. One data was treated as a label, about 1500 labels were made in this study.

Labels were organized and coded in every meaning as the first procedure before the first procedure. Labels were grouped preliminary in every keyword, because number of labels was enormous. After preliminary grouping, the grouping and coding involved identifying common concepts within the label and constructing categories represented the meaning. Then, categories classified as preliminary grouping were not considered the result of preliminary grouping, because the aim of preliminary grouping was to pigeonhole data. The aim of organizing groups was to collect labels vested one common meaning and to create label-bundle vested one common meaning. Every label-bundle was coded through the discussion to show meanings of each label-bundle. According to Kawakita(1996), the procedure of grouping label-bundles should be repeated until number of label-bundles is less than ten. Thus, the organizing groups were repeated on countless occasions until the best organizing group created and number of bundles was less than ten.

Interview survey included adversity out of workplace and the process of overcoming an adversity. In this study, a data of analysis was not confined to workplace. Narratives of adversities and processes of overcoming adversities at workplace and out of workplace were subject of analysis. It was assumed that labels were separated work career and life career. However, the process, support, and resource for overcoming adversity at work situation were judged identical or close resemblance with situation at out of workplace. Labels about adversities of workplace were regarded as equality, and treated like adversities over workplace at coding and organizing groups. The procedure was decided through a discussion by four analyzers. However, when labels urged about a phenomenon of a specific situation, the category was grouped and coded as a specific category. They were coded that to show identify singularity. Another reason was that we had an aim to obtain suggestions for building resilience from variety of perspectives. Since, the broad perspective about building resilience was needed to accomplish the purpose of this study.

After the organizing groups, we carried out to create special arrangement and illustrate (A type diagram) with codes created by organizing groups (Kawakita, 1996). Firstly, special arrangement of codes was discussed. Secondly, the relation of inter codes was discussed, and the relation was showed as illustration. The aim of these procedures was to lead A type diagram which included relation of every codes and the process of building resilience of fitness club employees. Moreover, B type describing was carried out for creating a story about findings from A type diagram.

Analysis was carried out by three student of graduate school and one researcher of organizational psychology who train for using KJ-method usually. In discussion, we used narrative of employees as information.

RESULTS

Organizing Groups

Result that of first collecting codes, 133 codes were created. Moreover, following 8 final codes were led by second collecting. 1) *Organizational Support*, 2) *Personality*, 3) *Adversity*, 4) *Positive Effect from Unsuccessful Experience*, 5) *Negative Effect of Adversity*, 6) *Successful Experience*, 7) *Transition of Cognitive Frame*, 8) *Desirable Mental State*. Result of organizing groups, codes obtained from KJ-method analysis were structured codes about experience on work mostly. It was found a few codes that experience based on out of workplace such as sports and university entrance examination. Organizational support was constructed 30 factors. The 30 factors were categorized following 6 subordinate concepts. The 6 subordinate concepts were 1) *Creating positive mood for support*, 2) *Application of feedback from the clients*, 3) *Leading to desirable mental state*, 4) *Promoting the challenge*, 5) *Promoting effort for helping themselves*, 6) *Official personnel policy*.

A Type Diagram

Next procedure was special arrangement of final 8 codes and illustration of A type diagram. As a result, the diagram was created that shows the process of building resilience (see Figure 1). The relation of inter codes was shown with arrows. Arrows about organizational support was shown with a thick line. The outline of A type diagram was shown as B type describing.

B Type Describing

B type describing was carried out to describe about A type diagram. All phenomena showed with A type diagram was happened in the organization. *Organizational support* was illustrated most outside on the diagram. The most outside line started from *organizational support* was imagined store of the fitness club. When fitness club employees faced any adversity, the experience was recognized as successful or unsuccessful experience. When it was recognized as successful experience, *successful experience* influences directly desirable mental state or any *transition of cognitive frame* based on *successful experience* mediate *desirable mental state*. It was typical pattern resulted from successful experience.

By contrast, when the experience was recognized as unsuccessful experience, any positive aspect was found from the experience or fallen into disorder of mind or body. As well, also positive aspect was found with disorder. There were two typical patterns which promote building resilience from experience recognized unsuccessful. One of them was that *positive effect from unsuccessful experience* influences directly *personality* contributed to resilience. Another was that transition of thinking through experience mediate *desirable mental state*. These processes based on both successful experiences and unsuccessful experiences were found that *adversity* was a trigger. *Adversity* serves a function as a trigger at the process for building resilience. However, it sometime happens that adversity bring about *negative effect of adversity* to employees. It was thought *negative effect of adversity* was reduced by *personality* and *desirable mental state*. On the other hand, *evil caused by adversity* negatively influences to resilience, thinking, and cognition. Organization can provide a wide variety of support to all of the process for building resilience or overcoming adversity. Organization could intervene directly in event like adversity, and promote or reinforce *transition of cognitive frame*.

The organization supported for the process which employees overcome adversity. The support was wide variety of kinds. Especially, employees were received feedback, advice, encouraging, motivating and active listening by coworkers. Coworkers included bosses, elders, subordinates and coworkers joined in the same year. Moreover, employees received feedbacks by clients. Client's feedbacks had significant influence. Client's feedbacks had both positive and negative effect. It was important that employees were received feedback, advice, encouraging, motivating and active listening by coworkers and clients while the process of overcoming adversities. Additionally, employees were received supports at any time and any situation on the process of overcoming difficulties.

A type diagram and B type writing were attention making every effort to reject cognitive bias. However, they were led by subjectivity of four analyzers. We read description of data of interviews repeatedly and collated A type

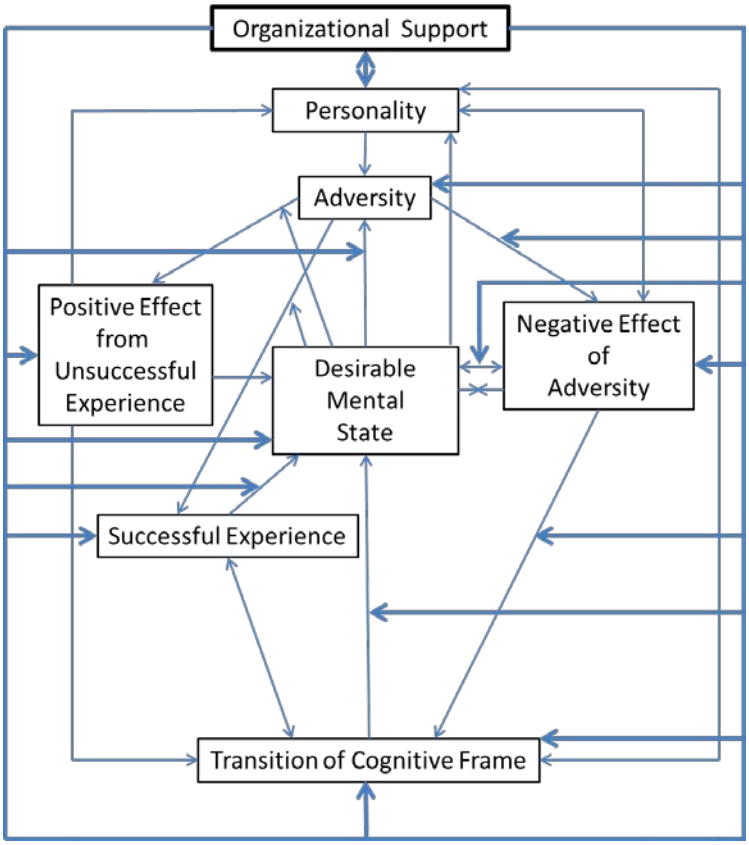

Figure 1. The process of building resilience

diagram with narrative of participants. As a result, A type diagram was inferred that it was possible to explain phenomena happening at fitness club. Additionally, it was inferred consistency of diagram.

DISCUSSION

We discussed A type diagram led by KJ-method. In addition, we discussed point of view to support based on the process shown as diagram for building resilience. The discussion was based on perspective of career management.

A Type Diagram

Adversity was inferred that was trigger during the process of building resilience showed as A type diagram. According to Experiential Learning theory of Kolb(1984), learning cycle was structured concrete experience, reflective observation, abstract conceptualization and active experimentation. *Adversity* of A type diagram considered that *adversity* was looked like concrete experience. In this study, experience was separated successful experience and unsuccessful experience by difference in cognition. *Successful experience* affects only *desirable mental state*. Beside, experience recognized unsuccessful affects *personality* and *desirable mental state*. Their influences were showed left side on A type diagram. In other hands, negative influence coded *negative effect of adversity* was showed right side on A type diagram. In previous study, resilience factors separated innate factors from acquired factors (Hirano, 2012). In this study, it was considered that we discussed about acquired factors. Acquired factors were separated *personality* from *desirable mental state* on A type diagram showed by this study. In addition, it was illustrated that a difference based on way of cognition to experience separated route to comeback to next adversity. For example, unsuccessful experience promoted to acquire problem-solving skills in *personality*. *Successful experience* promoted to acquire self-confidence in *desirable mental state*. Employees confronted next or

progressing adversity using acquired *desirable mental state* and *personality* as resource to overcome it. It was consistent with previous study about post traumatic growth and growth following adversity that mental state and skill change through confronting adversity (Joseph,2005; Linley,2004).

Personality was showed as an only pair affecting mutually with *organizational support* on A type diagram. O*rganizational support* was thought as the organization, and *personality* was thought as individuals. Because, we considered organization and individuals were affecting each other. For example, employees required organization to obtain feedbacks and supports.

The followings were about special arrangement on A type diagram. *Successful experience* was arranged under the *positive effect from unsuccessful experience*. *Successful experience* was separated two cases. One of them was a case recognized as *successful experience* immediately. Another was a case renewed cognition as *successful experience* subsequently to recognize as unsuccessful experience once. Similarly, there was the case that *transition of cognitive frame* mediates to renew cognition after to recognize as *successful experience* once. All *adversities* were considered to include any unsuccessful experience. Thus, *positive effect from unsuccessful experience* was arrangement firstly. Subsequently, *successful experience* was arranged distantly compare with *positive effect from unsuccessful experience* with being conscious of time series. It was considered *Adversity* included any failures, *adversity* influenced both positively and negatively. A flow affected the positive effect was arranged the left side, a flow of the negative effect was arranged the right side based on *adversity* arranged the center on A type diagram. *Transition of cognitive frame* was arranged the antithetical position from *personality*. Because, *transition of cognitive frame* had possibilities as critical transition present patterns of behavior and thinking. *Personality* and *desirable mental state* were been utterly different across from *adversity*, because they were completely different resources. Specifically, *personality* was considered stable resources, and *desirable mental state* was considered unsteady resources.

Organizational Support

The process of building resilience started from adversity. Previous study showed similarly result, adversity was a trigger to outgrow (fletcher, 2012). *Promoting the challenge* was subordinate concept of *organizational support*. We discussed that how the organization promotes challenging for employees. The organization was required to evaluate positively if employees failed the challenge. The organization should not evaluate negatively to failure. The organization should show positive evaluation to challenge itself. At study of development leadership, that is shown as mistake systems (Moxley, 2011). We considered that mistake systems was possible to make a reference in this study. Mistake systems is to encourage, promote and give reward for individuals taking challenging experience which include many learnings and possibility of mistake and failure (Moxley, 2011). If employees did not confront difficult tasks, the process for building resilience did not start. Hence, it was important to create a positive mood which to challenge was encouraged. Additionally, the organization should show the norm to induce to confront adversity with system like a mistake system or official personnel policy.

Besides, *Creating positive mood for support* was found as subordinate concept of organizational support. The organization was required to promote creating inter personal relationship of employees to create positive mood for support. In the analysis, provider of supports was kind of variety. Bosses, elders, subordinates, coworkers, coworker joined company in the same year support for the employee challenging to overcome adversity. Those key persons served to feedback, advice, encouraging, motivating and active listening in the process of overcoming adversity. It was necessary that employees were served some supports for challenging adversity. Employees were required to create inter personal relation for being served formal and informal feedbacks at any time. The organization should support for that employees construct positive inter personal relationship to be served support at any time.

The organization was required to face contradictory two tasks. On the one hand the organization might consider building resilience using adversity, but on the other hand it was required taking care for restraining evils. Especially, it was found that client's feedback influences employees significantly by interviews. The influence was covering both positive and negative side. Some employees fell into disorder as result of negative feedbacks from clients. On the other hands, there were cases which positive feedback may save disordered employees thinking about resignation. *Application of feedback from the clients* was found as subordinate concept of organizational support. At first sight, client's feedback was not looked organizational support. However, it was found that client's feedback had significant influence. Therefore, it was considered that how client's feedback was used. It was important to structure frame for collecting and managing feedback. It was required that to feed systemically clients' responses back to employees. Feedback from client had useful property to keep challenging at adversities. Some employees were encouraged and motivated by positive feedback from their client. Besides, it had a great impact for falling into disorder. There was a reason as following background. In fitness clubs, employees were required to make close

relation between them and clients. Most employees actually realize that. The close relationship brings significant influence. Employees felt a great delight by positive feedbacks from clients. While, it was considered that employees was struck by emotional exhaustion on providing human service. That was significant negative affect by negative feedbacks from clients. A recent investigation indicates human service's burnout is above emotional exhaustion (Kubo, 2007). According to such backgrounds, it was considered managing feedbacks was important.

CONCLUSIONS

It was found the processes of building resilience as A type diagram. It was found that the cycle which starting from adversity lurked in daily operation. Employees confront next or progressing adversity with obtained skill and ability through overcoming adversity. Based on the process, the view point of organizational support for building resilience was shown as followings. 1) It was required to construct mistake systems for promoting to challenge adversity positively, 2) It was required to promote creating inter personal relationship of employees and key persons, 3) It was required to structure a frame for collecting and managing feedbacks from the clients.

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Development of QOC Matrix- The Worker's Voice (part 1)

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ABSTRACT

The Faculty of chemical sciences and engineering form the Morelos University in México, has developed a tool called "QOC Matrix - the worker's voice". It is based on the logics of QOC (Questions, Options and Criterion), 6's philosophy, ISO International Standers about Ergonomic guiding principles, National Institute for Occupational Safety and Health – USA publications, among others. Quality concepts like the Voice of Customer VOC (activity to meet the customer's requirements), are used to obtain "The worker's voice", that will be used in the decision-making process about the design or redesign their workstation. The results obtained from the matrix have the objective to define if the workstations meet standards about cleanliness, organization and safety. Also, identify, the waste of "Talent" (underestimating as the creativity and intelligence of the workforce). All these having as a goal: "to create formal means to add value to the voice of the worker to express quality of working life that they want and need".

Keywords: Ergonomics, Safety and Health, Human Systems Integration, QOC notation.

INTRODUCTION

Mexico is one of the most important Emerging Markets in Latin America, second only to Brazil. The foreign industrial firms are located in the north of the country normally. These corporations have a business structure that allow them invest in safety and health issues indiscriminately. However, at the same time there are numerous of medium and small Mexican and international companies spread in all the country, that supply goods and raw materials to the large corporations, creating an invaluable supply chain that provides job to many people in Mexico. Unfortunately, these medium and small companies are trying to survive in a very competitive market and, they do not have enough economic resources to invest in safety and health. As a result of this, 316,271 occupational accidents and 4,853 occupational diseases were reported (STPS, 2013) in 2012 by the Secretaría del Trabajo y Prevision Social – STPS (Ministry of labor and Social Security). The Figure 1 shows the behavior of these issues for the last 10 years. The data comportment, indicate, there is no control about the working conditions inside the facilities for people whose work there. And the government has implemented a deficient regulation about that.

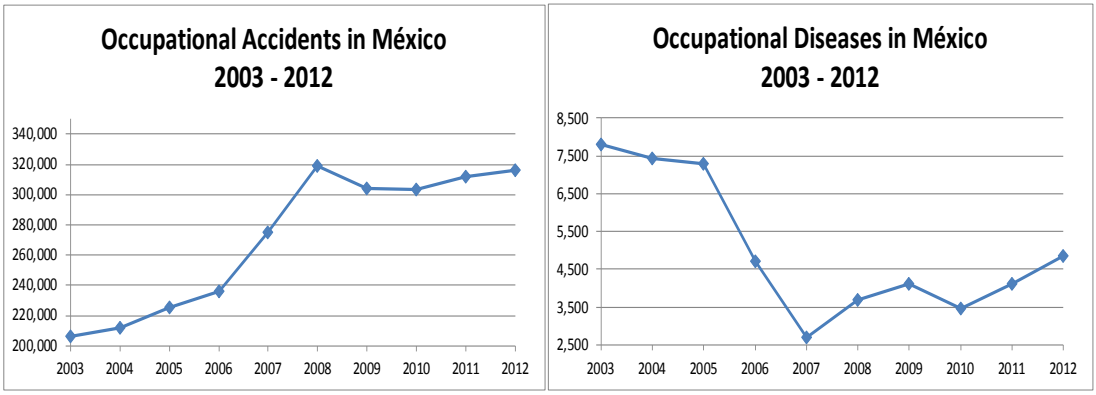


Figure 1. Occupational accidents and diseases reported by the Ministry of labor and Social Security from Mexico. (STPS, 2013)

At present, the legislation that can help to correct this health problem is poor and obsolete, compared to international standards. The Table 1, contains the national rules in place related with work design and environment control. Unfortunately they have not been updated, and contain incomplete ergonomic information.

Table 1: Mexican Official Standards issued by the Ministry of Labor and Social Security (STPS, 2013)

Mexican Official Standards issued by the Ministry of Labor and Social Security
NOM-004-STPS-1999 NOM-006-STPS-2000 NOM-007-STPS-2000 NOM-080-STPS-2001 NOM-011-STPS-2001 NOM-025-STPS-2008

According with Stephen Pheasant "*Ergonomics is the science of work: of the people who do it, and the ways it is done; the tools and equipment they use, the places they working, and the psychosocial aspects of the working situation"* (Pheasant, 2003). Thus, if Mexico wants, prevent occupational accidents and diseases efficiently it is necessary implement better polices to monitoring the working conditions. On the other hand, employers have not taken into account, the cost of lack safety. The productivity losses regarding incidents and disabilities are usually unknown. Fortunately, they can be identified, controlled and eliminated by the application of ergonomic considerations in the design of work and workplaces (Törnström, 2008).

Therefore, it is in this context, the Faculty of chemical sciences and engineering form the Morelos University in México, has developed a tool called "QOC Matrix - the worker's voice". It is based on the logics of QOC (Questions, Options and Criterion), 6's philosophy, ISO International Standers about Ergonomic guiding principles, National Institute for Occupational Safety and Health – USA publications, among others. Quality concepts like the Voice of Customer VOC (activity to meet the customer's requirements), are used to obtain "The worker's voice", that will be used in the decision-making process about the design or redesign their workstation. The results obtained from the matrix have the objective to define if the workstations meet standards about cleanliness, organization and safety. Also, identify, the waste of "Talent" (underestimating as the creativity and intelligence of the workforce). All these having as a goal: "to create formal means to add value to the voice of the worker to express quality of working life that they want and need".

The work in this paper focuses in the building of The QOC Matrix - the worker´s voice, it use and validation in real industrial environment.

DEVELOPING THE QOC MATRIX - THE WORKER'S VOICE.

QOC notation

The QOC notation is a Design Rationale representation for design artifacts which consist in two concepts: design space and evaluation space. The first one established the question design and its options (potential answers to the question), and the second define the "Criteria" the requirements for the final artefact (MacLean A. et. al 1989). Dutoit and Paech (Dutoit A. and Paech B., 2000) established the QOC notation. It represents the design rationale as arguments structured in rhetorical steps. Where: questions represent problems to be solved, such as a design issue, options represent considered alternatives for answering a question, criteria represent the qualities that are used to evaluate options in a certain context.

The QOC matrix

Decision Support Systems (DSS) is an interactive computer-based system that help people use computer communications, data, documents, knowledge and models to solve problems and make decisions (Power, 2002). In the same way the QOC matrix help people use ergonomic information to solve problems and make decisions to design of work and workplaces. Based on international and national ergonomic standard, we use the QOC methodology to design the matrix content, where: a) Questions were performed looking for information about the work: of the people who do it, and the ways it is done. b) Options are a categorization of the risk about the way the work is done. In this section, the worker's voice is stored. c) National and International standards related with the work design are used to evaluate the options. The Figure 2 shows the general design for the QOC Matrix.

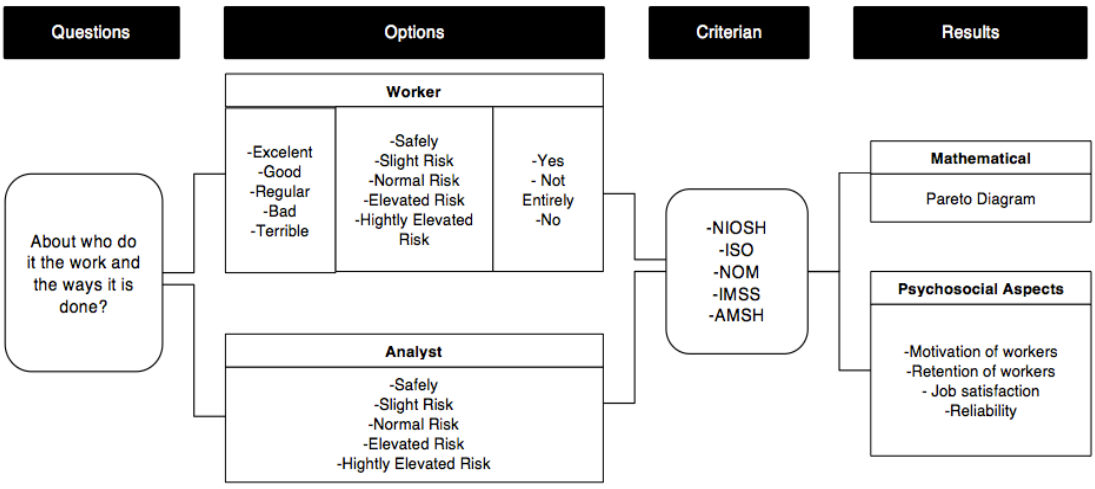


Figure 2. General design for the QOC Matrix.

The options are evaluations about the workspace, work conditions, work procedures, and work environment. This assessment takes place in two stages. First, the workers take the opportunity to assess their working area and provide ideas about how it can be redesigned. Secondly, a specialized analyst evaluates the area and links the ideas proposed by the worker with the national and international standards. It is important define, that the analyst cannot change the worker assessment done.

Building the QOC matrix

The first important decision about building the QOC matrix was to define, the environment that should be it developed. We analyzed several alternatives; the important matter was "the more easily to handle better". After a quickly analysis, we define developed it in an Excel Sheet. The table 2, illustrates part of this making decision. The objective was built a tool that helps people to use ergonomic information to solve problems and make decisions in the design or redesign of work and workplaces freedom of accidents and potential safety risk. The QOC matrix - the worker´s voice (English version) achieved is showed in the figure 4.

Table 2: Making decision on environment QOC matrix.

Questions	Options	Criteria
Is it necessary developing software? or Should we use commercial software to develop the matrix?	Access	• Save information in tables • Make inquiries • Do not process data
	Microsoft Excel	• Processes data in tables • **The most common in Mexico** • Included in the package office • **Easy to handle**
	Open Office Calc	• Processes data in tables • Not used in Mexico • Free Software
	IOS Numbers	• Processes data in tables • Expensive and unusual
	C++ or Java	• Requires a skilled programmer • Can cause faults during installation • Requires additional training for the user.

The tool developed is a book contained four excel tabs, ordered as follow: Analyst, worker, matrix and Pareto. The first tree tabs, enclosed the same questions for analysis, but the purpose is different for each one. The tabs called Analyst and worker are used as evaluation instrument. In Mexico the workforce is people whose has basic studies in the best case, thus it is difficult training them in ergonomics issues. Is for that reason the survey applied them are focused in their filings, complaints and motivations. Therefore, their evaluation answer is regards comfort sensation during the performance of their task. Accordingly, it is the moment when we get the *"worker´s voice"*, and now it represents the client requirements. The survey is applied to all workers in the area; we do not select people based in their skills.

On the other side, the specialized analyst, is a person whose knows about ergonomics and has to evaluate the work and the workstation with the objective to find the ergonomic risk associated with the "worker's voice". The results of the both evaluations are gathering in tab called matrix, see figure 3. Finally, a Pareto chart is generated automatically, with data obtained from the results stored in the matrix of results. This chart, allow us identify the main problem defined by the assessment. Now, we have identified the vital few ergonomic problems. Consequently, the ergonomic intervention will be focused in resolve the first problem showed by the Pareto chart.

Assessment process

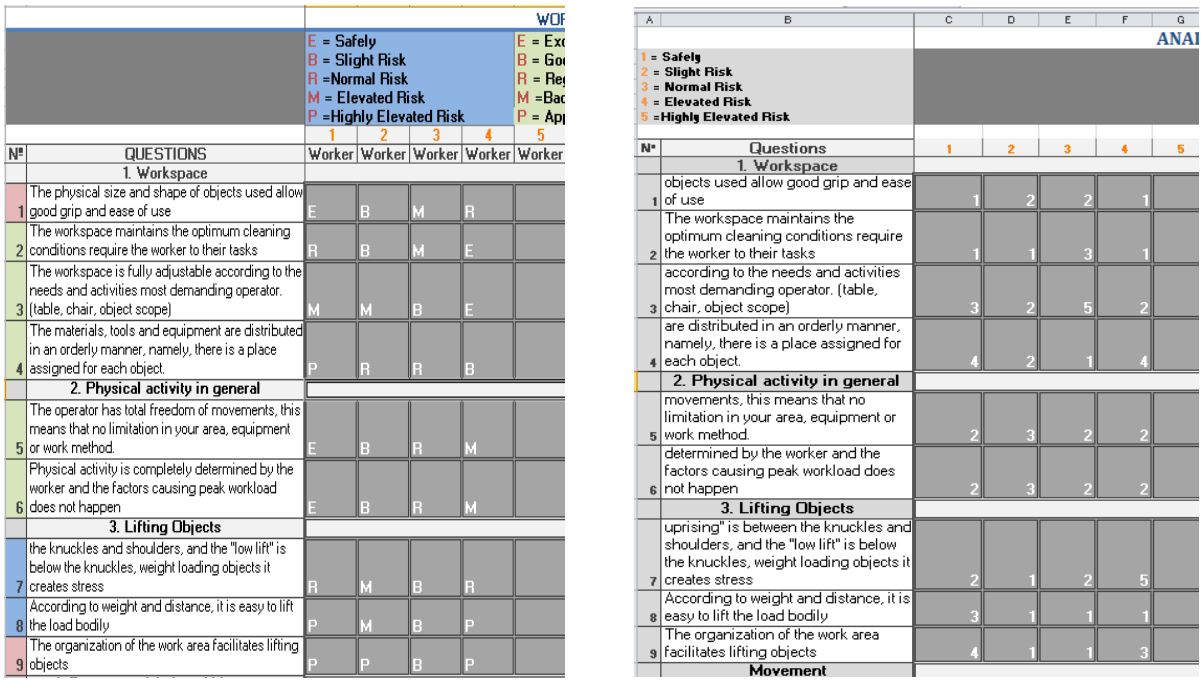
The evaluation activity was based in the methodology developed by the Mexican Association of Safety and Health (AMSH, 1996) where there are two points of view: the first one is the workers assessments who qualify the work conditions of his/her task. In order to choose an option, the workers select the letter that represents their evaluation, for example E for excellent or B for good (Bien). Each question and option is associated whit one color that indicates the kind of answer expected, see in figure 4 (a). The second point of view is presented by the specialized analyst who evaluates the risk of the task. The options that they have chosen are: Safety, slight risk, normal risk, elevated risk and highly elevated risk and each one is associated with a number code. See figure 4 (b).

FINAL ASSESSMENT

Nº	QUESTIONS	1	2	3	4	5	6	7	8	9	10
	1. Workspace										
1	The physical size and shape of objects used allow good grip and ease of use	1	4	6	4	2	4	3	2	4	3
2	The workspace maintains the optimum cleaning conditions require the worker to their tasks	4	3	7	1	2	4	0	2	4	0
3	The workspace is fully adjustable according to the needs and activities most demanding operator. (table, chair, object scope)	7	6	7	2	4	2	0	4	2	0
4	The materials, tools and equipment are distributed in an orderly manner, namely, there is a place assigned for each object.	9	5	4	6	3	3	2	3	3	2
	2. Physical activity in general										
5	The operator has total freedom of movements, this means that no limitation in your area, equipment or work method.	2	5	5	6	2	3	4	2	3	4
6	Physical activity is completely determined by the worker and the factors causing peak workload does not happen	2	5	5	6	2	3	4	2	3	4
	3. Lifting Objects										
7	Considering that the "normal uprising" is between the knuckles and shoulders, and the "low lift" is below the knuckles, weight loading objects it creates stress	5	5	4	8	4	2	3	4	2	3
8	According to weight and distance, it is easy to lift the load bodily	8	5	3	6	4	2	5	4	2	5
9	The organization of the work area facilitates lifting objects	9	6	3	8	5	2	5	5	2	5
	4. Postures at Work and Movement										
10	Risk of stress for neck and shoulders	0	2	4	3	2	4	3	2	4	3
11	The demand for power in elbows and wrists keeps tight	3	2	4	0	2	4	0	2	4	0
12	Postures during work creates stress in some area of the Back	4	4	2	0	4	2	0	4	2	0
13	The posture or movements of hip and leg heaviness or stress generates	5	3	3	2	3	3	2	3	3	2
	5. Risk of accidents										
14	The total lack of concentration at work can cause an accident	0	2	4	3	2	4	3	2	4	3
15	The conditions of the work area only require to be cautious to avoid an accident, or otherwise, must precisely follow the rules and safety measures	3	2	4	0	2	4	0	2	4	0
16	In case of accident in the workplace, there is only the risk of failure for a day, otherwise, prolonged or permanent disability	4	4	2	0	4	2	0	4	2	0
	6. Labour Content										
17	The operator performs all the work, that is, plans, implements, inspects and corrects the product or result, or just perform a specific activity	0	2	4	3	2	4	3	2	4	3
18	The operator also develops activities related to repair and material handling	3	2	4	0	2	4	0	2	4	0
	7. Activity Restrictions										
19	There is a risk that the activity is restricted by the pace of work of a machine, process or operatorsthat is, limits the freedom to choose how and when the work will be done	3	2	4	0	2	4	0	2	4	0
	8.- Ilumination										
20	According to the requirements of the activity, the level of illumination this:	3	2	4	0	2	4	0	2	4	0
	9.- Noise										
21	**The noise level creates a risk of stress**	3	2	4	0	2	4	0	2	4	0
	10. Communication Workers and Personal Contact										
22	There is special attention to facilitate communication and contacts between the same workers and superiors.	3	2	4	0	2	4	0	2	4	0
	11. Decision Making										
23	The operator is involved in decision making for the work method to follow, this means that the voice of the worker is taken into account	3	2	4	0	2	4	0	2	4	0
24	**OTHER (use of excessive force, ambient temperature, etc..)**	0	0	0	0	0	0	0	0	0	0

ANALYST | Workers | **Matrix** | Pareto

Figure 3. The QOC matrix - the worker´s voice (English version).



		E = Safely B = Slight Risk R =Normal Risk M = Elevated Risk P =Highly Elevated Risk				E = Exc B = Goo R = Reg M =Bad P = Apr
		1	2	3	4	5
Nº	QUESTIONS	Worker	Worker	Worker	Worker	Worker
	1. Workspace					
1	The physical size and shape of objects used allow good grip and ease of use	E	B	M	R	
2	The workspace maintains the optimum cleaning conditions require the worker to their tasks	R	B	M	E	
3	The workspace is fully adjustable according to the needs and activities most demanding operator. (table, chair, object scope)	M	M	B	E	
4	The materials, tools and equipment are distributed in an orderly manner, namely, there is a place assigned for each object.	P	R	R	B	
	2. Physical activity in general					
5	The operator has total freedom of movements, this means that no limitation in your area, equipment or work method.	E	B	R	M	
6	Physical activity is completely determined by the worker and the factors causing peak workload does not happen	E	B	R	M	
	3. Lifting Objects					
7	the knuckles and shoulders, and the "low lift" is below the knuckles, weight loading objects it creates stress	R	M	B	R	
8	According to weight and distance, it is easy to lift the load bodily	P	M	B	P	
9	The organization of the work area facilitates lifting objects	P	P	B	P	

Evaluation done by workers
(a)

A	B	C	D	E	F	G
						ANAI
1 = Safely 2 = Slight Risk 3 = Normal Risk 4 = Elevated Risk 5 =Highly Elevated Risk						
Nº	Questions	1	2	3	4	5
	1. Workspace					
1	objects used allow good grip and ease of use	1	2	2	1	
2	The workspace maintains the optimum cleaning conditions require the worker to their tasks	1	1	3	1	
3	according to the needs and activities most demanding operator. (table, chair, object scope)	3	2	5	2	
4	are distributed in an orderly manner, namely, there is a place assigned for each object.	4	2	1	4	
	2. Physical activity in general					
5	movements, this means that no limitation in your area, equipment or work method.	2	3	2	2	
6	determined by the worker and the factors causing peak workload does not happen	2	3	2	2	
	3. Lifting Objects					
7	uprising" is between the knuckles and shoulders, and the "low lift" is below the knuckles, weight loading objects it creates stress	2	1	2	5	
8	According to weight and distance, it is easy to lift the load bodily	3	1	1	1	
9	The organization of the work area facilitates lifting objects	4	1	1	3	
	Movement					

Evaluation done by the analyst
(b)

Figure 4. Evaluation procedure.

VALIDATION OF THE QOC MATRIX - THE WORKER'S VOICE

The validation process of the QOC Matrix, was implemented in two medium companies from Morelos State, Mexico. The first one is an auto parts manufacturing company. Therefore, we had the objective of confirm if the questions proposed in the matrix are adequate for developed an ergonomic intervention. The results obtained after apply the survey to 40 workers from ensemble area; indicate us that the questions were redundant and boring. Hence, we reduce the number of questions and implementing a colloquial language that can understand by the workers, making the survey more fluid and faster.

The second company is a producer of corrugated cardboard. In this company a total of 100 workers from three shifts were interviewed. We validate the results obtained from Pareto charts. In first instance, the chart was built using data summarized from each section in the matrix, but unfortunately each section has different number of questions, then the section with more questions has always the highest result. We change the formula In order to correct this situation. The chart obtained before is showed in the figure 5. The main problem identified is related with section 5 called “Risk of accidents” followed for section 4 “problems of work and movements”. The figure 6 shows the Pareto charts after formula correction. Now, we have a smoothed chart, however the main problem is the same. Then the ergonomic intervention has the objective to reduce the work accidents in the area.

CONCLUSIONS

The work in this paper is focused in the design and building of “The QOC Matrix - the worker´s voice”, an ergonomic tool to help people use ergonomic information to solve problems and make decisions to design and redesign work and workplaces. The instrument designed is a book contained four excel tabs, ordered as follow: Analyst, worker, matrix and Pareto. The result of the tab called worker is the identified as the *“worker´s voice”*. It will be used as client ergonomics requirements. A Pareto chart is generated automatically using the assessment that is stored in the matrix of results. The chart allow us identify the main ergonomic problem. Thus, the companies can save time and money during ergonomics interventions.

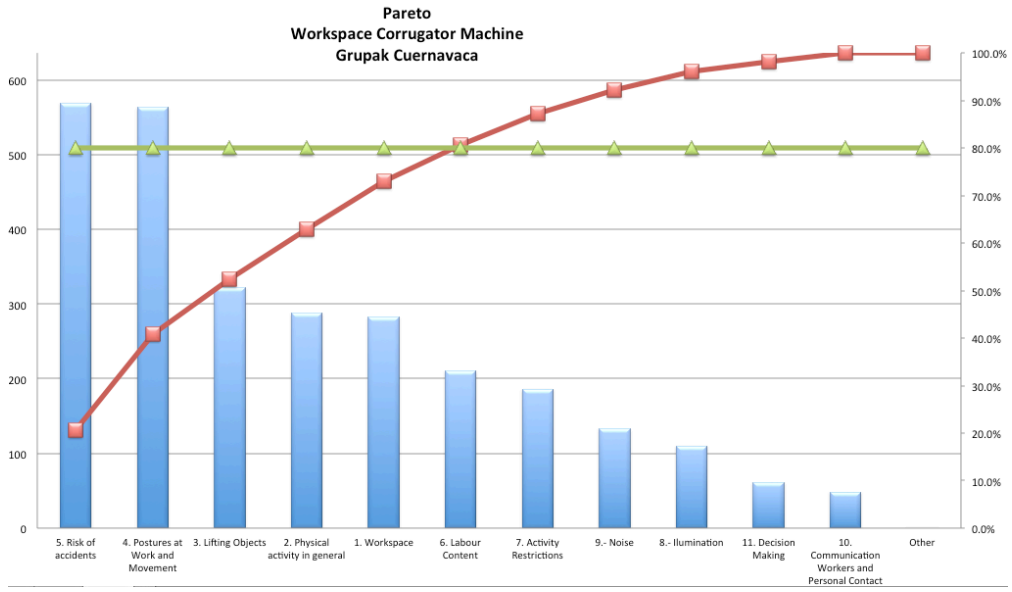


Figure 5. Pareto chart before formula correction.

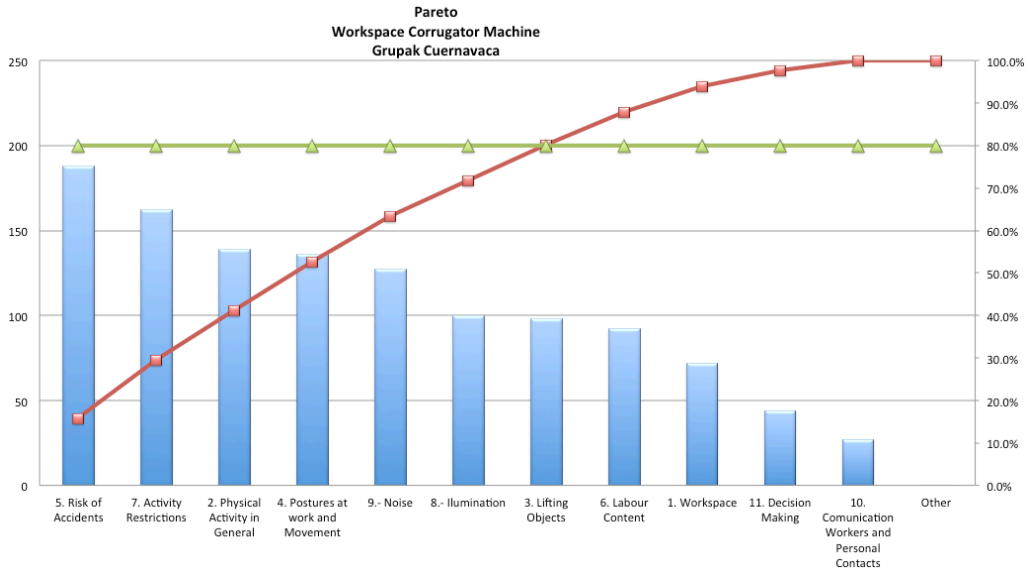


Figure 6. Pareto chart after formula correction.

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Organizational Design: Need for a Socio-technical Inclusive System Design Approach to meet 21st Century Workforce Challenges

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ABSTRACT

Changes occurring in the business and socio-economic global environments increase the complexity of working systems. The global workforce is becoming more diverse where people from different social, cultural, geographical and technical backgrounds work together in spite of their existing differences. Existence of varying human responses caused due to variations in individual's physical, physiological, psychological, social and cognitive responses to the organizational design becomes a real challenge for designers. Moreover, increase in the number of older workers, also requires the attention of designers, as they are different in many ways. These issues increase the complexity of organizational systems and have serious implications for human factors and ergonomics as this complexity challenges the way conventional organizational systems are designed and implemented. There is a great need to develop new strategies where human variations are rightly understood and then emphasized during organizational design process. A proposed Sociotechnical Inclusive System Design approach has been discussed for addressing social and technical issues of organizational design by integrating socio-technical principles with inclusive thinking so that these challenges might be addressed at the organizational and individual levels. This article briefly describes global workforce challenges like increase in diversity, ageing, and impact of individual level variations on workplace safety and task performance. Finally, it highlights the need to design organizational systems based on diversity and differences where social and technical inclusivity should be an integral part of any design decision so that organizations can effectively utilize their human capital. The suggested design approach can draw multiple benefits including employee satisfaction, workplace safety and well-being, high productivity and quality and retention of a skilled workforce for a longer time. All these benefits ultimately support the attainment of long term organizational sustainability.

Keywords: Organizational Design; Socio-technical System Design; Inclusive Design; Workforce Challenges; Ageing and Diversity

INTRODUCTION

Workforce diversity management is becoming a key area of focus due to the changes occurring in business and socio-economic global environments. Organizations wish to retain skilful and experienced workers for a longer time so that they can draw optimal benefit from them. However, efficient use of human capital is possible only if a healthy, safe and productive working environment is provided where workers feel themselves valued and empowered. This article demonstrates the need to reframe socio-technical design methodology by integrating inclusive design thinking as a necessary part of the organizational design so that differences in working attitudes, behaviors, and capabilities can be addressed properly. To meet the challenges caused by variations in human attitudes, behaviors and capabilities, there is a need to adopt a 'socio-technical-inclusive' system design approach, which aims to consider technical, social and inclusive concepts of organizational design simultaneously. This approach aims to substantially increase the accommodation level of organizational design factors, whilst providing a working environment that is acceptable for all in spite of existing differences. The socio-technical-inclusive design approach is more sophisticated in its nature as it aims to highlight and address work organization issues at the individual level. It also provides an opportunity to take a realistic view of the organizations design issues in a detailed way and how organizations can adopt a change.

FUTURE WORKFORCE CHALLENGES

Workforce demographics are changing and organizations are witnessing an increase in workforce diversity. Workforce diversity management is becoming a business case as 21st century organizations want to retain the very best available employees. Workforce diversity covers a wide range of dimensions such as age, gender, race, skill, cultural background, marital status etc. (Williams and O'Reilly, 1998). Because of this, workers share different attitudes, working behaviors, desires, needs and values; along with variations in physical, physiological and cognitive capabilities, that directly or indirectly affect work performance at individual and organizational levels. It comes with a number of potential benefits but also brings challenges as it increases variations in work performance caused due to human variability. Effective diversity management can provide an opportunity of better work performance by utilizing more diverse ideas in decision-making, increasing creativity, competitiveness and innovation along with a greater variety of perspectives and a broad range of task-related knowledge and skills (Roberge and Van Dick, 2010; Childs, 2005; Bassett-Jones, 2005; Richard, 2000; De Dreu). On the other side, failure to manage a diverse workforce may lead to an environment of conflicts, frustration and a sense of insecurity that can promote absenteeism, high turnover, job dissatisfaction and lower work commitment (Shore et al., 2009; Richard, 2000). In the light of this, it becomes important to understand human differences and promote strategies that can minimize effects of these.

A challenging fact is the ageing population. Over the last few decades, the proportion of older people is increasing in almost all parts of the world. According to United Nations Organization statistics (U.N.O., 2009), the average age of the population is increasing, so that approximately, one in ten persons are now 60 years or above and by 2050, one in five will be 60 years or older. The UK population is also ageing and there has been an increase of 1.7 million people aged 65 and over in last 25 years, but the UK is ageing less rapidly than other European countries like Germany and Italy (O.N.S., 2010). The United States Bureau of Labor Statistics (B.L.S) identified that the proportion of the workforce over 55 years of age is rapidly increasing whereas that of younger workers aged 16-19 years old is decreasing (B.L.S, 2010). The higher the number of older people available for work means higher the number of older people at work; however, accommodation and retention of older workers at work demands several critical factors to be addressed as older workers are different in many ways because of changes that occur with age. These changes, like decrease in muscular strength, flexibility, joint mobility, aerobic capacity and vision, directly affect task performing capabilities of workers and are linked with the level of risk of exposure to injuries, illnesses and mistakes (Sturnieks et al., 2008; Wanger et al., 1994; Chung and Wang, 2009; Chiacchiero et al., 2010; Falkenstein et al., 2006; Hultsch et al., 2002; Der and Deary, 2006; Sue, 2008; Boyce, 2008). Contrary to the above, older workers have many advantages that include sagacity, prudence, strategy, wisdom, decision making, logical

reasoning and critical thinking, experience, loyalty and more quality consciousness (Posthuma and Campion, 2009; Dychtwald et al., 2004; Tillsely and Taylor, 2001). Strategies for coping with or benefitting from an older workforce should therefore concentrate on utilizing and enhancing these positive characteristics whilst providing support and assistance (for example through workplace design) to ameliorate the physical aspects of ageing.

As mentioned earlier, individual level variations increase as diversity increases. As far as human factors or ergonomics is concerned, individual factors like demographics, age, work, anthropometry, psychological, life style, comorbidity, past history and social factors are thought to affect the individual's response to workplace risk exposure (Cole and Rivilis, 2004; Kerr, 2000; Wahlström, 2005). In relation to workplace safety and ergonomic interventions, the following sections explain the effect of individual differences on work safety.

In many studies it has been concluded that women are more likely to be exposed to work related musculoskeletal disorders as they are more exposed to physical and psychological work conditions at work (Punnett and Herbert, 2000, Treaster and Burr, 2004, Wahlström, 2005, Karlqvist et al., 2002, Aittomäki et al., 2005). However, a few studies such as Hooftman et al. (2009) found no gender differences regarding the prevalence of WMSDs and concluded that men and women are equally vulnerable to risk factors at work. Like gender, again age has an association with injuries at work, as older workers often suffer from more serious but less frequent workplace illnesses and injuries than younger workers. Moreover, promotion of age-friendly workplaces and environments may lead to higher productivity, competitiveness and sustainable business practices (Ilmarinen, 2002, Welch at al., 2008, Silverstein, 2008). Different people like to perform their work in different ways, especially when they have an option. Moreover, variations in working strategies are also linked with the risk at work (Keyserling et al., 2010; Dahlberg et al., 2004; Palmeud et al., 2012; Lindegård et al. 2003; Guo et al., 2004)

In recent years, more attention has been paid on exploring the relationship between psychological factors and work related musculoskeletal disorders. It has been found that factors like high job stress, job dissatisfaction, lack of job control, inadequate work support, high job demands and perception of insufficient safety climate are contributing factors (Smith et al., 2004, Sobeih et al., 2006, Hofmann and Mark, 2006, Hollman et al., 2001, Stone et al., 2007, Simon et al., 2008, Lacey et al., 2007).

In conclusion to the above discussion, organizations are facing a challenge of diversity management where human variability issues will be more prominent in future. Furthermore, individual differences caused by variations in physical, physiological, psychological, cognitive and social interactions have great relevance for ergonomics and human factors, as principles of ergonomics are used in assuring workplace safety, human well-being, empowerment, optimal work performance along with sustained productivity and quality. There is a need to deal with these issues by developing and promoting new design approaches that have the ability to address the needs of individuals in any organizational system.

HUMAN FACTORS AND SOCIO-TECHNICAL SYSTEM DESIGN

Socio-technical system design thinking firstly emerged at the UK Tavistock Institute, where relationships between social and technical aspects of workplace design were explored and identified (Trist and Bamforth 1951; Trist et al., 1963). Socio-technical system theory is based on the concept that performance of a system can be improved if social and technical aspects of a system are treated together during the design process (Clegg, 2000; Cherns, 1976). Organizations comprise of a number of interrelated functions and multiple stakeholders, and this increases the complexity of organizational systems. This increase is because of changes occurring in the business and socio-economic environment (Hendrick, 1997). Vicente (1999) listed a number of dimensions of the complexity of working systems, like many people working together but having different organizational, cultural, educational and geographical backgrounds and different age groups etc. In this respect, increase in work system complexity creates some challenges, as designing a change in the system without considering the effects of this change on multiple stakeholders might influence overall work performance badly and limits system effectiveness.

As mentioned previously, workforce diversity is increasing where the effective utilization of a diverse workforce is simply related to how organizations can address working needs of different people in the same system. In relation to workforce diversity management, design, implementation and maintenance of socio-technical systems becomes a challenge for human factors and ergonomics researchers and professionals. The main focus of socio-technical design thinking has been on the design and implementation of new technologies. However, it was broadened from

advanced manufacturing technologies to office work and service design (Clegg, 2000; White et al., 2010; Rice, 1958; Trist and Bamforth, 1951; Mumford, 1983). Moreover, a clear focus on socio-technical system design can be visualized in addressing the challenges of information and communication technologies. In this respect, socio-technical practitioners and researchers have provided a critical insight and useful advice on some of the large scale IT projects like the National Programme for Information Technology (NPfIT) in the National Health Service (NHS) and later on providing a new IT system for delivering social care to the people in an appropriate, effective and useful way (Clegg, 2000; Clegg and Shepherd, 2007; Eason, 2007; White 2010).

Additionally, socio-technical systems thinking has significant impact on addressing social aspects of organizational design. For example, organization of work and job design are the key areas where effective contribution of socio-technical design approach has been recognized (Grant et al., 2011; Wall et al., 1980). More precisely, designing organizational working systems on the basis of fundamental principles highlighted by socio-technical theory, helped in achieving a system where employees were motivated, satisfied and more productive in terms of work output. All these factors influence organizational work performance positively (Grant et al., 2011; Birdi et al., 2008).

In the light of above discussion, we may say that socio-technical systems thinking has been applied to a number of key areas, notably focusing on the design of new technologies and workplaces by improving job design and work organization related issues and its effectiveness has been noted. It has been further noted that socio-technical thinking has a potential to address work related issues by addressing job needs of workers in more logical and systematic ways. However, the theory still needs to be shifted from theoretical frameworks to practices, so that real benefits can be achieved. Furthermore, socio-technical system theory has been debated in a way where social and technical issues have been discussed, however, little has been highlighted about individual factors and their implications for socio-technical system design approach. No doubt, socio-technical thinking in itself is an approach that focuses on considering social and technical aspects of design at the same time but still there is a need to further deepen our consideration of this so that the issues like individual differences based on ageing, culture, educational background and gender might be addressed.

INCLUSIVE DESIGN METHOD

"Design is the process of converting an idea or market need into the detailed information from which a product or system can be made" (Royal Academy of Engineering, 2012). The British Standards Institute (2005) defines inclusive design as "The design of mainstream products and/or services that are accessible to, and usable by, as many people as reasonably possible ... without the need for special adaptation or specialized design". Later on, the inclusive design term has also been related to providing quality of life and independent living for the ageing population (Waller and Clarkson, 2009). Other terms like Universal Design, Design for All, Barrier-free Design and Accessible Design have been used in different parts of the world. For example, the term Universal Design was first used in the United States by Ronald L. Mace in 1985. Universal Design was referred to as a design approach that can be used to design products, services and environments that could be used by a wide range of users. The Universal Design term has also been used in Japan; whereas Inclusive Design and Design for All are popular terms in the United Kingdom and most parts of northern and central Europe (Ostroff, 2011).

Previously, the United Kingdom has been an innovative place for providing new design solutions for the ageing population, as in for example the Design Age Programme at the Royal College of Art in London (Coleman, 2011). It has been concluded that Inclusive Design is a successful business strategy by Clarkson et al. (2003). Much legislation like the Disability Discrimination Act in the UK (1995) and the Americans with Disability Act (1990) at US have played a significant role in promoting the level of awareness and importance of inclusive design requirements. So, these days, Inclusive Design practice brings financial as well as legislative incentives for individuals and organizations.

As discussed in the previous section, variations in human capabilities influence task performing capabilities and are directly linked with workplace safety, as it is known that work organization is the way work is structured, distributed, processed and supervised. At The National Institute of Occupational Safety and Health, work organization deals with job design, scheduling, interpersonal issues, career concerns, management style and organizational characteristics (Carayon and Smith, 2000). In the light of this, we can see the importance and

relationship between individual's characteristics and work performance. For example, the job design process considers a variety of aspects such as task complexity, level of skill and effort required and degree of control. Furthermore, human variability has a direct link with all these aspects because variations in the level of skill, task complexity etc. cause changes in the working strategies adopted by different workers. Or, conversely, an imposed change in working strategy raises human variability issues. In a similar fashion, all other domains of work organization are directly linked with human variability and create many challenges for designers, engineers and ergonomists. As mentioned, the Inclusive Design method aims to address the design needs of a broad range of the population where the design process is carried out by understanding and examining the differences in human capabilities and then providing such design solutions where the gap between capabilities and task requirements are at a minimum. Although 100 percent design inclusion is not possible, the inclusive design methodology successfully tries to improve the level of acceptability of a single design solution among the variety of users. Moreover, availability of human capabilities data and design assessment tools has been a great challenge for practitioners. A digital human modelling based tool HADRIAN has been developed at Loughborough University which is integrated with a task analysis system that provides an opportunity to use individual's capabilities data to get an assessment of the inclusivity of any design scenario as it has capabilities data of a broad range of the population, including older people and people with disabilities (Marshall et al., 2010; Case et al., 2001). Similarly, for encouraging the design community, the Inclusive Design research group at the Cambridge Engineering Design Centre, has developed some inclusive design tools, materials and methods; these include an Inclusive Design Toolkit; Impairment Simulation; Exclusion Audit and a Database for User Methods (Cardoso and Clarkson, 2006; Waller and Clarkson., 2009; Waller et al., 2008; Goodman et al., 2008; and Clarkson et al., 2007)

From the above discussion, it can be concluded that the inclusive design approach aims to address the design needs of a wide range of the population by focusing on understanding the differences in task performing capabilities and task requirements at the individual level, and then minimizing the gap between requirements and capabilities. So, in order to address the issue of workforce diversity management, that is to realistically understand human differences caused by many factors, and then to promote such work practices that are equally acceptable for the majority of the working population, the inclusive design approach should be the part of organizational design process.

SOCIO-TECHNICAL INCLUSIVE DESIGN APPROACH - A WAY FORWARD

As described previously, socio-technical theory was developed to address organizational work related social and technical issues simultaneously. However, less emphasis has been given on exploring relationships of different organizational design factors at the individual level. Currently, organizations are becoming more diverse where individual variations and differences have implications for individuals and organizational work performance. Figure 1 shows a proposed a socio-technical-inclusive design approach for organizational design. As workforce diversity brings many opportunities as well as challenges, excellence in effective diversity management is not possible until individual differences caused due to diversity are properly understood and valued. The concept shows that there should be three key considerations for an organizational design; these are:

- Technical System Design
- Social System Design
- Inclusive System Design

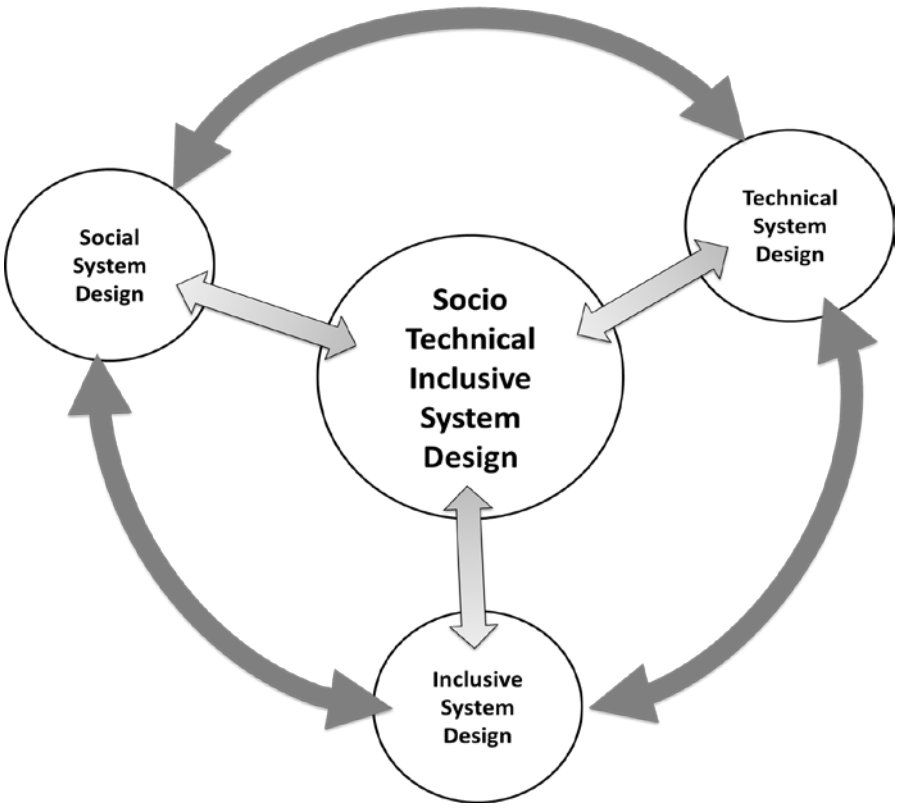

Figure 1: Organizational Design: Components of Socio-Technical-Inclusive System Design Approach

Technical system design considerations focus on the optimized use of equipment, machinery, processes, procedures, physical work settings and arrangements, types of production technology and flexibility etc. On the other side, social design consideration includes worker's attitudes, behavioral styles, organizational culture, degree of communication openness, organizational power structure, reward system, and values etc. The third important area to focus on is to achieve organizational design inclusivity by understanding, highlighting and promoting such design practices that can minimize the effects of individual differences and variations, caused due to varying levels of physical, physiological, and cognitive capabilities; differences in the level of skill, experience, cultural background and attitude towards work. Unlike previous studies, in this approach a special consideration has been given to achieve organizational design optimization by valuing individual level differences and proactively integrating these within the system design process so that the adverse effects of diversity could be reduced to a minimum. Organizational design inclusivity can be promoted by considering the acceptability of any design at the individual level by engaging individuals in the design process. So a socio-technical-inclusive system design approach may achieve optimization of organizational design by putting a parallel focus on technical, social and inclusive deigns thinking in a design process.

CONCLUSIONS

This article reveals the need to design organizational systems in the context of accommodating the needs and desires at individual level as workforce demographics are changing globally. These days, organizations have to manage a diverse workforce where their differences must be valued to attain higher level of organizational productivity. To meet these upcoming challenges, a socio-technical-inclusive system design approach has been proposed. It has three components which are interrelated with each other. Parallel focus on technical, social and inclusive aspects of organizational design can potentially promote a working culture where individuals with their existing differences can perform in a productive way. Moreover, older workers can be utilized in more efficient ways by addressing their concerns related to organizational design. Future research will focus on validation of the proposed concept by conducting case studies and exploring the impact of human factors and ergonomics interventions in relation to

socio-technical-inclusive design approach.

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Possibilities and Challenges of Communication in Six Finnish Industrial and Planning Organizations

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ABSTRACT

In this paper, I study work-related communication in six Finnish industrial and planning organizations. I analyzed the communication through a comparison of distant and face-to-face examples showing how distance negatively influences communication because the distant communicants don't have same contextual information. Sharing of situational information can help mitigate the negative impact of distance. Face-to-face communication was seen as important in the case organizations, as it enables informal communication and builds trust and commitment. Nevertheless, face-to-face communication does not automatically produce documentation, and proper minute keeping and documentation were demonstrably important.

Keywords: Communication, Industrial and Planning Organizations, Distance, Face-to-face Communication

INTRODUCTION

Face-to-face communication is still valued in the workplace, even though many technological solutions exist to overcome distance. When the distance between workplaces exceeds 30 m, people communicate dramatically less (Allen, 1977; Kraut and Streeter, 1995). Beyond 30 m, distance is not a critical factor. For example, in Armstrong and Cole's study (2002), managers reported that communication with a site 15 km away is as difficult as communicating with one 800 km away. Furthermore, research has shown that face-to-face meetings create trust and commitment, and they decrease misunderstandings. However, face-to-face communications do have negative consequences, such as travel time and loss of productions while in meetings. Spontaneously showing up in someone's office may also disturb his or her work (Kiesler and Cummings, 2002; Nardi and Whittaker, 2002), although it has been shown that many problems are solved and innovations achieved "informally" in ad hoc discussions (see e.g., Conway, 1995; Herbsleb and Grinter, 1999). Informal communication usually happens face to face, and technology does not effectively support it, which makes informal communication across distances difficult (Kraut et al., 2002).

In the findings reported in this paper, the effect of distance on communication is also visible. All the subject organizations had some sort of distance problem, and they all stressed the importance of face-to-face communication. In this paper, I describe and analyze communication in the case organizations through a comparison of face-to-face and distant, technologically mediated communications. In the next section, I present the study methodology. In the sections after that, I present the empirical analysis with descriptions of communicative events in the case organizations. I then draw conclusions regarding research and practice.

METHODS

This study follows an ethnographic approach that allows for the understanding of phenomena from "the insider's perspective" due to the lengthy fieldwork periods (in this study, 3 months / 10-20 days per organization). Ethnography is a qualitative approach in social scientific and anthropological research. It has no single, standard definition, as researchers use it in different settings and with different theoretical lens. Despite this, ethnographic studies share some general characteristics. For one, ethnographers enter a field to study daily routines in their contexts. Furthermore, ethnography is the joint construction of a researcher and his or her informants about a phenomenon that is the object of research. Ethnographers also use multiple sources of data, and usually, the results include descriptions, explanations and theories. Finally, quantification and statistical analyses usually fall outside the scope of ethnographic accounts (Hammersley and Atkinson, 2007, 1-9; see also Moore, 1999, 9-19).

I collected and analyzed the data following grounded theory methodology (Strauss and Corbin, 1998), in which simultaneous and rotating data collection and analysis is performed to form general, inductive explanations for a social phenomenon. I chose grounded theory methodology to systematize data collection and analysis. Furthermore, I chose research participants according to purposeful sampling (i.e., working groups were chosen in discussion with the case organizations, and in the case of smaller organizations, all personnel were involved). I also did snowball sampling while in the field: I followed the hints informants gave me to attend interesting events and find right people to speak with. I made theoretical sampling in the later phases of the fieldwork as my knowledge of the phenomenon increased. I constantly analyzed the data by comparing cases, informants and evolving theoretical assumptions. The data consists of observational notes and video files.

The case organizations varied in size, and 10-20 days of observation occurred for each of them. Additionally, the observation reports were presented to the subject organizations for their validation. Subsequently, two development workshops were organized in each of the organizations. In these workshops, observed communication challenges in the case organizations were discussed and concrete development plans were made to solve them. There were 10-20 participants in each workshop; these included employees and managers. Four workshops were recorded on video in two case organizations; the others did not permit video recording. In these cases, comprehensive notes were made in the workshops. Finally, a background questionnaire relating to communication was distributes throughout all organizations, and it received 448 answers (the answer rate per organization varied between 50 and 100 %).

COMMUNICATION IN THE CASE ORGANIZATIONS

Organization 1

Organization 1 is a fast-growing company that employs committed young people who want to develop their careers. They are forthright about problems and see this attribute as an asset. One challenge in this organization is the geographical spread of its functions and some of its teams. The sales department is mainly located 600 km from the head office and has several smaller units abroad. The R&D department is located 300 km from the head office. Human resources is approximately 200 km from sales and 600 from the head office. The department of support, the department of solutions and the department of accounting and finance are together with the head office, and the delivery team is dispersed among many of these locations, including some abroad. Only once a year do the whole staff from different locations meet, at a summer party for the entire organization.

Organization 1 relies heavily on videoconferencing, customer relationship management (CRM) programs, Lync, email and telephones for communication. The human resources manager often works through videoconferencing but thought that it is important to visit all the locations regularly. Furthermore, employees of this organization felt that some meetings are problematic because accurate minutes are not often kept and the decisions made in meetings are not executed. A culture of multi-tasking also exists; people use many communication media simultaneously, such as having a discussion and opening emails in a meeting or speaking on the telephone while having a face-to-face meeting.

The teams in the head office found it difficult to communicate with Sales, and the latter were blamed for many things that caused extra work for others. It seems that other departments did not clearly understand what the sales department does, and this was illustrated in the workshops.

In the first workshop, the participants are from all departments except Sales. Participants think that Sales does not follow the organization's processes, and this harms other departments. For example, Sales does not correctly input information in the CRM program or deliver contracts on time or in the correct form. Some members of Sales are hard to reach and do not answer questions.

Conversely, in the second workshop, one participant is from Sales and the atmosphere is rather different. The member from Sales says that the CRM program is very difficult to use and takes a long time to use, taking time away from the actual sales. In addition, the product is constantly developing and customers often want customized solutions. Sales does not acquire the proper product information from Solutions; things in the catalogues can be very difficult and expensive to make, even though they are in no way separated from the more standard solutions. Thus, in this workshop, participants from other departments are very understanding to the sales department's problems, and the discussion concentrates on the CRM program, which is under development and still quite hard to use in some functions.

Furthermore, in the second workshop, a person representing Sales Support (a function that should support Sales in technical issues), located in the same place as Sales, stresses the importance of informal, face-to-face communication. For instance, he thinks that common coffee breaks are crucial for information creation and exchange. Thus, he feels that he is missing much technical information because he is located 600 km away from Solutions.

Organization 2

Organization 2 thinks that its main competitive advantages are agility and flexibility toward customers. Internally, this requires employees to move back and forth between tasks, an act that is reflected in the working environment. Many tools and materials used in multiple tasks are without a clear place, which causes extra work when employees must find what they need for a new task. In addition, time is short for the maintenance of tools and machines, and some of them are constantly broken and repaired only when in urgent need. The production in this organization is very noisy and employees have to communicate mainly through gestures. Moreover, not all of them are native Finnish speakers, which occasionally causes problems in communication.

Two employees are about to move a heavy metal plate to a processing machine that is quite new to the firm and in constant need of adjustment. The plate has to be exactly at the right place, and the employees are constantly measuring the position, one measure for one side of the plate and another for the other. The employees are shouting measurements to each other, but it is difficult to do this because of the noise and language differences. The Finnish worker is constantly walking to the non-Finnish speaker's side to check the measurement.

This organization's office staff communicates with customers and thinks that it performs well in face-to-face meetings, finding today's email culture challenging. However, at present, the organization's highly competitive market runs almost exclusively through email quotes and orders. Customers don't want to meet face-to-face anymore, which organization 2 sees harmful for making business. Many times the representatives of a customer have not understood technical issues; "they just compare the prices," as the organization's CEO stated.

Organization 3

On the questionnaire, many employees of this organization said that it is the best place they have ever worked. The work objectives are clear, the jobs permanent, and the tasks interesting and versatile.

There is a positive atmosphere in the organization, and monthly meetings are well organized; in every meeting, the "to-do list" is updated and every employees' tasks and task-based problems are discussed collaboratively. Furthermore, documentation of the meetings is systematic. In every meeting, laptops or mobile phones are limited to those who need to present something or to those who must be in call. Silent attention is expected when someone else is talking, and disturbances are regarded as inappropriate. In many meetings, coffee and snacks are provided, and this seems to be in appreciation for the time spent together.

Organization 3 is part of a larger conglomerate. Consequently, information sharing about on-going projects between teams and different subsidiaries of the conglomerate is problematic. This organization is responsible for a system that demands highly precise and up-to-date documentation. The system is also safety critical, which adds pressure to keep it running properly. However, the organization's staff felt it was problematic that employees could not always

have prompt information about changes made to the system during repairs and construction. Instead, information often comes from informal channels, on paper, for example, even though employees should use the information system.

Employees of a sister organization visit the study organization's customer service office during a coffee break. They discuss many things, including work. Members of organization 3 show their coming orders and ask the employees of the sister organization how their current orders are going. Both groups are critical of management and their preparedness for new orders.

The organization's documentation personnel, who are responsible of keeping the system's documentation updated, are frustrated because they do not acquire information about changes promptly or in the correct form. They need to "listen through doors" if something has been changed, constantly asking about changes and reminding others to bring them information. They would like to have information straight from the work management system but are usually informed face to face, on the telephone, on paper or via email.

Organization 4

Organization 4 sees communication as vital to its success. It also has systematic development practices; if something is to be done, there is always someone named to do it. This organization's cooperating units work in very different environments, and misunderstandings occasionally occur between them. For example, in the construction sites around the world, the days are "constant chaos," while the workshop supporting those sites is much more organized. Often, people on site cannot get to teleconference meetings on time, and they do not always inform the workshop staff about this. Thus, more than once, the workshop staff has waited for hours to conduct a meeting, finding it rude that the on-site staff does not take the time to communicate that they are running late.

I should be at a site–workshop teleconference meeting in the workshop, but it has not started. Every now and then, I visit the project manager's office, and she continually says that the on-site staff are not online yet. She is upset with these recurrent delays because they always keep her from going to the firm's once-a-week recreational activity.

Another challenge in this organization is the communication between supervisors and assemblers, especially on the construction sites. In the questionnaire, employees reported that supervisors are rude, proud and do not listen to them. They also felt that the projects are not well organized. Conversely, supervisors said that employees hide and distort information and are quite stubborn. In the development workshops, this was discussed, revealing that feedback is usually negative. Furthermore, many changes occurred in the projects, due to revisions to the plans, and employees felt frustrated when they needed to reassemble or repair something that should have been ready. Assemblers were poorly informed about what caused these changes, and they thought that it had been bad planning. The picture is not so simple, though, as there are many actors in the construction sites whose work depends on each other, including the plans at the level of site management.

Representatives of this organization, the construction site manager and the final customer are having a meeting about the project's progress. The customer is worried about the many revisions, as the project should be ready as soon as possible. The site manager complains that the organization 4 has not responded to her questions fast enough – the organization's representatives say that they should have gotten the questions half a year ago, during the planning period. Now, lots of stuff is built that has to be redone according to changes in plans. The atmosphere in the meeting is nervous, and the representatives of the organization need to make many phone calls and access printouts to answer the site manager's questions. A safety inspection is due the following week, and many revisions need to be done quickly, before the inspection.

Material management at the construction sites was seen as problematic in this organization. Often, not all the materials needed for an assembly were there on time, and this caused delays for days. No one was responsible for tracking the amount of materials or ordering more, as needed. For example, employees frequently had to wait for racks.

Another company at the construction site provides the racks, and almost all the organizations working on site need them. They are ordered for one place but are sometimes taken away before the work is done, as someone else orders them for another place. Thus, they need to be reordered, and the employees have to wait for them before resuming work.

Organization 5

Every morning, this organization has a team leader meeting with supervisors, then a supervisor meeting, then a production and purchases meeting and, finally, a management team meeting. These meetings last from 10-30 min, discussing the situation from the previous day and the day's agenda. Information is transferred from one meeting to the next, and the management team fills out a specific report form. In addition, after the meeting, the management team often goes for a coffee and informally continues the discussion.

Today, in the management team meeting, a production stoppage from the day before, which lasted more than an hour, is analyzed. The painters from the evening shift two days ago used a slightly off color, and the parts had to be repainted. The painters had tried to call the production engineer, but he did not answer because he had forgotten his phone at his cottage. Two layers of paint had spoiled the surface of the parts, which then could not be used the morning before the meeting. In addition, an important tool was broken, and this increased the delay. On the morning of the meeting, there are more problems with painting; some parts have received the wrong color, probably because the tanks had not been properly washed. The management team thinks that there have been many problems with painting, as its team leader has been on a long sick leave. In general, the sick leave rate has been higher than normal at that time, and production has suffered from a lack of workers.

In this organization, communication challenges relate to changes in products and production problem situations. For example, changes made in the R&D department are not properly communicated to the purchases or storage departments. Furthermore, the use of the wrong parts leads to stoppages in production and the rebuilding of products. This information about stoppages or retooling does not reach all relevant teams; nor does information about quality problems. These situations frequently recur in a year, are repeated from year to year and nothing is done to correct them.

I am following the quality inspector around the production floor. He states that "there is no day without a rush," as we go to solve a problem with parts on which the paint is not adhering. The reason for this is a specific protection oil that cannot be removed in the normal wash. The quality inspector has to check all those parts, scratching them. Luckily, only one gets rejected; in the rest, the oil is in places where it does not matter. The production engineer joins us, and we go on to the painting department, which also does the washing. They say that it might be helpful to slow down the washing line, which is now running faster than normal. Wash could be more efficient then. It is decided to do this the next morning, whereby two employees are ordered to pre-wash the parts. On the next morning, the problem is discussed in the management team's daily meeting, and they wonder who made the decision to speed up the washing line. Anyway, the slower line has not been helping, and they decide to start outsourcing the washing. They add that this same problem occurred a year ago, but obviously, nothing was learned.

This organization's head office is located in a different continent, and some challenges relate to this. The head office is seen as bureaucratic and old-fashioned; it has to approve many things, such as press releases, which slows down the processes. The members of this organization's management team also commented that it is hard to make changes and develop "bottom up" strategies, instead of receiving development initiatives (or orders) from the top down. Furthermore, a time difference causes some meetings to be held at odd hours for the Finnish members.

The organization's sales occur throughout Northern Europe (sales management is in Finland), and I followed a one-day seminar, in which employees from all the locations were in attendance:

The seminar occurs outside of the city, in the organization's test center. The place is cozy, and attendees are offered coffee and snacks, as well as lunch. During the morning, a selling strategy for a new product is discussed; during the afternoon, that product is tested. The cooperation between different countries seems smooth and discussion is lively during the meeting and at breaks. Ideas are presented and analyzed, and much positive feedback is given. When the product is tested, it is carefully scrutinized, and some development ideas are born. These are later communicated to the R&D department, which consider what could be done with them.

Organization 6

Organization 6 has been growing through the successful acquisition of plants. Three of its units, including the head office, are in one city, and the newest plant is 500 km away from them. The newest plant's business is different from the others, and sometimes, the top management of the organization does not understand (and is unwilling even to try to understand) what the newest plant does.

Many people in the newest plant tell me that they find it rude that one of the top managers has not visited the plant. He is still deciding many things concerning it. The plant was bought many years ago, "but he still has not even visited it," they complain.

In general, this organization's management is quite concentrated in the hands of the CEO and his family, and middle managers reported that it is unclear what they can and cannot decide. They said that some responsibility is given on occasion, but it can suddenly be taken away. Essentially, everything must be given the CEO's permit or signature, and this slows down decision-making.

A meeting with local management and the head office occurs at the newest plant. Product quality is discussed at length, and the CEO proposes solutions that the local participants comment. Later, the local management tells me how odd it was that the CEO, who is not a specialist in their business, tried to advise them. Then, in the meeting, employee attire is discussed. The clothes have gotten old and the laundry service does not work. Thus, employees have to wash their own clothes, which took time away from their actual work. The day before, when the CEO arrived in the evening and visited the plant, no one was working in the hall. Today, during lunch, he asked the hall's supervisor where the workers were. They were doing laundry. After the meeting, local managers think that it was useful to show the CEO the problem and address it concretely. A quality manager has asked two laundry services for quotes on a full work-clothing service, and the manager presents them to the CEO in the meeting. The price is almost the same between them, but one has better clothing; one worker has tested them. The CEO says that the quality manager can proceed with the clothing initiative as he sees fit. After the meeting, the local management is happy with this, but they still doubt whether they can get the CEO's signature on the contracts once he will see the price.

Employees of this organization are quite independent and know their work well. They also inform supervisors and middle managers about problems in the production and propose solutions. In addition, they are flexible with their hours; they can do overtime, if needed, and keep their holidays during seasons of lower productivity. Most employees work in two or three shifts—supervisors in a day shift and managers flexibly. Despite having 7am-3.30 pm working time daily, some supervisors answer the phone if evening-shift employees call.

An employee comes to a plant manager's office and proposes presently using a holiday scheduled for the following week because there is no work for him at present. In the coming week, there will be. The manager accepts this and organizes the schedule. At the same time, an employee with a birthday cake enters; his birthday will be the following weekend. The manager discusses the planned overtime for that weekend, compromising with the employee, who will come in to work Saturday morning.

ANALYSIS

In organizations 1, 4, 5 and 6, clear geographical distances influenced collaboration. In these organizations, the departments in different locations did not know much about each other; this led to ignorance and doubts between them. People are more likely to assign dispositional attributions (i.e., they tend to think that behavior is determined internally and not by the characteristics of a situation) to dispersed colleagues because distance reduces situational information (Cramton, 2001; 2002).

In organization 4, the construction-site members ignored the workshop members instead of informing the latter that they were running late for teleconference meetings. The plant employees interpreted this as rude (dispositional attribution). In addition, the communication with the construction-site manager (located in a different country) was problematic. The construction-site manager had not reacted to the organization's plans early enough, which led to many revisions and rebuilds. The reasons for rebuilding were not well communicated to the assemblers, which annoyed the latter, which, in turn, negatively influenced their relations with supervisors and managers. The assemblers thought that it was "bad planning" (dispositional attribution). Furthermore, in organization 6, the remote plant workers wanted top management to visit them in person. They did not trust one top manager who had not done this and thought that he neglected them (dispositional attribution). The importance of being someplace in person, at least sometimes, is also reported in many of the articles of *Distributed Work* (Hines and Kiesler, 2002). This act facilitates building mutual situational awareness and understanding, trust, commitment and group cohesion.

In organization 1, the sales department, located 600 km from the head office, was accused of not following the organization's processes (dispositional attribution). However, when Sales explained the situation from their

perspective to the employees from the head office, both groups started to think together to tackle common problems relating to their CRM system, and the attribution became more situational. Thus, the sharing of situational information moderates the tendency to make attribution errors (Cramton, 2001; 2002) and helps in building cohesiveness in dispersed groups (Armstrong and Cole, 2002).

The members of organization 2 wished for more face-to-face contact with customers. They thought that it would help to know customers' needs and, thus, to offer better quotes. This was also reported in Nardi and Whittaker's article (2002), where informants reported lost business when they could not meet their clients face to face. Sometimes, issues are easier to resolve face to face, and sometimes, face-to-face meetings are necessary to show the customer "that you exist and are working on their stuff". (Nardi and Whittaker, 2002.) Organization 1 heavily relied on videoconferencing, for example, but its members thought that it is crucial to be physically present at informal discussions, in which much information is shared. This is why the sales department of organization 5 held a seminar day; all the Nordic offices of that organization attended to plan a strategy for a new product. The seminar was productive, in no small part because it allowed for informal discussions. Furthermore, in all the case organizations, supervision and problem solving usually occurred face to face; when a situation arose in production or construction, supervisors, managers and quality inspectors would go to see the situation rather than place a phone call. In addition, employees would visit offices if they needed to consult supervisors or managers. This is not nearly as effective across distances.

Nevertheless, there are negative consequences with face-to-face communication. For example, it does not automatically produce a tangible record that can be reviewed later or by other people. The discussed items might not reach everyone who needs the information. A member of the sales support team in organization 1 said that he missed much technical information because he was located in a different office than the source of that technical information. The discussed items can also be easily forgotten, and if something is agreed to, there is no a proof of agreement. In organization 5, many problems were repeated because they were only discussed face to face, and then they were forgotten. Organization 5 had daily morning meetings, in which a specific report was filled, but the report's form did more to account for a situation than it did to support the development of solutions. Furthermore, in organization 1, the decisions made in meetings were not executed because of the poor minute keeping. Conversely, in organization 3, the meeting practice was structured and the minutes were kept precisely; therefore, projects progressed.

In organization 3, the sharing of important information face to face instead of through the work management system was seen as problematic. The documentation workers wanted all the information from the system right away, rather than collecting it in small pieces through different media. Why then did the others not use the work management system? Apparently, they did not perceive the system as useful enough or easy enough to use (Davis, 1989) and would rather communicate face to face. Consequently, it would be interesting to study the following question in future research: why and when would people rather use an information system than communicate face to face? Finally, in organizations 2, 4 and 6, there were challenges other than communicative distance – noise and language differences in the workplace, coordination problems (e.g., racks in the organization 4 case) and decision-making problems. These were minimized in this paper but will probably be studied later on.

CONCLUSIONS

Distance influenced the case organizations' communication, causing attribution errors that hindered collaboration. The sharing of situational information helped to resolve this problem. Employees appreciated face-to-face communication and felt that it was necessary, at least sometimes, to build trust and commitment. If possible, they would handle many issues face to face, either in the office or on the production floor. However, this was also viewed negatively because important things that were discussed informally did not reach everyone who needed the information. Face-to-face communication is also problematic because it does not automatically produce a document. Hence, precise minute keeping and documentation allows projects to progress if done properly. In the case organizations where the minutes were poorly kept or without a useable form, projects were not developed efficiently and decisions were not executed.

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Measurement of Cognitive Workload by Use of Combined Methods Including Brain-Computer Interfaces

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ABSTRACT

Cognitive load measurement is a challenging research area that many methods have been provided to get more accurate results. Limitations which are pointed by Cognitive Load Theory (CLT) make this area both special and difficult. Subjective, behavioral, and physiological methods all have some advantages and disadvantages. That's why the use of combined methods has been increasing to make more accurate and better cognitive workload predictions. Technologies such as eye tracking systems, physiological and physical parameters monitoring systems are able to support the relevant researches in this area. On the other hand, there have been some developments which aim different benefits. One of them is Brain-Computer Interface (BCI) technology that works based on Electroencephalography (EEG), detect P300 component of Event Related Potentials and Steady State Evoked Potentials (SSVEP) and offer motor imagery applications. Therefore, they have potential benefits to support cognitive workload measurement methods. In this study, relationships between brain potentials and cognitive workload are researched. Further, opportunities to create new combined cognitive workload measurement methods including BCI, eye-tracking, physiological, and physical parameters are discussed.

Keyword: Brain Computer Interfaces, cognitive load, eye tracking

INTRODUCTION

Reducing human errors is one of the most important areas relevant to human factor and ergonomics. Accidents which are caused by human errors may be fatal sometimes or they slow down the progression of systems. Since human beings have limited physical and mental capacity, work environments and human machine systems must be designed considering the human limits. Measuring physical capacity and fatigue is relatively easier than measuring cognitive components. That's why a lot of studies about cognitive ergonomics have been done in recent years. Increasing technology helps researchers to use more various tools such as BCI and eye trackers in their studies. There are no any methods to measure cognitive load certainly. However it is possible to increase reliability of estimations by using hybrid methods.

Cognitive aspect of human beings' performance is not only depends on their cognitive workload caused by the task. There are some other important cognitive factors such as demands and difficulties of the task, environmental and organizational stressors and personal mental strain of human beings. That's why especially for highly critical tasks it may be better to monitor the cognitive state of the human beings before the task instead of measuring how much they are loaded mentally during the task.

COGNITIVE LOAD

Cognitive load has a lot of definitions. However, it can be shortly defined as the relationship between requirements of the work and competences of the person. When cognitive load improves, risks of accidents decrease and satisfaction of the workers increases. Since there are lots of components of cognitive load it is extremely hard to measure it. However, there are three main factors that affect cognitive load presented below:

- Specifications of the work,
- Skills and qualifications of the person,
- Environmental factors.

Tracy and Alberts (2006) state that when the cognitive load increases, the ability to perform effectively slowly decreases until the person reaches a point of cognitive overload.

According to Hussain et al. (2011) monitoring cognitive load is crucial for developing adaptive systems aware of the user's mental workload. Because such systems can reduce error related risks during task-critical operations.

Cain (2007) states that, a commonly accepted definition of workload does not exist. However, it is possible to characterize workload as a mental structure that reflects the mental strain caused by performing a task under specific environmental and operational conditions, besides the capability of the operator to respond to demands of the task.

Although there is no any widely common definitions of cognitive load most of the different approaches reach the same point indicating the relationship between cognitive load and work performance. That's why measurement of cognitive load has an critical importance

COGNITIVE LOAD MEASUREMENT

It is possible to summarize cognitive load measurement methods in three groups as:

- Subjective methods,
- Behavioral methods,
- Physiological methods.

Subjective methods reflect the person's opinions and feelings directly. Participants answer some questions right after the completion of the task and a quantitative result is obtained based on their answers. NASA-TLX (Hart and Staveland (1988) is the most common subjective cognitive load measurement tool. Since these tools are easy to use and give a direct score lots of researches prefer to use them. Figure 1 illustrates an example of computer-based NASA-TLX application.

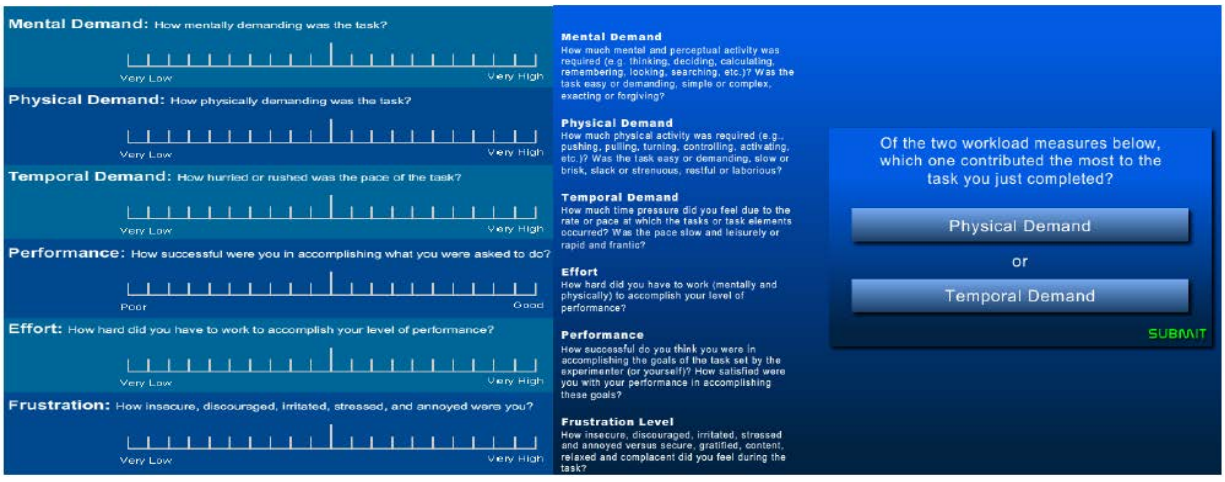

Figure 1. A Sample of Nasa-TLX Screens (www.nasatlx.com)

NASA-TLX has six sub-scales; mental demand, physical demand, temporal demand, performance, effort, and frustration. These subscales can be grouped according to the three factors assumed to produce workload (Embrey, 2006). The first one is task factor including mental, physical and temporal demand sub-scales. The second one is the factor of behavioral and skill and it is related to performance and effort subscales. The last factor is individual and it includes the frustration subscale.

Behavioral methods are based on tasks performances. It is possible to use only one task and estimating the cognitive load by using task completion time and performance. However, to increase sensitivity, participants usually work on two tasks that called primary task and secondary task. Primary tasks create the cognitive load and secondary tasks are used as metric of the performance. The both tasks are performed concurrently then participant's task completion time and the level of the success are considered to estimate the cognitive load.

Physiological methods are relatively more objective methods, because physical symptoms that are used to estimate the cognitive load are not directly controlled by the participant. Most of the symptoms such as hearth rate variability, galvanic skin response, pupil dilation are controlled by autonomic nerve system. On the other use of EEG is one of the popular tools on this area. Investigating change of brain waves and event related potentials (ERP) gives some information about the cognitive situation of the participants. In fact, all of these symptoms are also relevant to the level of stress and anxiety of the participant. Since stress and anxiety have relationship with cognitive load level these facts can be used to estimate the level of cognitive load.

There are a lot of empirical and non-empirical studies that aim to measure cognitive load in the literature.

Antonenko et al. (2010) focused on comparing using NASA-TLX and EEG data and stated using EEG data is a more objective approach to measure cognitive load.

Haapalainen et al. (2010) stated using multiple physical symptoms makes the cognitive load estimation more realistic. The study is an experimental one and data were collected on 20 participants while they were completing the task given by the researchers. The physical symptoms are:

- Changes on pupil sizes,
- Eye movements,
- Number and duration of eye blinking,
- Heart rate variability,
- Respiration, and
- Monitoring brainwaves.

Walcyzk et al. (2012) explain that there is a relationship between telling lies and pupil sizes. They conducted a scenario based experiment with 145 participants. Some of the participants watched a video record of real crimes and they were asked to tell lies about them. The rest of the participants were asked to tell truth. The results were compared using statistical analysis methods.

Based on the literature review, it can be stated that there is an increase in using remote eye trackers to investigate eye reactions as a metric of cognitive load. Palinko et al. (2010) conducted a study to estimate cognitive load of participants using driving simulator. Klingner et al. (2008) conducted three experiments about mental multiplication, short term memory and aural vigilation and they used task evoked pupillary response to measure participant's cognitive load levels via remote eye tracker.

Eye trackers are technological systems using infrared cameras and following eye movements, fixations and pupil reactions. Figure 2 illustrates an example of screen type remote eye tracker.

Figure 2. Screen type eye tracker (www.tobii.com)

BRAIN COMPUTER INTERFACES (BCI)

BCI are technological systems including a computer, relevant software, EEG components (bonnet, electrodes etc.), and an amplifier. They work based on EEG and simply brain activities and convert them to comments for the computer using interfaces (See Figure 4). The goal of BCI research for the last thirty years has been to develope a brain-controlled communication device for paralyzed individuals who keep cognitive abilities (Mak et al., 2011). However it is also possible to use these interfaces for other cognitive researches related with ERP and other brain activities. Blankertz et al. (2010) published a review article to investigate non-medical use of BCI technology. In the study they mentioned about some possible areas to use BCI including mental state monitoring, cognitive load measurement and attention.

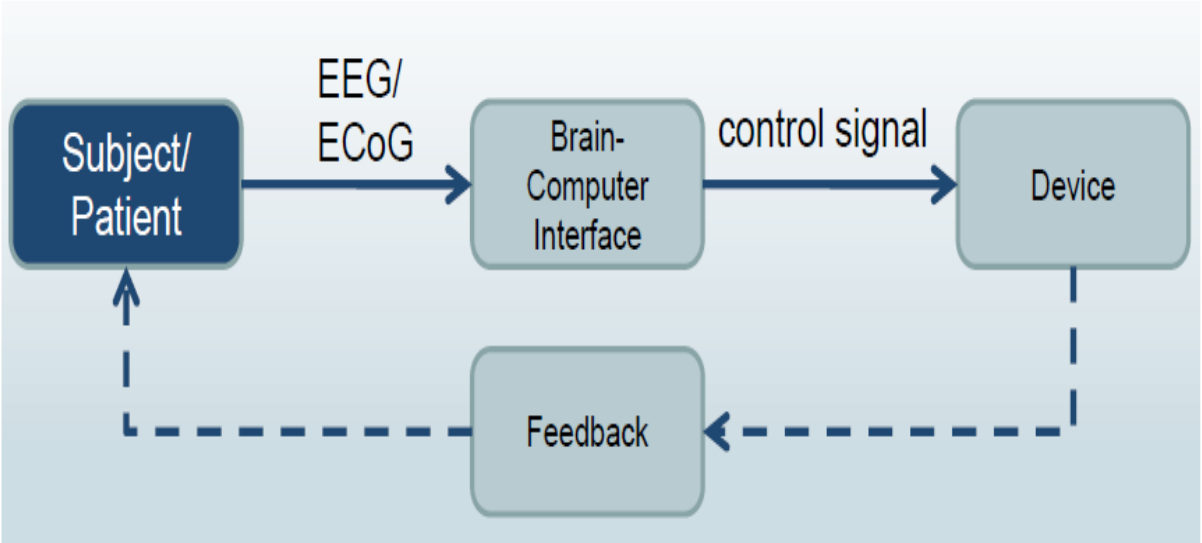

Figure 3. Operation Diagram of BCI (www.gtec.at)

Karagoz et al. (2005) explain that BCI's basically use three main neurophysiological facts first of these facts is P300. This potential appears when a problem is solved, a decision is made or an uncertainty is gone in 300 ms. Alkac (2009) stated that P300 doesn't appear with the standard stimulates but it appears with the target stimulates. That's why this potential is used in the studies about gathering attention and focusing. The relevant interface of P300 is usually a letter matrix that columns and rows flash and the participant tries to focus on his/her target letter to type it on the screen (See Figure 5).

Since P300 is directly related with decision making, problem solving and detecting occasional target stimulus it is an attractive phenomenon also for cognitive load researchers. Schulteis and Jameson (2004) conducted an experimental study. The task of the experiment is reading written materials with various level of difficulty. They used an EEG, remote eye tracker and subjective scale to measure the cognitive load and according to the results more difficult texts led to lower reading speed, higher subjective load ratings, and a reduced P300 amplitude. Zhao et al. (2011) used P300 in their experimental study as an indicator of mental fatigue. In the study subjects completed a 90 min. Driving simulation task. In addition they were requested to perform an Oddball task at the beginning and at the end of the driving task.

Figure 4. Letter Matrix on BCI (www.gtec.at)

Another brain potential which is used by BCI's is SSVEP. BCI's use this potentials with flashing controls (See Figure 6). The controls flash with different frequencies and the participant tries to focus on her/his target control to give the comment. This application makes possible to control some electronic systems (Gencer et al., 2010). This application also requires a high-level of attention and concentration to be able to follow quick flickers. SSVEP has also become an attractive fact for cognitive load researchers. Pegelo et al. (2011) conducted an experimental study and they state that the test show SSVEP based BCI can be used for psychometric test.

Figure 6. A sample SSVEP Application (www.gtec.at)

The third neurophysiologic fact used by BCI's is changes on motor sections of the brain when participant imagine moving to a specific direction (Gencer et al., 2010). When we think to move our right hand, an activity appears on the left side of our brain. BCI system catches this activity via electrodes and converts it to a comment for the computer. It makes possible to control cursor on the screen to respond visual stimulates. Creating the appropriate responses requires high level of attention and focusing.

Uses of some BCI applications are summarized at the Table 1.

Tablo 1. Summary of some BCI Applications

Common BCI Applications (Tasks)	Required Brain Activity	Method	Outcome
Motor Imagery	Event Related Desynchronization/Event Related Synchronization	Imagination of hand movement (ıght or left)	The Cursor moves
Letter Matrix	Event Related Potential (P300)	Focusing on a specific flashing character	The character appears on the screen
Controlling Electronic Devices	Steady State Visual Evoked Potential	Focusing on flickering light with specific frequency	The device moves

COMBINED METHOD

Since the current cognitive load measuring methods are not enough to give an exact result, researchers tend to combine some of them in their studies to increase reliability. Some physical indicators of cognitive load, task performance results and subjective ratings are usually combined. Of course all methods have their own advantages and limitations (See Table 1) that's why usually it is not possible to use more than a few methods concurrently.

Table 2. Summary of Some Cognitive Load Measurement Methods

METHODS	ADVANTAGES	DISADVANTAGES
Subjective (NASA-TLX)	* Easy and quick to use * Low cost * A common technique	* Personal Results * Low objectivity
Behavioral (Primary/Secondary Task Performance Measurement)	* Easy to use * More sensitive than subjective methods	* Choosing secondary task is very critical * Secondary task performance may be affected by personal qualifications
Physiological (HRV)	* Continuous data recording * Can not be controlled by the subject	* Too sensitive to environmental conditions * A sensor must be attached on subject's body
Physiological (GSR)	* Continuous data recording * Can not be controlled by the subject * Sensors can be attached to the fingers	* Too sensitive to environmental conditions.

Physiological (EEG)	* Continuous data recording * Can not be controlled by the subject	* Too sensitive to environmental conditions * Electrocodes must be attached on subject's head * It is difficult to interprete the output.
Physiological (Respiration)	* Continuous data recording	* Too sensitive to environmental conditions * A sensor must be attached on subject's body
Physiological (Pupil Diameter)	* Continuous data recording * Can not be controlled by the subject * Remote data collection is possible	* Too sensitive to environmental conditions. * Technical limitations of devices. * Expensive equipment.

BCI's are expected to bring new opportunities for combining methods to measure cognitive load. Their pre-developed interfaces and ability of tracing ERP make them potentially useful tool for cognitive researches. On the other hand applications of BCI that can be used as experimental tasks in the combined method are simple for everybody and they are not related to any personal qualifications or personal area of interest. That's why task performances of this method are much more related to cognitive facts.

In this study, a BCI system developed by G.Tec is investigated. G.Tec's BCI system works based on MATLAB and its amplifier allows using GSR, Respiration, and HR&HRV sensors as well. When a remote eye tracker and a subjective cognitive load method are added to the combination, a multi aspect process can be available.

BCI applications can be used as tasks and the tasks can be defined as follows:

- Letter Matrix (P300): Typing words,
- SSVEP application: Making the target moves,
- Motor Imagery: Giving the right directions to the cursor.

Possible steps of the method can be summarized as below:

- Completing BCI tasks respectively and recording physical data (HRV, GSR, Respiration, Pupil Size) concurrently,
- Record the task performance (number of errors etc.),
- Analysis of the data and comparing the results,
- Conducting a subjective measurement method as basis.

There are some limitations of the methods:

- Not applicable in real work environment. Experiments should be conducted in a silent and properly arranged environment.
- BCI tasks are not suitable to be used as a second task due to requirement of high level of attention and focusing.
- Not very suitable to measure a specific real task's cognitive load. It is better to estimate mental fatigue or monitor the person's cognitive load just before or right after the real world task.

Strengths of the method can be summarized as follows:

- It is possible to trace most important physical cognitive load indicators concurrently,

- The task performance is almost completely related to attention and focusing level of the participant,

- It is possible to investigate and analyze EEG data as well,

- Task difficulties can be arranged by changing number and frequency of relevant stimuli,

- It makes possible to trace a person's cognitive situation with periodical executions.

DISCUSSION AND CONCLUSION

Relevant studies in recent years shows that cognitive load researchers tend to combine the existing methods. Developing technology brings some advantages to collect more sensitive data in shorter times.

Obtaining more realistic and objective results is required combining existing method and using the advanced technology. Nowadays, it is possible to give tasks to the participants with BCI. Tasks on the BCI's eliminate the performance deflections caused by the qualifications and skills of participants. Because according to the Cognitive Load Theory, two persons may complete the same task at the same time with the same level of success. However, it does not mean that both of them have the same level of cognitive load. It is impossible to understand which of them is closer to make an error. When the personal differences and tendencies are eliminated by using such simple tasks as writing a word on the screen, moving a robot to somewhere and locating the cursor on the target point, it may be possible to see more clearly cognitive fatigue levels and capacities of the participants.

This study constitutes one of the initial steps in the exploration new combined cognitive load measurement methods including BCI's. Future studies will include experimental data and statistical analyses to investigate the performance of proposed methods.

FUTURE WORK

The planned next steps of the study are listed as follows:

- Sectorial based data collection; experiments focus on the sectors that employees are under the high level of accident risk,
- Age based data collection; since some cognitive skills may disappear in older age it is important to identify the age effect on the cognitive state,
- Developing new risk analysis methods that including cognitive aspects.

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Section 7

Hand-Arm and Workstation Design

Effects of Pen Holding Posture on Handwriting Motion

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ABSTRACT

Exploring the nature of skill is useful to understand the specific feature of handwriting or calligraphy. Although we learn the holding posture in handwriting at elementary school, and we notice that the holding posture must be one of the important factors to improve skills in handwriting or calligraphy, it has not been explored how the holding posture of pen or brush affects the handwriting efficiency or performance. In this study, we categorized the holding posture of a pen into three types according to the angle of the joints of the fingers; weak grip which is generally recognized correct as holding style and recommended at elementary school education in Japan, strong grip under which fingers are strongly bent, and others (types I and II). The motion of fingers, the writing pressure and the holding posture of a pen, and the gripping pressure during handwriting were measured to verify the rationality of the weak grip type which is in general recommended at elementary schools in Japan.

Keywords: Hand Writing, Holding Posture, Gripping Pressure, Writing Pressure.

INTRODUCTION

In order to understand the skill in calligraphy and make use of this for the proposal of an effective instruction method, the investigation of hand-eye coordination must be essential. Although there seem to be many approaches that made an attempt to develop an effective calligraphy instruction method, few studies paid attention to a hand-eye coordination skill. In calligraphy, we are much interested in how we gaze at paper and draw characters on paper. Murata et al. (2009), Murata et. al. (2011) and Murata et. al. (2012) made an attempt to simultaneously measure the brush tip movement and the eye gaze position during calligraphy. Exploring the nature of skill is useful to understand the specific feature of handwriting or calligraphy. Although we learn the holding posture in handwriting at elementary school, and we notice that the holding posture must be one of the important factors to improve skills in handwriting or calligraphy, it has not been explored how the holding posture of pen or brush affects the handwriting efficiency or performance.

In this study, we categorized the holding posture of a pen into three types according to the angle of the joints of the fingers (see Figure 2); weak grip which is generally recognized correct as holding style and recommended at elementary school education in Japan, strong grip under which fingers are strongly bent, and others (types I and II). The motion of fingers, the writing pressure and the holding posture of a pen, and the gripping pressure during handwriting were measured to verify the rationality of the weak grip type which is in general recommended at elementary schools in Japan.

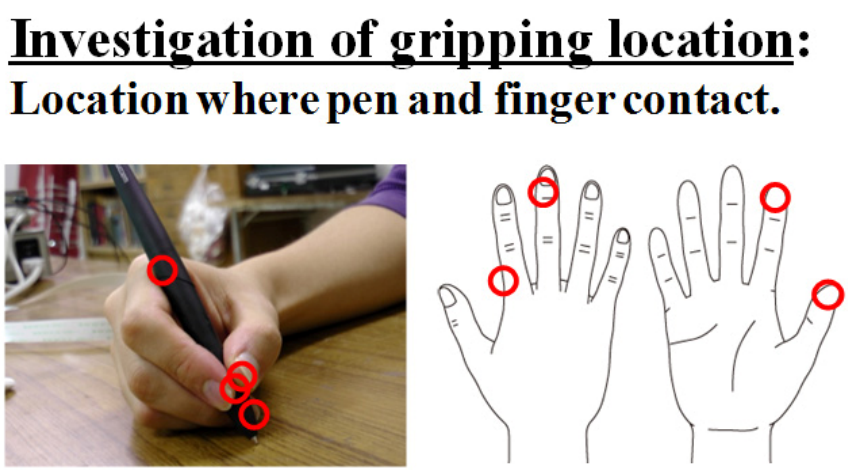

Figure 1. Investigation of grip locations for classification of holding posture (style) of a pen.

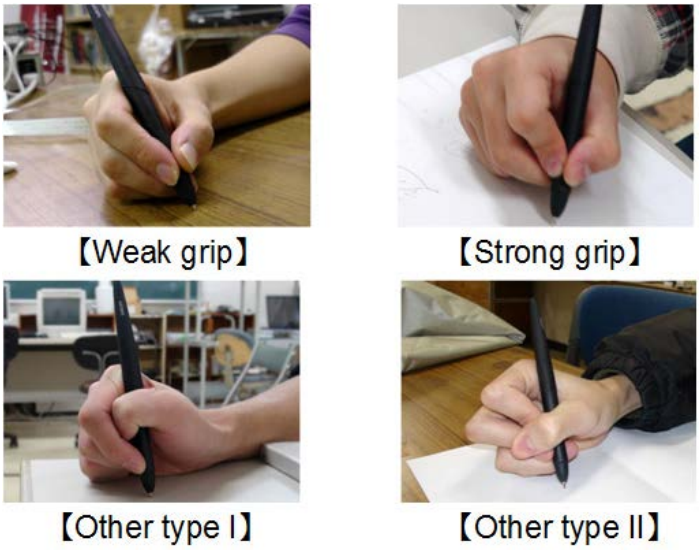

Figure 2. Classification of holding postures used in the experiment.

METHOD

Participants

Eight right-handed undergraduate students participated in the experiment. They were all healthy and had no orthopedic disease. All signed the document on informed consent after receiving a brief explanation of the aim and the contents of the experiment.

Acquisition of basic information

As a first stage of the experiment, basic information such as the gripping location of a pen, the tilt (slope) of a pen, and the moveable area of thumb, index finger, and middle finger was acquired. In short, the investigation of gripping location was carried out before the experimental task according to Figure 1. Consequently, the holding posture of a pen was into three types according to the angle of the joints of the fingers; weak grip, strong grip, and others (types I and II) (see Figure 2).

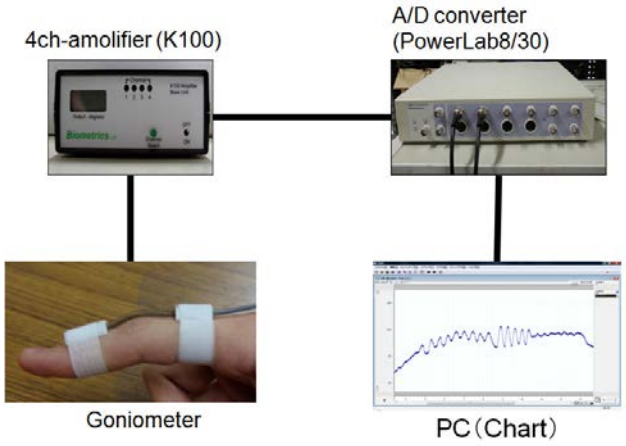

Figure 3. Measurement system of finger joint angle.

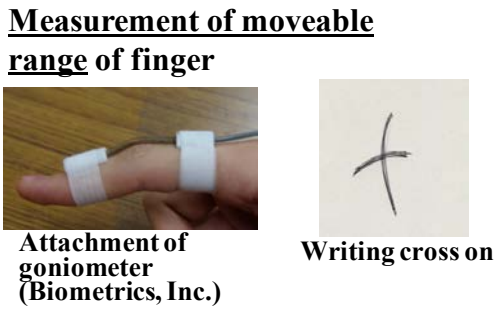

Figure 4. Procedure for measurement of moveable range of finger.

Figure 5. Measurement system for pen holding posture.

Apparatus

The moveable ranges of each finger while holding a pen was measured using a goniometer (F35, Biometrics Inc) (see Figure 3 and Figure 4). The tilt (slope) of a pen was measured using OceanServer (OceanServer Technology, Inc) (see Figure 5. and Figure 6). The writing pressure was measured using Intuos5 touch small (Wacom) (see Figure 7). The gripping pressure during handwriting was measured using OctSense (Nitta) (see Figure 8 and Figure 9).

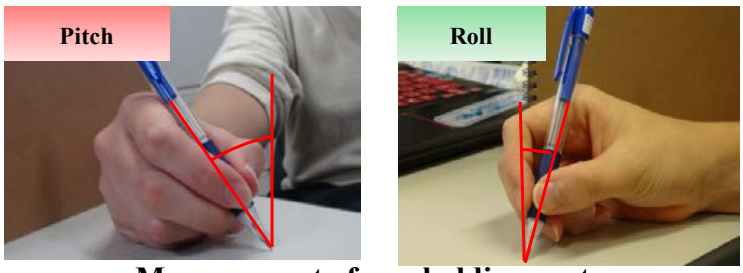

Figure 6. Definition of pitch and roll angles.

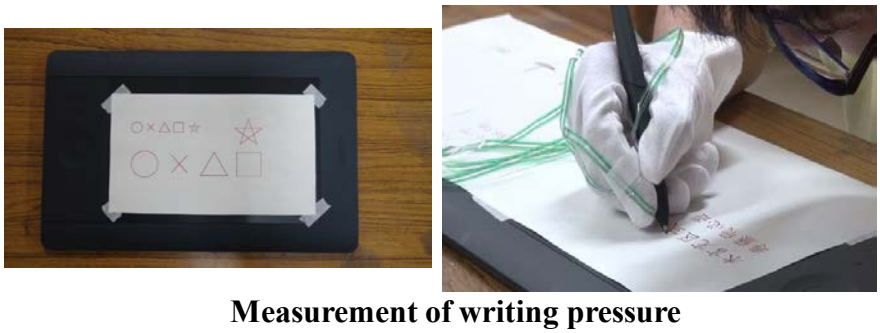

Figure 7. Measurement system of writing pressure.

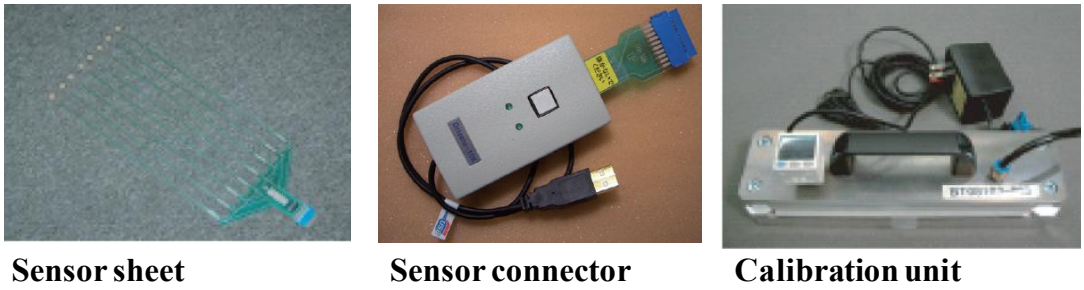

Figure 8. Apparatus for measuring gripping pressure.

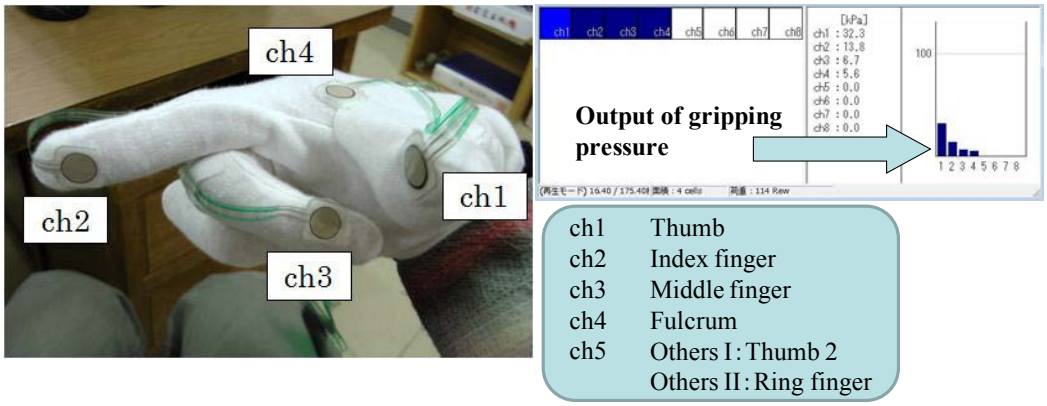

Figure 9. Attachment of sensors for measuring gripping pressure and an example of actual measurement of gripping pressure.

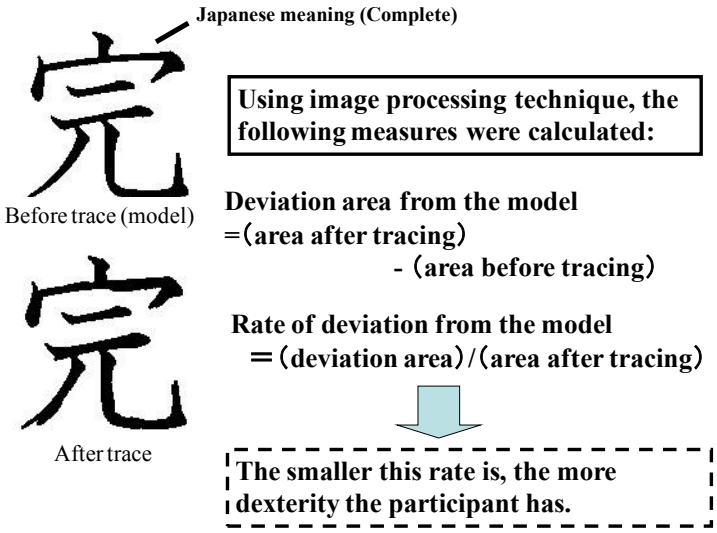

Figure 10. Calculation procedure of deviation from the model.

Procedure

In Japan especially in elementary school education, generally accepted and recommended correct holding style (posture) of a pen is regarded to have the following advantages:

(1) less fatigued.
(2) easily movable finger joint.
(3) make use of the weight of a pen in writing.
(4) fast writing.

On the other hand, the disadvantages induce the following outcome:

(1) more fatigued and long duration of writing is impossible.
(2) aesthetic writing is impossible.
(3) slow writing speed.

Taking the advantages and the disadvantages above into account, the following measures for identifying the correct holding style (posture) of a pen:

(A) tilt (slope) of a pen (see Figure 5 and Figure 6).
(B) moveable area of finger joint (see Figure 3 and Figure 4).
(C) gripping pressure during writing (see Figure 8 and Figure 9).
(D) dexterity (measured by the tracing deviation from the model) (see Figure 10).
(E) writing pressure (see Figure 7).

The moveable ranges of three fingers (thumb, index finger, and middle finger) while holding a pen, the tilt (posture) of a pen, the holding position, the gripping pressure during handwriting, the holding posture and the writing pressure during handwriting (tracing) were measured. The dexterity in handwriting was evaluated by means of the performance of the tracing task (the difference of area of the model (example) shapes or characters and the area of actual writing) (in more detail, see Figure 10). These areas were calculated in pixel unit by inputting each image to a computer and processing each image.

The experimental procedure is summarized in Figure 11. On the first stage, basic information mentioned in 2.2 were collected. On the third stage, the participants carried out a handwriting task of 1,200 Japanese characters. On the second and the fourth stages, the participants were instructed to trace printed shapes and kanji characters shown in Figure 12 with a pen.

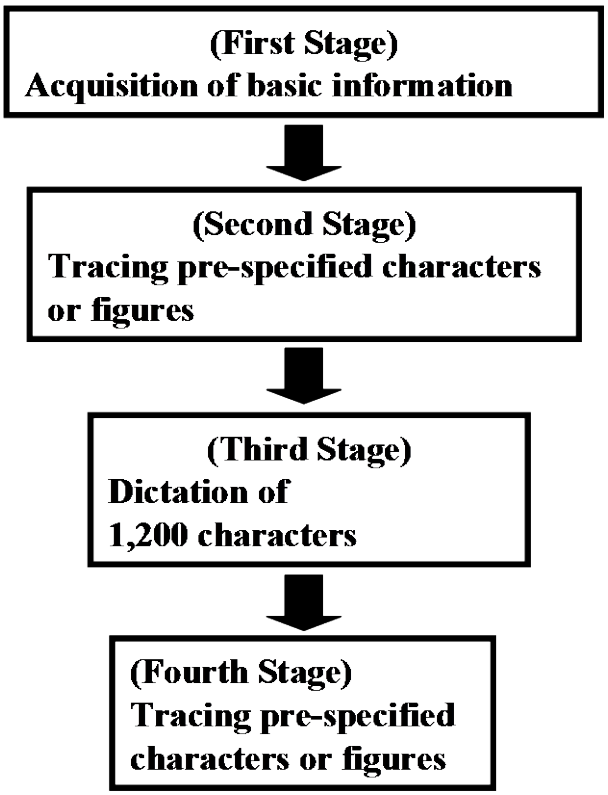

Figure 11. Experimental procedure.

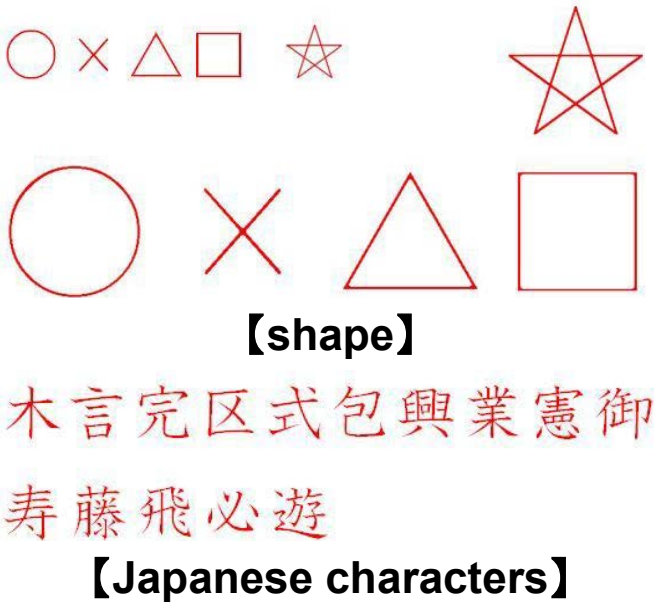

Figure 12. Shape and Japanese character used in the experiment.

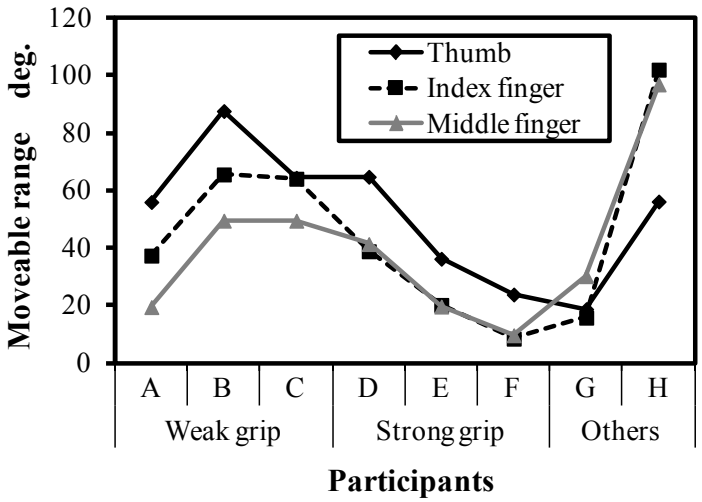

Figure 13. Moveable range of fingers as a function of type of holding posture (thumb, middle finger, and index finger).

Table 1. Gripping pressure compared among holding postures of a pen.

Unit [kPa]	Shapes		Kanji characters	
	Before task	After task	Before task	After task
Weak grip	64.21	22.31	55.27	16.85
Strong grip	62.47	55.12	55.16	45.84
Other type I	18.76	35.96	42.30	21.08
Other type II	137.00	24.62	66.22	24.62

RESULTS

The experimental results showed that the range of motion of fingers was larger in weak grip than in strong grip (see Figure 13). Holding pressure was different among the holding postures (weak grip, strong grip and other types (I and II)) (see Table 1). No differences of tracing performance, and the tilt angle (pitch and roll) were detected among the holding postures.

For all participants, the pitch angle was significantly larger than the roll angle. The pitch and roll angles ranged from 24 to 40 deg (Figure 14). As for characters, the rate of tracing deviation from model for figures was significantly different among holding styles (postures) (see Figure 15). On the other hand, no significant difference of this measure was detected among holding styles (postures). As shown in Figure 16, the writing pressure of Weak grip type was apparently smaller (Figure 16). The gripping pressure is compared among three fingers and between weak and strong holding postures in Figure 17.

DISCUSSION

Moveable range of finger of weak grip is regarded to be wider than that of strong grip, and lead to superiority in writing. The results in this study corresponded with this prediction (see Figure 13). This might be effective when writing characters or figures of large size.

As for the tilt (slope) of a pen, no significant differences were detected among holding posture conditions of a pen, and he pitch and roll angles ranged from 24 to 40 deg (see Figure 14). Although such a tendency was observed in

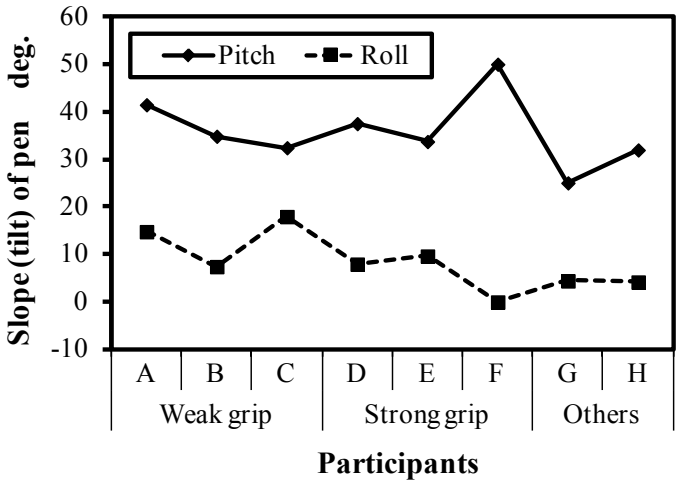

Figure 14. Slope (tilt) (pitch and roll angles) of a pen as a function of type of holding style (posture).

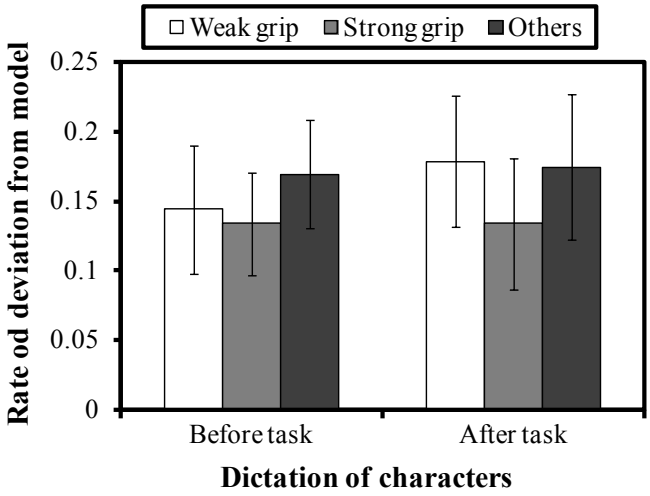

Figure 15. Rate of deviation before and after task as a function of holding (gripping) style of a pen.

Figure 16. Examples of traced characters for weak holding type, strong holding type, and other types I and II.

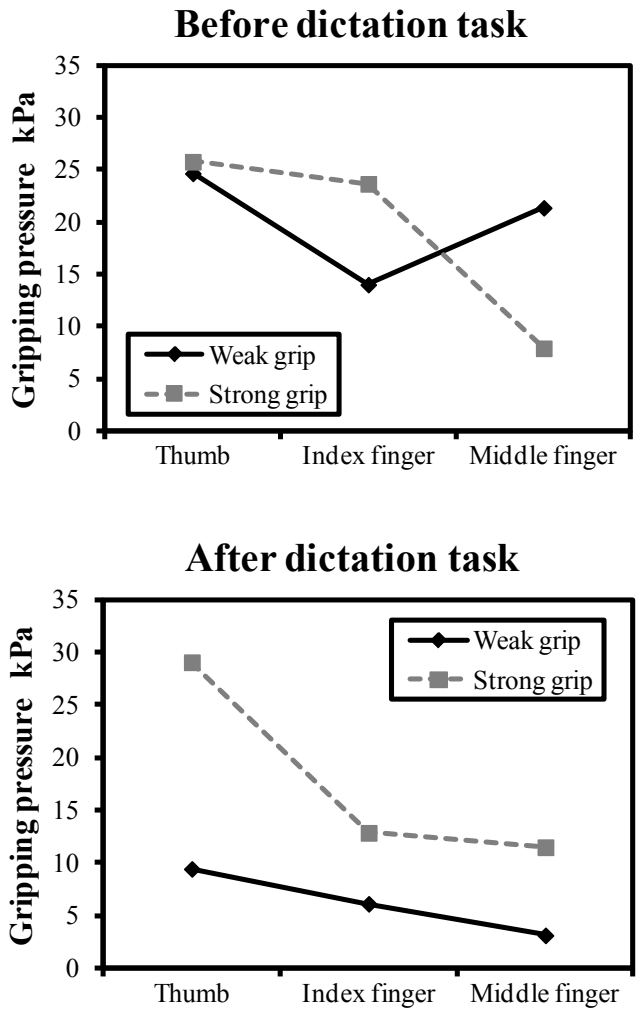

Figure 17. Gripping pressure for thumb, index finger, and middle finger compared between weak and strong grip (holding) types.

this study, the tilt angle of a pen must be one determinant factor that specifies the writing performance. Therefore, the effects of tilt angle of a pen when writing on writing performance or comfort should be explored more systematically. As the obtained measurement characteristics might differ by the type of a pen used, the proper holding posture must be explored for a variety of pens.

Concerning the rate of deviation from the model for figures, no significant difference of this measure was detected among holding postures. The reason might be inferred as follows. When tracing a figure shown in Figure 12, the trace is carried out with one stroke without intermission. This must lead to the dispersion among the participants. Interpretation of the results for characters in Figure 15 might lead to the following conclusions from the viewpoint of the rate of deviation from the model:

Before dictation task:
Weak grip = Strong grip > Others I & II

After dictation task:
Strong grip > Weak grip = Others I & II

In general, the holding posture of a pen which enables one to write characters or figures with smaller gripping pressure induces less muscle workload and eventually less fatigue. Therefore, the weak grip is more practical than the strong grip. Interpreting the results on the gripping pressure, the following conclusions might be reasonable from the perspective of gripping pressure.

Before dictation task:
Others II > Weak grip = Strong grip > Others I

After dictation task:
Strong grip > Others I = Others II > Weak grip

As mentioned above, only for characters, significant difference of rate of trace deviation was detected among holding postures (weak grip, strong grip, and others). Moreover, only for figures, significant differences of gripping pressure were observed among holding postures. The trace of figures might require one to maintain dexterity, while the spontaneous dexterity might be necessary for the trace of characters. This viewpoint must be verified in future research.

Each measurement items (A) tilt (slope) of a pen, (B) moveable area of finger joint, (C) gripping pressure during writing, (D) dexterity (measured by the tracing deviation from the model), and (E) writing pressure were separately evaluated. In order to deepen the understanding on how the proper holding posture of a pen should be and identify the desirable holding posture of a pen, the relevance of these measurement items should be clarified in more detail.

CONCLUSIONS

It was explored how the holding posture (style) of a pen affected the writing performance such as the tilt (slope) of a pen, the moveable area of finger joint, the gripping pressure during writing, dexterity (measured by the tracing deviation from the model), and the writing pressure. While there were no significant differences of moveable range of fingers among three types of holding postures (styles), it was indicated that the weak grip and the strong grip types excels other types before the dictation task, and the strong grip type was superior to other types after the dictation task. Each holding posture, as a whole, has advantages (merits) and disadvantages (demerits). Thus, in the range of this experiment, we cannot judge which holding posture is recommended like Japanese elementary school education generally recommends weak grip as a basic and standard holding posture (style).

In the range of this experiment, we could not reach a definite conclusion (find specific rationale) that weak grip is superior to other holding postures as generally believed to be proper and taught at elementary school, because no remarkable differences of tracing performance, and the tilt angle (pitch and roll) between holding styles (postures) were observed. Future research should increase the sample number, verify and confirm the results in this study, and approach to the ultimate solution on what the ideal holding posture of a pen should be.

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Application of Sensory Thermography on Workers with Carpal Tunnel Syndrome of a Textile Industry in Mexico

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ABSTRACT

This research study deals with the application of sensory thermography on workers of the textile industry who are working in areas where they do Highly Repetitive Movements (HRM). **Objectives**: To analyze those with variations of temperature generated in the wrist area during a period operation of 2 hours 30, showing the feasibility of the implementation of the sensory thermography in this area evaluated. **Methodology**: A total of the workers of the workstation called high risk were evaluated, where 3 men and 3 women (they showed Carpal Tunnel Syndrome CTS of their dominant hand), who carried out their normal activity using a defined protocol for this experiment. **Results**: The maximum temperature was obtained in the experiment of the worker 3 in the right wrist with 35.586°C attained in the time of 1 h 34 min 21; and in the worker 6 was obtained in the left wrist with 34.633°C for a period of 1 h 34 min 56. **Conclusions**: We conclude that in 86% of the cases analyzed in both wrists, there was similarity in patterns of temperature from a wrist to another regardless of the gender and of their dominant hand. All data adjust to the distributions of the three parameters Weibull and Weibull for the wrists.

Keywords: Temperature, thermography, Wrist, Carpal tunnel syndrome.

INTRODUCTION

Musculoskeletal disorders (MSDs), including those localized to the Upper Extremity Musculoskeletal Disorders (UEMSDs) such as CTS and forearm tendinitis, are common, widespread and disabling. They comprised 29% of the approximately 1.2 million total workplace illnesses and injuries resulting in lost days from work in 2007 in the United States (BLS, 2008). In a general European working population (Andersen et al., 2007), found neck/shoulder pain prevalence of approximately 30–50% and arm pain prevalence of 11–28%. In service sector workers, slightly lower prevalence's prevailed. 51% of workers in the European Union used a computer at work in 2005, with an annual growth rate ranging from 3% to 4% (Demunter, 2006).

It has long been known that repetitive motions of the different anatomical structures of the hand and upper extremities can cause injury and disability of one or both limbs. The National Institute of Occupational Safety and Health. Estimates that over 20% of the labor force involved in jobs of repetitive nature is at risk of developing Cumulative Trauma Disorder (Mallory and Bradford, 1989). The most common forms of Cumulative Trauma Disorder (CTDs) are: Tendonitis, tenosynovitis, epicondylitis, bursitis, and CTS. The latter is disabling condition of the hand(s) that can be caused, precipitated, or aggravated by repetitive motions combined with forceful and/or awkward postures (Putz, 1988; Tichauer, 1986). CTS are a specific form of neuropathy in which nerve injury results from compression of neighboring anatomical structures. It occurs up to 10 times with more frequency in women

than men, and it is often seen concomitant to hysterectomy, diabetes mellitus, ophorectomy, and pregnancy (Armstrong, 1983; Benson and Dermott, 1987; Cannon et al., 1981; Hymovich et al., 1966; Phalen, 1966).

Although CTDs are believed to occur in a relatively large segment of the population, they generally go underreported in industry because workers may not associate the symptoms with their jobs, especially when there occur at night after they have left their jobs. In addition, some workers may not report their symptoms for fear of loosing their jobs, or being placed in another area if they complain (Armstrong and Graffon, 1979).

Thermography is a noninvasive technique without biologic hazard. It detects, measures, and converts invisible, surface body heat into a visible display, which is then photographed or videotaped as a permanent record. It graphically depicts temperature gradients over a given body surface are at a given time and has been used to study biologic thermoregulatory abnormalities directly or indirectly influencing skin temperature (Feldman, 1991). Infrared thermography (IR) is widely used to display temperature patterns on the surfaces of the skin by taking pictures (Zontak et al., 1998), unlike thermography sensory which bases its operation as its name says in sensors. This technology has its historical basis in the development of underwater digital temperature recorders used to measure the temperature under the water in natural environments, and with potential applications in areas such as oceanography, marine ecology, and industry, among others (López, 1992).

The contribution of this paper is to analyze and evaluate the variation in body temperature generated in the wrist area with RW and LW through sensory thermography and potential symptoms, emulating an operation of the textile industry with repetitive motion. Also, prove if the data adjusts to a normal distribution and/or what type of distribution, carrying out tests for normality and distribution adjustments based on the data. This investigation allowed the making of questions as: What is the behavior of the temperatures of workers to perform highly repetitive motion over a period of time of 2 hours and 30 minutes? What are the maximum temperatures (Tmax) achieved and its symptoms? Do the temperatures show a similarity on the patterns? Data fit a third order polynomial? What type of distribution data stick?

A review of the state of the art research or sensory thermography applications so far not has been found, but the IR which serves as reference for this research study.

Changes in body surface heat have interested physicians since the days of Hippocrates (Feldman, 1991). It took another 100 years to develop infrared technology, but in then became a classified World War II priority not to be released until 1960s (Accairri et al., 1978; Berthold, 1986; Brelsford and Uematsu, 1985).

Therefore it look over 4000 years-from heat estimation by touch when “fingers did the scanning,” to sixteenth century thermometry, and then another three centuries before thermometers became a staple of medical practice-to arrive at thermography, today’s thermometry of the skin surface. The body’s thermal homeostasis and central control of surface temperature is maintained by a hypothalamic regulating center operating through feedback mechanisms (AMA Council Report, 1987). Both sides of the body are affected uniformly and simultaneously; thus, thermal symmetry is the hallmark of normality, whereas skin surface asymmetry strongly suggests abnormality (Feldman, 1991).

The skin is one of the body’s chief thermoregulators via its large vascular network and associated complex of nerve fibers which together control blood flow within millimeters of the body surface. Superficial perfusion is largely influenced by the sympathetic nervous system. When stimulated by nerve root or peripheral nerve irritation, the sympathetic nervous system causes active vasoconstriction and decreased skin temperature, whereas it greater compromise or complete interruption causes vasodilatation and increased skin temperature. Up to date, the two most commonly used heat detection systems in clinical practice include infrared telethermography and liquid crystal contact thermography (Feldman, 1991).

A review of the state of the art research or sensory thermography applications so far have not been found, but only for the IR which serve as reference for this research study.

The thermography scan can calculate temperature changes in small parts of the body surface. They illustrated the contribution of the IR in diagnosing and corroborating acute, recurrent and chronic clinical symptoms (Feldman, 1991). A study was published to characterize the effect of exercise (balance for 15 min) and responses in the skin temperatures in people with and without carpal tunnel syndrome (Tchou et al., 1992). It was also published a study characterizing the effect of exercise (on an ergonomics bike) and responses in the skin temperatures due to

controlled levels of exercise and temperature conditions (Zontak et al., 1998).

A study was published on the detection of breast cancer by thermography, which has become a powerful tool in conjunction with mammography for diagnostic purposes. Breast cancer is one of the most common diseases among women around the world in these times and is caused by epithelial cells (Dixon et al., 1999). In recent times, its applications have extended to fields such as engineering and in particular to medicine. It is passive in nature and because of that, will not emit any radiation that could harm the patient or put him in some kind of risk. The ideal temperature for making thermal images is between 20 and 25˚C, and as to the percentage of moisture, this must be between 40% and 60% (Ng and Kaw, 2005).

Another study which was aimed to characterize the differences in skin temperatures of between three groups of office workers assessed by dynamic thermography (writing of 9 min). Post-typing differences in skin temperature in response to a 9 min typing challenge were detectable through infrared thermography in three groups of office workers: asymptomatic controls, those with distal UEMSDs without cold hands, and those with distal UEMSDs with cold hands (Gold et al., 2004).

Another study aimed to examine the suitability of using mean dorsal hand skin temperature, before and after a short typing task as an indicator of UEMSD severity. It demonstrated a reliable physicologic method of determining UEMSD severity in office workers through the measurement of dorsal hand temperature using IR under a controlled ambient environment from 18 to 22˚C recommended (Wolf et al., 2009).

A study was published about an analysis of carpal tunnel syndrome developed in the military population of the United States which showed a predominant significance of the group of military women. The unadjusted incidence rate of carpal tunnel diagnoses in our population was 3.98 per 1,000 person-years. The adjusted incidence rate ratio for >= 40 year-old group with the < 20 year-old group as the referent category was 11.63 (95% CI, 10.90, 12.41) (Gold et al., 2009).

A study was published to estimate the temperature conditions that could cause mental stress, this by immersing both hands in a container of water at a temperature of 3˚C (Kim et al., 2006). In addition, a study was published about a professional swimmer, and reflected the skin temperature analysis, in which temperatures were analysed with regard to the swimming styles developed in the experiment (Zaidi et al., 2007).

A study was published to determine the thermographic changes in temperature associated with the elderly and young people. Which consisted of knee flexion with weight of 1 kilogram added to it during 3 minutes? The results contribute to improve the understanding about temperature changes in elderly people (Ferreira et al., 2008). Note that it is mentioned that for a cumulative trauma disorder can be detected, this must have developed well in advance. It's so that a clinical criteria has limited use in developing a model of prevention, in early detection, and the minimization of days lost due to disability (Young et al., 1995).

The contents of this paper are organized as follows: initially presents a general introduction to CTD, IR. Then it shows the materials and methods. Then, results are presented, and finally the conclusion and future research on the topic.

MATERIALS

The material and equipment used in this research study were the following: Digital Sköll thermograph with 4 sensors with a temperature range of 0˚C to 40˚C, precision ±0.3˚C, and a resolution of 0.1˚C (López, 1992); micropore tape; adhesive tape; stop watch; personal computer. For programming the thermographers, the Akela program was used. Lastly, Minitab®16 and Microsoft® Office Excel 2008 statistical packages were utilized.

METHODS

The experiment was applied to 6 workers of a textile industry in Mexico, one of the pre-requisites for the experiment was that the workers did not perform any physical activity during the 20 minutes prior to the start of this experiment (Gold et al., 2004; Gold et al., 2009), this interval was derived based on previous research, in which it was stated that the required time to stabilize the body temperature after undertaking physical activity was approximately 20 minutes (Ng et al., 2001). On the other hand, it was also asked to the workers to avoid the consumption of alcohol or tobacco (Gold et al., 2009; Wolf et al., 2009), due to the fact that smoking induces a reduction in body temperature (Puig, 1993), in contrast, alcohol rises the body temperature (Kim, 2006; A. A. Puig, 1993).

The following step consisted of keeping the company temperature between 20ºC and 25ºC (Ng et al., 2001), controlled by their system of air-condition. After that, the workers sat in the ergonomic chair and the sensors of the thermograph were placed in both wrists (in nerve region). Once the thermographs were in position, both arms were laid down on an entirely horizontal table, in line with the height of the ribs (Ng and Kee, 2008), this position was adopted for the 20 minutes prior to the experiment and after the experiment. Furthermore, a questionnaire was applied to the worker s, aiming to gather some general information related to the age, height, weight, previous injuries and/or traumas.

Then, the workers started a HRM operation for 2 hours and 30 minutes, given the fact that this corresponds to the maximum time a HRM is performed in this textile industry. The HRM operation involved the movements of reaching, taking, and dropping, among others. During the experiment anomalies were identified, discomfort and pain was also registered.

Finally, the after completing the cycle of 2:30 hours and resting for 20 minutes (Gold et al., 2009), the thermographs were detached, the data was downloaded in Microsoft® Office Excel 2008 for post processing, and finally the analysis and validation of data was done with Minitab®16.

The workers that participated in this research were three men and three women work, they were not in normal physical condition, since they show inflammation in the middle nerve (CTS) of their right hand, who carried out their normal activity using a defined protocol for this experiment; during the development of the experiment the environment temperature in the facility was controlled between 20 and 25°C. The main anthropometric characteristics of the workers are summarized in Table 1. It is important to point out, that none of the workers presented lumbar problems, arterial pressure (high or low) problems; moreover, none reported to have any type of alcohol/tobacco addiction.

Table 1. Anthropometric characteristics of the workers

Worker	Age	Gender	BMI (kg/m^2)	Dominant hand	Previous problems
1	33	Male	21.58	Right	Yes, CTS
2	38	Male	23.14	Right	Yes, CTS
3	36	Male	24.15	Right	Yes, CTS
4	30	Female	27.41	Right	Yes, CTS
5	31	Female	22.22	Right	Yes, CTS
6	33	Female	27.83	Right	Yes, CTS

RESULTS

After carrying out the experiment, the results shown in Table 2 were obtained. For the experimental analysis of the results worker 3 was selected, given the fact that this worker presented the maximum temperature of the whole experiment sequence, because this presented the highest temperature (specifically in the right wrist).

Table 2 shows the results of the Anderson Darling analysis, which indicates the type of distribution followed by the data, in this case it was detected that a normal distribution was not trailed by any of the experiments applied. Table 2 also shows the determination coefficient that indicates the percentage of variation of the data.

Table 2. Temperature Patterns

Worker	Tmax in RW	Tmax in LW	Time to obtain Tmax in RW	Time to obtain Tmax in LW	Std. Deviation in RW	Std. Deviation in LW	AD in RW	AD in LW	R^2 Adjusted in RW	R^2 Adjusted in LW
1	35.291	33.012	1:16:29	1:25:27	0.307	0.230	111.6	43.3	58.6	36.1
2	35.274	33.575	1:27:28	1:06:42	0.463	0.312	93.3	56.8	71.2	58.0
3	35.586	33.561	1:34:21	1:34:23	0.455	0.297	114.6	87.9	74.8	69.1
4	34.828	34.390	1:50:13	1:49:58	0.180	0.183	245.7	116.6	77.5	75.2
5	35.039	34.593	1:29:00	1:09:08	0.210	0.374	921.9	892.1	89.2	69.8
6	34.574	34.633	1:08:13	1:34:56	0.239	0.283	216.6	83.5	87.0	86.7

The results of this experiment case can be observed in Figure 1 and Figure 2, for both wrists it was possible to apply a third order polynomial adjustment curve to represent the behaviour of the temperatures during the experiment, bearing in mind that the corresponding coefficient R Square shows this as a results of the experiment. For the right wrist, (Figure 1, temperature versus time) a coefficient R Square of 74.8% was obtained. Successively, it is possible to indicate that the maximum temperature was 35.586ºC, and it occurred after 1 hour 34 minutes 21 seconds. Since the beginning of this experiment until the time that the maximum temperatures are achieved, an increase of 2.862ºC was registered. It is relevant to point out that during the middle part of the experiment; this worker mentioned that he had right wrist discomfort, which prevailed throughout the last part of the experiment in a moderate level of discomfort. Additionally, after 30 minutes of this experiment the worker felt some type of numbness in the fingers.

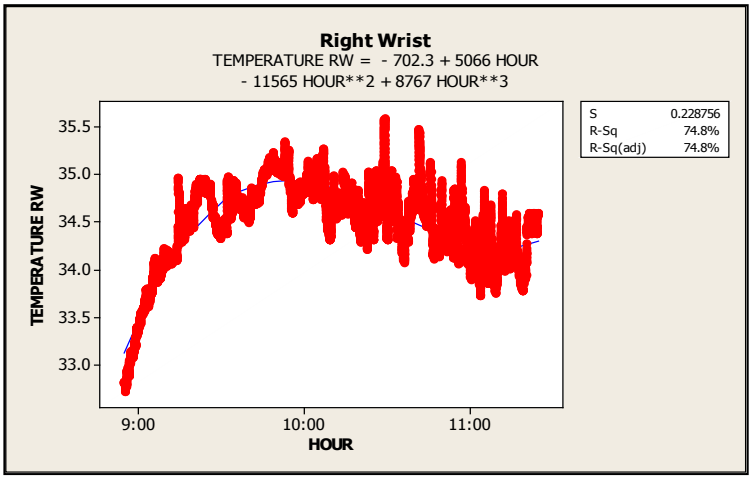

Fig. 1. Worker 3 right wrist Polynomial Adjustment

For the left wrist (Figure 2, temperature versus time), a coefficient R Square of 69.1% was derived. In comparison with the right wrist, it can be observed that the patterns of temperature are very similar. A comparable behaviour was also detected in the results of the other worker, where it is clear that during the first hour there is a constant rise of temperature. Moreover, the maximum temperature reached during the experiment for the left wrist was of 33.561°C, after 1 hour 34 minutes 23 seconds of testing. Since the beginning of the experiment until the time that the maximum temperatures are achieved, an increase of 1.912ºC was registered. It is relevant to point out that during the final part of the experiment; this worker mentioned that he had left wrist discomfort.

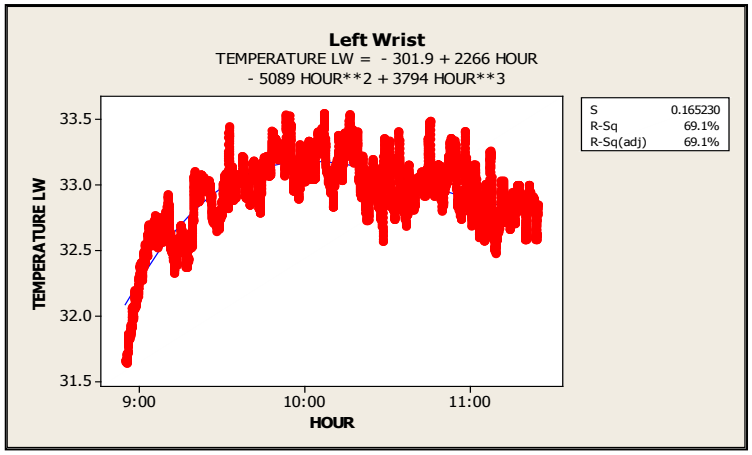

Fig. 2. Worker 3 test day 2 left wrist Polynomial Adjustment

Another part of the analysis that served as evidence to prove that a normal distribution is not followed by the data is shown in Figures 3 and 4, RW and LW respectively; it is possible to visualize that the temperatures with the highest frequencies oscillate between 34.3 and 35.1ºC for the RW (see, Figure 3), and between 32.8 and 33.6ºC for the LW (see, Figure 4).

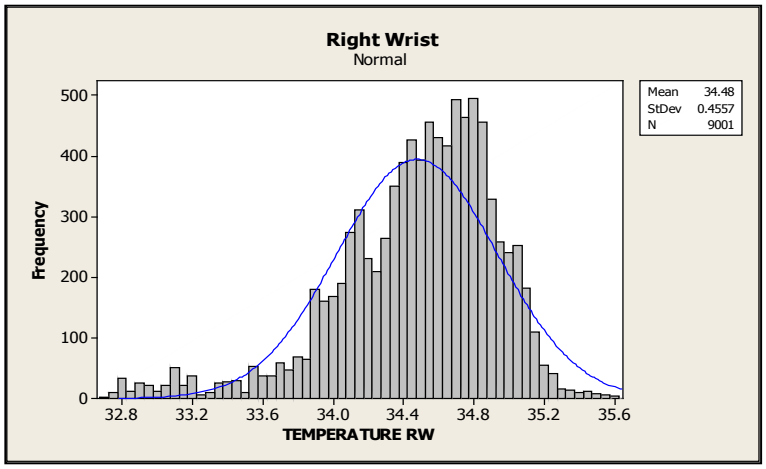

Figure 3. Worker 3 right wrist Histogram.

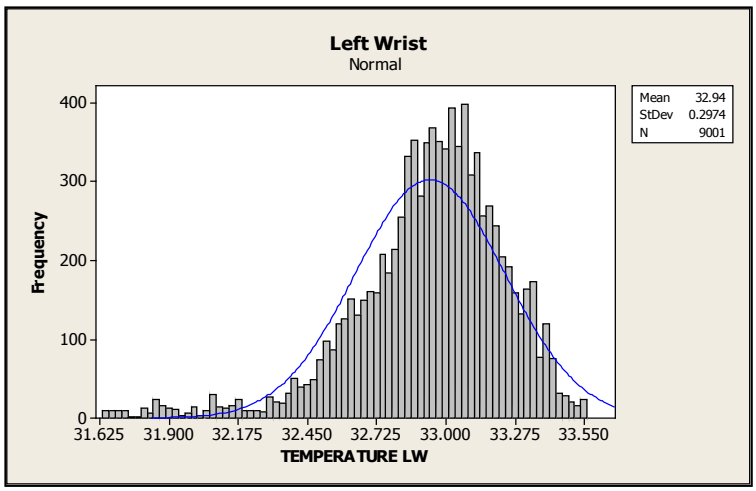

Figure 4. Worker 3 left wrist Histogram.

Figure 5 and Figure 6 show the normality test. For every output dataset from the experiment the next hypothesis was followed: a) Null Hypothesis (H_0) = the dataset follows a normal distribution; b) Alternative Hypothesis (H_1) = the dataset does not follow a normal distribution.

Figure 5 shows the results of the Anderson Darling (AD) assessment, a value of 114.657 is obtained, meaning that the distribution is not normal; it is also visible that the resulting p-value is clearly lower when compared to the significant level that was previously established at 0.05, therefore we must reject the null hypothesis that indicates that the data follows a normal distribution, and follow the same procedure as before to find a distribution that more accurately fits the spread of the dataset showing temperature on the right wrist.

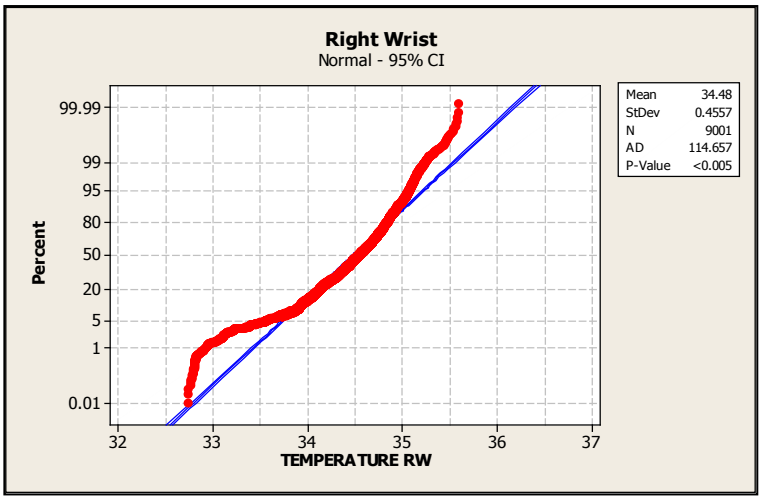

Figure 5. Worker 3 right wrist Normality test.

Figure 6 it can be visualized that for the left wrist the AD analysis produces a value of 87.917, which indicates that a normal distribution is not followed by the dataset, in this case we can confirm that a normal distribution is not followed by checking the p-value, which in fact is also lower than the significant level (set to 0.05, same as for the right wrist), furthermore, the null hypothesis is also rejected for the right wrist. Moreover, it can be concluded that in both AD analysis the statistical values are significantly large.

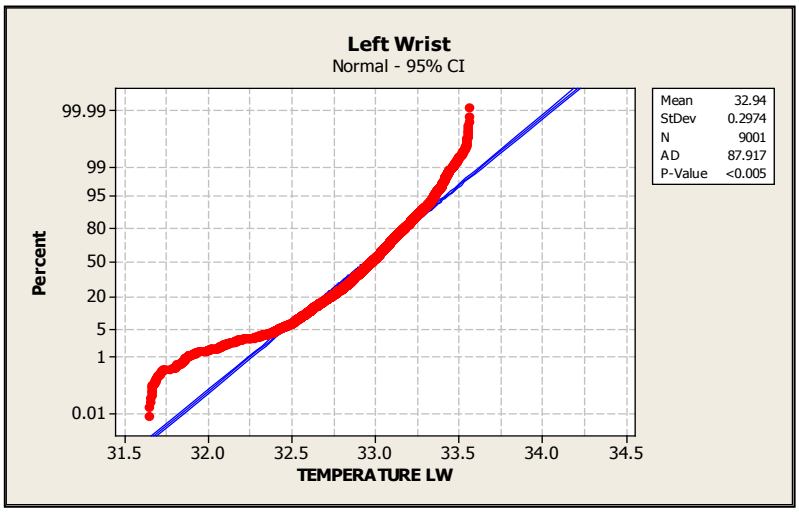

Figure 6. Worker 3 left wrist Normality test.

Table 3, it was showed that in both wrists was possible to set some kind of probability distribution, which was the 3-parameters Weibull distribution (3PW), the Weibull (W) and 3-parameter lognormal (3PL). In all tests, it was the 3PW distribution the best fit to the data (see table 4).

Table 3. Probability distributions of the worker 3

Distribution	Anderson-Darling (adj) RW	Correlation-Coefficient RW	Anderson-Darling (adj) LW	Correlation-Coefficient LW
Weibull	3.669	0.995	14.879	0.996
Lognormal	118.470	0.967	85.238	0.976
3-Parameter Weibull	3.429	0.995	15.864	0.985
3-Parameter Lognormal	109.861	0.967	79.994	0.978

Table 4 shows the summary of the results presented in the experiments in three days. This table is approached from a viewpoint in binary code to represent whether or not the polynomial curve fitting of third order, whether there is similarity in the patterns of temperature, and if one or more probability distributions were present to discuss the RW or LW, as was the case. This is 1 is affirmative and 0 is negative.

Table 4.Probability distributions and settings for all tests

Worker / Test Day	Polynomial fit RW	Polynomial fit LW	Pattern similarity	W RW	3PW RW	3PL RW	W LW	3PW LW	3PL LW
1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	0	1	1	0
5	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1

It can be summarized that the most representative distributions of the 6 workers during the experiment, show whether or not a similitude in temperature patterns was found, furthermore, they datasets can determine if the distribution of the data follows one or more probabilistic distribution for the right wrist or left. Based on the results, we were able to conclude that the dataset shows large resemblances in the patterns of temperature for all three distributions (Weibull and 3 parameters Weibull) for both wrists.

CONCLUSIONS

This research allowed to answer the questions in introduction, being the maximum temperatures reached for the worker 3 in RW 35.586°C over a period of 1 hour and 34 minutes, and 21 seconds (in the experiment 3 , explained in detail in results section) since the beginning of the experiment until the time the temperatures maximum is reached and recorded an increase of 2.86ºC; and the worker 6 in the LW 34.633°C for a period of 1 h 34 min 56.°C in a period of 1 hours and 34 minutes, and 56 seconds (in the experiment 6), since the beginning of the experiment

until the time the temperatures maximum is reached and recorded an increase of 0.657ºC. It is important to mention that in all of the experiments detected discomfort in the right wrist in the time range where the Maximum Temperatures were identified.

It is concluded that temperatures show a similar pattern (see Table 4), that the data fit a polynomial of third order, and that it gets the type of distribution that would fit more the data, such as the parameters 3 Weibull distribution. The sensory thermography offers the early detection of cumulative trauma disorders and with it, it would be possible to prevent further injuries, and perhaps prevent CTD's from occurring. Disorders like the Carpal tunnel disorder or tendinitis could be avoided by using an early monitoring system like the sensory thermography, which in fact provides a cost benefit acceptable relation

It is concluded that the data does not fit a normal distribution for RW and LW, but the distribution fitted Weibull parameters 3 for RW and LW with a correlation coefficient between 0.96 to 0.99, with a significance level of 5%.

Future work is to evaluate a greater number of workers under the same methodological conditions, including the evaluation of elbow and shoulder. C. Camargo, E. J de la Vega, J. Olguín and J. López are currently exploring this research study. In addition to proposing predictive models for the detection and reduction of CTDs in the workplace.

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Refining the Understanding of Workplace Characteristics from an Occupant Centered Perspective with Emphasis on the Influence of Seating Preference

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ABSTRACT

Workplace design not only influences the people's feeling, but also the work or task performance, knowledge innovation, and the employees' loyalty and commitment to their employer. The main purpose of this research is to investigate the subjects' seating preference at workplace and the environmental factors impact their decision. A field survey was carried out on the campus of Dresden University of Technology, and 119 subjects participated in this study. Furniture placement in three different functions of room was employed to conduct this survey. The self-pictured seating preferences indicate that room function influences the subjects' decision of seating area. Having sense of control over physical workplace and privacy significantly impacted the subjects' decisions. However, subjects are not always aware the environmental factors affect their behavior. Subjects attracted by outdoor view and good lighting condition in a general way.

Keywords: Workplace, occupants, furniture placement, seating preference, behavior

1 INTRODUCTION

Workplace changes rapidly with technology development, especially the information technology of the Internet, which is forcing almost all the organizations rethink and regroup. As part of these changes, the environment for work has been conceptualized as the concept of workplace as an active support or tool for getting work done. It is no longer to be the passive setting for work. How building occupants behave as a function of workplace characteristics became one of the growing research interests among the results of this shift. Evidences from empirical researches revealed that employees might spend their precious time and energy to deal with poorly designed workplaces rather than in work. Studies about how occupants interact with and affect by office environment suggest that the quality of architectural workplace has significant effects on occupants' comfort and satisfaction. Achieving high level of comfort and satisfaction at workplace is necessary to guarantee effective work. Vischer (2008) described two measures of workspace quality: functional comfort and satisfaction. The former was defined as the environmental support to work related performance or activities. Functional comfort links occupants' assessment of their work environment to their task performing requirements. The later intend to evaluate the positive or negative feelings (satisfy/dissatisfy) about the work environment. Moreover, physical workplace features have been found correlate to work motivation, sense of well-being, job satisfaction and productivities by previous studies (Carlopio & Gardner, 1992; Olhman, 1988; Wineman, 1986).

Veitch and Newsham (1998) argued that from behavioral point of view, workplace features, occupants and activities happening at workplace are significant factors to determine lighting quality. Subjective measure of perception, preference and performance are the important markers of lighting quality. This study broadens this argument to workplace quality base on human centered theory of built environment. We focus on examining subjects' seating preference in an enclosed space. Occupants seating preferences in a space can provide deep insight of understanding

the subjects' preferences of architectural space features. Researches suggested that people has strong desire of having access to outdoor view in workplace because they sit for long time at their desk (Cuttle, 1983; Collins, 1975; Nagy, Yasunaga, & Kose, 1995), and having window in workplace can increase job satisfaction and achieve higher comfort rating (Finnegan & Solomon, 1981; Leather et al., 1998). However, other researchers found out that proximity to window may cause the sense of lack of privacy (Yildirima et al., 2007). Most of current occupants' preference studies in built environment are through post-occupancy evaluation. These evaluations are aim to the follow-up actions rather than understanding the causal relationship between architectural space factors and occupants behavior. Wang (2010) described having sense of control and privacy were two concealed factors influence occupants' behavior regarding to the distance between sun patch on the floor and subjects in a sunlit room. Another research revealed that having high level of control over physical workplace significantly and positively relate to job satisfaction and group cohesiveness (Lee & Brand, 2005). We proposed two hypotheses concerning occupants' preference in an enclosed space: (1) Occupants' preferred seating positions are correlated to space function; (2) Having control over physical space significantly affect the determination of occupants' seating location.

2 METHOD

The field survey was carried out on the campus of Dresden University of Technology (TUD). Participants came from different departments of TUD. In total 119 subjects contributed to this study. 58% of them are male and 42% are female. They age from 17 years old to 32 years old, and only one researcher at his age of 37 years old. 73% of participants have been worked in office before. The questionnaires were collected by physical distribution of hard copies. Furniture placement in an unfurnished space (Figure 2.1) with natural outdoor view was employed in present investigation. The test room is 4.5m * 6m. Three pieces of furniture were used to represent three common functions of the workplaces. There are meeting table, relaxing set and individual work desk (Figure 2.2). Meanwhile, possible reasons for furniture placement were provided. Participants were asked to rank these reasons for their options. These items were adapted from previous research (Wang, 2010).

Subjects were given three copies of room plan with identical layouts, representing three independent test rooms. They were asked to place meeting table first, a relaxing set next, then a work desk on the floor plans of the three rooms separately. Participants were told to imagine their activities with furniture and indicate their preferred sitting spots in these three rooms. Although subjects were not sitting in an actual room and moving the actual furniture, they were provided the images of an unfurnished room with natural outdoor view and the task furniture to provoke the psychological stimulations. Moreover, the subjects were having adequate freedom to picture their activities. Thus, mapping technique is an effective way to study occupants' seating preferences and the patterns of their occupation for different scenarios. The environmental factors, the purpose of room and subjects' activities might affect their seating preference and decisions.

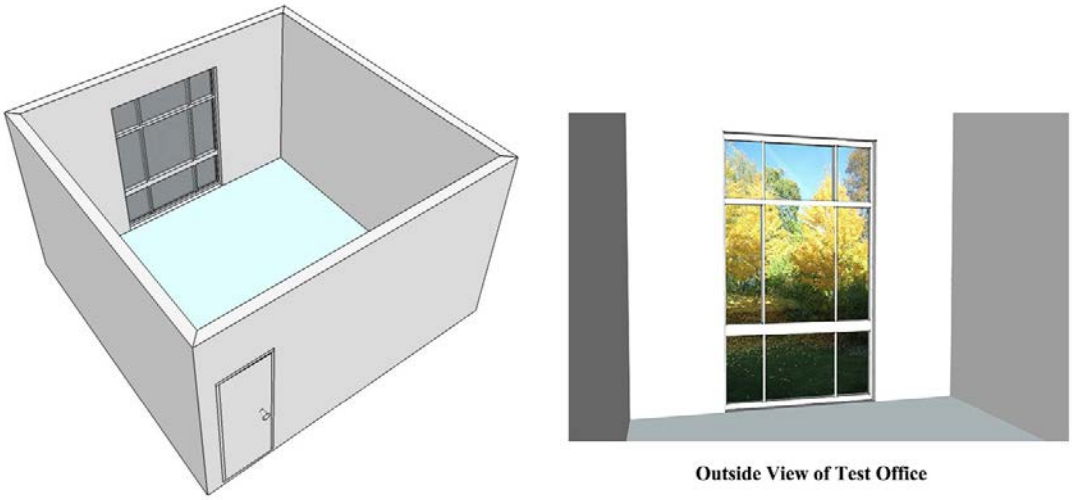

Figure 2.1. Model of test office

Figure 2.2. Three pieces of furniture from left to right: meeting table, relaxing set and single work desk

3 RESULTS

Of 357 total plans, 303 had adequate data on relevant variables and were thus included in analysis. We overlapped each set of 101 plans with the same type of furniture. The results are analyzed and presented from three aspects:

(1) The relationship between subjects reported preferred seating spot and outdoor view, whole space;

(2) The most popular orientations that subjects selected relative to outdoor view and whole space;

(3) The major reasons that affect the determination of their activities.

3.1 Meeting table

The majority of subjects 61% arrange meeting table in the center of the room (Figure 3.1). The top two reasons (Chart 3.1) for meeting table arrangement are in the center of the room (27%) and lighting (26%). There was no significant statistic difference between these two reasons. Subjects (27%) mention that they use to have meeting table in the central of the room and easy traffic for the people attending a meeting. Having good lighting conditions are also appreciated by subjects. Therefore, the subjects' former spatial experience and room's function affect their decision of furniture arrangement. Figure 3.2 presents 63% of subjects chose to orientate the long edge of meeting table paralleled the long edge of room; 30% orientated the long edge of meeting table verticalize the long side of room (Figure 3.3); 7% people orientated their meeting table in other directions like 60° or 120° with long side of room.

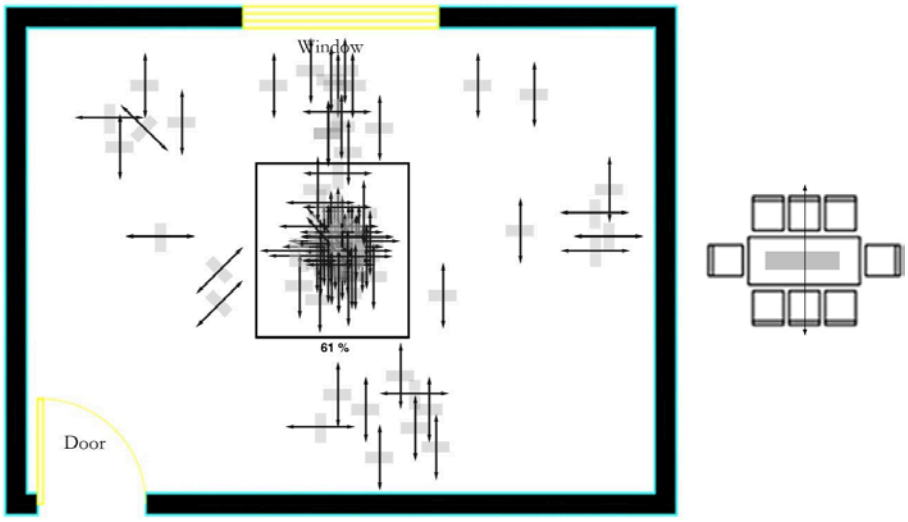

Figure 3.1. Meeting table arrangement

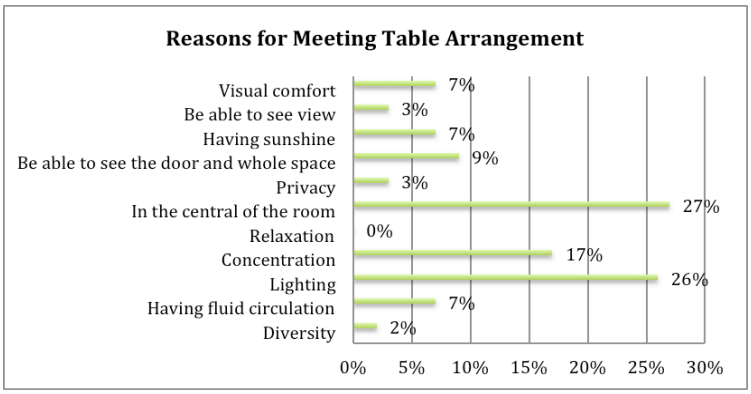

Chart 3.1. Reasons for meeting table arrangement

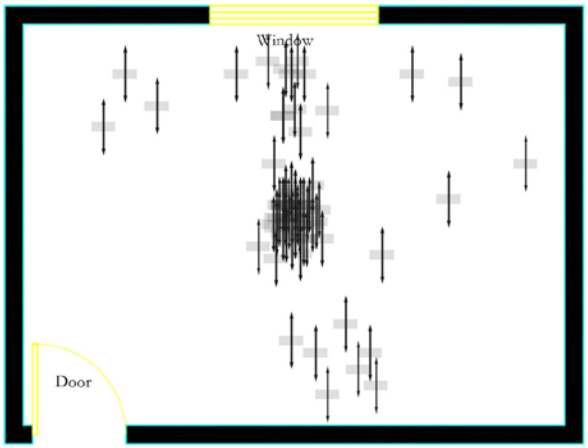

Figure 3.2. 63% orientating meeting table paralleled window

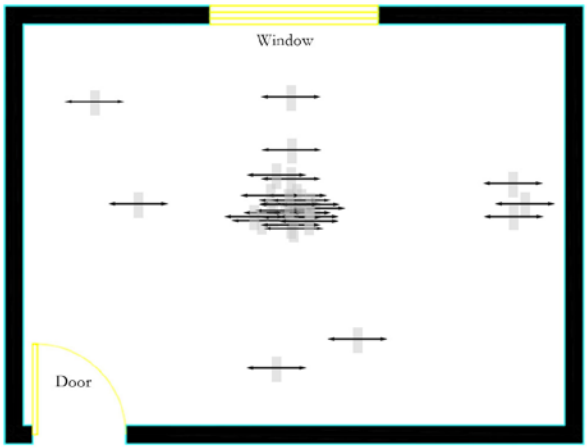

Figure 3.3. 30% orientating meeting table verticalize window

3.2 Relaxing set

From the map of relaxing set, there are three favorite spots: over 60% subjects prefer to locate relaxing set in the corners of room away from the entrance. Figure 3.4 shows 30% subjects prefer to arrange relaxing set at right down corner of the room; 26% of them prefer to seat close to window for relaxation; 24% willing to place relaxing set at right up corner of the room; only 7% subjects prefer to seat at the left up corner of the room. Obviously, right down corner of the room is the most popular zone in the room for relaxation.

Relaxation (29%) was the most selected reason for relaxing set arrangement; being able to see the outdoor view was appreciated by 17% of subjects; privacy was ranked as the third consideration for relaxing chair placement (Chart 3.2). Figure 3.5 to Figure 3.7 present the subjects' preferred orientations for relaxing set in the room. Figure 3.5 indicates 39% subjects prefer to orientate relaxing set to be able to see both of the entire room and outdoor view; 17% people prefer to view the entire room (Figure 3.6); 35% prefer to orientate the relaxing chair and table to view outside of the room (Figure 3.7). Having visual dominance of the entire room is the most significant consideration while subject orientate the relaxing set in the room. However, this feature wasn't rank as the top reason for their desired activity with relaxing chair and table in the room.

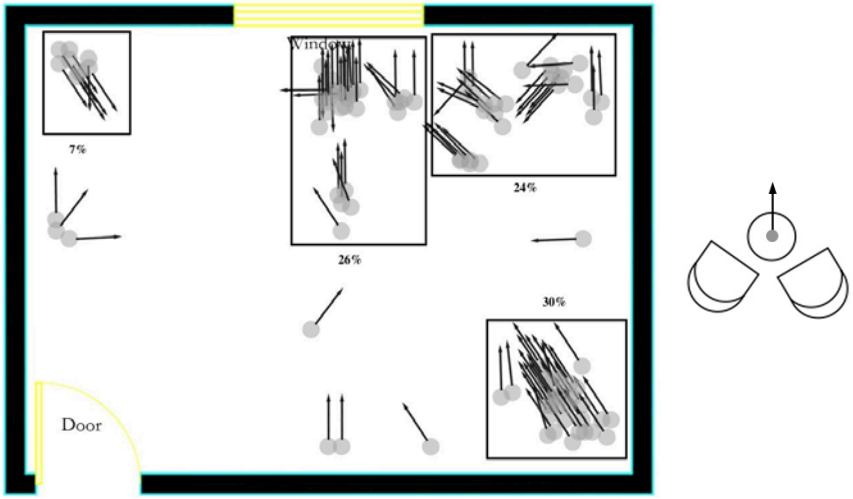

Figure 3.4 Relaxing set arrangement

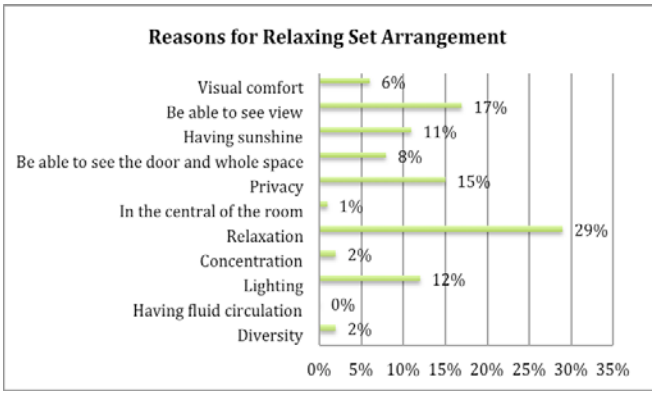

Chart 3.2 Reasons for relaxing set arrangement

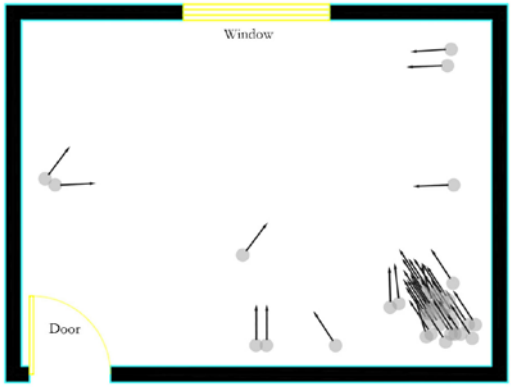

Figure 3.5. 39% subjects viewing whole space & outdoor view

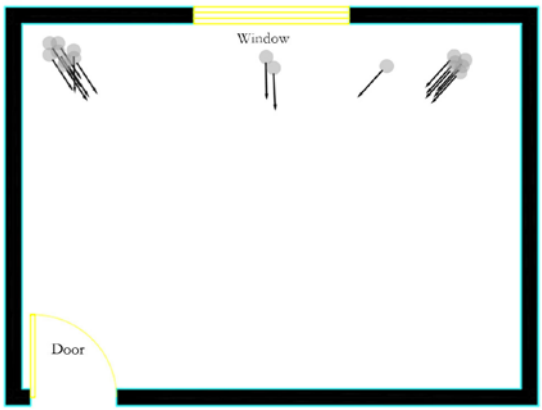

Figure 3.6. 17% subjects viewing whole space

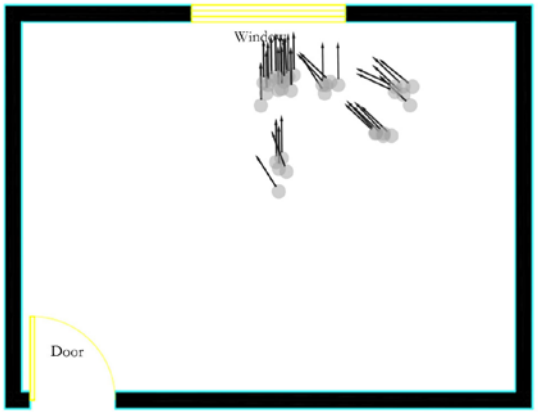

Figure 3.7. 35% subjects viewing outdoor view

3.3 Individual work desk

Different from placing relaxing chair and meeting table, many subjects (45%) prefer to put the individual work desk close to window; 14% of subjects prefer to place their individual work desk at the right center of the room and close to the wall (Figure 3.8). Having good lighting (32%) condition has been found as the first consideration while individual work desk arrangement. 23% of subjects considered concentration for individual work desk arrangement. Having sunshine and privacy were appreciated by same numbers of subjects (14%). The nature of individual work influences subjects' decision of work desk arrangement to

concentrate. For the seating orientation, 34% of subjects chose to orientate their workstation to see the both entire room and outdoor view through window (Figure 3.9); 29% prefer to view outdoor view (Figure 3.11) and 22% participant prefer to orientate the work desk to view entire room (Figure 3.10).

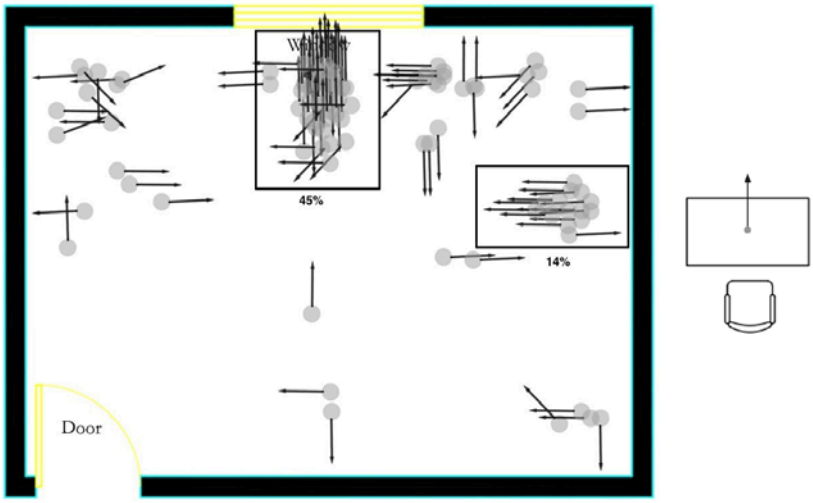

Figure 3.8 Individual work desk arrangement

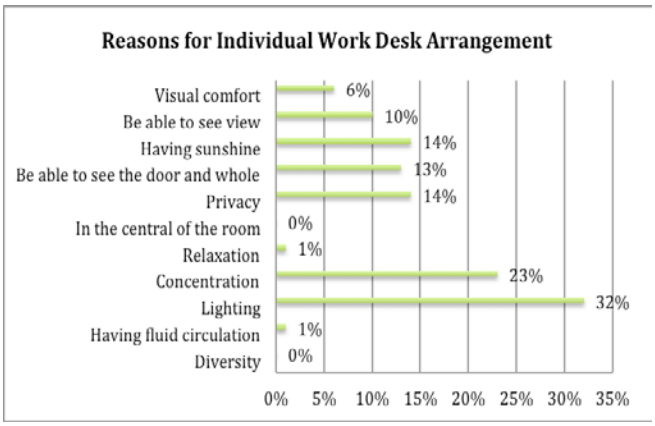

Chart 3.3. Reasons for individual work desk arrangement

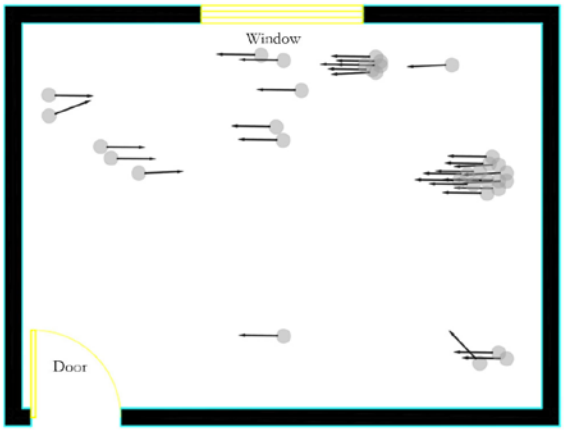

Figure 3.9. 34% subjects viewing whole space and outdoor view

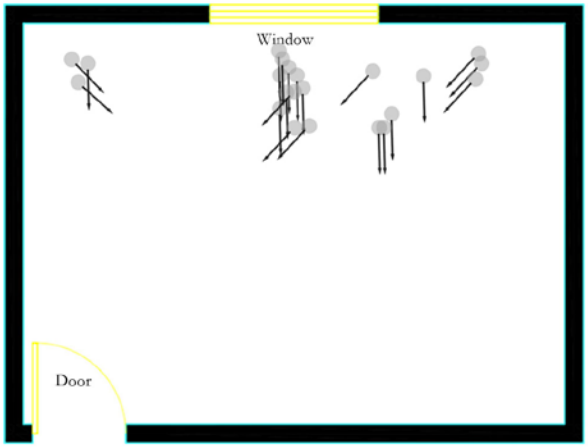

Figure 3.10. 22% subjects viewing whole space

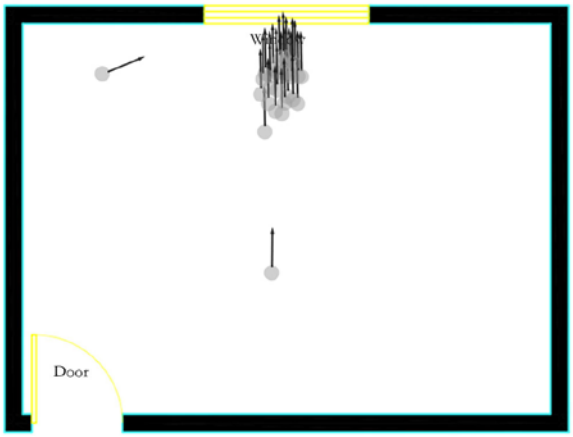

Figure 3.11. 29% subjects viewing outdoor view

4 CONCLUSIONS

We consider workplace quality from occupants' behavior point of view to study occupants' seating preference in an enclosed room. This study was aim to identify the physical environmental factors influence subjects' occupancy in a workplace. We hypothesized that space function affect the determination of occupants' preferred seating position. This hypothesis was supported by the findings. Occupants' consideration of their activities with given furniture in different functions of space vary from each other. Meeting table was desired to put in the center of the room. Unlike meeting room, corners away from the door and viewing outside are more appreciated for relaxing area. The area where close to window was attracted more attention for individual concentration and having the outdoor view and natural light. The findings also suggest that occupants' former spatial experience somewhat affect their decisions.

The results of subjects' self-pictured behavior maps supported the hypothesis of having control over physical space and privacy significant impact occupants' activities in a room. They impacted subjects' preferences and planed activities in a significant way. Majority subjects prefer to seat in a spot where having access control over the entire room, away from the entrance, high level of privacy and having visual contact with outdoor view. However, they were not selected as the most popular factors that affect occupants' activities in a room. Therefore, subjects are not always aware the environmental factors that influence their behavior.

The present study has several limitations. One important limitation of this investigation is that subjects were not sitting in a real room with proposed test conditions. They were given pictures of the test room model and furniture, and were asked to imagine they were in that room. The results demonstrated that without real environment stimulus, the subjects somehow cannot fully understand and aware the listed environmental factors that might influence the determination of their activities with given furniture. Another limitation concerns that our test spaces are unfurnished empty space. We simplified the room condition. Some other environment factors might influence subjects' preferences were ignored, like interior color, texture, facilities. Further research could add these factors in the test space to see if a strong correlation appears.

These limitations should be viewed as potential directions for future research since they cannot be addressed in present studies. A set of controlled test rooms with common layout could be better stimulating the physical architectural factors. Gradually varying color and texture of the interior wall, adding working related facilities or reference into the basic unfurnished test room to study how these factors influence occupants' preference and activities in a workplace.

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Ergonomic Principles and Regulatory Standards Related to Personal Protective Equipment (PPE) Used in the Textile Industry

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ABSTRACT

The article describes a survey that aimed to point ergonomic principles and regulatory standards related to personal protective equipment (PPE) used by workers in textile industries in Joinville, SC, Brazil. The research took place in the form of semi-open questionnaire, along with seventy-three workers from the productive sector of two textile companies in Joinville, including men and women of various ages. One of the companies was of medium size, with a focus on textile processing. The second was a large one, focused on manufacturing knitwear and clothing. Through research it was possible to identify types of safety equipment used in this industry segment and, thus, it emerged that are not used particular PPE but the same as used in other areas of work involving risks to physical and psychological integrity of the employee. From the relationship between the ergonomic principles and regulatory standards it could be suggested aspects that deserve attention in the design and analysis of PPE. As well, some questions emerged that may originate other studies in this area.

Keywords: PPE, Textile Industry, Ergonomics, Regulatory Standards.

INTRODUCTION

This article describes an exploratory research project aimed at identifying ergonomic principles and regulatory standards related to PPE used by workers in the textile industry in Joinville, SC.

PPE consist of devices and accessories for use by workers whose job puts their health or physical integrity at risk. The use of this equipment is obligatory when the safety measures to be taken are not effective (Brasil, 2011). However, studies show the misuse or even the non use of PPE by operators and workers due to being inconvenient or uncomfortable, or to a lack of information regarding their correct use or, in some cases, a lack of safety management programs at work (Pelloso and Zandonadi, 2012). Based on this scenario, a group from the textile segment was selected from among many others, not just because of the connection with one of the authors who had worked in this sector but because the city in which the study was conducted is one of the centers of this segment in the region. For this study, theoretical aspects about ergonomics were investigated, as well as their importance for PPE, in addition to regulatory standards related to textile industry activities. The study, which was descriptive in nature, was divided into three stages: (1) literary revision of ergonomics and their importance in PPE. Learning about the regulatory standards found in textile industries, through bibliographic means, documents, books and in scientific articles related to ergonomics, PPE and regulatory standards; (2) identification of PPE types used in the textile industries of Joinville; (3) study of ergonomic principles and regulatory standards related to PPE used in the textile industry.

PPE AND REGULATORY STANDARDS

According to the Regulatory Standard no. 6 – NR 6 (BRASIL, web), personal protective equipment includes the "device or product for individual use by the worker as protection against risks likely to threaten safety and health at the work place". Thus, PPE is intended to protect the worker, preventing or lessening the severity of accidents and protecting the body and organism from the harmful effects of toxic substances, excessive noise etc. The use of such devices is provided for in laws for certain activities and in the service and industrial segments such as textile, metal mechanics, civil construction and printing, among others.

According to Bitencourt and Quelhas (1998), on 8th July 1987, Ordinance No. 3,214 was implemented, which defines Regulatory Standards (Normas Regulamentadoras-NRs). These, which are still in effect, refer to work safety and medicine and determine that companies must comply with the standards set in order to minimize or avoid problems related to the work environment and to occupational health (Bitencourt and Quelhas, 1998). With the evolution of large industries, various standards have been created. Currently, there are 36 NRs, among which is the standard that regulates the use of PPE, implemented on 8th July 1987, under Ordinance No. 3,214 (Brasil, 2008).

The standard which specifically covers the use of PPE is NR 6. This standard determines the obligatory use of PPE, which must be appropriate to the risk and freely distributed to workers by the company when overall accident prevention measures do not offer complete protection (Brasil, 2011). The NR 6 further states that it is the responsibility of the employer to ensure the proper use of PPE and keep a record of their distribution to the worker (Brasil, 2011). The worker should be given guidance on correct use, methods of conservation, how to clean and periodic maintenance of the PPE that they are provided with (Brasil, 2011). Thus, the worker is obliged to use the protection equipment in the proper manner for the purpose for which it was intended while being responsible for storing and looking after the PPE in compliance with proper use of the equipment as determined by the employer (Brasil, 2011). In addition to NR 6 related to PPE, it is also important for this study to mention the standard that refers to Ergonomics.

The NR 17 establishes the adaptation of work conditions to the psycho-physiological characteristics of the workers so as to provide maximum comfort, performance and safety, including work conditions in aspects related to transport, handling and unloading of materials, from the furniture and equipment to environmental conditions at the work station, as well as its organization (Brasil, 2007).

It is thus verified that the aim of ergonomic measures such as PPE is to offer safety and well being to the worker in the work environment. Therefore, considering the object of this study, it can be said that the NR 6 and the NR 17 are supplements. The importance of recognizing the ergonomic principles applied to products should be emphasized in order to be able to establish analysis criteria as well as to guide questions addressed to the operators who are the target of this study.

ERGONOMICS

With the increase of capital and the evolution of industries, the role of their workers have become more complex with the passing of time, leading to an increase in work accidents and incidents (Iida, 2002). Considering this, Ergonomics can provide safety measures through reducing work related psycho-physiological factors, thus offering improved suitability or adaptation of the object to individuals, aimed at their safety and comfort as well as the efficient use or operation of the objects in human activities and tasks (Gomes Filho, 2003). The author (2006) further points out that Ergonomics addresses problems related to physical configurations and features such as the functional and perceptual qualities of use by making use of analytical and diagnostic tools as well as observing detected problems. These are related to various factors, possibly contributing to a decrease in the quality and performance of human activities as well as causing insecurity and discomfort for the user (Gomes Filho, 2006).

According to Soares et al. (2001), most accidents with products can be attributed to their use, to design related

factors, to the environment in which they are used and also to user behavior. Given this, it is worth remembering that PPE does not overall prevent accidents but it does prevent injuries, natural accidents such as contact with toxic agents. In order for this equipment to follow ergonomic principles it must offer the user comfort, safety and efficiency at work.

ERGONOMIC AND REGULATORY ASPECTS RELATED TO PPE USED IN THE TEXTILE INDUSTRY

A study was conducted on the types of PPE used in the textile industry with seventy-three workers from the productive sector of two textile companies in Joinville, consisting of men and women of varying ages. One of the companies was of medium size, focused on textile processing. The other was a much larger company, focused on manufacturing knitwear and clothing. Information was collected through a semi-open questionnaire conducted by Pozza *et al.* (2014).

Thus, among the PPE used in the textile segment, the following can be cited: ear plugs, muffler, helmet, breathing mask, face mask, goggles, gloves, aprons, overalls, special pants, leather shoes and boots. The most commonly used PPE is the leather shoe, which was used by almost all the productive sectors in the companies studied (Pozza *et al*., 2014). Other PPE is distributed in accordance with the job performed by the worker. It is understood, however, that the productive sector of a single company has different functions, each one with its own functional specifics and safety needs. Taking the Ergonomic objects into account, as highlighted by Gomes Filho, and the objects of the exploratory research herein described, it can be said that the ergonomic aspects related to PPE include both the psycho-physiological factors of the users as well as the suitability of the equipment for these users, providing them with safety, comfort and efficiency in performing their tasks. While considering PPE ergonomics as an isolated product, it is deemed important to pay attention to their physical features and configurations. It has been found that PPE is used in various sectors in textile companies for different functions and by people with varying body compositions, including both men and women. Thus, it is important to verify PPE characteristics such as: material from which it is made; modeling or shape; size, weight, colors, mode of wearing. When taking the ergonomics of the PPE into account as work equipment for workers to carry out their tasks, it is important to analyze the functional and perceptual qualities of the equipment. The functional qualities may establish: if the equipment is comfortable; if it helps the worker in performing the task. The perceptual aspects can cover questions related to the psychological well being of the user regarding the PPE, seeking to establish if it is considered to be ugly or beautiful and if the worker feels confident in performing his/her task using said equipment.

In relation to the NRs 6 and 17 pertaining to PPE and Ergonomics, respectively, there are several aspects that can guide research focused on PPE in various segments other than the textile segment. The NR 6 states that the PPE must be adapted to the risk to which the user is subject to. In this case, does the PPE offered to workers today meet this criterion? Does it provide adequate safety for the user when performing of their tasks? Another point highlighted in the NR 6 is the importance of the proper use of the PPE as well as guidance on its correct use, conservation methods, ways of cleaning and periodic maintenance. Based in this, an opportunity was identified for instructional design projects that could guide users in relation to the use, care and maintenance of PPE. The NR 17 relates to Ergonomics and addresses the ergonomic principles already mentioned in this topic – efficiency, comfort and safety.

CONCLUSIONS

The aim of the aspects addressed in this article was to relate the ergonomic principles and regulatory standards to the PPE used in the textile industries. Through the research it was possible to identify the types of safety equipment used in this industrial segment and, thus, ascertain that specific PPE is not used, and the equipment that is used is the same as the equipment in other work areas the physical and psychological integrity of the worker is at risk.

Based on the relationship established between the main ergonomics and regulatory standards, this can suggest aspects that deserve attention in the PPE project and analysis. Furthermore, certain questions appeared that could give rise to other studies in this area.

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Section 8

Experience and Performance

New Trend Line of Research About Comfort Evaluation: Proposal of a Framework for Weighing and Evaluating Contributes Coming From Cognitive, Postural And Physiologic Comfort Perceptions

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ABSTRACT

In HMI design, several parameters have to be correctly evaluated in order to guarantee a good level of safety and well-being of users (humans) and to avoid health problems like muscular-skeletal diseases. ISO Standards give us a good reference on Ergonomics and Comfort: ISO 11228 regulation deals with several parameters for evaluating Postural Ergonomics in manual loads' push/pull, in manual loads' lifting and carrying and in repetitive actions. Those parameters can be synthesized in a "Postural Load Index" that represents the Ergonomics level of examined posture. Nothing has be done, by ISO, in order to give a method/criterion for evaluating comfort performances of products and workplaces. More than 100.000 scientific papers dealing with comfort and discomfort can be easily found in main scientific databases and most of these speak about relationship between environmental factors (like temperature, humidity, applied forces etc.) and perceived comfort/discomfort. Several papers follow the assumption that there is a relationship between self-reported discomfort and musculoskeletal injuries and that those injuries affect the perceived comfort; however, the theories relating comfort to products/processes and products/processes' design characteristics are rather underdeveloped. One of the most recent and interesting paper about comfort perception and its evaluation is the Vink-Hallbeck (2012) one in which the Moes' comfort perception model (2005) has been developed and improved. In our paper, a simplified model of comfort perception, that seems to work well with the Vink-Hallbeck one, has been proposed and takes into account four aspects that strongly affect the global comfort perception: (B) – User Biomechanics/Posture, (P) - Physiologic factor, (E) – Environment contribute, (C) – Cognitive factor. Each of these aspects can be split in sub-aspects that have to be taken into account in order to be evaluated and correlated to subjective comfort perception. This paper want to explain all those sub-aspects, analyze the state of the art about their evaluation and propose an easy-to-use framework for weighing and evaluating contributes coming from cognitive, postural and physiologic comfort perceptions (no environment's factors have been studied) to the global comfort perception.

Keywords: Comfort evaluation, cognitive comfort, postural comfort, fusion rules

INTRODUCTION

What are new trend lines of research about comfort evaluation and about the objective and predictive techniques for quantifying and qualifying the comfort perception by human? As we will explain in next paragraphs, researchers are attempting to give answers to this question but in a wide literature overview, it is possible to highlight many partial aspects that have been studied very well. Just a few researchers (Moes 2005 and Vink-Hallbeck 2012) have studied

the problem of comfort perception and evaluation under a wider point of view. Nevertheless, some aspects seems to be not still taken into account! In this paper, we try to extend the Vink-Hallbeck model in order to build a comfort perception/evaluation matrix in which four kinds of comfort, related to different humans' perception, have been studied and linked to the whole working environment's characteristics.

STATE OF THE ART ABOUT COMFORT/DISCOMFORT PERCEPTION MODELING AND EVALUATION

One of the most studied aspect of comfort perception is the one due to postural configuration (Naddeo and Memoli, 2009). The existing literature proposes many different methods for an ergonomics evaluation by assuming that postural comfort is related to musculoskeletal disease; the most common and well-known evaluation methods are the following:

1. RULA - Rapid Upper Limb Assessment (Lynn McAtamney and E. Nigel Corlet, 1993);
2. REBA - Rapid Entire Body Assessment (Sue Hignett and Lynn McAtamney, 2000);
3. LUBA - Loading of the Upper Body Assessment (Dohyung Kee, Waldermar Karwowski, 2001).

These methods are based on the measurement of anthropometric parameters. Generally, the "Comfort" can be defined as the "level of well-being" perceived by humans in a working environment; this level is extremely difficult to detect and measure because it is affected by individual judgments that can be analyzed using quantitative and qualitative methods. Some methods, such as the "Rating of Perceived Exertion" (Borg, 1982), have been developed to "measure" postural comfort under exertion conditions, but this approach seems insufficient for decoding the whole perception. Looking at scientific literature from the past 30 years, it is possible to identify more than 100,000 scientific papers dealing with comfort and discomfort; the majority discuss the relationship between environmental factors (temperature, humidity, applied forces, etc.) that can affect the perceived comfort or discomfort (Tilley A. R., 2001). Several papers follow the assumption that there is a relationship between self-reported discomfort and musculoskeletal injuries, with these injuries affecting the perceived comfort (Holzreiter S. H. and Köhle M. E., 1993). However, the theories linking comfort to products and product design characteristics are rather underdeveloped; the rare papers explaining the concept of comfort include Helander and Zhang, 1997, De Looze et al., 2003, Kuijt-Evers et al., 2004 and Moes, 2005. Five main topics have been identified as the ones address the relationship between the subjective perception of comfort or discomfort and the factors of product, process, interaction, environment, and user characteristics:

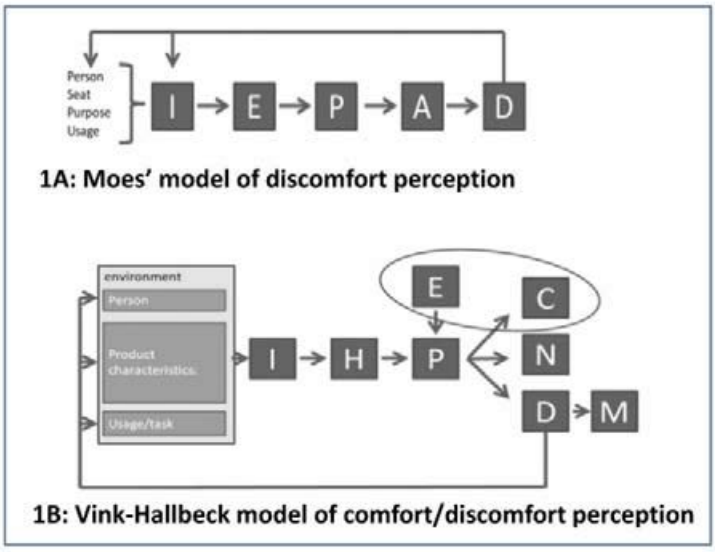

Figure 1. Models of comfort and discomfort perception

1. Sensory input (De Korte, 2012 and Vink et al., 2012);
2. Activities during the measurement that influence comfort (Groenesteijn et al., Ellgast et al., 2012);
3. Different bodily regions (Franz et al., 2012, Kong et al., 2012);
4. Effect of the product contour on the comfort experience (D'oria et al. 2010; Kamp, 2012; Noro et al. 2012);
5. Physical loading (Kee and Lee, 2012; Naddeo and Memoli, 2009; Zenk et al., 2012; Di Pardo et al. 2008).

Considering these factors, Vink & Hallbeck (2012) provide an interesting schematization of the mechanism of comfort/discomfort perception based on Moes' (2005) model represented in Fig.1A. In this model, the process that causes a discomfort experience is represented as five phases: interaction (I), effect in the internal body (E), perceived effects (P), appreciation of the effects (A), and discomfort (D). Moes developed a model of comfort perception applying it to seat comfort. He highlighted that perception process is "dependent on the person, the object in work-space (seat), the purpose and why this object is used." In particular he schematizes the process describing that if a person uses a seat with a specific purpose, interaction (I) arises. For example, the interaction may involve the pressure distribution of the contact area between the subject and seat. An interaction results in internal body effects (E), such as tissue deformation or the compression of nerves and blood vessels. These effects can be perceived (P) and interpreted as pain for instance. The next phase is the appreciation (A) of the perception. If these factors are not appreciated, it can lead to feelings of discomfort (D).

Moes' model, modified by Vink and Hallbeck, is depicted in Fig.1B: The interaction (I) with an environment is caused by the contact (also non-physical contact, like a signal in the study of De Korte et al., 2012 between the human and the product and its usage). This can result in internal human body effects (H), such as tactile sensations, body posture change, and muscle activation. The perceived effects (P) are influenced by the human body effects, but also by expectations (E). These are interpreted as "comfortable" (C) or "you feel nothing" (N), or they can lead to "feelings of discomfort" (D) (Vink and Hallbeck 2012).

In this work, we try to expand and detail the Vink-Hallbeck model in order to take into account other new aspects of the problem. Most part of scientific works deal with relations explained in the Vink-Hallbeck model, but there are also papers that treated the influence of the environment and the effects of the devices used for the comfort evaluation. All these factors need to be studied with a higher precision in order to deploy the macro-voices of Vink-Hallbeck model and to define a fusion rule for all the aspects that affects the comfort perception.

PROPOSAL OF A WIDER MODEL FOR COMFORT/DISCOMFORT PERCEPTION

A wider model that seems to work well and include the Vink-Hallbeck one can be easily explained in the following figure:

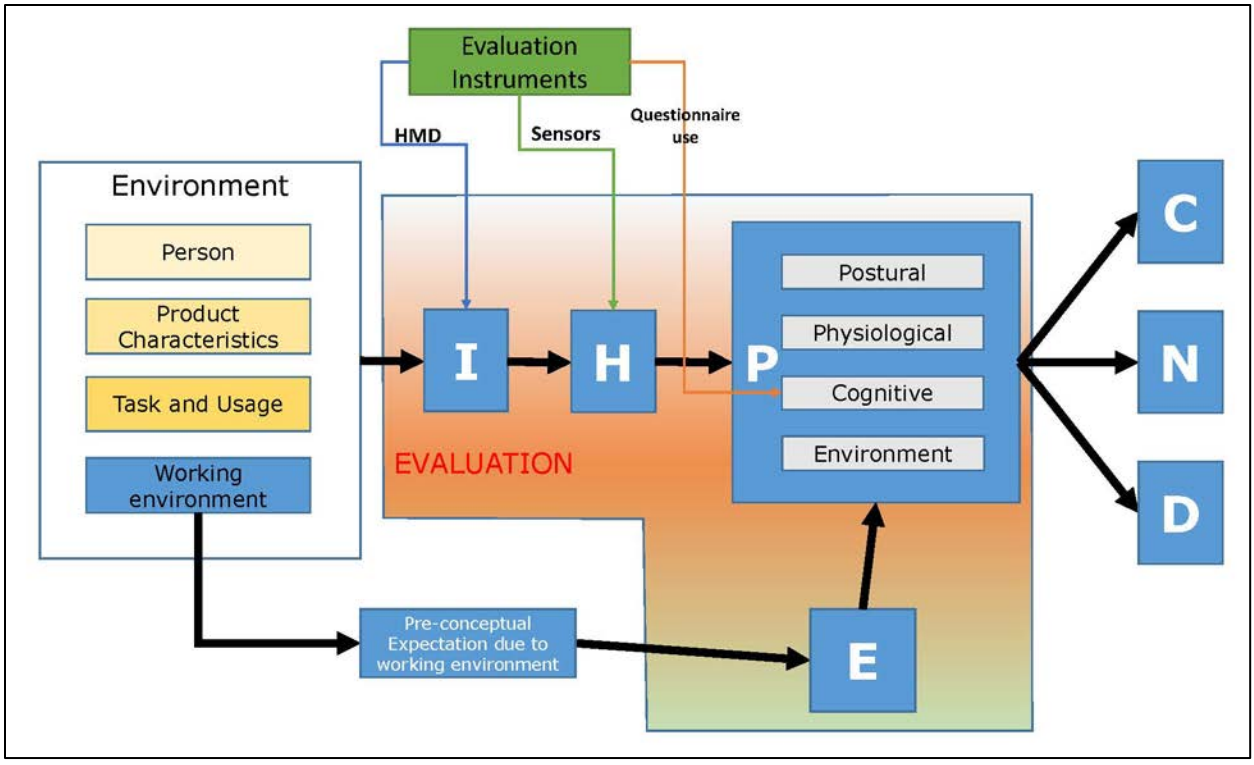

Figure 2. New proposal for comfort perception model

In this model, the Environment is represented by the logic sum of five main aspects that contributes to HMI description and classification:

1. Person (Pe): represent the whole body geometric and personal characteristics of human involved in tasks;
2. Product (Pr): represent all geometric and non-geometric characteristics that describe the element that come in contact with the human body during task execution (shape, materials, colour, surfaces' treatment and so on…);
3. Task/Usage (T): represent all the task or the use that humans can do during HMI experience (kind of contact, timing, kind of interaction);
4. Working environment (We): represent the set of parameters that characterizes the working environment, both under climate and under layout point of view (temperature, humidity, lighting, working seat, kind of workspace);
5. Satisfaction/Gratification level (Gl): represent the set of work characteristics that contributes the satisfaction/dissatisfaction of worker (job position in organization chart, working shifts, gratification, salary and so on) and is widely related to the general environment.

The Vink/Hallbeck model (2012) is integrated with a relation that directly connects the Working environment with the expectation through the coding of several pre-conceptual aspects due to not only the same working environment but also to the cultural/experience background of the analyzed worker. An aspect that cannot be underestimated because it is always present when a comfort/discomfort evaluation is performed also integrates this model: the perception modification due to experimental devices needed to evaluate comfort. These "devices" can modify most of contributes to the formation of the comfort/discomfort perception.

For example, a HMD (Head mounted display) used for VR (Virtual Reality) application in HMI evaluation can modify the Postural Comfort Perception (Interaction – I); the use of markers/sensors on the naked body to perform pressure/temperature/movement data acquisition can change the Physiological Comfort Perception (Human Body effect – H); the use of questionnaire can annoy the workers and directly modify his Cognitive Comfort perception (Perceived effects – P).

COMFORT CONTRIBUTES FUSION RULE

Vink-Hallbeck framework, such as modified by Naddeo and Cappetti (NC-Model of perception), is able to synthetize the concept through which we explain that comfort and discomfort are the measure of the degree of appreciation linked to expectation and due to the perception of the interaction level (I) between person (H) and Environment (Env).

Our work starts from the definition of the wider number of elements that can be linked to Environment's aspect and their classification through two main axioms:

The first axiom asserts that "Each element involved in HMI experience can contribute to one or more kinds among four types of comfort: Postural, Cognitive, Physiologic and Environmental (Naddeo, 2013). An excellent example of what asserted can be found in the following figure in which the influence on comfort and on body effects is deployed for personal characteristics (Pe) of the user/person:

This macro-schematization of comfort/discomfort experience allows individuating the most part of the elements that contributes to comfort/discomfort experience and to classify them in terms of Human body effects related to four types of comfort/discomfort perception.

The second axiom asserts that "Each element involved in HMI experience can be classified as primary element or as modifier element": a primary element is defined as an element that directly contributes to the formation of the comfort/discomfort perception (such as anthropometric measures for the postural Comfort – Cappetti et al., 2013); a modifier element is defined as an element that can modify a previously formed perception (such as time of sitting in physiologic Comfort).

The primary elements are the ones that weigh on the real interaction ability of a person while the secondary elements (modifier) weigh on the perception ability and are related to person and environment characteristics. The expectation acts on a person and can sensibly influence the level of threshold between comfort and discomfort.

				Perceived Comfort			Perceived Comfort			Perceived Comfort			Perceived Comfort	
			PHYSIOLOGICAL COMFORT	Primary element	Modifier element	EMOTIONAL-COGNITIVE COMFORT	Primary element	Modifier element	ORGANIZATIONAL-ENVIROMENTAL COMFORT	Primary element	Modifier element	POSTURAL COMFORT	Primary element	Modifier element
1.PERSONAL CHARACTERISTICS	PHYSICAL CHARACTERISTICS	anthropometric measures			x			x				posture overload, muscle complaint	x	
		physique (BMI)	localized blood pressure, body temperature, heart rate, metabolism	x		level of perceived tiredness		x				muscle effort, posture overload, muscle complaint	x	
		physical problems (chronic illness, trauma, and previous fractures)	tactile sensation, localized blood pressure, body temperature, heart rate	x		work overload, level of perceived tiredness		x				muscle effort, posture overload, muscle complaint	x	
	MENTAL STATUS	personality			x	work overload,level of perceived safety, aggressiveness and irritability, level of perceived tiredness, stress, lack of attention	x							x
		psychological diseases (anxiety, stress)	body temperature, heart rate		x	level of perceived safety, aggressiveness and irritability, level of perceived tiredness, stress, lack of attention	x							x
	PERSONAL DATA	gender	localized blood pressure, body tenmperature, heart rate, metabolism	x			x						x	
		age	tactile sensation, localized blood pressure, body temperature, heart rate, metabolism	x		lack of attention	x					muscle effort	x	
	LIFESTYLE/EXPECTATIONS	lifestyle (diet, smoking, sports, sedentary lifestyle,. ..)	body tenmperature, heart rate, metabolism	x		aggressiveness and irritability, lack of attention		x				muscle effort		x
		expectations			x	level of perceived safety, aggressiveness and irritability, stress	x							x

Figure 3. Deployment of comfort-framework for Personal Characteristics

Thanks to the axioms and the NC-Model, Comfort (C) and Discomfort (D) can be represented by these formulas:

$$C_i = f_i(I, H) * P_i - E_i$$

$$D_i = g_i(I, H) * P_i + E_i$$

For i in $\{Postural, Cognitive, Physiologic, Environmental\}$

Immediately it can be highlighted that the Comfort rule is different by the Discomfort one (the first is not the negation of the second)

The extended form of formulas can be written by taking into account that modifiers (function mod) can be used as a scale-factor for perceptions:

$$C_i(P) = mod(P) * m_C(H) - E =$$

$$mod(P) * m_C\big(h(I)\big) - E =$$

$$mod(P) * m_C(h\big(f(Pe, Pr, T, We, Gl)\big) - E$$

In the same way, the Discomfort rule can be written as:

$$D_i(P) = mod(P) * m_D(h\big(f(Pe, Pr, T, We, Gl)\big) + E$$

Both m_C and m_D can be written as general function; in references, a lot of studies about the functional links between one or few parameters/characteristics have been conducted but it can be found that several aspects are not taken into accounts. For example, some of them are:

- Systematic definition of all primary and secondary aspects in Pe, Pr, T, We and Gl;
- The interaction analysis between the aspects that affect the perception;
- The standardization of comfort-evaluation scale in order to have just one uniform and rational scale to measure the four different types of comfort perception.

The first of these open issues is extensively treated in the following paragraph.

FRAMEWORK FOR COMFORT/DISCOMFORT CODING

The NC-Model has been deployed and detailed. For each kind of interaction (I), one or more human body effects (H) have been found through a wide research within the ergonomic/comfort bibliography. Our research work took life while looking for the most important factors that are related to the comfort and discomfort aspects, including ones that the ergonomic/comfort bibliography had never taken up.

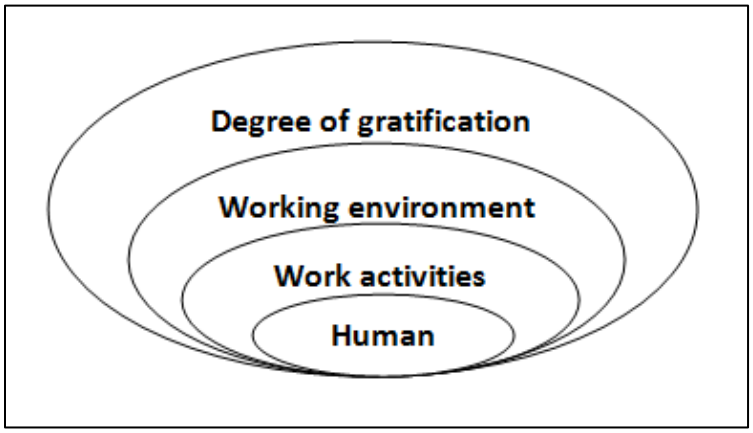

Figure 4. The world of comfort/discomfort evaluation

In order to list and classify those factors we proceeded gradually.

The main step allowed codifying and understanding the domain in which we have to define the comfort/discomfort perception. Comfort domain can be defined as the whole experience that gives to human a degree/level of gratification and this level can be affected both by comfort/discomfort experience and by working environment's intrinsic characteristics.

This comfort experience has to be done in a working environment in which the interaction (I) is performed. In working environment, human's experience consists of the human body that react in properly mode while making a work activity (task/usage) with products and while perceiving (P) an effect.

Accordingly to the fig.4, we have identified five classes, in the world of comfort evaluation, whose characteristics affect the interactions:

Class "Human" that contains the characteristics of the individual; these characteristics identify all those features and information that are proper of the individual and that can affect the comfort perception.

Class "Product" and Class "Task" that are useful to describe the Work Activity; Characteristics of the work activities identify the parameters of tasks and products that humans have to interface which.

Class "Environment" in which these activities are performed; Characteristics of working environment stand for all those aspects that are related with the environment, the thermal, visual and acoustic wellness and layout of workspaces.

Class "Degree of Gratification", that describe the intrinsic characteristics that affect the whole comfort experience and are related to the content of the work, the relationships between colleagues and the job-position in the organization chart.

These classes exactly correspond to the five aspects that contribute to HMI experience: Pe, Pr, T, We and Gl. The framework has the purpose to explain the connections among the interactions (I) with human body effects (H), in order to evaluate how and if these effects are perceived(P) and how and if they affect the four identified kind of comfort/discomfort perception: postural, cognitive, environmental and physiological.

All data have been organized in a big comfort-matrix that is divided in 5 sections represented in fig. 3, 5, 6, 7 and 8. Most of matrix rows have been defined through the literary study.

				Perceived Comfort			Perceived Comfort		Perceived Comfort			Perceived Comfort	
			PHYSIOLOGICAL COMFORT	Primary element	Modifier element	EMOTIONAL-COGNITIVE COMFORT	Primary element	Modifier element	ORGANIZATIONAL-ENVIROMENTAL COMFORT	Primary element	Modifier element	POSTURAL COMFORT	Primary element	Modifier element
2.WORK/TASK CHARACTERISTICS	WORKSTATION	posture: angles and joints			x			x			x	muscle effort, posture overload, muscle complaint	x	
		individual safety equipment: overall dimensions and heaviness	tactile sensation, localized blood pressure, body temperature		x	level of perceived safety, lack of attention		x			x	muscle effort, posture overload, muscle complaint		x
	WORK ACTIVITY & TASK	type of loads and actuation (lifting, pulling, pushing)	localized blood pressure, body temperature, heart rate		x	level of perceived tiredness		x			x	muscle effort, posture overload, muscle complaint	x	
		oparating speed	body temperature		x	work overload,level of perceived tiredness, stress		x		x		muscle effort, posture overload, muscle complaint		x
		actions' frequency	body temperature		x	work overload, level of perceived tiredness, stress		x		x		muscle effort, posture overload, muscle complaint		x
		rest-pause duration and frequency			x	work overload, level of perceived safety, aggressiveness and irritability, level of perceived tiredness, stress, lack of attention		x		x		muscle effort, posture overload, muscle complaint		x
		level of precision			x	aggressiveness and irritability, level of perceived tiredness, stress, lack of attention		x		x		muscle effort, posture overload, muscle complaint		x
		time maintaining of the posture with and/or without loads	localized blood pressure, body temperature, heart rate		x	aggressiveness and irritability, level of perceived tiredness		x			x	muscle effort, posture overload, muscle complaint	x	
		time and duration of work activity/tasks			x	work overload,aggressiveness and irritability, level of perceived tiredness, stress, lack of attention		x		x		muscle effort, posture overload, muscle complaint		x
		work-shifts	muskular exertion, aggressiveness, nervousness, tiredness		x	work overload, level of perceived safety, aggressiveness and irritability, level of perceived tiredness, lack of attention		x	level of perceived safety	x				x
	CHARACTERISTICS OF TOOLS/OBJECTS WITH WHICH A PERSON INTERACTS	shape			x			x			x	muscle effort, posture overload, muscle complaint	x	
		weight			x			x	level of perceived safety		x	muscle effort, posture overload, muscle complaint	x	
		relative position between person and object/tool			x			x	level of perceived safety		x	muscle effort, posture overload, muscle complaint	x	
		frequency of lifting / pulling / pushing	heart rate, localized blood pressure, body temperature		x	level of perceived tiredness	x				x	muscle effort, posture overload, muscle complaint		x
		handling characteristics (grip, grasp, pinch, ...)			x			x			x	muscle effort, posture overload, muscle complaint	x	
		customization of the workstation (sitting)	tactile sensation		x	level of perceived tiredness		x	level of perceived safety		x	muscle effort, posture overload, muscle complaint	x	
		commands' layout			x			x				muscle effort, posture overload, muscle complaint	x	

Figure 5. Deployment of comfort-framework for Work/Task Characteristics

			PHYSIOLOGICAL COMFORT	Perceived Comfort		EMOTIONAL-COGNITIVE COMFORT	Perceived Comfort		ORGANIZATIONAL-ENVIROMENTAL COMFORT	Perceived Comfort		POSTURAL COMFORT	Perceived Comfort		Laboratory tests	
				Primary element	Modifier element		Primary element	Modifier element		Primary element	Modifier element		Primary element	Modifier element	To be eliminated through standardization	To be eliminated through the control of lab-environment
3.WORKING ENVIRONMENTS' CHARACTERISTICS	VISUAL WELL-BEING	colors			X	aggressiveness and irritability, level of perceived tiredness, lack of attention		X		X				X		X
		artificial lightinging conditions			X	level of perceived safety, aggressiveness and irritability,level of perceived tiredness		X	level of perceived safety	X		muscle complaint		X		X
		natural lighting conditions			X	aggressiveness and irritability, level of perceived tiredness		X		X		muscle complaint		X		
		lights' reflection and refraction on walls and objects			X	aggressiveness and irritability, level of perceived tiredness, lack of attention		X		X		muscle complaint		X		X
	OLFACTORY WELL-BEING	air quality	aggressiveness, nervousness		X	aggressiveness and irritability		X		X				X		X
		odors			X	aggressiveness and irritability, lack of attention		X		X				X		X
	AUDITIVE WELL-BEING	noises			X	level of perceived safety, aggressiveness and irritability, level of perceived tiredness, lack of attention		X	level of perceived safety	X				X		X
		vibrations			X	work overload, level of perceived safety, aggressiveness and irritability, level of perceived tiredness, lack of attention		X		X		muscle effort, posture overload, muscle complaint	X			X
	SPACES	workspace	muskular exertion, aggressiveness, nervousness		X	level of perceived safety, aggressiveness and irritability		X	level of perceived safety	X		muscle effort, posture overload, muscle complaint		X		X
		plant-layout			X			X	level of perceived safety	X				X		X
		condition and inclination of the floor (only in the case of the standing posture)			X			X	level of perceived safety	X		muscle effort, posture overload, muscle complaint		X		X
	ENVIROMENT CHARACTERISTICS	cleanliness			X	aggressiveness and irritability		X		X				X		X
		tidiness			X	work overload, aggressiveness and irritability		X		X				X		X
	THERMAL WELL-BEING	air-temperature	body temperature, aggressiveness and nervousness		X	aggressiveness and irritability, lack of attention		X	level of perceived safety	X				X		X
		interface temperature	tactile sensation, localized blood pressure, body temperature	X		lack of attention		X			X			X		
		humidity	localized blood pressure		X			X		X				X		X
		thermal resistance of clothing	tactile sensation, localized blood pressure, body temperature	X				X			X			X		X
		persistence in a thermal condition	tactile sensation, localized blood pressure, body temperature, aggressiveness, nervousness	X		aggressiveness and irritability, lack of attention		X	level of perceived safety		X			X		X
		contact pressure	tactile sensation, localized blood pressure	X				X			X			X		
		air speed	body temperature		X			X		X				X		X

Figure 6. Deployment of comfort-framework for Working Environment Characteristics

			PHYSIOLOGICAL COMFORT	Perceived Comfort		EMOTIONAL-COGNITIVE COMFORT	Perceived Comfort		ORGANIZATIONAL-ENVIROMENTAL COMFORT	Perceived Comfort		POSTURAL COMFORT	Perceived Comfort	
				Primary element	Modifier element		Primary element	Modifier element		Primary element	Modifier element		Primary element	Modifier element
4. LEVEL OF GRATIFICATION	GRATIFICATION LINKED TO THE CONTENT OF WORK	rewards and money-grants			X	aggressiveness and irritability, stress	X				X			X
		direct work responsibilities			X	work overload, aggressiveness and irritability, level of perceived tiredness, stress	X				X			X
		growth opportunities			X	aggressiveness and irritability	X				X			X
	ORGANIZATION/ ENVIRONMENT	collaboration with colleagues			X	aggressiveness and irritability, stress	X				X			X
		rigidity of the regulations and procedures			X	level of perceived safety, aggressiveness and irritability, stress	X				X			X
		relationship with managements			X	aggressiveness and irritability, stress	X				X			X
		attractiveness of the environments and furniture			X	aggressiveness and irritability	X				X			X
		level of tiredness	muskular exertion, aggressiveness, nervousness, tiredness		X	work overload, aggressiveness and irritability, level of perceived tiredness, stress, lack of attention	X				X			X

Figure 7. Deployment of comfort-framework for Level of Gratification

			PHYSIOLOGICAL COMFORT	Perceived Comfort		EMOTIONAL-COGNITIVE COMFORT	Perceived Comfort		ORGANIZATIONAL-ENVIROMENTAL COMFORT	Perceived Comfort		POSTURAL COMFORT	Perceived Comfort	
				Primary element	Modifier element		Primary element	Modifier element		Primary element	Modifier element		Primary element	Modifier element
5. TOOLS AND INSTRUMENTS FOR COMFORT MEASURING		invasivity			X	aggressiveness and irritability, lack of attention		X			X			X
		obstruction			X	work overload, level of perceived safety, aggressiveness and irritability, lack of attention		X			X	muscle effort, posture overload		X
		tactile interference	tactile sensation, localized blood pressure		X	lack of attention		X			X			X
		restriction of movements			X	work overload, aggressiveness and irritability, level of perceived tiredness, lack of attention		X			X	muscle effort, posture overload, muscle complaint		X
		visual limitation			X	level of perceived safety, aggressiveness and irritability, level of perceived tiredness, lack of attention		X			X			X
		override of action/ position			X	level of perceived safety, aggressiveness and irritability, level of perceived tiredness, lack of attention		X			X	muscle effort, posture overload, muscle complaint		X

Figure 8. Deployment of comfort-framework for Evaluation devices

The first class of factors is related to the human's characteristics i.e. physical characteristics, mental state, personal data, lifestyle and expectations. It has been verified that human's characteristics influence physiological, cognitive and postural comfort while there is not a correlation between the human's characteristics and the quality of the work environment. Each subclass of human's characteristics has been deployed in order to consider it in all own aspects. Particularly, the physical characteristics are related to anthropometric measures (Thariq et al., 2010), physique and physical problems/disease. The mental state takes into account the human personality (Nimbarte et al., 2012) and the psychological diseases. The personal data are related to age and gender. In the matrix, it has been also considered the lifestyle such as sport playing, eating habits and personal expectations.

The second class of factors is related to the work's characteristics. If the comfort is the result of the interaction between man and the activity that he does, it is not possible not to consider the work's characteristics and the environment ones. These factors concern aspects related to the work-station/seat characteristics, the type of activity and the objects' element with which user has to interfaces himself for the task's execution. For the work-station/seat, both the posture that man has to take in order to do the task and the kind of individual safety equipment have been considered. Both aspects affect the comfort perception: for example, in Alessandro Apostolico et al., 2013, has been demonstrated that posture configuration can strongly influence the level of comfort perceived. Another aspect of the work's characteristics that influences the comfort is the type of task that man has to do. Because of the comfort-matrix has to be applied for any type of work, we have listed the key features that define a generic work activity and influence the perceived comfort. Some aspects that we have considered are: level of precision required (Reuben S Escorpizo et al., 2007), time maintaining of the posture (Dohyung Kee et al., 2001) and work shifts (Anjali Nag et. al, 2004). The last aspect is related to the objects/tools that are used for the task's execution. It has been demonstrated that the shapes of the objects (L.F.M. Kuijt-Evers et al., 2004) or their careful positioning in the workspace (Rolf P. Ellegast et al., 2012) can facilitate the user to execute the task. The result can be an increase of the level of comfort.

The third class of factors that has to be considered is related to the characteristics of the work environment. If we consider that a person has to stay in a specific place for several hours, we have to consider that a pleasant environment may significantly affect the person's well-being. The work environment is composed of: visual, olfactory, acoustic and thermal well-being, wellbeing associated to the workspace and wellbeing associated to the state of maintenance of the environment. The visual comfort is related both to the conditions of lighting inside the environment and to the colors used. For example in (Eliza Szczepanska-Rosiak et al., 2013), the evaluation of the visual comfort have been made considering the lighting conditions, both the artificial and the natural one, the workspace colors and the effects of light-reflection on the walls. The perceived comfort is, obviously, associated also to the worker's satisfaction for the air quality. For this reasons the indoor air quality and the odors have to be considered such as elements that can affect the whole comfort perception. Noises and vibrations have been considered when talking about the acoustic wellbeing: unwanted noises and vibrations, in fact, are huge distractions and can cause stress conditions in the workplace.

Another aspect that influences the worker's comfort is the thermal condition: in (F.R.D'Ambrosio et al., 2004). The thermal aspect is treated as the consequence of influence of factors humidity, temperature and thermal-resistance of the clothes. The last two aspects we found in literature are the space, interpreted both as workspace in (Cascioli et al., 2011) and as plant/office layout, and the state of maintenance of the environment. If the worker is obliged to work in a small area, to do forced movements and to stay in a dirty or in a messy place his level of comfort strongly decreases.

The last class of factors that has to be considered is related to the degree of gratification. A job, or in general an activity, can be more or less satisfying in relation both to the content and to the context of the work. The content of the work includes several factors i.e. the level of recognition, the direct responsibility of the work and the possibility to grow up (Lars Goran Wallgren et al., 2007). A work can have a degree of content too high or too low and it can be the cause of the absence of incentive and the decrease of the level of comfort. In the context of the work, for example, the relationships with the colleagues and managers or the rigidity of the norms and procedures have been considered.

The interaction that individual has with these classes of factors causes effects on worker and contributes to the development of a comfort perception. The effects are several for each type of comfort among postural, cognitive, physiological and environmental. The comfort matrix explain and deploy each kind of class and describes the relationships among causes (Interactions) and effects (Body effects) for each kind of perceived comfort. Some

matrix-reading example are in the following examples:

In matrix, you can find that the most important in the postural comfort are muscular effort and postural overload and the factor "time of postural keeping with/without load" that belongs to the second class, causes and affects both effects. It is obvious that if a person remains in a position for long time the muscles are stressed and the posture becomes uncomfortable. The most important effects on the physiological comfort are body temperature, pulse rate and tactile sensation, for example, these effects have a different impact in function of the "lifestyle". Aggressiveness, nervousness degree of tiredness, stress and distractions have effects on the cognitive comfort and are mainly related to the characteristics of the working environment and degree of gratification. The main effect related to the environment comfort is the level of safety that depends by the organization of the layout and the keeping of the environment.

SEAT COMFORT EXAMPLE

Simply using the whole comfort matrix, we have individuated all factors that affect office-Seat comfort and we have created a sub-matrix (in Fig.9) in which all the aspects, that have to be studied, have been highlighted.

Using the previously defined fusion rules, we can easily individuate the aspects, the methods and the literature about issues that characterize the seat comfort problem.

CONCLUSIONS AND FUTURE DEVELOPMENTS

In HMI design, several parameters have to be correctly evaluated in order to guarantee a good level of safety and well-being of users (humans) and to avoid health problems like muscular-skeletal or psychological diseases.

Several papers follow the assumption that there is a relationship between self-reported discomfort and musculoskeletal injuries and that those injuries affect the perceived comfort and more than 100.000 scientific papers dealing with comfort and discomfort can be easily found in main scientific databases and most of these speak about relationship between environmental and perceived comfort/discomfort. However the theories relating comfort to products/processes and products/processes' design characteristics are rather underdeveloped.

In addition, experimental devices are needed for improving methods and for making numerical/experimental correlations. The accuracy and the easiness are the most important characteristics that those methods/devices may have; the integration of those evaluation methods in a DHM software for ergonomic/comfort application can strongly enhance the product/process prototyping in CAD/CAE environment and can give to designers a powerful instruments to preventively evaluate the comfort level of a HMI.

Starting our work from literature analysis, a classification of all the elements that seems to be important in global comfort evaluation has been done; types of human sensation and perception have been classified and linked to the human body effects.

Two axioms have been set out:

- "Each element involved in HMI experience can contribute to one or more kinds among four types of comfort: Postural, Cognitive, Physiologic and Environmental", so the Vink-Hallbeck model can be concurrently applied in four aspects that strongly affect the global comfort perception: (Bi) – User Biomechanics/Posture, (Ph) - Physiologic factor, (En) – Environment contribute, (Co) – Cognitive factor.

- "Each element involved in HMI experience can be classified as a primary element or as modifier element": a primary element is defined as an element that directly contributes to the formation of the comfort/discomfort perception; a modifier element is defined as an element that can modify a previously formed perception.

	seat			Perceived Comfort			Perceived Comfort			Perceived Comfort			Perceived Comfort	
			PHYSIOLOGICAL COMFORT	Primary element	Modifier element	EMOTIONAL-COGNITIVE COMFORT	Primary element	Modifier element	ORGANIZATIONAL-ENVIROMENTAL COMFORT	Primary element	Modifier element	POSTURAL COMFORT	Primary element	Modifier element
1.PERSONAL CHARACTERISTICS	PHYSICAL CHARACTERISTICS	anthropometric measures			X			X				posture overload, muscle complaint	X	
		physique (BMI)	localized blood pressure, body temperature, heart rate, metabolism	X		level of perceived tiredness		X				muscle effort, posture overload, muscle complaint	X	
		physical problems (chronic illness, trauma, and previous fractures)	tactile sensation, localized blood pressure, body temperature, heart rate	X		work overload, level of perceived tiredness		X				muscle effort, posture overload, muscle complaint	X	
	PERSONAL DATA	gender	localized blood pressure, body temperature, heart rate, metabolism	X			X						X	
		age	tactile sensation, localized blood pressure, body temperature, heart rate, metabolism.	X		lack of attention	X					muscle effort	X	
	EXPECTATIONS	expectations			X	level of perceived safety , aggressiveness and irritability, stress	X							X
2.WORK/TASK CHARACTERISTICS	WORKSTATION	posture: angles and joints			X			X			X	muscle effort, posture overload, muscle complaint	X	
	CHARACTERISTICS OF TOOLS/OBJECTS WITH WHICH A PERSON INTERACTS	shape			X			X			X	muscle effort, posture overload, muscle complaint	X	
		customization of the workstation (sitting)	tactile sensation		X	level of perceived tiredness		X	level of perceived safety		X	muscle effort, posture overload, muscle complaint	X	
3. WORKING ENVIRONMENTS' CHARACTERISTICS	VISUAL WELL-BEING	colors			X	aggressiveness and irritability, level of perceived tiredness , lack of attention		X		X				X
		odors			X	aggressiveness and irritability, lack of attention		X		X				X
	AUDITIVE WELL-BEING	vibrations			X	work overload, level of perceived safety, aggressiveness and irritability, level of perceived tiredness , lack of attention		X		X		muscle effort, posture overload, muscle complaint	X	
	THERMAL WELL-BEING	interface temperature	tactile sensation, localized blood pressure, body temperature	X		lack of attention		X			X			X
		thermal resistance of clothing	tactile sensation, localized blood pressure, body temperature	X				X			X			X
		persistence in a thermal condition	tactile sensation, localized blood pressure, body temperature, aggressiveness, nervousness	X		aggressiveness and irritability, lack of attention		X	level of perceived safety		X			X
		contact pressure	tactile sensation, localized blood pressure	X				X			X			X
5. TOOLS AND INSTRUMENTS FOR COMFORT MEASURING		invasivity			X	aggressiveness and irritability , lack of attention		X			X			X
		tactile interference	tactile sensation, localized blood pressure		X	lack of attention		X			X			X
		restriction of movements			X	work overload, aggressiveness and irritability, level of perceived tiredness , lack of attention		X			X	muscle effort, posture overload, muscle complaint		X
		override of action/ position			X	level of perceived safety, aggressiveness and irritability, level of perceived tiredness , lack of attention		X			X	muscle effort, posture overload, muscle complaint		X

Figure 9. Seat comfort evaluation sub-matrix

The proposed NC-Model of perception and the Comfort framework can help researchers to evaluate what can be the trend line of their research and how and in what direction they have to concentrate their efforts to better improve the results and contribute to study the missing aspects of problems.

An example of application of the framework to the seat-comfort problem has been presented and allowed to highlight missing and open problems in Seat comfort evaluation.

The comfort-matrix analysis allow highlighting that there are some aspects of comfort/discomfort perception evaluation that are under-studied or missing. In examined papers, authors cannot identify a homogeneous comfort rating scale so highlighting an emerging difficult in synthesis of a comfort rating system for the global comfort. No one, since now, have distinguished the comfort parameters between primary and modifier classes.

The proposed framework allows to better organize studies about comfort evaluation and to face problems both in global and in particular way. Furthermore, the elements in the proposed framework suggest us, as a trend-line, to detect towards which the comfort studies needs to be directed. Up to us, the most important and urgent for which researchers have to develop methods are:

- Postural Comfort evaluation: Significance of rest posture and of human joints' neutral position, gravitational effect, arms support (like headrest, armrest or other rest surfaces), postural equilibrium (weight distribution and operative spatial conditions), handhold type, repetitive actions' frequency, Posture-keeping time, Muscular fatigue, tools to measures human joints' angles both in static then in dynamic postures.

- Cognitive Comfort Evaluation: Devices to evaluate HMI tactile interaction without altering it during measurement operation, devices/methods to evaluate HMI visual interaction during operation-time, methods for allowing users/workers to describe and analyze their own sensations during operation/use time without affecting their perception, a method to integrate the other three senses in the evaluation (hearing, taste and olfaction).

- Physiologic Comfort evaluation: devices to measure HMI temperature without altering it during measurement operation, devices to measure HMI pressure without altering it during measurement operation, devices to measure HMI transpiration (water-vapor migration) without altering it during measurement operation, a method to correlate the previously described parameters each other, a method to correlate parameters values and their combination to an accepted level of comfort, a method for taking into account physiologic condition vs. elapsed time (prolonged postures).

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Enhancing the Vigilance of Car Drivers: a Review on Fatigue Caused by the Driving Task and Possible Countermeasures

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ABSTRACT

Before fatigue caused by the driving task becomes a safety threat, it already has a negative effect on well-being. Therefore, it is desirable to intervene in an early stage of the fatiguing process to decrease the perceived load from a monotonous driving task and to create a more pleasurable driving experience. Enhancing driver vigilance could also create a competitive advantage for the car manufacturer. This paper reviews the existing body of knowledge concerning driver fatigue theories and countermeasures against driver fatigue. Current (automotive) features concerning fatigue are also evaluated. A fatigue countermeasure system should measure and/or predict fatigue, intervene with a stimulus and subsequently restore performance and alertness. A distinction can be made between physical and cognitive fatigue. Physical fatigue results mainly from static sitting issues. This type of fatigue can be countered with micro-movements and the stimulation of postural change. Cognitive fatigue can be further divided into task-related and sleep-related fatigue. Fatigue resulting from task overload can be countered with automation and assist systems. Fatigue from task underload can be countered with a variety of stimulation. Sleep-related fatigue is considered intervention resistant by some researchers, although it also seems to be possible to manipulate the circadian rhythm with blue light.

Keywords: driver fatigue, countermeasures, comfort

INTRODUCTION

Driver fatigue is often quoted as a causal factor in accidents (Ahlstrom et al., 2013; Horne and Reyner, 2001). Before becoming an actual threat to safety, however, fatigue caused by the driving task also has a negative effect on well-being when the driver becomes drowsy in the course of a trip. Enhancing driver vigilance in order to increase comfort is not only beneficial for the user, but could also create a competitive advantage for the car manufacturer.

Therefore, it would be desirable to already intervene in an early stage of the fatiguing process in order to decrease the perceived load from the monotonous driving task and create a more pleasurable driving experience. In order to understand how fatigue is established, different types of fatigue and their causes according to literature research are evaluated. Next, existing countermeasures on these causal factors as well as promising theories providing starting points for countermeasures are discussed. This results in a theoretical framework for driver vitalization and its countermeasures. Finally, the measurable effects of fatigue countermeasures are evaluated.

METHOD

A literature review was conducted, focusing on research concerning driver fatigue theories and the different focuses on driver fatigue, studies on possible countermeasures against these different types of fatigue, as well as studies on different methods for measuring fatigue. Furthermore, current automotive features concerning fatigue and safety were evaluated. The publications used for the literature review were retrieved with a search in Scopus in the period of March to August 2013.The following keywords or a combination of these keywords were used for the search: “driver” OR “car” OR “vehicle” AND “fatigue” OR “cognitive fatigue” OR “physical fatigue” OR “discomfort” OR “vitalization” OR “vigilance” OR “refreshment” OR “countermeasures”. Papers considering driver fatigue in relation to shift work specifically were left out of account since they focus rather on circadian rhythm issues. Relevant references from the selected articles were also reviewed, leading to a subsequent search on the keywords “micro-movements”, “macro-movements”, “seating” AND “discomfort”, and “sympathetic nervous system activation”.

DRIVER FATIGUE THEORY

The manifestation of driver fatigue is a process influenced by several factors. The distinction of different factors contributing to driver fatigue is important in order to evaluate measures for fatigue detection and countering (May and Baldwin, 2009). Thus, this knowledge is important for car manufacturers as the starting point of the development of fatigue countermeasures.

Grandjean (1979) distinguishes mental fatigue, boredom and physical fatigue. Physical fatigue consists of discomfort from overstressed muscles, whereas mental fatigue results in weariness caused by the cognitive aspects of a task. Boredom occurs when there is little to no demand. Hancock and Desmond (2001) determine two types of fatigue. The first, active fatigue, is derived from lasting perceptual-motor response requirements of the driving task. The second, passive fatigue, results from system monitoring with either little or no perceptual-motor response requirements. Hancock and Desmond (2001) also point out that fatigued drivers are especially at risk when demand is low.

There are also two types of fatigue according to May and Baldwin (2009): sleep-related fatigue and task-related fatigue. Sleep-related fatigue ensues from sleep deprivation, extended duration of a need for alertness and circadian rhythm effect. Circadian is relating to a period of 24 hours, especially to the changes in people’s or animals’ bodies that happen during this period (Macmillan English Dictionary, 2007). Task-related fatigue can be further subdivided into fatigue either caused by mental overload or underload: a similar distinction as Grandjean’s mental fatigue and boredom (1979). Vigilance (Parasuraman et al., 1998) is a general state of wakefulness characterized as arousal or alertness. Environmental factors influencing vigilance are noise, vibration, ambient temperature, frequency and variety of stimulation, as well as environmental pollutants.

The theory provided here forms the foundation for the framework presented in figure 1. This framework distinguishes between physical and cognitive fatigue and their different causes, further explained in the sections 3.1 and 3.2. In reality, however, it seems to be the case that driver fatigue does not purely establishes itself in the form of one of these types of fatigue. As is the case with well-being in general (according to the comfort model of De Looze et al., 2003), fatigue probably develops from a combination of several contextual factors such as the embodiment of cockpit and seat, task duration and intensity, emotional and physical state of the driver, and goal of the drive. The bottom of the figure shows several measures for counteracting the different types of fatigue, which are discussed in section 4.

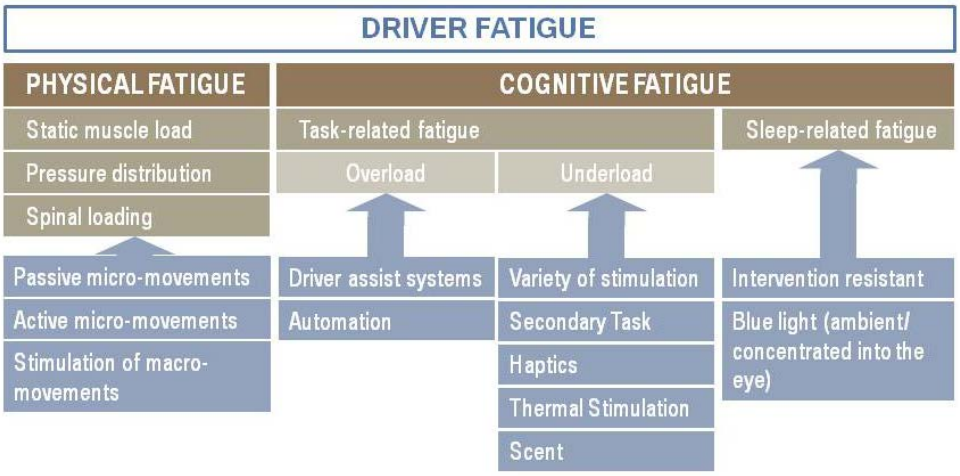

Fig. 1 Driver fatigue model

Physical fatigue

In the case of driving a car, physical fatigue is related to perceptual-motor adjustments specific to the driving task (holding and operating the steering wheel, using the foot levers) and to discomfort caused by prolonged sitting. Prolonged sitting is associated with several types of discomfort and, in general, it is encouraged to periodically engage in non-sedentary activities (Beach et al., 2005). Ebe and Griffin (2000) argue that in cars discomfort is mainly influenced by the static seat characteristics and that vibration can be ruled out as an influence of physical fatigue in high quality cars. De Looze et al. (2003) propose three seat characteristics influencing discomfort that can be measured objectively: pressure distribution, muscle activity and lumbar curvature. This is in agreement with the main factors contributing to driver fatigue according to Grujicic et al. (2010): the maximum level of muscle activity and the number of muscles activated, shear force and spinal force.

Previous studies have already developed an ideal pressure distribution for a car seat with minimal pressure in the intervertebral discs (Zenk, 2008). Furthermore, it is generally accepted that continuous, static muscle activity results in discomfort (e.g. Falla et al., 2007). Also, flexed lumbar spine postures can result in an increase in the relative contribution of the passive tissues to holding the torso upright during sitting (Beach et al., 2005). Despite the elaborate efforts to develop the ideal seat in the automotive field as well as in other fields (i.e. office furniture), an often stated hypothesis is that movement or frequent posture change is desirable in order to improve seating comfort (Lueder, 2003). Graf et al. (1995) suggest that natural movements are desirable and necessary as long as they are within an acceptable range. Leuder (2003) stresses the importance of variation between severable stable and healthy body postures.

Several studies on seating in general describe a relation between seating time, discomfort and body movement. Telfer et al. (2009) found that subjective discomfort and movement increase over time. The amount of movement was found to be greater in chairs rated most uncomfortable. Vergara and Page (2002) propose that macro-movements are a good indicator of discomfort. Fujimaki and Noro (2005) also found discomfort to increase over time, but argue that macro-movements occur in order to decrease discomfort in a repeating pattern during prolonged sitting. In agreement with this statement, Graf et al. (1995) already found that work tasks which resulted in more musculo-skeletal disorders allowed for less frequent and less marked postural change. Finally, Callaghan and McGill (2001) suggest that humans redistribute their muscular loads according to their comfort level using posture adjustment.

Studies focusing specifically on physical fatigue when driving concluded similar findings. Lee (1995), for instance, found that the driver moves more frequently when he/she feels uncomfortable. Na et al. (2005) found significantly more discomfort after driving in a simulator for 45 minutes. During this study, a correlation between body pressure variation and subjective discomfort was also discovered. Furthermore, Cheng et al. (2011) found that during long-time driving, people either bend forward or slouch down. However, Falou et al. (2003) measured EMG in two different car seats without a driving task for 150 minutes with and without added vibration and found no significant

difference over time. Muscle fatigue should result in compressed EMG signals or frequency changes in the EMG frequency spectrum (Hagg et al., 2000).

Cognitive fatigue

As suggested by May and Baldwin (2009), cognitive fatigue is either caused by overload or underload of the driving task or caused by sleep deprivation and circadian rhythm. Sleep-related fatigue is considered intervention resistant by these researchers. Task demand and duration exclusively can produce task-related fatigue without the contribution of any sleep-related factors. Task overload relates to an intense and perhaps stressful task, whereas task underload relates to a monotonous, monitoring task. It is possible to prevent fatigue from task underload and enhance vigilance by offering driver stimulation, since "environmental factors influencing vigilance are … frequency and variety of stimulation" (Parasuraman et al., 1998).

There is no consensus on the amount of driving time needed for task-related fatigue to establish. Nilsson et al. (1997) evaluated the maximum amount of time one could drive in a simulator and found quitting time to lie between 90 and 240 minutes. However, Liu and Wu (2009) found that fatigue is produced after 60 minutes of driving and surprisingly found no difference between monotonous or complex roads. Unlike Thiffault and Bergerson (2003), who found that a monotonous road side has a negative effect on the driving performance as well as a time-on-task effect on fatigue. This corresponds with previously described theories on driver fatigue. However, there seem to be difficulties when distinguishing task-related fatigue from overload or underload and, in reality, it seems to be the case that a combination of these three occurs.

FATIGUE COUNTERMEASURES

Literature on countermeasures against cognitive fatigue

Most literature discussing driver fatigue countermeasures focuses on cognitive fatigue. Desmond and Matthews (1997) developed the following criteria for a countermeasure system. First, there must be a valid indication of fatigue. Next, there must be a stimulus upon detected weariness in order to restore performance. Balkin et al. (2011) defined three criteria for the ideal system: i) it can predict fatigue based on factors that produce it (i.e. sleep history), ii) it can measure fatigue and performance, and iii) it can intervene, restore and sustain performance and alertness.

Since fatigued drivers are especially at risk when demand is low, Desmond and Matthews (1997) think that a secondary task (i.e. monitoring an in-car guidance system) is beneficial whenever the primary task demand is low. However, since in-car guidance systems are now well established in modern cars, it seems that a secondary task should be designed differently. May and Baldwin (2009) define automation (to counteract on sleep-related fatigue) and interactive technology (i.e. a game as a secondary task to counteract task-related fatigue) as promising countermeasures for fatigue.

Gershon et al. (2009) actually found that a secondary, manual-dexterity task has a positive effect on subjective fatigue as well as alertness. They also found that non-professional and professional drivers already have different strategies to counteract cognitive fatigue (Gershon et al., 2011), such as listening to the radio, talking, opening the window and drinking coffee. Generally, it can be stated that providing variety from the monotonous driving task seems to have a positive effect on task-related cognitive fatigue. Schmidt et al. (2011) for instance found that communication has a positive effect on fatigue. Furthermore, chevrons, rumble strips and message signs also have a short-lived, positive effect on cognitive fatigue (Merat and Jamson, 2013). Next to this, haptic seat alerts decrease reaction time (Fitch et al., 2011). Since "vigilance is influenced by frequency and variety of stimulation" (Parasuraman et al., 1998), a fatigue countermeasure system should implement a palette of different stimuli in the vehicle interior in order to evoke driver vitalization.

Current in-car systems against fatigue

Car manufacturers obviously have also been working on the development of systems to counteract driving fatigue. There are several systems in the industry that assess fatigue and suggest a break (Volvo, Ford, Daimler, BMW etc.). These systems usually monitor driving performance or time on task and encourage the driver to rest or actively alert the driver on impending errors. Thus, most of these systems focus on preventing accidents without being an actual

countermeasure to task-related driver fatigue. Furthermore, Karrer-Gauß (2001) indicates that systems detecting and presenting fatigue level could be counterproductive and lead to drivers taking more risk.

When looking at other modes of travel, similarities can be found in terms of fatigue although the driving task is missing. This is for instance the case for airplane passengers, who experience physical fatigue from sitting as well as sleep-related fatigue. Airplane passengers are advised to do exercises approximately every hour, like tilting the feet, rotating ankles, stretching fingers etc. (KLM, 2013). Hitos et al. (2007) found that foot exercises against increased resistance positively enhanced blood volume flow and that other types of exercises moderated the negative effect.

There have also been successful attempts on counteracting on sleep-related fatigue in this field. Achim Leder (2012) used blue light in air plane interiors in order to decrease the production of sleeping hormones and evoke fitness. Another study focusing on medical personnel also found that blue light could be a countermeasure for fatigue especially at night (Harvard Medical School, 2006). However, providing car passengers with ambient, blue light at night is difficult since this will obstruct the driver's view. A possibility to evade this problem is to emit the blue light directly into the eye. Researchers have for instance been able to develop LED light-glasses with blue light to manipulate the circadian rhythm (Winslow, 2007).

Micro-movements

A general hypothesis is that micro-movements could decrease discomfort from sitting. Since it is not possible to enable great postural change in a car due to the limitations of the driving task, this could be a promising measure for an automotive application. However, generally accepted recommendations on micro-movements are not yet established.

Graf (1995) stated that studies are needed on how often the sitting position should be changed and what the optimal range of changes is. Vergara and Page (2002) define a macro-movement as a distinctive change of posture every 5 to 6 minutes. Callaghan and McGill (2001) define a dynamic, multiple posture strategy during unsupported sitting as consisting of 3 postures over 2 hours. Helander et al. (2000) found that sensitivity of postural change results from the response from body tissues and joints. They established just noticeable differences in seat height, seat pan angle and backrest angle. Dunk and Callaghan (2010) found that micro-movements are a way to reduce discomfort from restlessness, body stiffness, lack of circulation or seat pressure and that fidgeting occurs every 40-50 seconds.

Several efforts have been made to develop dynamic seating with both passive as well as active micro-movements. Passive rotation of a pig cadaver spine results in an immediate increase of disc height at a rotation of less than 2 degrees (Van Deursen, 2001). Beach et al. (2003), however, tested a continuous passive motion device in an office chair, which resulted in no difference in EMG or locally perceived discomfort. Passive rotation in an office chair compared to no passive micro-movement for the same office tasks, resulted in significantly less spinal length in the static chair (Van Deursen, 2001). Nevertheless, a long term study on the effects of a similar passive motion device on low back pain found no advantage of the device (Lengsfeld et al. 2007).

Other than applying passive micro-movements, dynamic sitting could produce active micro-movements. Kingma and Van Dieen (2009-1) evaluated sitting on an exercise ball and concluded that, although it is questionable if there are benefits for the spine, there is more EMG variation in the back which could have positive effects. However, the disadvantages of having no support would probably outweigh the advantages of the sitting ball. Prolonged sitting on a dynamic, unstable surface does not significantly affect muscle activation, spine posture, spinal loads, or overall spine stability according to McGill et al. (2006). O'Sullivan (2012) also thinks that there is no evidence supporting the use of dynamic seating as a stand-alone approach for low back pain.

Nevertheless, Kingma and Van Dieën (2009-2) found that a vertically dynamic lumber support when driving a car results in a small reduction of vibration and a substantial reduction of low back EMG. In another study, Van Dieën (2001) found that working on a dynamic office chair results in an increase in body stature, but trunk kinematics and EMG were more affected by task. A chair with an unstable seat pan consisting of a pixel mat with an under layer of springs, results in significant lower heart rate as well as the maintenance of oxygen levels in the tissues surrounding the ischial tuberosities (Mahksous et al., 2008).

Next to reducing discomfort while seated, there is another relationship between micro-movements and fatigue. Rogé et al. (2001) found that during simulated driving subsidiary body movements increase when vigilance decreases. Micro-movements also seem to be a defense system against cognitive fatigue. The study shows that variation of non-specific activities is an indication of subject's arousal and that self-centered gestures (movements of one or both hands towards the body) as well as postural adjustments have the purpose of reactivation. Takanishi et al. (2010)

also found an increase of habitual behaviors (touching face, arms) related to a decrease in heart rate variation (which is a measurement of sympathetic nervous system activity). They state that distractive behaviors against monotony are an indication for decreasing performance. Thus, it seems that micro-movements are also a natural countermeasure against fatigue.

Thermal Stimuli

In order to prevent fatigue caused by mental underload, the driver should be stimulated and the monotonic aspect of the trip should be diminished. Next to providing the car driver with a secondary manual task, offering physiological stimulation is an option. Table 1 shows an overview of literature mentioning this effect.

There are several studies indicating that local cooling leads to activation of the sympathetic nervous system. Activation of the sympathetic nervous system results into a (physiological) shift from a state of rest to a state of alertness: the sympathetic nervous system is responsible for priming the body for action (Van Halem, 2009) . Jansky et al. (2013) found that cooling of the lower legs with 12° water results in activation of the sympathetic nervous system within 3-10 minutes. Another study showed that immersion of the hand in cold (5°) water activates the SNS, measured by blood pressure and heart rate (LeBlanc et al., 1975). Koehn et al. (2012) found sympathetic activation by cooling head and neck with cold gel (4°). Furthermore, Sendowski et al. (1999) found that the SNS is activated when immersing the right hand or the left hand and right index finger in 5° water within 5 minutes, but not for immersion of only the right index finger. Ramautar et al. (2013) also found a cohesion between skin temperature fluctuations and objective vigilance. Another positive effect of alternating hot and cold temperatures is the increase of local blood flow (Cochrane, 2004) which could counteract on effects from physical fatigue resulting from static seating.

Since cooling body parts with 10° C water results in a shift of perceived thermal comfort from warm to cold (Tamura and An, 1993), however, it is challenging to develop automotive features with these extreme cooling effects without inducing overall discomfort. Additionally, there could be technical difficulties concerning the implementation of such low temperatures. Therefore, it is of interest to activate the sympathetic nervous system with as little difference in temperature as possible. Tham and Willem (2010) found that exposure to 20° room temperature already leads to a cooling sensation on the skin and to better accuracy versus a 24° waiting room in an office in the tropics. This small difference in temperature could be a promising notion for implementation of such features in cars.

Another possibility for activating the sympathetic nervous system is to use scent. According to Horii et al. (2013) aromatherapy can be used for alleviating stress as well as invigorating the body: the usage of grapefruit oil results in elevated sympathetic nerve activity.

Table 1: Effects of local cooling

Author	Year	Body part	Temperature (° C)	Time (min.)	Effect
Jansky et al.	2013	Lower legs	12	3-10	SNS Activation
Koehn et al.	2012	Head and neck	4	Immediate effect	SNS Activation
LeBlanc et al.	1975	One hand	5	2	SNS Activation
Sendowski et al.	1999	Right hand/ left hand and right index finger	5	<5	SNS Activation
Tamura and An	1993	10 Different body regions independently	10	30	Thermal comfort shift from warm to cold
Tham and Willem	2010	Overall: environment	20	Continuous effects over 240	Cooling sensation and better accuracy

MEASURABLE EFFECTS OF FATIGUE COUNTERMEASURES

There are three types of possible effects to a fatigue countermeasure: a physical, a mental and an emotional effect. Table 2 provides an overview of different methods of fatigue effect measurement used in experimental studies found during the literature review.

The physical effect is measurable with for instance heart rate (Backs et al., 2003; Mehler et al. 2008; Mehler et al., 2012; Reimer et al., 2011; Schmidt et al., 2011; Gershon et al., 2009; Patel et al., 2011; Yang et al., 2010) and skin conductance (Collet et al., 2003; Mehler et al., 2012). Another physiological effect of fatigue can be found in eye movements and pupillometry (Ahlstrom, 2013; DiStasi et al., 2012; Merat and Jamson, 2013; Schmidt et al., 2011; Yang et al., 2010). Furthermore, respiration frequency is used as a measure of sympathetic nervous system activity (Backs et al., 2003).

The mental effect consists of the cognitive processing of the driving task. This can be measured both objectively and subjectively. Objective measurements often used are EEG representing brain activity (Ahlstrom, 2013; Gillberg et al., 1996; Kar et al., 2010; Lal et al., 2003; Schmidt et al., 2011; Simon et al., 2011) and task performance such as reaction time and steering wheel movement (DiStasi et al., 2012; Gershon et al., 2009; Merat and Jamson, 2013; Nilsson et al., 1997; Sung et al., 2005; Thiffault and Bergeron, 2001; Ting et al., 2008). There are different questionnaires and scales evaluating workload and perceived fatigue as subjective measurements. For workload, a common tool is the NASA-TLX (Hart and Staveland, 1988) but there is also a Mental Workload Test (DiStasi et al., 2009). Two questionnaires often used to evaluate fatigue are the Karolinska Sleepiness Scale and the Stanford Sleepiness Scale.

The emotional effects can be measured subjectively. Concerning the topic of fatigue, it is of interest to evaluate the driver's state regarding boredom vs. arousal. This can be assessed with for instance Likert-scales attached to words describing emotions and user's state or tools as the Self Assessment Mannikin (SAM, Bradley and Lang, 1994) based on a model on pleasure, arousal and dominance or Emocards (Desmet et al., 2001).

Table 2: Methods of cognitive driver fatigue measurement

Author	Year	ECG	SCL	Respi-ration	Eye measure-ments	EEG	Perfor-mance	Subjective evaluation
Ahlstrom et al.	2013	-	-	-	X	X	-	X
Backs et al.	2003	X	-	X	-	-	-	-
Collet et al.	2003	-	X	-	-	-	-	X
Desmond and Matthews	1997	-	-	-	-	-	-	X
DiStasi et al.	2012	-	-	-	X	-	-	X
Gershon et al.	2009	X	-	-	-	-	X	X
Gillberg et al.	1996	-	-	-	-	X	X	X
Kar et al.	2010	-	-	-	-	X	-	-
Lal et al.	2003	-	-	-	-	X	-	-
Liu and Wu	2009	-	-	-	-	-	-	X
Mehler et al.	2008	X	-	-	-	-	X	-
Mehler et al.	2012	X	X	-	X	-	X	-
Merat and Jamson	2013	-	-	-	X	-	X	-
Patel et al.	2011	X	-	-	-	-	-	-
Reimer et al.	2011	X	-	-	-	-	X	
Schmidt et al.	2011	X	-	-	X	-	-	X
Simon et al.	2011	-	-	-	-	X	-	-
Sung et al.	2005	-	-	-	-	-	X	X
Thiffault and Bergeron	2003	-	-	-	-	-	X	-
Ting et al.	2008	-	-	-	-	-	X	X
Yang et al.	2010	X	-	-	X	-	-	-

CONCLUSION

Driver fatigue consists of physical and/or cognitive fatigue. Physical fatigue is related to perceptual-motor adjustments specific to the driving task (holding and operating the steering wheel, using the foot levers) and to discomfort caused by prolonged sitting. Possible countermeasures against physical fatigue are passive or active micro-movements and the stimulation of macro-movements. Cognitive fatigue can be subdivided in task-related and

sleep-related fatigue. Sleep-related fatigue is considered intervention resistant by some researchers although there are studies that show a positive effect of blue light on this type of fatigue. Task-related fatigue is caused from task-overload or underload. In the case of task-overload, driver assist systems and automation provide a solution. In the case of task-underload a variety of stimulation is needed which can consist of a secondary task, haptics, thermal stimulation and scent. There are several objective and subjective measurements one can apply to evaluate a person's fatigue state.

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Mock-Up Test of Two Train Toilet Modules

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ABSTRACT

Train toilets are perceived to be dirty and as a consequence train travelers rate the toilet as insufficient. While the train toilet is mainly used to urinate it is for men impossible to keep the train toilet clean without spilling urine outside the bowl while standing. This causes women to hover while urinating and as a result they add to the soiling of the train toilet, by spilling drips over the seat. A 'hygienic train toilet' will make train travel more attractive, and it can remove one of the obstacles to travelling by train, particularly for the elderly and families with young children. A possible solution to improve hygiene in the train toilet is splitting its interior based on the posture while urinating. Accordingly, a toilet with two modules was designed: One for urinating standing and the other for the seated or hovered toilet use which was 'inclusively designed', thus the interior is enhanced with adaptations such as toddler platforms, a diaper changing table, extra support and enough space for wheel-chair manipulation. The observation and questionnaire both with 26 users of 3-68 years old (some wheel chair users) showed that the mock-up of the train toilet indirectly scored a 7.1 on a 10 point scale (1= very bad, 10= very good), but there is room for improvement, for instance a sanitary waste bin, an extra support bar on the left side of the toilet and a toddler platform under the urinal were lacking.

Keywords: Train toilet, Hygiene, Inclusive Design, Mock-up testing, Observational research.

INTRODUCTION

Public toilets are a necessity and perceived to be dirty (Kira, 1976; Greed, 2003; Barcan, 2005; Greed, 2006; George, 2008, Williams, 2009). Train travelers also complain about dirty toilets and that is the main reason why 83% of the train travelers avoid them (Omnibus survey, 2009, Loth & Molenbroek, 2011). The presence of a train toilet seems to be very important to the train travelers and 5 to 8% of the train travelers, actually use it (Louts, 2011, Loth et al., 2014). Particularly for the elderly and families with young children the dirty train toilet can even be a reason to avoid train travel (Buzink et al., 2008; Molenbroek et al., 2011; Loth et al, 2014).

In addition, this group of train travelers appears to travel by train more often during off-peak hours, the time when there are plenty of seats available in the train as the average occupancy during off-peak- hours is merely 30% making them a potentially interesting customer group for the NS (Boer et al., 2008).

In an attempt to change this undesirable situation, the project 'Hygienic Train Toilet' was started which is a cooperation between Delft University of Technology, Faculty of Industrial Design Engineering and the NS (Dutch national Railways). The project encompasses the research and product development of toilets with a focus on the perception of (un) hygienic train toilets. The main purpose of the project is to significantly improve train toilet hygiene so that 'taking the train' becomes more attractive, or more specifically that the train traveler will rate the train toilet as sufficient. It will not be straightforward to improve and make train toilets more hygienic as they should be suitable for a wide variety of users (Molenbroek and De Bruin, 2011). These users vary in age, physical capacities and in gender (Loth et al., 2014). The design challenge is to research through design a train toilet that is accessible and suitable for everyone who is able to travel by train (Hekkert et al., 2009).

From our earlier research (Loth & Molenbroek, 2011, Loth et al, 2014) we concluded that the train toilet is mainly used to urinate and that the vast majority of men use a standing position while urinating. For them it is probably impossible to keep the train toilet clean without spilling urine outside the bowl. In addition, more than half of the women hover over the toilet because the toilet (seat) is perceived to be dirty. This hovering position can also cause a significant soiling of the toilet seat and floor (Kira, 1976; Greed, 2003).

Since people use toilets in different ways, this variety in usages may not be compatible with one physical design.
More effective is to have two different designs of collecting urine and faeces and therefore we propose to split the toilet interior into two modules: one for urinating in a standing position and one for the seated or hovered toilet use. As a consequence one module serves as a train urinal, see figure 1 and another module reflects a family sit toilet, see figure 2 to improve the hygienic and ergonomical wishes of its users. Consequently, the design of the family sit toilet is enhanced with small adaptations, such as toddler platforms, a baby changing table, enough space for wheel chair manipulation and extra bars at strategic places to be stable in a moving train (Molenbroek et al., 2011; Anthony and Dufresne, 2007; BTA; DTO; WTO; Inclusive Design Toolkit; Greed, 2003).

Figure 1. Interior of train urinal

Figure 2. Interior of Family sit toilet

As part of larger studies this present paper demonstrates the assessment of two train toilet modules including the train urinal and some aspects of the family sit toilet based on observational research (Kanis and Rooden, 2005; Kumar, 2005).

DESIGN OF THE MOCKUP

The design challenge is that the train toilet should be suitable and accessible to everyone who is able to travel by train. Accordingly, the train urinal is designed for men and boys who urinate standing up whereas the family sit toilet is designed for other usage.
Three important characteristics can be distinguished in the design of the two mock-ups as a unity presenting a train toilet:

1. Separate urinal for males facilitating a reduction in distance to the bowl for them when using the toilet. The effect should be that the other toilet seat should stay clean.
2. Inclusive design of the family sit toilet module: wheelchair access guaranteed, both sexes of every age can use it. There is enough space for wheelchair manipulation. A toddler platform and a baby diaper-changing table are at hand, see figure 2.
3. Extra support. Extra bars will be positioned at strategic places in the interior enhancing stability in a riding train. (Buzink et al., 2011). An extra broad toilet seat is available for toddlers and the transfer of wheelchair users

(van Dijk, 2010; McClelland and I.L.Ward, 1982), see figure 2 and figure 6.

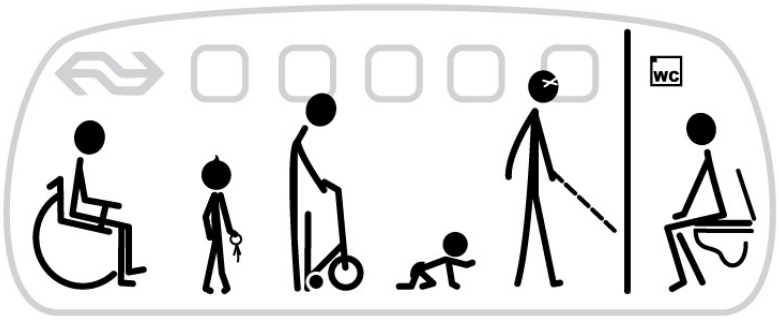

Figure 3. Inclusion of specific user groups in the design: Inclusive design of the train toilet.

The next three steps were followed in the design of the train toilet:

1. Differentiation of the train toilet interior into two separate modules.
2. Outline of the basic form of the interiors.
3. Integration of the key-elements and the adaptations into the interior.

The design of the two different modules is described below.

1. Train urinal and washbasin combination.

The starting point for the design of the urinal, see figure 1 and 4 is to create a certain visible and physical distance between the urinal and the washbasin, however both are combined and connected. Firstly, the visible distance is created by designing the washbasin next to the urinal and not above the urinal which is already an existing product idea (Cijffers, 1996, Kim, 2010). Secondly, according to the physical distance, the man has to take an extra step to use the washbasin. Reason for this is to involve somehow a distinction in seemingly contradictory activities. Namely using a urinal is to 'relieve' yourself in contrast to using a washbasin what is used to clean yourself. Thus it is important in the design to create a certain distance between a 'clean' activity (washing the hands) and a 'dirty' activity (urinating in an urinal).

According the design of the urinal a round separation wall has been chosen to have a same form integration with the family sit toilet module. Thus although the two separate train toilet modules have a different design approach, they still belong together as their function is a train toilet. Therefore they belong to each other and this is translated in a roughly same round form characteristic.

The urinal is designed for men and boys who urinate standing up, see figure 1. The urinal is combined with a washbasin reminding the man or boy to wash his hands. The space is partially open, there is no door, but the visitors' privacy is guaranteed. The same idea is shown in the current street urinal of Amsterdam 'the krul' and in the design of a 'hygienic train urinal' (Van den Meiracker, 2011). The range of facilities nearby is fairly basic: a 'waterfall' faucet, a soap dispenser and an electric hand dryer are available. Because of the presence of a hand dryer it is presumed that a waste bin would not be necessary. The absence of paper towels will provide a cleaner impression, as they cannot be disposed of on the floor.

The room is designed as a touch free area meaning that a man doesn't need to touch any button or tap. Hand washing and the urinal facility are combined in one product to encourage hand washing and therefore hygienic behavior after the use of the urinal. It is stated that upon hearing and seeing the flowing water, the user is encouraged to wash his hands.

This positive hygienic behavior seems to be triggered by means of a sensor. This sensor activates the discharge of the water from the tap as soon as the man steps away from the urinal. The sight and sound of water flowing into the basin along with the passage to the urinal reminds a user to wash his hands and the same 'grey' water will also flush the urinal (Loth, 2011, 2013).

Figure 4. Exterior of train urinal module

Figure 5. Interior Family Sit Toilet' module

2. Family sit toilet module

The starting point for this design, see figure 2 and 5 was to make it accessible for many types of users. It is a spacious, wheelchair accessible train toilet that accommodates anyone wanting to use the toilet in a sitting or hovering position. It offers additional facilities for the elderly (extra support bars), parents with small children (toddler platform) and babies (baby changing table) and an extra broad toilet seat is available.
The design of the toilet seat has the following characteristics, see figure 6: Firstly, the broad rim supports toddlers while climbing on the toilet and assists wheel chair users with the transfer to the toilet. Men can sit comfortably on it as well, as the wider opening of the seat prevents contact between the penis and the toilet while sitting on the seat (van Dijk, 2010; McClelland and I.L.Ward, 1982).

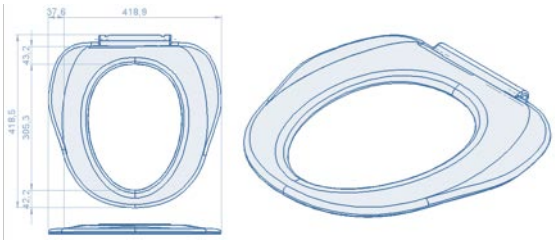

Figure 6. Extra broad toilet seat with larger opening compared to current toilet seat.

The question for the mock-up testing was how this new mockup is assessed by the passengers using the toilet.

METHODS

Subjects and Procedure

26 subjects with a large variation in age (3-68 years), gender and physical capacity (elderly walker/rollator (2) and wheelchair users (5) participated in testing the effect of the designed mockup consisting of two modules. During their 'dry' usage they were recorded by four cameras, which were later observed and tapped and interviewed, whereby a man interviewed a man and a woman interviewed a woman. This procedure was chosen because of the private nature of a visit to the toilet. It is quite comprehensible, for example, that a participant would not be pleased to discuss issues as wiping with a representative of another sex.

The participants are asked to sign a confidentiality agreement and a consent form in advance. Fortunately and remarkably, the signing did not lead to discussions or problems with any single participant in contrary to what was stated by (Rauhala M, 2011).

The Location of the Mock-Up Test

The mock-up testing is conducted in three steps in two different rooms. The first room serves to receive the participants and inform them about the research method. In the second room the actual mock-up testing takes place. The rooms are situated close to one another in the same corridor. The first room is called the 'hospitality lab' because of its function of receiving the participants. As the name seemingly mentions it has a relaxing atmosphere and a homely interior. There is a television, for example, a couch and domestic lighting.

The other spacious room in which the mock-up testing is executed houses the two different mock-ups. The train urinal is situated on one side, on the other side the family toilet. Consistent with the participants' answer to the introduction question in the hospitality lab which option they will choose to urinate in the train –either the urinal or the family toilet-, a researcher covers one of the mock-ups so as to make only the chosen mock-up visible and usable for the participant, see figure 7.

Figure 7. Mock-up testing in Family sit toilet module with toddler girl and her father, the train urinal is covered with a curtain and therefore not visible for the participant. She uses the platform to climb on the toilet.

The Three Steps of the Mock-Up Test

The research is carried out in three steps:
1/
The first step is completing a questionnaire about general issues of the train trip connected with the train toilet. For example, how often they travel by train, whether they use the toilet in the train, how they rate the toilet in the train and questions about age, gender, length and weight.
2/
The next step of the mock-up testing comprehends passing through the research protocol of the observations during which procedure a personal conversation with the participant takes place. The consent form is signed in which they give permission to be videotaped whilst the researchers guarantee their privacy. They also sign a confidentiality agreement in order to exclude issues concerning the patent application of the urinal.
In the personal conversation the use of cameras is explained and the researcher emphasizes that the participant does not do anything wrong by taking part in the experiment, thus making sure that the participant will feel at ease.
3/
Finally the participant is brought to the mock-up testing room and a next researcher asks the participant to use the train toilet mock-up in the usual way, fully clothed. During the 'dry' use of the train toilet module the researcher interrogates the participant about toilet behaviour and usage. The questionnaire concerns the different elements in the toilet such as an answer to the question if there is enough space. To conclude with the participant receives a gift certificate of 10 Euro as a token of gratitude and for compensation.

RESULTS

Observations were split in results concerning using the family toilet and using the urinal. Regarding the family sit toilet the following results from observation were striking:

Observations showed that participants (especially wheelchair users and toddlers) looked for support on the left side of the family toilet while sitting down on and getting up from the seat, so a bar on this spot seemed to be necessary. A vertical bar was placed in the front of the family-toilet. Observation showed that it was used by the participants, especially by women who hovered above the seat and it seemed that it is useful, see figure 8.

Figure 8.
A female participant uses the vertical bar in front of the toilet while hovering above the seat.

Probably because of the rough design of the facility to clean the seat, it was not clear to the participants that this was the case, a participant mentioned that she was wondering what it was when asking about the facility. Therefore the facility raised questions by the participants and needed to be explained. In addition, it was mainly used by the three toddlers as an extra support possibility. When explaining and asking specifically about the facility the participants were positive about it and would like to use it.

Several women (2 out of 6) admitted that they sometimes throw hygiene products into the toilet which can cause blockage of the (delicate) train toilet flushing system.

The washbasin had a low position of 800 mm above the floor. The observations showed that children and wheelchair users could use the washbasin well in this position and also the taller participants were able to wash their hands. Some tall participants bent forward but it seemed feasible. The questionnaires gave the same impression.

The new form of the toilet seat scored on a scale from 1-10 (1=very bad, 10=very good) an average rating of 6.9 that means it was appreciated. Meanwhile we cannot compare it with a current toilet seat as we did not test or ask to rate a current toilet seat. The toilet seat was fixed. Some participants nevertheless tried to put it upwards. The opinions on a wooden toilet seat varied from ‘dirty’, ‘sharp’, ‘unhygienic’ to ‘cozy’, ‘warm’ and ‘firm’.

Observations showed that all toddlers used the platform to climb on the toilet, see figure 7.

The Questionnaires, see table 1, showed that there was enough space. On a scale from 1-10 (1=small, 10=large) the average rating was 7.3. The wheelchair users had an average of 5.7, which shows that they perceived the space as rather small. In the observations it was clear that one wheelchair user with a small wheelchair was capable of making the whole turn, see figure 9 whilst the others had difficulties in turning. Two users experienced the room as very small.

Figure 9.
Wheel-chair user with a small wheel chair in the mock-up

One father participant closed the toilet lid so that his daughter could stand on it in the vicinity of her ‘sister or brother’ (in real it was a puppet), while the father changed her nappy.
One woman had concerns that the head of the baby, the puppet, could fall in the gap next to the baby-changing table,

see figure 2. The table below shows the results from the questionnaire of the family sit toilet.

Table 1:Questionnaires of Female and Male, Wheelchair and Rollator users in the mock-up testing of the family sit toilet.

Family sit toilet **F: Female** **M: Male** **W: Wheelchair** **R: Rollator**	**Rating and remarks toilet seat:** **1: very bad-** **10: very good**	**Toilet seat inviting to sit down?** **1. yes** **2. no** **3. ?**	**Rating and remarks space:** **1: too limited-** **10: too large**	**Height and remarks washbasin:** **1. too low** **2. good** **3. too high** **4. no opinion**	**Remarks Female hygiene**
1F	10, Good sitting, enough legroom	2. No, Always hover	10, Too large	1. Too low, Height acceptable	Tampons, throwing in toilet
2F	-, No opinion, I always hover.	2. No	9, Large for a train toilet, not necessary.	2. Good, Cannot see the tap.	Not applicable
3F	7, Good support	3. I always sit down, same as current toilet seats.	8, Very large	1. Too low, Cannot see my hands.	Tampons and sanitary pads.
4F	7.5, Good sitting	1.Yes, habit to sit down	9, Satisfied, comfortable	1. Too low. Low height, no problem	Tampons, not in train, afraid for infection. Thin sanitary pads.
5F	8, Not bad, normal toilet seat.		7, Perfect, just right	2. Good, Cannot see my hands.	Tampons. Sanitary pads. If there is not a small plastic bag available, I throw it in the toilet.
6F	6, Not special or remarkable.	2. No	7, -	1. Too low, A little bit too low.	Tampons.
7M	8, Spacious in front. Wood feels warm.	1. Yes, Because it looks solid and firm.	8, -	2. Good, -	Not applicable
8M	7, Opening of toilet seat large enough.	1.Yes, If it is clean	8, -	1. Too low, -	Not applicable
12FW	3, Preference for plastic seat. Wood not hygienic.	2. No, It looks poor	2, -	2. good, -	Not applicable
13FW	3, Don't like the wooden material, Sharp, no support, no bars.	2. No.	1, Space is too small, Nearly nothing fits in it.	1. Too low, Cannot see the tap.	Sanitary pads. Difficult to take of the strip and find the waste bin.
14FW	7, Normal, as at home.	1.Yes, I always sit down, safer.	7, -	2. good, -	Not applicable
15MW	7, Common toilet seat.	1. Yes, Different material, gives something extra, better than plastic.	5, Just good, can even make a whole turn.	2. good, Good height.	Not applicable
16MW	8, Preference for plastic.	1. Yes, A man needs to open the toilet seat.	8-9, Too large, young people can go together.	2.good, Reachable while in wheel-chair.	Not applicable
17MR	8-9, Fine.	1. Yes, In the train always standing posture.	10, Pleasant size. There is space for the rollator. Standing up goes well.	1. too low, Appropriate for the children.	Not applicable.
18FR	6, Moderate.	1. Yes, I always sit down	6.5, -	2. good, -	Not applicable

Finally, from the observation of the urinal it was remarkable that two young boys showed a preference for using it while the mother also encouraged the use of the urinal although for these small boys the position of the urinal was too high. The table below shows the results from the questionnaire of the train urinal.

Table 2: Questionnaires of 2 Boys and 6 Men in the mock-up testing of the train urinal.

Train Urinal **M: Male** **B:Boy**	**Height urinal:** **1. too low** **2. good** **3. too high** **4. no opinion**	**Height washbasin:** **1. too low** **2. good** **3. too high** **4. no opinion**	**Hand-washing suitable** **1. Yes,** **2. No,**	**Handwashing understandable** **1. Yes,** **2. No,**	**Encouraging Hand-washing?** **1. Yes,** **2. No,**	**Enough privacy?** **1.Yes** **2. No** **3.No opinion**	**Providing Enough safety?** **1.Yes** **2. No** **3.No opinion**	**Rating passage** **1: too limited-10: too large**
19M	2.good	2. good	1.Yes, Basin large enough.	1.Yes	1.Yes	1. Yes	1.Yes	8
20M	1.too low, Little bit,(body-length 1.86)	2. good	1.Yes	1.Yes	1.Yes, Rewarding by flushing	1. Yes, Perhaps sometimes problematic	1. Yes,	10, Too large.
21M	2. good	2. good	2.No, Washbasin too close to urinal.	1.Yes	1.Yes, Seems cleaner 2.No, don't like the combination (clean and dirty).	1.Yes, Space offers enough privacy 2. No, Location urinal offers not enough privacy	1.Yes, Not afraid	5, Little bit too limited.
22M	2.good,	2.good, Tap needs to be lower.	1.Yes, Tap too high	1.Yes	1. Yes, When turning, you pass the washbasin	1.Yes, Sure	1. Yes, Unless someone intentionall y enters	9
23B* (10 years)	3. too high On tiptoes reachable	2.good	2. No, Sleeve becomes wet.	-	-	2. No, I can hear the footsteps	Yes and No, Afraid that someone will enter.	5
24B (12 years)	2. good	2.good	1.Yes, Tap too much out.	1. Yes, Good for the environment	1. Yes, Due to the flushing	2. No, People come too close by	1. Yes 2. No, If it's full with other passengers	8
25B (25 years).	2. good	2.good	1. Yes, Enough space	1.Yes	2. No, No difference.	1. Yes	1. Yes	6
26M	2. good	2.good, Higher than normal, but good.	1. Yes	1.Yes	Always wash my hands, perhaps yes.	1. Yes, semi-transparen cy works well.	1. Yes, More sense of supervision	6-7, Just good

DISCUSSIONS

The main proposed solution to enhance train toilet hygiene is to add a urinal to facilitate a reduction in distance to the bowl for men using the toilet in a standing position while urinating. The effect should be that mainly the toilet seat is cleaner. Furthermore a family sit toilet is introduced for people who need or prefer to sit, which also includes men who prefer to use the toilet whilst seated. As a result we hope that more women dare to sit on the toilet seat as there is no spillage of urine when the user is seated (Loth & Molenbroek, 2011).

This family sit toilet is enhanced according the 'inclusive design theory' with small adaptations such as toddler platforms, a baby changing table, enough space for wheel chair manipulation, extra bars at strategic places to be stable in a moving train and finally an extra broad toilet seat (Molenbroek et al., 2011, Inclusive Design Toolkit).

Regarding the question whether this new two-way mockup is positively assessed by the train passengers the answer based on the observations and the answers given in the questionnaire is 'yes'. However, this research also has the next shortcomings:

Participants
As priority is given to involving a large variety in users, the number of participants per specific user-group is low. For example, only two rollator users and two toddler girls used the family sit toilet and it is hard to generalize their results to the whole group. However for a user research this number will give a good indication and direction (Kanis &Arisz, 2000).

Assessment
The scores given on the assessment of different features can been influenced by the following aspects:

First, the judgments can be positively influenced because of the (positive) context of the mock-up testing, namely the context is a lab-situation in a university environment. This situation does not involve a toilet on a riding train, while shaking of the train could influence observations. Moreover, the mock-up was not used and therefore not dirty at all. In addition, it was not an assessment of the cleanliness of the design but of the design itself. Still, the clean, unused state of the design could have had a positive effect on the assessment.

Next, to minimize the *Hawthorne Effect* we have not asked directly to give a score to the complete mock-up as we considered that the participants should give a more positive score to please the researcher for the close attention that is given by the researcher. Accordingly, we measured the assessment indirectly by asking a score of important elements in the mock-up including the toilet seat and the space of the family sit toilet and the passage of the urinal. Nevertheless, low ratings are given, so a positive influence of the judgments known as *the Hawthorne effect* is not really demonstrated (Kumar, 2005).

Although, giving a score between 1-10 was understandable and did not raise unclarity it was by some participants differently interpreted. Namely for example one participant rated a five for the space, see table 1, 15MW, while he said it was just perfect, so not too small and not too large. Since we defined a five as a negative score, in this case the five was not meant to be negative. So this specific case had a negative influence on the average assessment of the space, while it was actually positive. On the contrast, for example one participant gave a 10 to the toilet seat, see table 1 1F and when asking to explain this high score she said that she had enough legroom, it was good and the sitting went well.

Besides, about the wheelchair users using the mock-up it was remarkable that two (out of five) of the wheelchair users rated the inner space low, see table 1 12 FW and 13FW, as the observations showed that they could manipulate their wheelchair sufficiently, but were not able to take a turn. Compared to the current train toilet the inner space of the family sit toilet is larger and the women for example rated the inner space as big. Someone specifically remarked that she could dance in the mock-up.

To conclude the scores were personal and sometimes differently interpreted, but we thought too negative and too positive scores were in balance.

Design

The next design features mentioned per module will be discussed, namely the toilet seat, spray facility, extra support, sanitary waste bin and hand cloth.

1. Family sit toilet

To start with the toilet seat, the larger opening of the toilet seat approved to offer men more comfort while sitting

compared to a current toilet seat and both male participants remarked the extra sitting comfort due to the larger opening, see table 1 7M and 8M. However it needs to be further researched upon with more female participants as one female participant specifically mentioned that the opening was too large and that she fell through the opening of the toilet seat. So, the extra broad rim at the back and side of the toilet seat is recommended and its larger opening compared to a current toilet seat needs to be further researched with more female participants. Furthermore, it cannot be concluded that this new type of toilet seat will encourage the user to sit on the toilet, although one participant mentioned specifically that he would sit down because of the broad rim of the toilet seat. This is perhaps mainly influenced by the material and finishing of the toilet seat. In the mock-up testing the material was wood and the finishing was not optimal. To be able to draw conclusions a toilet seat needs to be tested that is as close to the reality as possible.

It can be expected that people are more willing to sit down on the toilet seat if they can clean the toilet seat in advance. So a facility to clean the toilet seat in advance is recommended. These solutions already exist in some public places, but not in train toilets.

It can be concluded from the observations as well as from the questionnaires that an extra support bar on the left side of the toilet is still necessary. In addition, the majority of the participants expect an extra support bar on this spot whereas it was previously thought that the extra broad rim of the toilet seat at the back and side would serve as an extra support possibility and therefore could substitute an extra support bar.

Next to a horizontal bar in front of the user a vertical bar in front of the user is also recommended to support women when hovering above the toilet and it is hoped that by using the vertical support bar the distance to the bowl will be reduced while hovering above the toilet. Besides, it is also positioned at a strategic place to stable enhance stability for people such as the elderly in a riding train. (Buzink et al. 2006, Molenbroek et al., 2011, Loth & Molenbroek, 2011).

An additional sanitary waste bin in the vicinity of the toilet bowl is recommended to prevent blockage of the (delicate) train toilet flushing system as several women (2 out of 6) admitted that they throw female hygiene products into ‘the nearest bin’ thus the toilet. (Williams, E. Y. 2009, Greed, 2003))

In conclusion the participants appreciated the family sit toilet mock-up module mainly because of the extra space offered in the family sit toilet module and extra facilities such as supports and child-elements.

2. Train urinal

Regarding the urinal the male participants were positive about the design and possibility to use it. Firstly, it was clear how to use it and they thought it would catch the urine properly. Another aspect is that it offered enough privacy and lastly the washbasin combination encouraged the hand washing sufficiently, see table 2 results questionnaire train urinal.

Although the absence of hand cloth can reduce waste on the ground, it needs to be further researched if the substitution of drying the hands by an electric hand dryer is appreciated by the user in connection to hygienic experience.

Small boys also want to use the urinal, for them a toddler platform is necessary as to reach the urinal properly.

CONCLUSION

As a general conclusion, the mock-up is positively assessed based on observations and questionnaires as it scored indirectly a 7.1 on a scale from 0-10 (1= very bad, 10= very good), whereby the toilet seat was rated with an average of 6.9, the space in the family sit toilet scored a 7.3 and finally the passage of the urinal scored a 7.2.
So, the new split train toilet design is understood and positively assessed by the 26 participants, but still improvements in the design are necessary and as part of larger studies these recommendations will be executed and tested in following mock-up testing.

The next recommendations for further design, mentioned per module can be concluded by the mock-up testing and will be executed and tested in following mock-up testing.

A. Family sit toilet:

1. An extra support bar on the left side of the toilet is necessary.
2. As well as a horizontal bar as a vertical bar in front of the user or toilet is necessary.
3. A facility to clean the toilet seat (in advance) is recommended as people are more willing to sit down on the toilet seat. If more people are seated less urine will be spilt in the toilet environment (Loth and Molenbroek, 2011).
4. The extra broad rim at the back and side of the toilet seat is recommended.
5. An additional sanitary waste bin in the vicinity of the toilet bowl is recommended to prevent blockage of the (delicate) train toilet flushing system.
6. The height of the washbasin (800 mm), as also stated by Greed(2003) is evaluated acceptable.

B. Train urinal

7. Toddler platforms are necessary for toddlers to reach the toilet and consequently also a toddler platform under the urinal is necessary as to reach the urinal properly.
8. An open space of the urinal with semi-transparent elements, see figure 1,4 and 10 offers enough safety and privacy for the man.

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A Method for Assessing Customer's Confidence in Safety in a Railroad Company

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ABSTRACT

Users of railroad service have to choose a railroad company. When they choose them, they think about convenience, price, how safe they actually are, and how safe users can subjectively feel. We call the subjective degree of safety users feel confidence in safety (CIS). Some railroad companies need to assess CIS for their branding strategy. Therefore, we propose the assessment method of CIS in this paper.

Keywords: Branding Strategy, Safety in Railroad, Confidence in Safety

INTRODUCTION

Users of railroad service have to choose a railroad company. When they choose them, they think about convenience, price, how safe they actually are, and how safe users can subjectively feel. We call the subjective degree of safety users feel confidence in safety (CIS). Actually, CIS is important factor of choosing a railroad company. In many cases, unless CIS was analyzed quantitatively, most of user evaluate CIS subjectively rather than actual safety to choose railroad company. In fact, users choose a railroad company without researching the number of accidents. In Japan, the number of serious accidents about railroad service has been declining. Therefore, they don't take the trouble to research how safety the railroad company which they will use before using railroad service.

"A Railroad" which is one of the railroad companies in Japan aims at raising a brand of security and safety by evaluating CIS. (Figure1.)(Figure2.)This paper is intended to propose the assessment method of CIS. Then, we assessed the CIS of particular railroad company using some indexes.

Ⅰ. Information about the consciousness of the customer

Ⅱ. Objection information from a customer

Ⅲ. Consciousness about the safe activity of the employee

Figure1.Image of raising a brand of safety and security

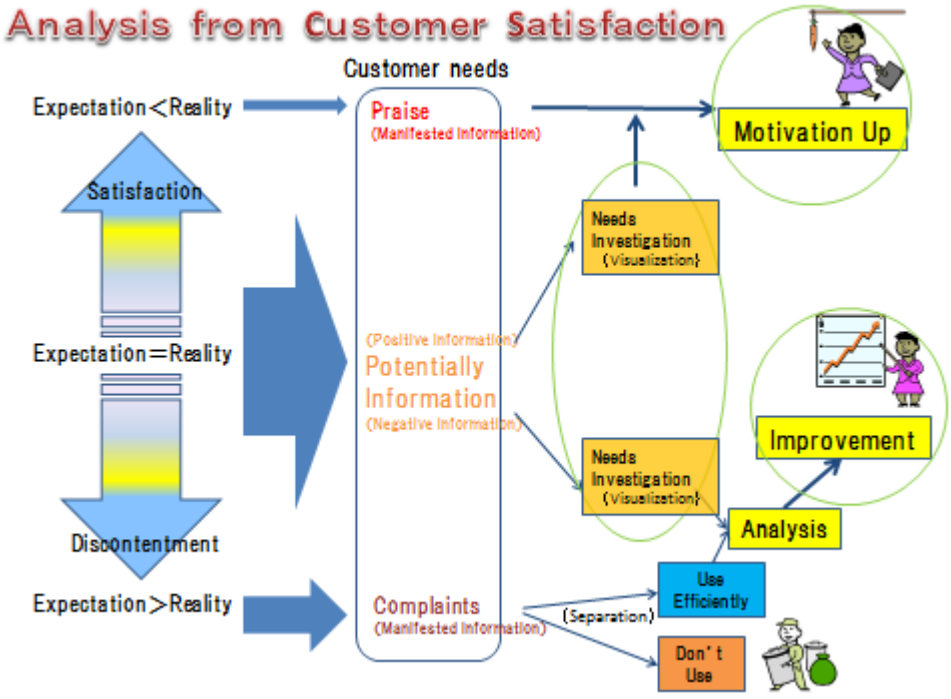


Figure2.Image of using customer information in Railroad Company

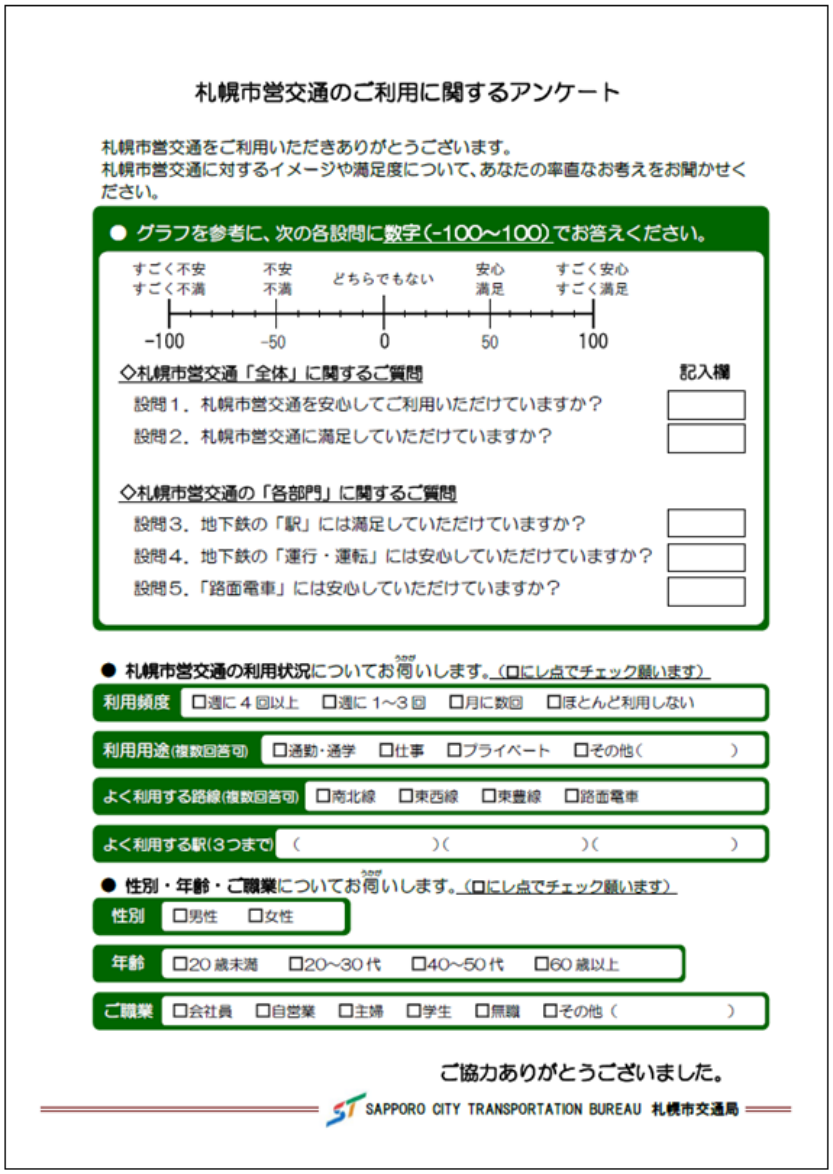
EVALUATIONS ABOUT THE CONSCIOUSNESS OF THE CUSTOMER

We give evaluation standards concretely as follows. We used three standards such as “CIS of the railroad company,” ” CIS of station service,” ”CIS of train service”.

① CIS of the railroad company

② CIS of station service

③ CIS of train service



札幌市営交通のご利用に関するアンケート

札幌市営交通をご利用いただきありがとうございます。
札幌市営交通に対するイメージや満足度について、あなたの率直なお考えをお聞かせください。

● グラフを参考に、次の各設問に数字(-100~100)でお答えください。

すごく不安 すごく不満 / 不安 不満 / どちらでもない / 安心 満足 / すごく安心 すごく満足

-100 -50 0 50 100

◇札幌市営交通「全体」に関するご質問　記入欄

設問1．札幌市営交通を安心してご利用いただけていますか？
設問2．札幌市営交通に満足していただけていますか？

◇札幌市営交通の「各部門」に関するご質問

設問3．地下鉄の「駅」には満足していただけていますか？
設問4．地下鉄の「運行・運転」には安心していただけていますか？
設問5．「路面電車」には安心していただけていますか？

● 札幌市営交通の利用状況についてお伺いします。(□にレ点でチェック願います)

利用頻度　□週に4回以上　□週に1~3回　□月に数回　□ほとんど利用しない

利用用途(複数回答可)　□通勤・通学　□仕事　□プライベート　□その他(　　)

よく利用する路線(複数回答可)　□南北線　□東西線　□東豊線　□路面電車

よく利用する駅(3つまで)　(　　)(　　)(　　)

● 性別・年齢・ご職業についてお伺いします。(□にレ点でチェック願います)

性別　□男性　□女性

年齢　□20歳未満　□20~30代　□40~50代　□60歳以上

ご職業　□会社員　□自営業　□主婦　□学生　□無職　□その他(　　)

ご協力ありがとうございました。

SAPPORO CITY TRANSPORTATION BUREAU 札幌市交通局

Figure3.A sample of questionnaire sheet in Japanese

FINDINGS ABOUT THE CONSCIOUSNESS OF THE CUSTOMER

We investigated above indexes to 500 customers. Then, we did principal component analysis and correspondence analysis for that. From Figure4 and Figure5, we got knowledge like those.

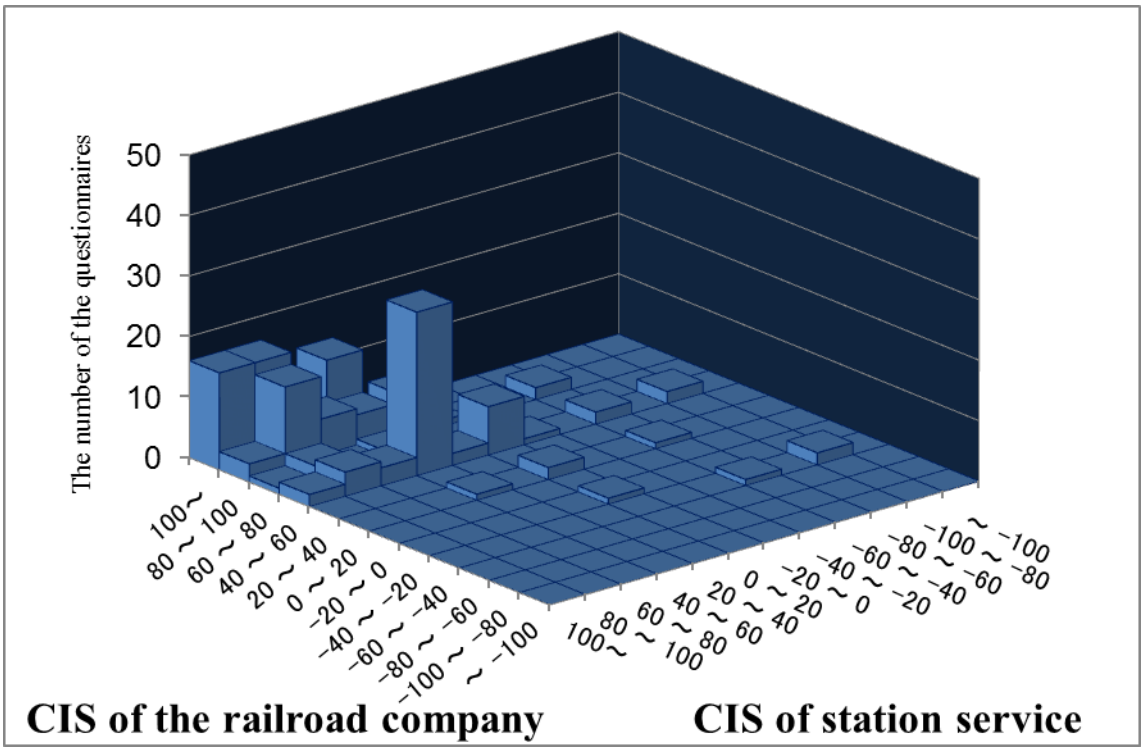


Figure 4.Total results of questionnaire about ① and ②

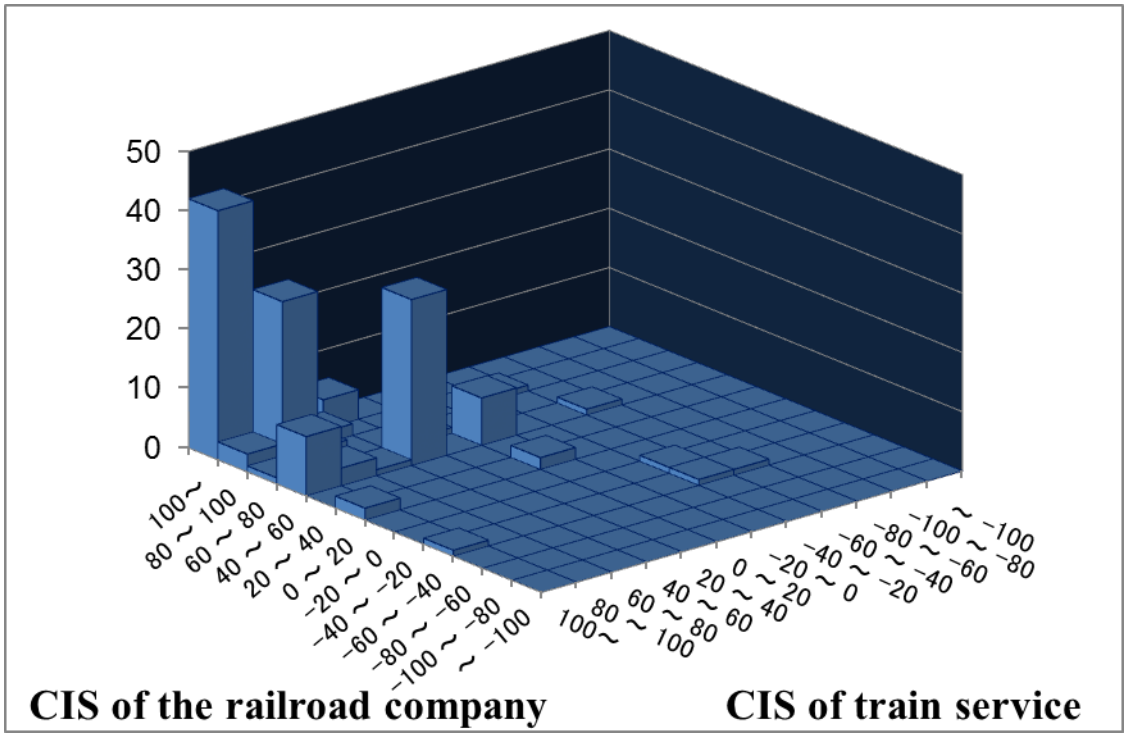


Figure 5. Total results of questionnaire about ① and ③

ANALYSIS ABOUT THE CONSCIOUSNESS OF THE CUSTOMER

- there were interrelations between subjective evaluation value and CIS
- there were much influence on institution rather than railroad man service about ②
- there were more complaints from people who use rarely rather than frequently

COMPLAINTS INFORMATION OF THE RAILROAD COMPANY

Then, we performed analysis about complaints information of the railroad company.

DIVIDING AND COUNTING COMPLAINTS INFORMATION OF THE RAILROAD COMPANY

We analyzed complaints information of the railroad company which was being collected on daily basis. We divided complaints by words and did phrase analysis. Then, we found that those could be divided some groups. First, we divided three groups such as “Danger”, “Anxiety”, “Security and Safety”. Then we divided hardware such as “Facilities”, “Information”, “People” and software such as “Perception”, “Cognition”, “Communication” and “Action”.

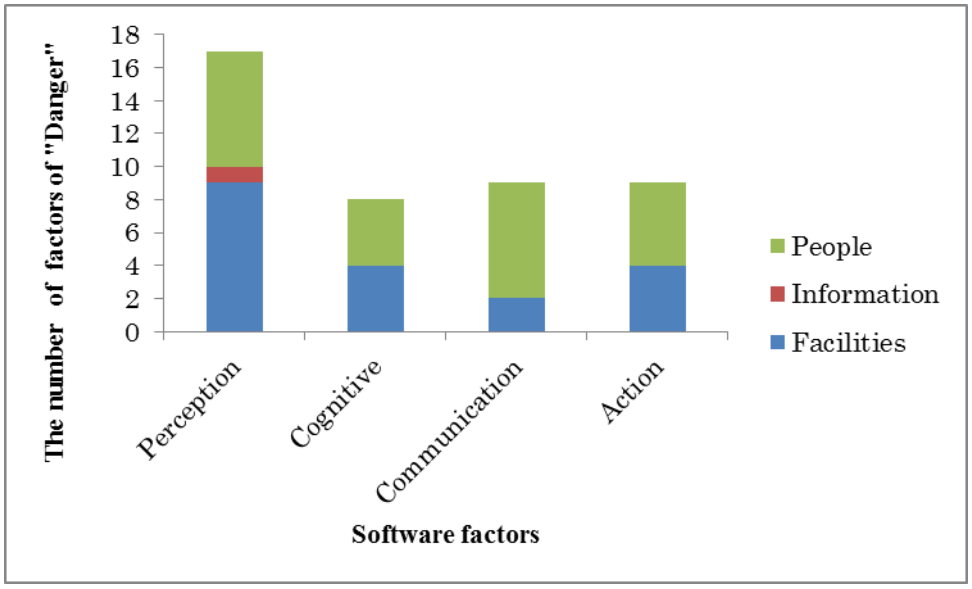


Figure6.The number of factors of “Danger”

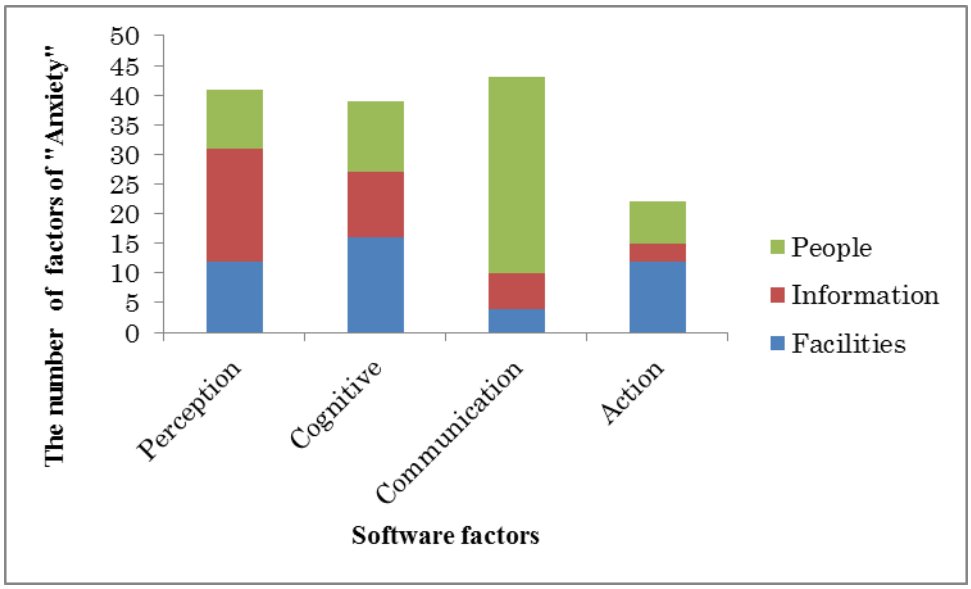


Figure7. The number of factors of “Anxiety”

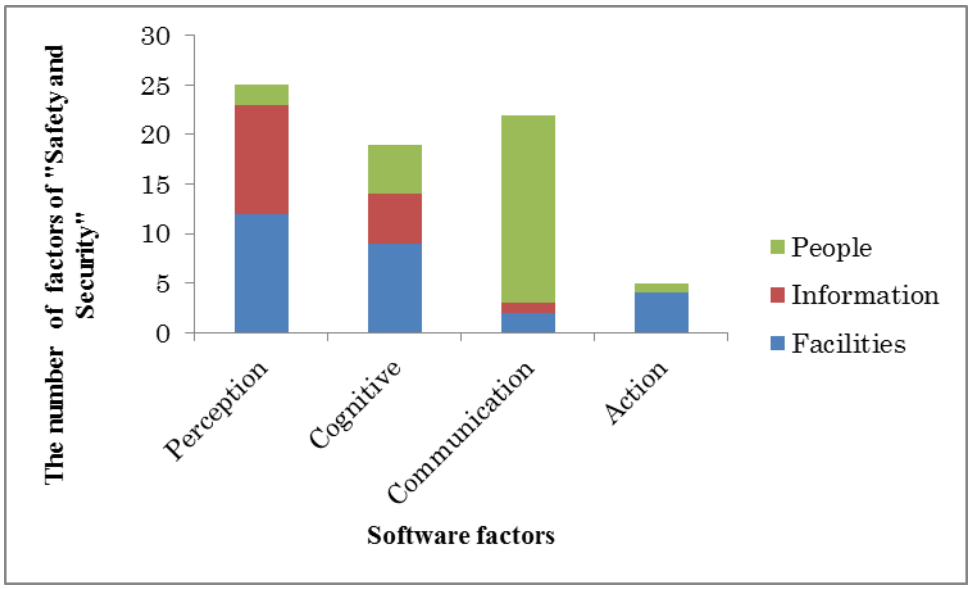


Figure8. The number of factors of “Safety and Security”

ANALYSIS OF COMPLAINTS INFORMATION OF THE RAILROAD COMPANY

From the above analysis and investigation, we got knowledge like those.

- activation of publicity activity of safety activity for customers (widely known of safety activity)
- there were interrelation between safety activity and assessment of business in general

We let the class of managers of the organization feedback these results and let them deepen the argument about the center of gravity of the significance of developing customer-centered safe activity and the development.

CONSCIOUSNESSES ABOUT THE SAFE ACTIVITY OF THE EMPLOYEE

This company did safety activity positively and they educated employee to do safety activity with customer's point of view simultaneously. We did principal component analysis for investigation results on employee's comprehension degree about safety activity. There was 1600 employee. Then, we found that employee who understands the relation of safety activity and customer satisfaction was particularly increased.

These were cleared by various aspects of investigation about employee's business in general.

As an example,

- The participation in safe activity will is apt to become low so as to go from the head office to the spot.
- This associated with "a tendency to let a cause return to the individual" and "participation in safe activity will" became clear than a multidirectional investigation for the duties activity whole for the employee..

CONCLUSIONS

From analyzing above aspects, we can suppose how security activity carrying out in railroad companies affects CIS of customers. Until now the railroad company has collected various data for three years. We are planning that how to change safety activity to CIS of customers. Also, we are planning to practice that plan in the future.

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A New Generation of Tractor Seats

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ABSTRACT

Tractor drivers have an 8-fold higher risk of getting back pain compared to office workers. Reasons therefore are being a long time in awkward postures and being forced to whole-body vibrations. With that biomechanics knowledge and the help of input user studies a totally new tractor seat generation was developed. Hereby a unique seat feature was integrated which has never been on the market before. The goal of this experimental study was to investigate the healthy and comfort potential of the new feature.Objective as well as subjective measurements have been done to observe whether the new seat feature is better compared to the serial seat without that feature. Objective methods were EMG measurements and body posture detection. The objective measures were done in the laboratory with 3 test persons. A field test has been done with 10 professional drivers to get the subjective ratings of the comfort. The results showed a difference in the muscle activity. The new feature reduced the activity of up to 30%. Slightly differences in the posture could have been seen. Posture detection revealed strong interindividual differences. All test drivers gave a good subjective feedback regarding the comfort of the new feature. In summary this is the most promising feature in the area of tractor seats with respect to short-term and long-term comfort. Additionally the feature leads to a muscle activity reduction. This comes along with a reduced fatigue and might protect the driver's spine in the long term against impairments.

Keywords: back pain, tractor seat, awkward posture, muscle fatigue

INTRODUCTION

Musculoskeletal disorders lead to enormous costs and absence times. One of the most frequent diseases out of this group is back pain. Back pain was the second most common cause of absence in Germany in 2011 (Badura et al. 2012). Causes of back pain are for example static sitting postures (e.g. Videman et al. 1976), whole-body vibration or awkward postures like for example twisting (Nordin 2004). The prevention of back pain or musculoskeletal disorders has an enormous potential of keeping the work performance on a maximum level and reducing the primary (loss of productivity) and secondary (e.g. alternative employee, quality problems) costs for the company.

There exist several epidemiological studies which showed that farmers have a higher risk (annually prevalence rate of low back pain: 72%) of getting back pain in comparison to the European population (annually prevalence rate for low back pain: 38%). Next to a higher percentage rate of low back pain tractor drivers also might have a higher risk of getting visible disk degenerations (45.8% of the investigated tractor drivers, limitation: no control group; Stawczyk 1983). Another study showed that tractor drivers have an 8-fold higher risk of getting back pain compared to office workers (Punnett et al. 2005). In general there is evidence that tractor drivers are a risk group of getting back pain. Reasons therefore are being a long time in awkward postures and being forced to whole-body vibrations. Nordin (2004) developed a model reflecting the situation of many commercial vehicle drivers with respect to the risk of getting back pain. In this model sitting itself might induce back pain. The combination of sitting with whole body vibrations or sitting with awkward postures leads to an increase of the risk of getting back pain. The worst case is the combination of all three parameters (see Figure 1).

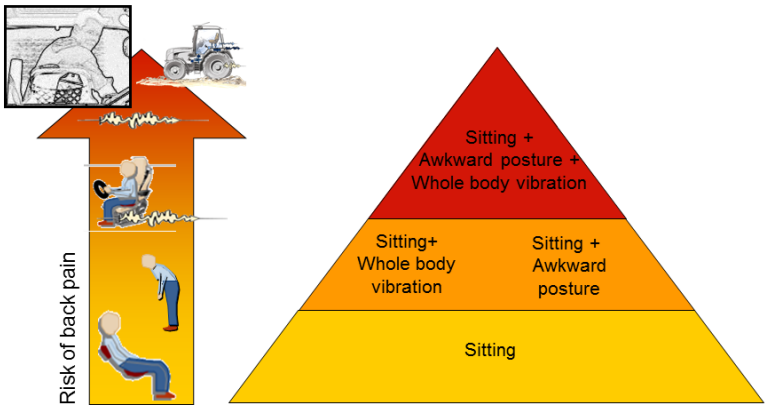


Figure 1. Risk factors contributing to the development of back pain. (Adapted from Nordin, 2005)

With the above mentioned biomechanical knowledge and the help of input user studies a totally new tractor seat generation was developed. Hereby a unique seat feature was integrated which has never been on the market before. The goal of this experimental pilot study was to investigate the preventive and comfort potential of the new feature.

MATERIALS & METHODS

To investigate the preventive and comfort potential of the new tractor seat a laboratory pilot study and subjective field tests have been done. The pilot study was planned to objectify the differences of the two seats regarding muscle activity and motion patterns. The field test has been done to determine the subjective short and long-term comfort of the new feature Dualmotion.

New tractor seat with Dualmotion

The new tractor seat includes a new feature called Dualmotion. This backrest extension can be moved from the neutral driving situation (see Figure 2 left picture) to a left-side oriented position (see Figure 2 right picture) in which the driver is supported while sitting backwards rotated. This new seat was compared to the current series seat (without backrest extension). Both seats were adjusted equally regarding seat height, backrest inclination, armrest adjustment and seat cushion inclination.

Figure 2. New tractor seat with Dualmotion and its adjustment range. The two end positions are the neutral (left) and sideward position (right).

In the pilot study (see next chapter) three seat arrangements have been compared:

A) the series seat without Dualmotion (no backrest extension at all) = series

B) the new tractor seat with Dualmotion = new + Dualmotion

C) the new tractor seat with Dualmotion and using the swivel (30°) = new + Dualmotion + swivel

Test procedure pilot study

A first pilot study was done which reflected the field situation. To ensure a systematic way of movements a protocol was fixed and shown to the test persons. The content of that protocol was the position of the feet and the left as well as the right hand in 4 different body postures together with the order to look at 4 different markers on the floor (see Figure 2). The simulated body postures were the following:

1) neutral posture reflecting forward driving (Figure 3, marker 1)

2) rotated body posture reflecting observing the right edge of e.g. a trailer (Figure 3, marker 2)

3) rotated body posture reflecting observing an attachment behind the tractor (Figure 3, marker 3)

4) rotated body posture reflecting observing e.g. the end of a plough (Figure 3, marker 4)

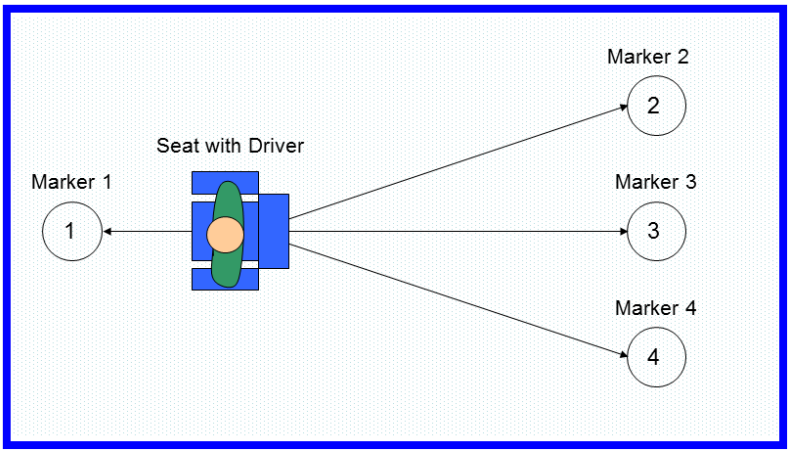


Figure 3. Study design: positions of the seat with the test person (shown here: neutral posture, no 1) and the markers which had to be observed.

Three test persons have been involved in the pilot laboratory experiment. Electromyography and motion analysis has been done.

Electromyography (EMG) analysis

For the EMG analysis the system “myomuscle” with a DTS Desk Receiver EMG system and the software “Noraxon MR3.4” was used. The following muscle types have been investigated according to the specifications of Konrad (2006): Musculus sternocleidomastoideus, cervical extensors, musculus trapezius pars descendens, lumbal back extensors. The pilot study has been done together with the company Velamed. After the laboratory test procedure each test person had to perform a maximum voluntary contraction (MVC). All EMG results have been set in reference to the MVC value. The mean values were used for the normalization procedure.

Kinematic analysis

For the kinematic analysis the inertial sensor technology of the company Noraxon was used with the software

"Noraxon MR3.4". The system includes 16 sensors and leads to 21 anatomical angles. The calibration of the motion system was done by starting each measurement series with a calibration posture. In that posture the body angles were set 0° (wrist, spine, shoulder) respective 90°.

Field tests

A field test has been done with 10 professional drivers to get the subjective ratings of the comfort. The tests started in June 2012 and are lasting on till then. Two evaluation steps have been done after 8 weeks and after 1 year. The test procedure was a nondirective half-structured interview.

RESULTS

Electromyography (EMG) analysis

The muscle activity of the lumbar back extensors (left & right) showed values below 10% of MVC in the case of all test persons, all seat arrangements (A-C) as well as in all conditions (posture 1-4, see Figure 3).

Test person 2 and 3 showed MVC-values of the cervical extensors (left & right) below 10% except one situation which was 15% (test person 2, new + Dualmotion, posture 4, right cervical extensor). Test person 1 showed an activity of the cervical extensors above 10% MVC during posture 2 (new + Dualmotion + swivel, left & right cervical extensor) and posture 3 (series, right cervical extensor / new + Dualmotion, left and right cervical extensors). Sitting in posture 4 led to an increase in muscle activity compared to the neutral posture (1) in the case of test person 1 in all seat arrangements with a tendency of a decrease of cervical muscle activity (left & right) from the series seat up to the new seat + Dualmotion + swivel.

There was no muscle activity of the right musculus sternocleidomastoideus except in one case (test person 3, series seat, posture 4). The activity of the left musculus sternocleidomastoideus showed MVC activity levels below 10% in the neutral posture in the case of all test persons (see Table 1). There is a tendency of an increase of the muscle activity in all test persons and all seat arrangements from posture 2 to posture 4 (except series seat, test person 2). A comparison of the 3 seat arrangements showed a clear trend of muscle activity reduction in the case of posture 2 (all test persons) from the series seat up to the new seat + Dualmotion + swivel. The same trend was seen for test person 3 in posture 3 and 4. Test persons 1 and 2 did not show this clear trend for posture 3 and 4 (see Table 1).

Test person 1 showed no muscle activity of the musculus trapezius (left & right) except in one case (new + Dualmotion + swivel, posture 2, right side). Test person 2 and 3 showed MVC-values mainly below or slightly above 10 % MVC in the neutral posture (left and right musculus trapezius). Both test persons (2 and 3) showed a trend of a decrease of the activity of the left and right musculus trapezius in all active postures (2-4) from the series seat to the new seat + Dualmotion + swivel (except test person 2, new seat + Dualmotion, posture 4) (see Table 2 and 3).

Table 1: MVC values (%) left musculus sternocleidomastoideus

		Posture 1	Posture 2	Posture 3	Posture 4
P_1	Series seat	<10% MVC	<10% MVC	25	36
	New + Dualmotion	<10% MVC	18	27	34
	New + Dualmotion + swivel	<10% MVC	29	35	35
P_2	Series seat	<10% MVC	45	37	36
	New + Dualmotion	<10% MVC	33	40	53
	New + Dualmotion + swivel	<10% MVC	21	28	35
P_3	Series seat	<10% MVC	32	37	58
	New + Dualmotion	<10% MVC	18	27	33
	New + Dualmotion + swivel	<10% MVC	<10% MVC	11	24

Table 2: MVC values (%) left musculus trapezius

		Posture 1	Posture 2	Posture 3	Posture 4
P_1	Series seat	<10% MVC	<10% MVC	<10% MVC	<10% MVC
	New + Dualmotion	<10% MVC	<10% MVC	<10% MVC	<10% MVC
	New+ Dualmotion + swivel	<10% MVC	<10% MVC	<10% MVC	<10% MVC
P_2	Series seat	<10% MVC	12	17	16
	New + Dualmotion	<10% MVC	11	12	20
	New+ Dualmotion + swivel	<10% MVC	6	11	12
P_3	Series seat	13	48	44	53
	New + Dualmotion	10	16	20	22
	New+ Dualmotion + swivel	<10% MVC	<10% MVC	11	16

Table 3: MVC values (%) right musculus trapezius

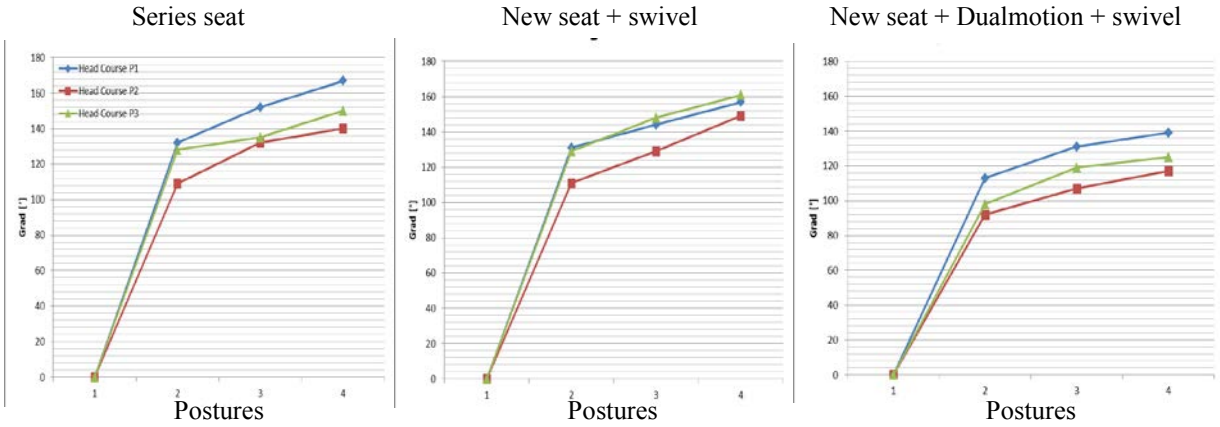
		Posture 1	Posture 2	Posture 3	Posture 4
P_1	Series seat	<10% MVC	<10% MVC	<10% MVC	<10% MVC
	New + Dualmotion	<10% MVC	<10% MVC	<10% MVC	<10% MVC
	New+ Dualmotion + swivel	<10% MVC	18	<10% MVC	<10% MVC
P_2	Series seat	<10% MVC	28	37	36
	New + Dualmotion	<10% MVC	25	40	53
	New+ Dualmotion + swivel	<10% MVC	15	28	35
P_3	Series seat	<10% MVC	31	33	58
	New + Dualmotion	<10% MVC	13	12	33
	New+ Dualmotion + swivel	<10% MVC	<10% MVC	11	24

The mean values of all test persons and the different postures (1-4 plus 2 additional postures not discussed here in detail) showed no relevant activity (muscle activity below 10% MVC) for the lumbar extensors, the left cervical extensor as well as the right musculus sternocleidomastoideus. The muscle activity (% MVC) of the left upper trapezius was 18% for the series seat, 13% for the new seat + Dualmotion and 8% for the new seat + Dualmotion + swivel. The muscle activity (% MVC) of the right upper trapezius was 17% for the series seat, 14% for the new seat + Dualmotion and 10% for the new seat + Dualmotion + swivel. The muscle activity (% MVC) of the right cervical extensors was 14% for the series seat, 15% for the new seat + Dualmotion and 10% for the new seat + Dualmotion + swivel. The muscle activity (% MVC) of the left musculus sternocleidomastoideus was 30% for the series seat, 32% for the new seat + Dualmotion and 22% for the new seat + Dualmotion + swivel.

Kinematic analysis

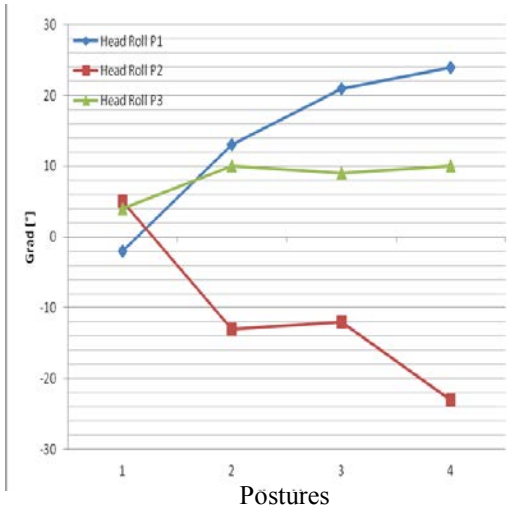
The kinematic analysis showed a clear reduction of the axial rotation of the whole spine (head, upper spine, lower spine, pelvis) on all test persons. There are only minor differences of the axial rotation using the series seat compared to the new seat + Dualmotion. This trend was seen in all segments of the spine. Figure 4 shows the trend for the axial rotation of the head.

Figure 4. Head rotation (°) by using the three seat arrangements: A) series B) new + Dualmotion C) new + Dualmotion + swivel of the three test persons (1 - blue line, 2 - red line, 3 - green line)



Interindividual differences could be seen in the movements occurring in the frontal and sagittal plane. Figure 5 shows the lateral bending of the head. Test person 1 and 3 showed a lateral bending to the right (positive values) and test person 3 showed a lateral bending to the left.

Figure 5. Head side bending (°) of the three test persons (1 - blue line, 2 - red line, 3 - green line) by using the series seat



Field test

Driver reactions after 8 weeks had been very positive in all 10 cases. All 10 test drivers gave a good feedback about the new feature Dualmotion. Additionally this is much higher to rate, because it was the first of all positive feedbacks the drivers gave, and this happened without a calling. This happened many times. Here is an overview of the feedbacks:

"…I'm amazed of the Dualmotion, because it is movable"
"…the Dualmotion is great, because we have to turn around very often"
"…the Dualmotion is very efficient, that's nice"
"…extremely useful, you get used to it very quick"
"…turning around is much more easier now and the rear view is significantly better"
"…the Dualmotion is great, it's much easier to look around"

The telephone interview after 1 year gave no relevant differences compared to the evaluation after 8 weeks.

DISCUSSION

The results showed a huge interindividual difference in the muscle activity between the seat arrangements and the test persons. This is reflected by the EMG values as well as the motion patterns. Due to the small size of test persons there is less redundancy between the motion patterns and corresponding muscle activity. This was a limitation of this small study.

An example for such a special motion pattern is shown in Figure 5. Test person 2 showed a head side bending to the left side in the seat arrangements "series seat" and "new + Dualmotion"(test person 1 and 3 showed a right side bending). A reason here for might be the (dis)ability of the test persons regarding flexibility and muscle status. This special motion pattern could not have been seen in the muscle activities of the cervical extensor or the musculus trapezius. Nevertheless the increased activity of the left musculus sternocleididomastoideus while sitting in the new seat + Dualmotion might reflect this individual motion pattern.

All test persons had less muscle activity of the lumbar and cervical extensors. A reason might be less side bending activity of these two muscle groups during the investigated motion. It might be an indicator for the ability of the seat at supporting the drivers during the backward oriented posture. Andersson et al. (1974) showed that a reclined backrest induced lower back muscle activities compared to a more vertical backrest. Additionally a larger support area showed a decrease in muscle activity. This comes along with a decrease of intradiscal pressure of the spine (Andersson et al. 1974). The underlying results of this study together with earlier findings (Andersson et al. 1974) show that all seats provide a good support in both the rotated and the neutral posture with respect to the activity of the spinal extensors.

Next to the low activity of lumbar and cervical extensors an increase of muscle activity of the left musculus sternocleidomastoideus was seen due to the increase of axial rotation related to the performed tasks (from posture 1 to 4). The same trend was seen for the right musculus trapezius but not for the left musculus trapezius. This increase, forced by the axial rotation of the test persons, was reduced by using the new seat. Especially in posture 2 there was a clear trend of decreased sternocleidomastoideus (all test persons) and upper trapezius muscle (test person 2 and 3) activity while using the new seat (with and without swivel). This trend was also seen for the upper trapezius in posture 3 and 4 (test person 2 and 3).

The mean values of all test persons and postures showed a reduction of up to 30% muscle activity while comparing the series seat with the new seat + Dualmotion (left upper musculus trapezius). A larger decrease of muscle activity could be seen while using the new seat + Dualmotion + swivel. The reductions of the axial rotation in all spine segments support the upper findings. Wilder et al. (1976) showed increased physical fatigue of the muscles and ligaments and Adams (2004) revealed increased fatigue of the neuromuscular coordination due to whole body vibration and loss of support. Therefore the reduction of muscle activity might prevent an early exhaustion. This is an indication of body load reduction especially when using the new seat with all features (Dualmotion and swivel). Together with the good subjective test ratings regarding short and long-term comfort the new seat might be a good preventive tool to reduce the load on the human body.

CONCLUSIONS

In summary the new feature Dualmotion especially in combination with a swivel is the most promising feature in the area of tractor seats with respect to short-term and long-term comfort. Additionally the feature (with and without using the swivel) leads to a muscle activity reduction. This comes along with a reduced fatigue and might protect the driver's spine in the long term against impairments. The underlying results of this study show that all seats provide a good support in both the rotated and the neutral posture.

Further studies have to investigate the most relevant muscles for the tractor driver´s movements and the test procedure has to be repeated including more test persons.

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Comfort Design Through Music and Emotion: Effects of Passengers' Activities on Comfort

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ABSTRACT

Comfort experiences are not caused by a single factor, but are the result of diverse components such as postures, cognitive- and emotional experiences, as well as a person's activity. The present empirical study investigated the experienced comfort of car passengers in the rear seat. We varied typical car passengers' activities such as listening to music, working, and looking out the window. Dependent variables were the passenger's comfort rating, his emotional valence- and arousal-related experience, his heart rate, and his seating position. The results (N = 23/16) showed that music positively influences comfort experiences. Moreover, correlation analysis between the dependent variables showed that comfort was significantly correlated only to the positive emotional valence component, and not to more physiological components such as emotional arousal, heart rate or seating position. The results suggest that car designers can improve the comfort of rear passengers by focussing on music and emotion design in contrast to the more conventional approach of physical ergonomics.

Keywords: emotions, gaming, watching, music, comfort, car interior.

INTRODUCTION

The domains of technology, ergonomics and design have potential to support the competitiveness of companies in the automotive sector. Technology expands possibilities, ergonomics supports the compatibility of products with people, whilst design provides a bridge between these domains. As an example, technology and ergonomics are implicated in seat design (Franz et al., 2011; Zenk et al., 2012).

A new field of interest for car manufacturers is the adaptation of the interior to the emotional state of the occupant, or to influence the emotional state of the occupant by the interior (Kamp, 2012). Emotions have multiple functions on both shaping and evaluating the interaction (Forlizzi and Battarbee, 2004), such as interaction between occupant

and interior. However, a question remains regarding how emotions of the occupant can be recorded and how external stimuli influence emotional state.

In automotive design, applications and research on passenger experience are relatively limited in number. As an example, Kamp (2012) proposed a game design in the back seat, which showed to contribute to a fitter and more refreshed feeling compared to other activities such as reading a book, performing tasks on a laptop computer or playing games on tablet PC. Based on Kamp's study, it can be argued that there is a relationship between an emotional feeling (such as 'feeling refreshed') and a performed activity.

The present study explores emotional effects and passenger activities. We studied the ordinary, typical activities of a passenger in a car context, such as listening to music, watching out of the window and working on a tablet computer. The research involves searching for the effects of these activities on passenger emotion and comfort, according to the main research question: "*What are the effects of typical rear-seat passengers' activities on emotional state and what is their relation with comfort perception?"*

Emotion

A broad range of literature exists on measuring and inducing emotions and moods as different affective states (Scherer, 2005). Psychologists have used two major methods to obtain forced-choice self-reports of emotional experience: (1) the discrete emotions approach, and (2) the dimensional approach (Scherer, 2005). The discrete emotions approach use emotion concepts from commonplace lexicon such as 'fear' or 'anger' which are typically "about something", i.e. an identifiable object or subject (Russell, 2003). Though different instruments exist to measure emotions following this approach, there are several problems that occur, including the analysis of different 'blends' of emotions (Scherer, 2005). The second (dimensional) approach is based on the original model of Wundt (1905, from: Scherer, 2005), which suggested a three-dimensional space defined by the axes: arousal (calm-exited); valence (positive-negative) and tension (tense-relaxed). Modern dimensional theorists often use a circular structure using only the valance and arousal axis (Scherer, 2005).

Related to components of emotion, Scherer (1987, 2001) defines emotion as "an episode of interrelated, synchronized changes in the states of all or most of the five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism". These 'subsystems' relate to several emotion components, among which a 'cognitive', 'neurophysiological' and a 'motor expression' component (Scherer, 2005). It is therefore arguable that measurement of emotion encompasses those emotion components. Furthermore, according to Scherer and Zentner (2001), self-report is "the only method that allows access to the subjective emotional experience". This argues for the use of self-report in the measurement of emotional effects in the present study.

Comfort

A similar distinction of 'emotion components' is made in several comfort models discussed by Vink and Hallbeck (2012). Inspired by these models, Vink and Hallbeck propose a new comfort model (see Figure 1). It proposes that perceived effects of an interaction are interpreted as comfortable, discomforting or a neutral feeling of nothing. This argues for the use of an overall comfort rating as well as individual measurements to study the relations of the different components to the overall comfort rating. An overall comfort rating is thus included in the self-report questionnaire of this present study. Vink and Hallbeck's model relates 'human body effects' ('H') to the 'neurophysiological' (heart rate) and 'motor expression' (seating position) emotion components, which brings the hypothesis of an existing relation between heart rate, seating position and comfort ratings. Furthermore, the described 'perceived effects' ('P'), as another component of comfort, might relate to the valence (pleasantness) levels of emotions.

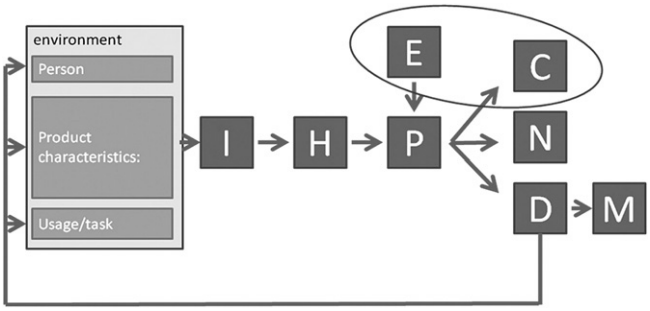

Figure 1. New comfort model (Vink and Hallbeck, 2012)

METHOD

Experiment Setup

BMW Group provided a BMW 3-serie passenger seat, for use in the experiments. Due to practical constrains of transportation (e.g. proportions of a whole rear-bench) and difficulty of using standalone (e.g. attachment of rear-bench in a setup and electrical equipment in high-end passenger seats), the usage of this mechanically adjustable seat was preferred above using a whole rear-bench or high-end passenger seat.

The experiment set-up is shown in Figure 2, with the apparatus consisting of the following elements: a BMW 3-serie passenger seat; two footrests (either 18mm or 72mm in height); partitioning walls; four cameras (ELRO; model: CS73Q); one microphone; two Logitech speakers (model S-120); one flat screen; 'Mflex FSA4' pressure mat, (model UT4010-7000); "Polar X-Trainer" heart rate equipment and body stickers. The two footrests were added to adjust the seating height to each subject's preference, minimizing the influence of seat height on possible discomfort scores. Subjects were seated in the black car seat that was covered with a grey pressure mat (see Figure 2).

Figure 2. Right and rear view of experiment setup

Independent Variables

Three common activities of passengers were selected as independent variables: 1) music listening, 2) watching the landscape outside, and 3) working on a tablet. To be able to measure effects on emotion and its different components, the intention was to induce both low and high levels of arousal. Since negative valence levels (i.e. levels of unpleasantness) are generally not preferred by users and do not typically occur in rear seating situations, we aimed to use stimuli which induce a relatively neutral feeling of pleasantness.

Taking interpersonal preferences into account, for the ‘music listening’ activity subjects were asked to select four tracks of music from their own playlist. This was formulated in the procedure for the user to select "two tracks that have a calming effect on you" and "two tracks that have an energizing effect on you". By stressing the personal "effect" of the tracks, we tried to prevent a selection based on labelling e.g. 'this is a calm track'. Two tracks were needed to be sure that each type of music was sufficiently long in duration to not finish before completion of an experiment condition. By asking subjects to select specific tracks from their own playlist, and rate those tracks on a

fixed scale, it was possible to work around ‘personal liking’ (prevention of negatively induced emotions by playing disliked songs) while maintaining possibilities for inter-subject comparisons. To create a baseline for establishing the main effects of music, a non-music control condition was added.

Our second independent variable, 'looking out of the car window', is considered to be a calming, low arousal inducing task, in comparison with our third variable 'playing a game on a tablet'. To operationalize the second variable, three movies were recorded from the rear seat view of a car driving on a provincial road, in the Netherlands. All movies were captured in the same landscape at one day thus with similar weather conditions, and were therefore very similar but slightly different to prevent induction of negative valence levels originating from visual repetition of movie content (i.e. unchanging scenery). To enhance the feeling of looking outside a car window, a left view was recorded, capturing the opposite driving lane, with occasional passing cars. The flat-screen TV screen used to screen the movies was placed on a table covered with a sheet (see Figure 2). The size of the shown movie was 69.7 x 34.5 cm (width x height). To simulate the situation of staring out of the window, but being mindful to prevent neck strain, the screen and table were placed at an angle, placing it perpendicular on the view-direction when subjects turned their head 40 degrees left from the straight orientation.

Furthermore, to enhance the simulation of a car environment, the screen height was placed having the screen midpoint at eye height when sitting. An A1 poster of a BMW car interior was hung in front of the car seat to further give an impression of a car environment for the participant. The flat-screen was connected to the frontal panel in such a way that the edge of the screen was matching the poster in height and the perspective of the road in the movies matched with the poster view.

Working on a tablet computer bringing a reasonable cognitive load, with an added time pressure, is considered an arousing passenger activity, compared with looking out of the window. To standardize this cognitive load across the experiment, a puzzle-game was selected as the stimulus (see Figure 3). "Unblock Me" (Kiragames, 2009-2012) is a game in which blocks have to be moved out of the way to move a specific red block out of the screen. After solving each level of the puzzle, a new puzzle is presented with increasing difficulty. Subjects were instructed to solve as many levels as possible in each game condition. Subjects would start their first game condition (the conditions were randomized between subjects) with puzzle number one and would, in the subsequent game conditions, continue puzzling with at the puzzle at which they ended the previous game condition.

Figure 3. iPad with 'Unblock-me' screenshot

In total, the experiment comprised 6 combinational conditions of independent variables (1 – 6) depicted in Table 1 as a 2 x 3 matrix: (watching movie / playing iPad Game) x (no music / calming music / energizing music).

	no music	calming music	energizing music
Playing iPad game (high arousal activity)	1	2	3
Watching movie (low arousal activity)	4	5	6

Table 1. Six test conditions

The six conditions were structurally randomized between subjects in a within subject design. Duration of each condition was set to 5 minutes, and the subjects remained seating throughout the experiment. Subjects received a 10 Euro compensation for participating.

Dependent variables

Emotion

In this experiment, the five components of emotion (Scherer, 2005) as discussed earlier, are measured individually. We did not include the 'motivational' component in this research nor did we include the 'subjective feeling' component. The latter component might however be slightly related to our goal dependent variable *comfort.* Measurement of the remaining components is explained below;

- The *cognitive component*, emotional valence, is tested in our experiment through a self-report questionnaire on core affect, developed by Yik et al. (2011). The questionnaire of Yik et al. (2012) elaborated on the circumplex model of core-affect proposed by Russell (1980, 2003), with a similar intention of clarifying the emotion concept (compared to models with few dimensions) to be used in self-report methods. Furthermore, the study compares three different response formats, i.e., "adjective", "agree-disagree" and "describes me" format on their 'fit' to the circumplex. Although the 'fit' of these formats is merely differentiated in some of the 12 segments of the circumplex, the 'agree-disagree' format seems to show the most evenly spread result over the whole circumplex, and seems to bias the results on reported emotions less. We applied the statements of Yik et al. (2011) using a 5-point Likert scale (from 'strongly disagree' to 'strongly agree').

- The *neurophysiological component* refers to bodily symptoms. Especially related to emotion induction through music, there is a wide range of literature studying bodily, physiological effects. Scherer and Zentner (2001), discussing and comparing existing studies on music-mood induction, conclude that it is difficult to argue that 'prototypical' physiological response patterns have been found distinguishing 'discrete' emotions. This shows that results in studies differ in outcomes, especially on physiological effects. It is also important to realize that some physiological measurements, such as ECG, are quite obtrusive and have potential to negatively influence comfort ratings. Heart rate, as a physiological response, was considered a non-intrusive measurement considering current sensing technologies. For the present test, heart rate changes were recorded using a "Polar X-Trainer" consisting of a chest-band sensor and a wristwatch. The measurement interval was set at 5 seconds throughout the experiment. As the first minute of each condition is considered as an emotion induction period, the first minute of data was not taken into account during analysis. It was also considered that subjects may sense the imminent completion of the 5-minute condition time, which in turn could influence their emotion. For this reason, also the last 30 seconds of data were omitted from analysis. Based on these decisions, and to keep the amount of data manageable, analysis of heart rate was limited to the second minute (min. 1:00 to 2:00) and half of third and fourth (min. 3:30 to 4:30) minute of each condition. For every condition, a mean value of heart rate was calculated for analysis. These means were calculated using the 24 heart rate values as measured in the two one-minute time segments.

- The *motor expression component* is reflected through posture. Conventionally an upright position is considered to be 'active' while a slumped position is considered as 'passive' (Riskind & Gotay, 1982). To test the hypothesis that energizing music and a high arousal iPad game induce an active seating position, and calming music and a low arousal movie induce a passive seating position, posture was measured using a pressure mat. The pressure mat was placed over the chair (see Figure 2) sensing posterior pressure. The pressure mat measurements were recorded and saved using "Flex" software with a log time of 5 frames a second throughout the experiment. Likewise heart rate analysis, the time periods 1:00-2:00min and 3:30-4:30min of each condition were analyzed. In the analysis it is

assumed that the highest pressure point indicates the position of the ischial tuberosity ('seating bones') as a reference of the seating position. The mean distance between the backrest of the chair and the seating position was determined for each of the six experiment conditions. A short distance indicates an upright and active seating posture and a longer distance indicates a slumped and passive seating posture. As a back-up measurement of posture, 9 stickers were applied on the right side of the participant (side of forehead, shoulder, elbow, wrist, 2*hip, knee, ankle and front of shoe) to be seen on one of the mounted camera's.

Comfort experience

Based on the new comfort model by Vink and Hallbeck (2012), overall comfort experience is in this experiment measured through self-report. A question asking participants to rate their perceived level of comfort is added to the questionnaire of Yik et al. (2011). Subjects are asked to rate the 'comfort in this position' on a 10 point Likert scale from 'not comfortable at all' to 'very comfortable'.

Instructions

The recruitment statement explained the experiments as part of a graduation research project in cooperation with BMW, concerning the subject of sound and sound speakers. This was so as not to cause bias for the subjects through an emphasis on mood and comfort.
After entering the test lab, situated in the Faculty of Industrial Design (DUT), subjects received a verbal introduction in which the recruitment statement was repeated and the number of test conditions was explained. Furthermore, subjects were informed of the heart rate-, pressure mat-, camera- and sound-recording as well as the stickers placed for analysis of posture. After signing the informed consent, subjects strapped the chest band of the heart rate monitor onto their chest in a private area of the lab. The apparatus was then switched on, heart rate connectivity was tested, and reference stickers were applied.
When sitting in the car seat, subjects were asked to indicate whether the height of the chair was satisfactory and when preferred, one of the two footrests (either 18mm or 72mm in height) was placed.
The activity (game or movie) of the first condition was explained to the subject. On commencement of the test, the music was started to match the particular test condition. After each condition, the researcher approached the seated subject and handed a pen and self-report questionnaire, picking it up when the subject had completed and then proceeding to explain the next test condition. After finishing all six conditions, subjects were asked to stand up from the chair. The researcher then ended all recordings, body stickers were removed, and subjects took off the heart rate band. Finally, to gather morphological data, the height and weight of each subject was measured.

RESULTS

Twenty-four healthy subjects (12 female, 12 men) participated. All subjects were students at the Delft University of Technology, aged between 20 and 28 (mean = 24.1). The height of the subjects ranged from 1479 - 1900mm (mean = 1726mm), with a weight range of 46.9 - 95.8kg (mean = 70.3kg). On completion, one of the 24 participants was removed from the dataset since he skipped a considerable amount (20%) of emotion and comfort questions, leaving the total set of participants at 23.

A repeated-measures analysis of variance (RM ANOVA) showed that comfort impression was significantly influenced by music but not by activity (i.e. watching the movie, or playing the iPad game). Music, independently of activity or the kind of music being played (energizing and calming), significantly increased comfort: main effect of music on comfort (F (2, 22)= 4.16, η_p^2= .16, p < .05 including Huynh-Feldt correction). Helmert contrast analyses showed that music significantly increased comfort as contrasted to no music (F(1, 23) = 5.33, η_p^2= .20, p < .04).

A RM analysis was conducted for the factors activity (watching, working) and music (no music, calming music, energizing music) on emotional valence and arousal. Activity proved to have a significant main effect on emotional arousal (F (1, 22)= 53.72, η_p^2= .71, p < .001) but not on emotional valence (p = 0.51). Working resulted in more arousal than watching out the window. Music had a significant main effect on arousal (F (2, 44)= 34.87, η_p^2= .61, p < .001) and on valence (F (2, 44)= 18.06, η_p^2= .45, p < .001). Interestingly, contrast analysis showed that calming music versus no music showed a significant increase in low arousal emotions and a decrease in high arousal

emotions (contrast interaction effect p = .01). Calming music thus had a calming effect on arousal compared to a situation where no music was played. Energizing music showed the opposite effect: an increase in high arousal emotions and decrease in low arousal emotions (contrast interaction effect calming versus energizing music on high arousal versus low arousal emotions p < .001). With regard to valence, calming music increased positive emotions and decreased negative ones (contrast interaction effect p = .01). Moreover, energizing music increased this effect (contrast interaction effect p = .02) resulting in most positive emotions.

A similar analysis was conducted for heart rate. Due to bad contact between the heart rate sensor (chest band) and skin of participants during 7 experiment sessions, considerable amount of heart rate data was missing. Limited elasticity of the strap of the chest band and/or too dry skin, seemed to cause these contact problems. Therefore these data had to be left out of the analysis. The remaining data of 16 participants were analysed, using the defined means of each experiment condition. Activity showed a significant effect on heart rate (F (1, 15)= 40.20, η_p^2= .73, p < .001) as well as music to a lesser but still significant (F (1, 15)= 3.46, η_p^2= .19, p < .05). As reflected by the difference in effect sizes, activity more strongly influences heart rate than music. Within the activity variable, all heart rate means of the three working conditions were higher than the three heart rate means in the watching condition – a significant difference as showed in the main effect. With regard to the music variable, only energizing music (not calm music) led to a significant increase of heart rate as compared to no music (F (1, 15)= 11.95, η_p^2= .44, p < .01).

A RM analysis on the effect of activity and music on seating position did not provide any significant results (resp. p = .38 and p = .88), using the described analysis method.

In order to gain the effects of the proposed comfort components, we performed a correlation analysis on comfort impression, emotion valence experience, emotion arousal experience, heart rate and seating position. All our subjects (N= 23) participated in the comfort and emotion questionnaire. However, due to technical problems some heart rate- and pressure mat-data were lost, leaving heart rate data of resp. 16 subjects and pressure mat-data of 20 subjects in those conditions. In order to compare the correlation effects between comfort rating and the proposed components in the research, we needed to reduce the data set to data representing only those participants whose data were gathered on all dependent variables. This resulted in a correlation analysis of 16 participants.

The emotional valence and arousal were analysed by computing the means of valence (V) and arousal (A) levels, in the following pairs: V-A+ and V+A+ to compute A+, V+A- and V-A- for A-, V-A- and V-A+ for V-, and V+A+ and V+A- for V+. The correlation analysis showed a significant relation of comfort with emotional positive valence (r_p= .49, p < .001) and emotional negative valence (r_p= - 0.43, p < .001) only, and not with emotional arousal, heart rate, or pressure mat differences.

An overview of the effects of passengers' activities on the dependent variables is given in Table 2.

<table>
<tr><th colspan="2" rowspan="2"></th><th rowspan="2">Comfort impression</th><th rowspan="2">Emotional arousal</th><th rowspan="2">Emotional valence</th><th colspan="2">Heart rate</th><th rowspan="2">Seating position</th></tr>
<tr><th>Main effect</th><th>Contrasts</th></tr>
<tr><td rowspan="3">Music</td><td>Energizing</td><td rowspan="3">high
V</td><td>high</td><td>highly positive
V</td><td rowspan="3">low
Λ</td><td>high</td><td rowspan="4">no effect</td></tr>
<tr><td>Calming</td><td>low</td><td>positive
V</td><td>no effect</td></tr>
<tr><td>No</td><td>low</td><td>no effect</td><td>neutral</td><td>low</td></tr>
<tr><td rowspan="2">Activity</td><td>Watching (out of the window)</td><td rowspan="2">no effect</td><td>low
Λ</td><td rowspan="2">no effect</td><td rowspan="2">high</td><td>low
Λ</td></tr>
<tr><td>Working (playing digital puzzle)</td><td>high</td><td>high</td></tr>
</table>

Table 2. Overview of the effects of passengers' activities

DISCUSSION

This study shows that music, more than activity, positively influences comfort experiences. Furthermore, energizing music leads to most positive emotional valence related emotions. Activity, in contrast, influences heart rate more than music did. Finally, we found that emotional valence is a more influential component of comfort than emotional arousal, heart rate or seating position. Altogether the results show that music and emotional valence are key components for design when designing for passengers' comfort. So it can be argued that, music and emotional valence should receive more attention than physical ergonomics when designing for comfort, at least concerning short term effects. Concerning the automotive industry, this study argues for a design approach in which users' activities take a central role. Long term effects of music and emotional valence on comfort is proposed as direction for future study.

Increased detailed measurement of physiological and physical variables might have led to more significant influences of activity and music. Especially the pressure mat data would qualify for a more robust statistical analysis. Despite a well calibrated pressure mat ('coefficient of variation' in the calibration <5%), the density of sensors in the mat proved to be too low to detect changes in seating position through the adopted analysis method. However, these physiological effects might still be less robust than the measured emotional effects.

It can be argued that undertaking work (iPad game play), watching outside (watching movie) and listening to calming/energizing music demand different levels of attention, but that inter-subject differences exist in the level of attention that is spend on each task as well. For instance, someone might attentively listen to calming music and look attentively out of the window, while another person might relax during work and during listening to energizing music. However, the results point in the typical and expected directions of effect: calming music was calming, energized music energizing and working was more demanding than looking outside the window. These directions support our choice of activities to induce calming and energizing effects. Yet, it can be argued that attention levels and performance of the activities might be different in real-life situations. Since emotions were measured on a fundamental level in this study, a similar tendency in the results would be expected in real-life traffic, though the influence of the different levels of activity might be distributed differently (e.g. calming music might prove less calming in real traffic situations). Furthermore, influences of context variables present in traffic might lead to different results. A study on emotion and comfort in real-life traffic situations is therefore proposed as future study topic.

Mehler et al. (2008) showed that subtypes exist in heart rate response to driving tasks, as well as differences in task performance between those subtypes. They argue that these differences in performance relate to the total workload that can be managed. Furthermore, Unal (2013) described the complexity of studying the effects of music, describing differences in the attention to listening music in relation to the varying cognitive load of different traffic situations. Altogether, these studies show that the cognitive load involved with performing tasks is related to both neurophysiological processes and the attention on listening music. A future experiment could investigate the variety of cognitive load between calming/energizing music listening, working and watching outside, and the possible relations of this cognitive load with components of comfort and emotion.

Regarding the independent variables a non-task condition, e.g. sleeping, was not deemed suitable for inclusion since it cannot be practically combined with listening to music (or, more specifically, listening to energizing music). Furthermore, inducing sleep was considered experimentally out of scope of this research. Yet, the effects of sleep on comfort might be considerable, and is therefore another suggested topic for further study.

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Research on Motivation Management for Project Members

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ABSTRACT :

In recent years, the success rate of enterprise IT projects has been said to be about 30% to 40%. IT projects tend to change dynamically during the project period, and project managers (PMs) must maintain a high level of motivation among the project members during that period. However PMs currently identify the motivation levels of project members in a vague manner relying on experience and intuition. Therefore, it is difficult for PMs to obtain a clear picture of the motivation levels of the members. It is thus important to create or identify a mechanism by which project managers can understand the motivation levels of members, and in this paper we propose such a mechanism. In the proposed method, the motivation of project members is first classified into two categories. Next, we measure the motivation in a manner suited to the characteristics of each classification category. Then, we propose a method for visualizing the motivation of members. Finally, we verify the effectiveness of the proposed method through an experiment where the proposed method is applied to actual enterprise projects.

Keywords: Motivation, Project management, Visualization, Herzberg's two-factor theory, Maslow’s hierarchy of needs

INTRODUCTION

The success rate of projects in the information technology (IT) industry in recent years is said to be between 30% and 40% (Yaguchi 2008). One reason for this low project success rate is the low motivation of project members. Motivation means both having the incentive to move toward a particular goal or in a certain direction of development and maintaining this incentive until the goal is achieved. Maintaining strong motivation can lead to high work performance.

Recent projects in the IT industry have been characterized by dynamic changes. Each project member must respond to these dynamic changes while performing their duties. Therefore, members should provide support with respect to the changes as part of the team, combine their knowledge, be proactive in learning new techniques and solving problems quickly, and communicate closely with other members within the project(Likert,R.1967 ,Locke&Latham 1984).

For all project members to follow the above standard of conduct, they must maintain strong motivation for their work.

However, thus far, project managers (PMs) of IT projects have relied on their intuition to obtain understanding of the motivation of each member, and therefore have failed to maintain a high level of motivation among project members.

In this study, we propose a method that allows PMs to maintain the motivation of project members in dynamically changing projects. The characteristics of this study include the separation of the concept of motivation into two separate categories (referred to as static motivation and dynamic motivation) and some proposed methods for managing these categories separately. Because the characteristics of the two types of motivation differ, assessment methods are specific to each type, and PMs are provided with support in terms of motivation management by visualizing the assessment results. The usefulness of the proposed method is verified through application to an actual project.

PROBLEMS WITH IT PROJECT MANAGEMENT

As mentioned, the success rate of IT projects in recent years tends to be low (30% to 40%). One reason for this low success rate is that project members cannot respond to dynamic changes in the project, and in some cases the final product does not meet client quality standards. Under these circumstances, project members must proactively adapt to changes in the project. The project success rate can be improved by combining the knowledge of all members and establishing cooperation between the project members. To ensure the active participation of project members, it is necessary to maintain their motivations at a high level. Therefore, PMs must determine the motivation in light of the project's characteristics. However, thus far PMs have been assessing motivation in an ill-defined manner, which has led to problems typified by the following cases.

Case 1: The PM determines each member's motivation on the basis of regular reports from each member to the PM during the course of the project. However, it is difficult for members to communicate all of their opinions in regular reports. Therefore, PMs cannot determine motivation levels accurately due to information loss. Project members may also be anxious about expressing their true opinions in regular reports. In such circumstances, it is necessary to reconsider the mechanism by which PMs inquire about the opinions of the project members.

Case 2: PMs assess the motivation of project members in an ill-defined manner, making it difficult to identify the reasons for the decrease in motivation among project members. At the same time, it is difficult to provide feedback to members who need help improving their motivation level.

Case 3: Because PMs assess the motivation of members in an ill-defined manner, they do not take appropriate measures. Therefore, it is difficult to know, for example, what the motivation of a member was several weeks in the past or why the motivation has suddenly declined.

The method proposed in this study solves the problems outlined in the above three cases.

PROPOSED METHOD

Basic Concepts

In this study, we consider the handling of motivation on the basis of the specifics of the IT project and the problems that arise within the project. IT projects are prone to undergo considerable changes. Therefore, various problems can arise if PMs assess motivation in a an ill-defined manner. To maintain a high level of motivation, the characteristics of the motivation of project members have to be clearly modeled. In this study, we focus on the following two ideas.

1) Each member works on the project in a certain environment and under certain conditions, which must be considered when determining motivation(Maslow 1954).

2) Projects tend to change dynamically, and members have to respond to those changes. Different members associate

the adaptation process either with difficulties or with a sense of accomplishment, and their motivation changes accordingly.

In this study, motivation is categorized into two types in consideration of the above two points. Subsequently, the characteristics of these two types of motivation are elucidated by using knowledge obtained from the field of cognitive psychology. From the results of this process, we propose a method that can elucidate the measures that should be taken with respect to motivation. The proposed two types of motivation are static motivation, relating to point 1) above, and dynamic motivation, relating to point 2) above. The motivation of project members is modeled according to these two types of motivation.

Herzberg's Two-Factor Theory

The motivation with regard to projects has been assessed in an ill-defined manner in the past. This study adopts the concept that there are two aspects to motivation. Thus, it is necessary to clarify to what these two types of motivation correspond. Without performing these steps, it is difficult to determine the motivation qualities of project members. Therefore, in this study, we adopt Herzberg's two-factor theory (Latham 2009), which is highly regarded in the field of cognitive psychology, as a theory of motivation in relation to work.

The two-factor theory (proposed by American clinical psychologist Frederick Herzberg) relates to the following factors of satisfaction and dissatisfaction at work.

1) Motivation: Satisfaction at work depends on factors such as achievement and recognition. Motivating factors satisfy needs belonging to the "Self-actualization," "Esteem," and "Social needs" layers in Maslow's hierarchy of needs (Latham 2009).

2) Hygiene factors: Dissatisfaction at work depends on factors such as company policies, company management, and salary. Hygiene factors satisfy needs belonging to the "Physiological needs," "Safety and security needs," and "Social needs" layers in Maslow's hierarchy of needs(Maslow 1943, McGregor 1960).

The model proposed in this study is a combination of static and dynamic motivation and expressed in a form suitable for Herzberg's two-factor theory (see Figure 1).

Definition and Characteristics of Static Motivation

1) Definition: Motivation used to determine the basic needs of each project member, based on the living environment and conditions. Translated into Maslow's hierarchy of needs, this corresponds to elements of the "Physiological needs," "Safety and security needs," and "Social needs" layers.

2) Characteristics: It is difficult to induce changes within a short period of time. Static motivation is a fundamental

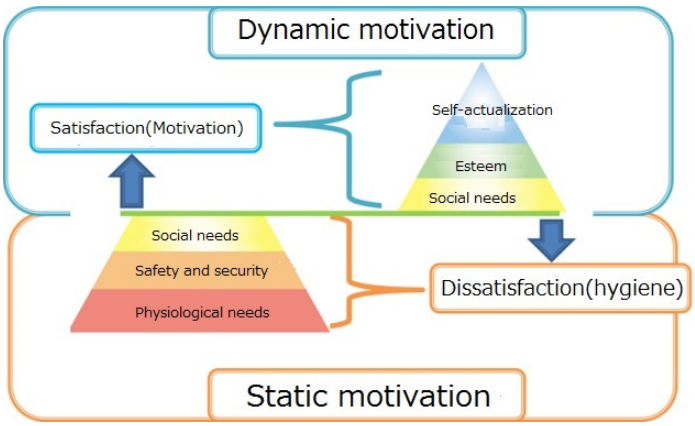

Figure 1. Model of motivation with regard to projects

type of motivation and an important part of members' lives.
3) Examples: Includes major life events of the project members, such as marriage or changes in salary. These events do not occur often for individual people. Therefore, changes in motivation induced by such events are unlikely to occur within a short period of time.
4) Measures: Changes in static motivation are unlikely to occur within a short period of time. Therefore, it is sufficient to perform a project-oriented assessment only once. The assessment is considered to be in the form of a personal statement about the living environment and private information about individual members. In this study, assessment is performed by survey.

Definition and Characteristics of Dynamic Motivation

1) Definition: Each member has a sense of impediment or accomplishment with regard to the project, and this type of motivation is seen in the process of focusing on work. Translated into Maslow's hierarchy of needs, it corresponds to elements of the "Self-actualization," "Esteem," and "Social needs" layers.

2) Characteristics: This type of motivation can change within a short period of time. Dynamic motivation affects work performance, and therefore it is an important factor of the quality of work (Furukawa 2011).

3) Example: Members have to adapt to continual changes in a project. This includes cases where the number of tasks that have to be completed before the deadline increases due to sudden changes in the specifications provided by the client, cases where mistakes are made due to a shortened deadline, and the converse cases, where members feel a sense of accomplishment because they produced the final results despite the shortened deadline. The events within a project change on a daily basis. Therefore, changes in this type of motivation are considered to occur within a short period of time (Ohta 2012).

4) Measures: Because dynamic motivation can change within a short period of time, it is necessary to assess the motivation with regard to the project on a daily basis. Since this motivation affects the way members perform their duties, it is necessary to observe the members' behavior.

Two-layer Motivation Assessment

Static motivation is a measure of the living environment and conditions of the members and tends to change little within a short period of time. Therefore, it is assessed before the member joins the project. In contrast, dynamic motivation focuses on the members' work. Therefore, this type of motivation must be assessed from the beginning to the end of a project. In addition, since it can change within a short period of time, it must be assessed every day for the duration of the project.

MOTIVATION ASSESSMENT METHOD

Assessment of Static Motivation

Static motivation is assessed by survey, whereby a questionnaire developed on the basis of Maslow's hierarchy of needs was proposed. Specifically, three questions were prepared for each of the three layers "Physiological needs," "Safety and security needs," and "Social needs," as follows.

● "Physiological needs" layer

1) Is your usual mood (state of mind) calm?
2) Do you have any physical problems (body condition)?
3) Is your living environment stable?

● "Safety and security needs" layer

4) Are you satisfied with the general wage standards in the company?

5) Overall, are you capable of performing your work well?
6) When you are not working, are you able to relax?

● “Social needs” layer
7) Do you feel that you are a good match for the company climate?
8) Do you have many close colleagues and superiors?
9) Do you feel like you are contributing to the company?

The assessment is based on the above questions.

Assessment of Dynamic Motivation

We conducted on-site interviews with PMs, and we focused on the following three points related to the assessment of members’ motivation.

1) Weekly reports: Regularly issued reports are reviewed by PMs to assess the motivation of members. These reports contain thoughts and notes about the working conditions of each member.

2) PC operation: Because the focus here is IT projects, the emphasis falls on work performed on PCs. Depending on the usage of PCs, qualitative and quantitative one-sided assessment of the motivation for work can be performed regularly.

3) Communication frequency: A factor essential to project success is close communication between members as well as between the PM and each member. To determine the motivation with respect to duties, we analyzed communication time and the content of the conversation.

To assess dynamic motivation, we set up tools and mechanisms pertaining to each item in the above three points.

METHODS

Assessment Method

In assessing motivation during the project evaluated in this study, we obtained data relating to static and dynamic motivation. The motivation assessment method is outlined below.

1) In the first step, the static motivation of each member was assessed by survey before commencing the project.

2) In the second step, which began with the commencement of the project, we collected PC operation data and communication data on a daily basis.

3) One week after the project commenced, each member completed a report.

4) The PM evaluated the dynamic motivation by using the PC operation data, communication data, and reports. At the same time, the total motivation was visualized by combining this evaluation with the static motivation data collected in the first step.

5) The PM inspected the visualized motivation for each member and provided feedback at the beginning of the following week.

6) Steps 3) to 5) were repeated each week until the end of the project as a way to manage member motivation.

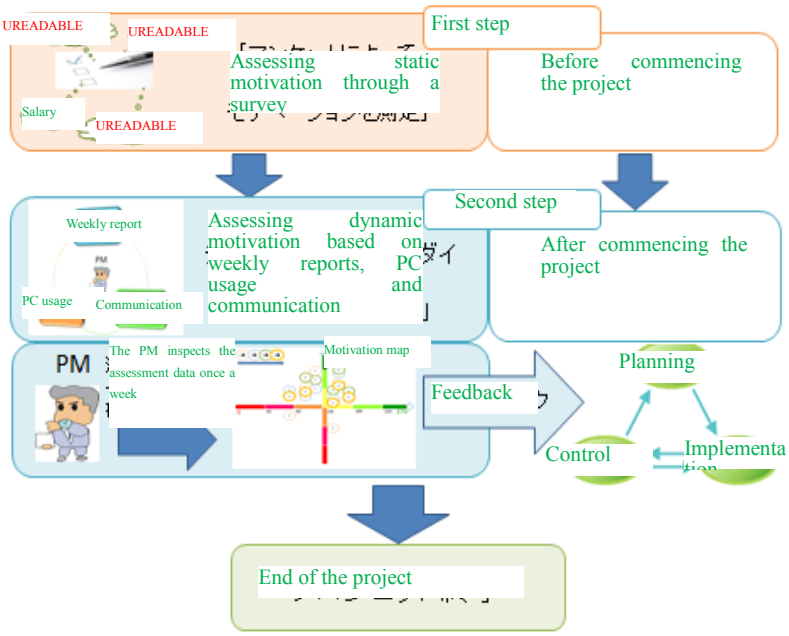

Figure 2. Assessment method.

Presentation of Motivation Data

The PM assesses the motivation of each member on the basis of the static and dynamic motivation data mentioned above. Furthermore, depending on the outcome of the assessment, the PM takes measures for each member. This is based on a mechanism in which the two types of motivation assessed in this study are summarized as a motivation map, which is presented to the PM.

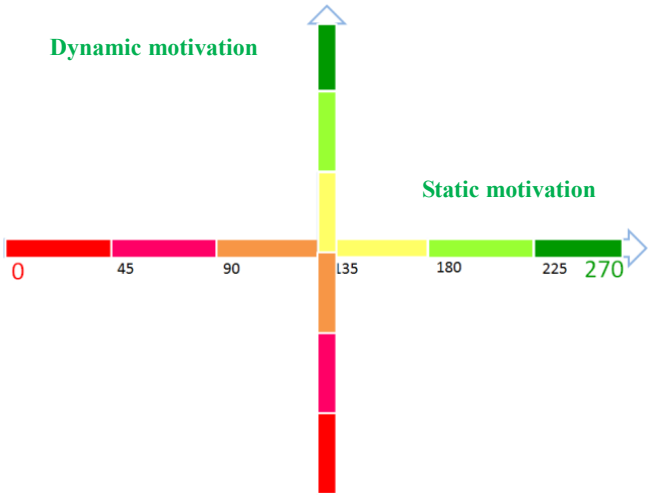

Figure 3. Motivation map

In the motivation map, the static and dynamic motivations are plotted along the horizontal and vertical axes, respectively. Each axis is color-coded with red, pink, orange, yellow, light green, and green sections representing different levels of motivation. Data collected in the assessment of static and dynamic motivation are plotted on this map, and the location of the data in the plot represents the level of motivation. After commencing the project, the motivation of each member is plotted on the basis of collected data, and the map is inspected by the PM. As the project

.progresses, the motivation of each member is plotted on the same motivation map each week, allowing the PM to determine the status of and trends in the motivation of each member.

EXPERIMENT

Goal of Experiment

We assessed the motivation of each member of a project at an actual company to determine whether motivation can be assessed on the basis of the concepts of static and dynamic motivation postulated in this study. Furthermore, we examined whether the motivation map (a map plotting data about static and dynamic motivation) is effectively utilized by the PM in the course of the project.

Overview of Experiment

We conducted an experiment that targeted the members of a project at an IT company whose name has been withheld. The project concerned the verification of a system requested by a client.

1) There were four members participating in this project.
2) All four participants were members of a partner company of the target IT company.
3) The project duration was one month, and the dynamic motivation was measured every day during that time.
4) The project members submitted weekly reports to the PM.
5) To determine the way PCs were used by the project members, the ManicTime time management software was installed on all PCs before the project commenced.
6) Arrangements were made for the project members to complete the communication sheets.
7) The project members were unaware that the purpose of this research was to evaluate their motivation.
8) The PM plotted the members' motivations on the motivation map once a week.
9) The PM examined the motivation of each member, as shown in the motivation map, and provided feedback to the members the following week.

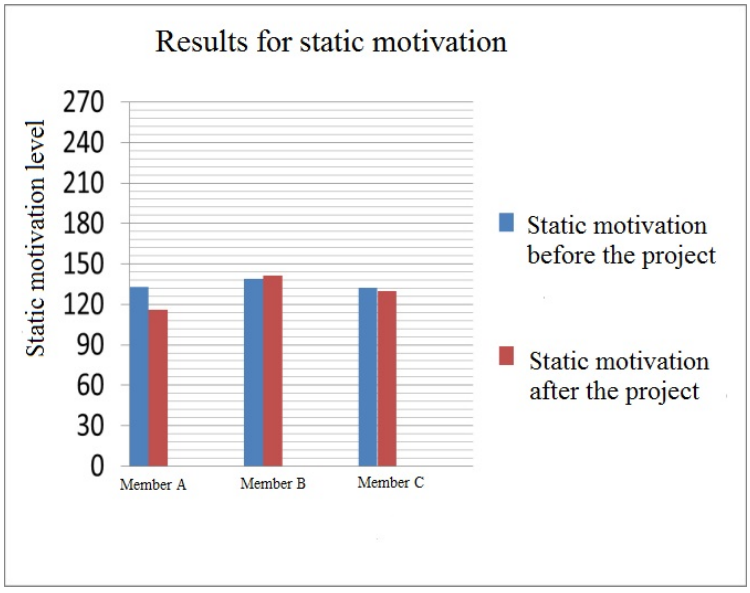

Figure 4. Assessment results for static motivation

Experimental Results

The experiment's results (see Figure 4) show the changes in motivation for three workers during the four weeks. Although the total number of people working on the project was higher, there were a number of substitutions during

the project period; only three workers were part of the project for the entire four weeks.

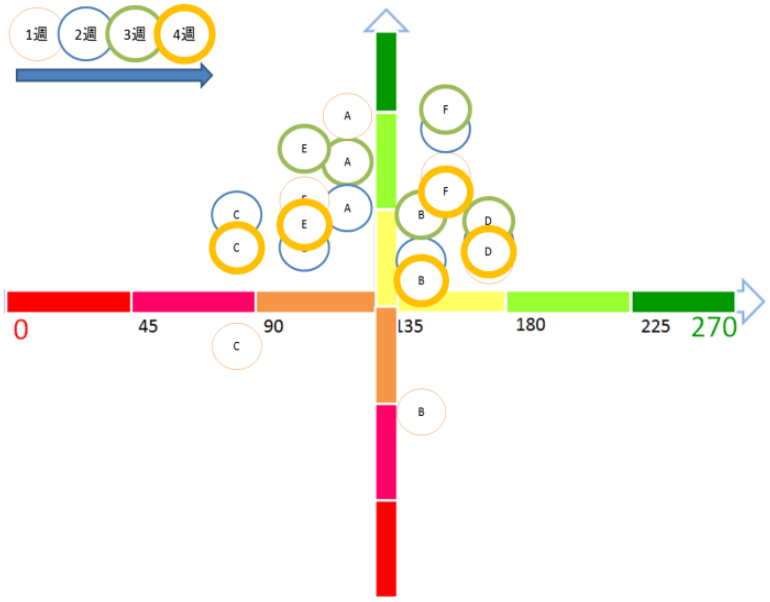

Figure 5. Assessment results presented as a motivation map.

DISCUSSION

In this study, the motivation with regard to a project was divided into static and dynamic parts, which were assessed by appropriate means.

In Figure 5, the static motivations of members A, B, and C did not change significantly between the assessments conducted immediately before the project commenced and after the project finished. The project period in the experiment was one month. Therefore, it can be considered that static motivation is unlikely to change within one month. In contrast, Figure 5 shows that dynamic motivation changed each week for each member. It is considered that dynamic motivation is affected by events occurring in a dynamically changing project, which in turn influences the work. Specific events in the project targeted in this experiment included sudden substitutions of project members and mistakes made by members. These results suggest that the categorization of project-related motivation as proposed in this study is useful.

Analysis of Measures

Case 1: In this study, project-related motivation was divided into static and dynamic parts, which were assessed by appropriate methods. As a result, it was found that although static motivation does not change within short periods of time, dynamic motivation does. This demonstrates that the division of motivation into two parts is both possible and appropriate. Plotting the static and dynamic motivation in a motivation map provides assistance to PMs in assessing the characteristics of each type of motivation.

Case 2: In this experiment, static motivation was found to be unlikely to change within one month (see Figure 4). This shows that the static motivation can be assessed through a survey before the project commences. In contrast, dynamic motivation depends on dynamic changes characteristic of the project, and so it changes accordingly (see Figure 5). However, throughout this project, certain assessments could not be adequately conducted during the evaluation of member activities. This is because there are presently no adequate techniques to assessing these items. However, data

pertaining to points such as communication and PC operation management displayed dynamic changes on a daily basis. For that reason, these data can be regarded as useful indicators for the assessment of dynamic motivation.

Case 3: In this study, the motivation of each member was displayed to the PM in the form of a motivation map, whose usefulness was evaluated in interviews during the project. By using a motivation map to visualize the past motivation level as understood by the PM, it was possible to determine the motivation state of each member for the preceding week. At the same time, the PM was able to reassess how they approached each member. The motivation map allowed the PM to know the motivation state of members at all times and to review their motivation history.

Phenomena Observed during the Experiment

The trends in changes in dynamic motivation depended on static motivation score (see Figure 5). Members with a static motivation score of 0.5 or above (right side of the figure) displayed a gradual increase in dynamic motivation after the first week. However, in the fourth week, their motivation tended to decline, which was likely due to the sense of relative calm in the last week of the project. In contrast, for members with a static motivation score of 0.5 or lower, the dynamic motivation did not show any particular trend. In other words, it can be said that the dynamic motivation of members who do not have a baseline level of static motivation is unstable.

CONCLUSIONS

In this study, we addressed the problem that over the course of projects, PMs assess members' motivation in an ill-defined manner. In this regard, we postulated that the motivation with regard to a project can be divided into two parts, and these parts have different characteristics. Thus, we assessed motivation as static and dynamic motivations and proposed assessment methods that rely on the characteristics of these aspects. As a result, we experimentally found that static motivation does not change within a short period of time, but dynamic motivation does, which supports the hypothesis proposed in this study.

In future work, we plan to conduct factor analysis on the surveys used to determine static motivation, as well as to develop a technique for determining dynamic motivation with even higher accuracy. We think the number of project member in experiment was not enough. We need much more number of project member in experiment. In the experiment mentioned before, we started the experiment with twelve members. But, during the project, 6 member were exchanged. So, we think that we should execute experiment more than twenty members. And, also we plan to the method that PMs can maintain the level of motivation of members high during the project period to success the IT project

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Heads in the Sand: The Failure to Engage With Our Ageing Society

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ABSTRACT

The increasing number of older people requires serious attention from policy makers and service providers if a crisis in care is to be avoided. This paper presents a biographical study of 9 months in the life of an elderly couple, looking at the problems experienced by them and their family when dealing with different stages of health and social care provision. The study covered periods of general health, hospitalization, reablement and separation. Studying the events arising in each period has provided insights into the requirements of the frail elderly and the adequacy of current provision.

Keywords: Frail Elderly, Carers

INTRODUCTION

An international crisis is looming as populations across the world are ageing. The changes in demographics will affect everyone. An increased number of older people means that services will change and that more people will be required to assist the elderly, many of whom will have a different range of illnesses and more complex expectations in terms of their quality of care than previous generations. Governments are responding to this through a variety of policy measures: e.g. in terms of changing employment and pension laws, and adaptations to health and social care provision to enable independent living. Designers and technology providers are developing assistive living products and new business models to tap into a potentially highly lucrative market. However the reality is that many older people do not or cannot access such products and services, and that service delivery of care in the home or in care-homes is rated as not fit for purpose.

The Select Committee on Public Service and Demographic Change (2013) opened with the following statement "*The UK population is ageing rapidly, but we have concluded that the Government and our society are woefully underprepared. Longer lives can be a great benefit, but there has been a collective failure to address the implications and without urgent action this great boon could turn into a series of miserable crises.* "(p7). Ipsos MORI showed that people are unprepared or unwilling to plan for old age because of "*assumptions (based on little knowledge), a fear of the unknown, denial, and negative connotations of being a 'pensioner' mean that we put off our financial planning until we are forced to*" . Additionally they do not contemplate or provide for future disability or mental illness, even to the extent of adapting houses to be suitable for older life. Many people assume that the State or their family will look after them.

A rapidly ageing society means older people living longer, often with one or more chronic long-term health conditions. For example, it is predicted that there will be 51% more people aged 65 and over, and 101% more people

aged 85 in England in 2030 when compared to 2010. For people aged 65 and over in England and Wales, 2010 to 2030 will witness the following increases: people with diabetes up by over 45%; people with arthritis, coronary heart disease, stroke, each up by over 50%; people with dementia (moderate or severe cognitive impairment) up by over 80% to 1.96 million; people with moderate or severe need for social care up by 90%. Over 50% more people will have three or more long-term conditions in England by 2018 compared to 2008. Changes in societal structure mean that extended or even nearly located families may not exist, even if family members were willing to look after ageing relatives. Additional marriage break ups, and remarriages in later life may mean that older couples no longer have shared histories or the required levels of social investment in each other to stay together in times of crisis.

Although most people want to live independently in their own homes for as long as possible, when help is needed, reports such as that published by the Equality and Human Rights Commission (2011) express concern as to the quality of care provided citing lack of training, rapid staff turnover and the inability of staff to deal with people's needs as causes of concern.

A basic requirement of living independently should be that it in itself does not become a chore, that services and products are accessible, comprehensible and 'joined up'. Woodcock et al (2013) cited research which showed that the elderly who experienced difficulties in everyday life just 'carried on' without looking for other support, and that designers of assisted living aids and products did not understand the context of use for their products, did not support higher level needs or the needs of the whole person.

This research specifically addresses these points by providing insights into the life of an elderly couple of average education, who wished to continue to live independently in their own home, for as long as possible. They represent the oldest old of the population (i.e. over 85 years of old (currently just over 2% of the population)). The study demonstrates why and how the oldest old become the heaviest users of health and social care services and shows that one of the reasons may be inefficiencies and lack of transparency of health services.

In this age group just under 40% of men and less than 10% of women live together, either as a married or cohabiting couple (Dunhall, 2008). The predicted expansion of this population requires more research on issues such as the effects of living with chronic disease of on (usually the female) partner's health, well-being and sense of identity (e.g. Hagedoorn et al, 2001), models of successful ageing (e.g. Baltes and Baltes, 1990) and the factors which influence it (e.g. acceptance of lower expectations about appearance, upkeep of the home, and the relationships with care workers, Aronson, 2002).

Aims

The aims of this study were to:

1. provide insights into the life of the frail elderly, living independently in their own home,.
2. document problems experienced in terms of everyday activities, their coping strategies and negotiations with the health and social care providers.
3. understand the way in which relationships with family, carers and service providers evolves over time.

METHOD

A biographical, case study approach has been adopted. Although the first stage of the study was presented as a participant observation study (Woodcock, 2014), this approach of data collection and analysis has been abandoned and the biographical nature of the work acknowledged in this paper as the study has been conducted with close family members of the author. Yin (1984) defined a case study as an intensive study of a person or situation, which can provide in depth information about situations or problems that are impractical to study in other ways. The case study began opportunistically, and was, from the outset conducted informally as a series of naturalistic observations with the researcher as both observer and participant. The move to a biographical study was felt necessary firstly, owing to the increased difficulty in recording and reflecting events objectively; secondly, because of the need to acknowledge the positionality of the researcher more fully; and thirdly because of the way in which the case study evolved after the reablement phase (see below).

The biographical method has '*proven to be an excellent way of making theoretical sense of social phenomena …..*

Biography is conceived as a 'social creation/construction', which 'constitutes both social reality and the subjects' worlds of knowledge and experience, and which is constantly affirmed and transformed within the dialectical relationship between life history knowledge and experiences and patterns presented by society' (Fischer-Rosenthal and Rosenthal 1997: 138).' (Apitzsch and Siouti, 2007). It has been used in areas such as sociology, educational science, psychology, medical and health sciences, theology, social work, and gender studies.

Denzin noted that this field may encompass: life, self, experience, epiphany, case, autobiography, ethnography, auto-ethnography, biography, ethnography story, discourse, narrative, narrator, fiction, history, personal history, oral history, case history, case study, writing presence, difference, life history, life story, and personal experience story. (1989, p. 27). Within this classification the current research may be termed as a personal experience story. It starts with personal experiences and uses sociological and psychological theory as interpretational and explanatory tools.

It follows in the tradition of the Chicago School of Sociology (eg, Zorbaugh, 1929; Shaw, 1930; Cornwell and Sutherland, 1937), concerning the experiences of the frail elderly (and their relatives) who currently have little social power and who are somewhat marginalized from society. The approach adopted enables a depth and richness of information and insight that other methodologies cannot provide. It is hoped that enough information is provided to make the research interesting, meaningful and accessible. It could not have been undertaken in any other way. To have the necessary level of impact it is important that the narrative makes 'imaginative contact' with readers (Goodson and Sikes, 2001), as through this, change may be possible. '*Shared humanity is a good basis for social enquiry'* (Sikes, 2006).

The motivations behind the following account and its articulation as a conference paper have to be acknowledged in accordance with the traditions of biographical research. The cathartic nature of writing has to be acknowledged, along with it a personal need to understand and explain what has been happening – i.e. the act of setting down events, looking for patterns and explanations is important. In so doing I want to hold up for inspection, what is mostly hidden, but what is increasingly commonplace, ordinary and not recorded. If such events are not captured, they cannot be used as vehicles of change. Indeed, as evidenced in the introduction, most of us are still in denial about growing old and the plight of the elderly. Whilst acknowledging my positionality (e.g. Guba and Lincoln, 1981; Chiseri-Strater, 1996; Roberts, 2002), it should be recognised that the value of the research may be limited by the amount of self disclosure made.

Motivations for using the case study approach are that it is hoped that others may learn vicariously from the case study through the narrative (Stake, 2005). This has affected the levels of disclosure. Events, medical conditions, and feelings are disclosed to a level where it is hoped that insights have been provided into the problems faced by the frail elderly and their families, which may be addressed by ergonomists specialising in the health care arena and which were not known by the researcher at the outset. Certain conclusions and events have had to be emphasized at the expense of others. The rationale for inclusion of certain items has been made because of the magnitude of its importance to the lives of Joshua and Ivy. However it is also recognised that proactive readers *'will add and subtract, invent and shape--reconstructing the knowledge in ways that leave it...more likely to be personally useful'* Stake (2005, p. 455).

In terms of disclosure and ethical considerations, all information has been anonymised and items which have been judged to be highly personal and of little bearing to the aims of the paper have been omitted. A third person narrative has been adopted, and as far as possible an objective lens has been used in documenting events. Having recognised the limitations of the approach, it is believed that the results are both generalizable and important as they represent a situation that is believed to be typical, or without action, will be typical of couples who come together late in life and who wish to remain independent in their own homes, but who have a steady decline in health and mobility. From the introduction it is clear that Western societies are finding it hard to cope with an aging population.

BACKGROUND

The case study centres around a close family member of the researcher (Joshua) and his partner (Ivy), both of whom were in their mid-80s and are considered to be representative of the frail elderly; having chronic conditions associated with old age, such as heart disease, diabetes, poor vision, arthritis, limited mobility and dementia. Whilst the definition of frailty is contested, it is used to describe the condition of people vulnerable to adverse health outcomes in later life. Fried et al. (2001) identified criteria to determine a frailty phenotype (three or more of weight loss, muscle weakness, and slow gait speed, low levels of physical activity and self-reported exhaustion). While

other researchers have also recognised cognitive decline (Abellan van Kan et al., 2010) and mental health and accumulated vulnerability (Bergman et al., 2007). The couple live approximately 25 miles from the researcher's home. At the start of the case study, visits were made twice a month by the researcher, her partner and family for family outings.

The recency of Ivy and Joshua's relationship needs to be highlighted. Joshua places a high value on female companionship, and had had 3 previous long term relationships. In his late 70s he placed a personal advert in the local newspaper for a new companion. As a couple, Joshua and Ivy had many shared memories of growing up in nearby streets. After about a year Ivy moved out of her house to take up residence with Joshua, and his dog, Fido. Anticipating a relatively healthy old age, Joshua had earlier sold his business and house and bought a small bungalow in a residential suburb, with a high number of older residents. He made building adaptations to cater for mobility issues (e.g. grab rails), bought a car rated highly in terms of its usability for older drivers, and continued to drive short distances (e.g. to the park to walk Fido) into his 80s, until his eyesight and mental faculties had deteriorated and he considered himself to be an unsafe and fearful driver.

The shortness of the 'happy time' in their relationship (about 5 years), when they were both in good health, also meant that they, and their families, did not have a shared past and a long term relationship to draw on, when their relationship deteriorated. However, during this period they became increasingly socially isolated and '*were quite content with each other's company, thank you very much'*, and hostile to any suggestions for home improvement as they '*had everything just as they wanted it*'. Indeed, the couple chose not to mix with other elderly residents or join any clubs. Instead their main activities were going to the local shops, to health centes, walking the dog and gardening. Although Joshua had made very good provision for his old age, he had not expected such a decline in his mobility or cognitive faculties.

The case study covers an approximate 9 month period. It coincides with more authority for health and social care being transferred to the author and her partner and a transition away from independent living. In the first stages of the case study the author and her partner acted merely as intermediaries with health and social care, and were able to witness (as participant observers) negotiation with health care providers (Woodcock, 2014), and discuss health care issues quite openly with them.

The case study can be divided into four main phases summarised below.

1. At the start of the case study (June 2013) the couple were suffering from numerous health problems associated with old age, including diabetes, crumbling vertebrae, macular degeneration, heart disease, arthritis and mobility problems. Ivy had a small mobility scooter, although Joshua had a larger one – it was too unwieldy to use and he behaved as if he was a car driver with it. Ivy suffered from severe loss of vision 9being registered blind towards the end of the study) and Joshua from Alzheimer's. Ivy could walk about 100 yards with a walking stick, Joshua had significantly less mobility, unless really motivated. Ivy had promised that she would never put Joshua into a home when she had agreed to move in. However, she had to assume the role as principle care giver as Joshua's Alzheimer's became worse. Joshua retained a firm control of the household and was deferred to at all times. Both were fiercely independent and rejected attempts to change their household routines, despite the mental, physical and emotional strain this placed on Ivy.

2. Hospitalisation. In August (2013) after a family holiday, Joshua was hospitalised for over a week and needed catheterisation. In order to accommodate his changed medical needs, refurbishments were made to the bungalow.

3. Reablement (August – November, 2013). Prior to Joshua's hospitalisation the couple had worked co-operatively to maintain their independence and had adapted successfully to old age. However, during this time, Joshua's catheterization and the continued deterioration of his mental faculties negatively affected their relationship, Ivy's self identity (as caregiver) and their ability to live independently. Social and personal care packages were initiated, with varying levels of success.

4. Separation (November, 2013 onwards). With Ivy's deteriorating health and eyesight and Joshua's mental deterioration, she admitted that she could no longer cope, and was asked that he be quickly removed from the bungalow to live with his relatives, be found respite /residential care or another form of assisted living. Having made this decision she never made contact with Joshua again. Although accepted for a week's trial in a potential care home, Joshua was unexpectedly expelled for unreasonable behaviour. His insistence on living in

his bungalow with his dog necessitated Ivy's immediate departure from the bungalow into sheltered accommodation. Case workers agreed that all possible efforts should be made to enable him to remain in his own home, even if that meant 4 care workers visiting a day. This was rejected as an unworkable and potentially life threatening arrangement and 24 hour living care was finally arranged after two weeks.

The following section details some of the problems which occurred in relation to health and social care in these periods.

RESULTS

Observations made at each stage showed systems that were overcomplicated and over bureaucratic, under resourced, and not fit for purpose. Meeting complex health care needs required negotiation with multiple service providers, all requiring different information, having different locations, appointment times and staffing. Taking over the management of the process for Joshua and Ivy, we found understanding and remembering the processes and information, and negotiating with health care providers very difficult. For those with failing memory, eyesight, cognitive faculties and mobility this is a real issue with simplicity, patient focused, joined up services an absolute priority.

Using medical services and products in old age

As people become older, managing health becomes a task in itself, which can control where and how people live. Successful ageing becomes a balance between coping with periods of illness, regaining health and learning to adapt to increasing frailty. Joshua and Ivy had developed successful coping strategies, compensating for lack of eyesight and mobility and doing household chores co-operatively. However, maintaining physiological and psychological well being and reassurance requires consistent liaison with multiple health care providers (e.g. opticians, chiropodists, dentists, local surgery and hospital departments). At this time Joshua and Ivy had at least one health related appointments every week, each of these required close management, and presented its own problems.

The table below shows typical issues.

Table 1: Issues with medications

Medical situation	**Human factors issues**	**Further information/solutions**
Appointment booking	• Reading and understanding appointments sent through the post. As these are made months in advance, or relate to referrals to clinics they are not familiar with, receipt of an appointment may be a cause of relief, stress or confusion • Correctly transferring information to the desk diary. Failing eyesight, handwriting and uncertainty meant that appointments were frequently recorded on the wrong date, and at the wrong time • Misplacement of appointments	• Mutual support, discussion and reinforcement • Use of magnifying glasses to read the appointments • Duplicate diary and cross checking to ensure appointments were entered correctly • Appointment letters attached with safety pin to the diary to stop them being lost
Travelling to appointments	• Poor mobility meant that travel to health providers was difficult • Location of clinics across the city, walking and use of public transport impractical and taxis unreliable (e.g. 10 mile round trip) • Mobility around hospitals and difficult • Navigation in hospitals confused	• Purchase of mobility scooter for Ivy for independent trips to surgery • Lifts provided to all appointments to ensure safe arrival and return • Walking aids provided; use of hospital buggies and wheelchairs on all visits • Family members in attendance at all times

	• On most occasions both Joshua and Ivy went to the hospital. However Joshua tended to wander off • Waiting rooms with little provision for 4 hours waiting times	• When a visit to a clinic or a nonsceheduled visit to the surgery needed, upto 4 hours was required for each visit. Companionship and appropriate entertainment was provided
Consultations	• Poor communication skills with medical professionals resulting in inability to provide correct information • Lack of joined up health services. Running as a health centre, different doctors were seen on each visit, resulting in no clear picture being built up of medical history, drug regimes etc • Lack of joined up health spine which meant that there was no record of medications • Appointments /emergency call outs/ or use of drop in surgery were made frequently as Joshu forgot who he had seen, his conditions did not improve, or he forgot he had seen a doctore	• Family members acted as advocates, and providers of sufficient information to enable speedy completion of some visits • Full lists of medications were recorded and handed to staff • Medicine reviews were requested • Although the surgery had a high proportion of elderly patients, no provision was made in terms of geriatric nurses or advisers
Prescriptions	• Lost prescription • Failure to include all medicines on the prescription • Prescriptions not ready on time • Build up of unused medicines • Failure to understand the purpose of medication • Noncompliance • Inability to see and manipulate tablets out of blister packs and read dosages • Lack of joined up provision, with different medicines needing to be collected from different places, at different times. • Blame on the patient not the provider	• Very rarely did prescriptions arrive complete or on time, even with automated services. This sometimes necessitated 3 separate visits to the chemist who failed to understand the stress they were causing (especially on Ivy who would have to make repeat visits). • Collection of medicines and negotiations with chemists was taken over by the family, although this did not solve the problems. • The delivery of pre packed medication was stopped when a backlog of 3- 6 months of unused medicines was discovered and blister packs half used • All Joshua's medicines (15 tablets a day) were put into clearly marked, easily openable containers. Only a couple of days supply was left at any one time, to check for noncompliance.

Noncompliance was a major issue with Joshua. Ivy had previously been hospitalised with a life threatening illness and the importance of compliance had been emphasized. However, her medication changed on a daily basis, requiring her to read instructions with a magnifying glass and locate very small tablets. Failure of the local surgery to recognise a medical condition had resulted in near death, so neither fully trusted the health service. The drug regimes of Joshua in particular may have produced side effects, but Ivy was unable to speak coherently about this. Medications related to the control of Alzheimer's were steadily resisted (either thrown away or omitted) either due to side effects (e.g. dizziness, nausea, drowsiness and hallucinations), misunderstandings about their long term benefits and required build up or the stigma attached to Alzheimer's.

Although these issues occurred regularly. Joshua and Ivy were still able to living independently, but started to need more support. However, Joshua's deteriorating health and cognitive abilities mean that the couple could no longer go out together (as Joshua would wander off) , he was increasingly incapable of holding a conversation (repeating he same question time and time again), staying awake, or being left on his own – as he would panic about Ivy's

whereabouts or would wreak havoc in the house. As he felt the house was being broken into locks were changed and the police called out many times. The constant worry over Joshua and her inability to perform satisfactorily as a care provider had a negative effect on Ivy's well being and cheerfulness (Hagedoom et al's 2001). A care agency was brought in to provide assistance and companionship but the couple could not make full use of this by letting go of household chores.

Hospitalisation

Although frail, both Joshua and Ivy looked forward to holidays. Observations and conversations on the last holiday (August 2014) revealed that Ivy was no longer happy with the relationship and was increasingly unable and unwilling to cope with the demands placed on her. Joshua was unable to engage in meaningful conversations, and his nightwakefulness (and that of his dog) caused major disruptions to sleep patterns.

On the holiday, Joshua developed a urine infection. With no local medical services, poor internet connectivity, a non responsive local surgery with irregular opening hours, an emergency surgery was located in a village 10 miles away. Treatment was ineffective and resulted in a call out 12 hours later to an emergency paramedic, who gave enough assurances for a 6 hour drive home to be undertaken. 3 days later, and with no great improvement in his health, Joshua was taken to his local surgery and again sent home to have his bladder emptied by the district nurse. Convinced of inaccurate readings on their monitor and the complications caused by diabetes, the district nurses refused to treat Joshua, thereby necessitating admittance to a urology department. During this time the researcher and her partner took over from Ivy as the main decision makers.

CQS (2013) noted the need for hospitals to recognise the needs of patients with dementia, to record it, and to have training that *"would help staff to identify the person with dementia and reduce length of stay by helping staff to respond effectively to dementia, for example by ensuring their nutritional needs are met."* The Alzheimer's Society recognise the impact of dementia on patient's outcomes; with longer stays, a worsening of dementia and physical health, a greater likelihood of being discharged in to a care home and a greater likelihood of antipsychotic medication being used.

Although treated quickly, compassionately and successfully, Joshua was kept in hospital for 10 days for observations, tests and to allow a care package to be arranged as part of reablement. Fortunately, no further medical complications arose, but the Alzheimer's proved difficult to manage, with Joshua having no memory of why he was there, how he had become ill, what the catheter was, what a hospital was, where he lived or when he would be released. As soon as one question was answered)'*but what is wrong with me, 'when can I go home,' 'can someone tell me what has happended to me'*) it was repeated again. Not having any clear answers to his questions about diagnosis or length of hospitalisation did not help. Problems included:

- Insufficient monitoring of food and fluid intake leading to the need for rehydration (via a drip, which he did not understand) and a weight loss of half a stone.
- Lack of entertainment in the ward meant that Joshua spent all day in bed, staring at a wall, unable to walk, read or engage in conversation with other patients. This resulted in stress and anxiety.
- Joshua's lack of memory meant that he did not remember seeing consultants or what was explained to him by the nurses. As nursing staff were rotated, it was difficult to find out what was happening. Information was written on pieces of paper and sellotaped to the wall (e.g. how many more days he had to stay in the hospital, what was wrong with him, what the catheter was and how it worked).
- Incorrect treatment, resulting in one incident when he was taken to theatre for an examination but given the wrong premeds and 'left to die in a cold basement'.
- The occupational therapist noticed he was soiling himself on a regular basis, and brought this to the attention of ward staff.

Visiting times were relaxed. Conversation revolved around showing holiday pictures, and continual reassurance of the same points. A sheet of Do's and Don't's in relation to the catheter were provided, with pictures. If these were not adhered to, the chances of Joshua being able to transfer back home were reduced.

Reablement and adaptation for special needs

The reablement team encourage independence after hospitalisation. They provided twice daily support and monitored long term needs for 6 weeks, after which other service providers had to be found. They provided social but not health care (e.g. they can remind the patients to take medicine but not give it to them). Patients with Alzheimer's and catheters fall between social and health care, so it was up to the local attendants to decide how much support they provided. The team was large, variably trained, with no regular attendants and unreliable. With their help Ivy was persuaded that she might be able to continue living with Joshua.

The occupational therapist admitted that catheterization was normally the tipping point for people with Alzheimer's, and would ultimately require residential care. To postpone this and manage increasingly difficult hygiene issues, the bathroom was converted into a disabled friendly wet room with a bidet toilet; a second bedroom was created so Ivy could have uninterrupted sleep, and the house was decluttered to provide ease of access, cleaning and space for the social care assistants. Problems experienced during this period included:

- Poor installation of bathroom by the specialis supplier, including wrong shower head, and a radiator positioned too close to the toilet where it would burn legs if switched on
- Extensive decluttering which was finally accepted by Ivy to help her gain a sense of control and to aid cleaning. However, Joshua lost his context *('why would anyone live here,'do I live here', 'have you one this – well you've done a good job*'). Books and personal artefacts were reintroduced.
- A new television and CD player required careful positioning and firm attachment to walls as they would be taken apart. Ivy managed to understand their operation. Joshua did not
- The new sleeping arrangements were rejected as an unwanted intrusion on personal life (*'I don't tell you to stop sleeping with your wife…*)
- Visiting everyday, it became clear that the couple were being targeted by nuisance callers (despite being on a register) who gradually amassing details about the couple.
- Night time hunger and wandering became a safety risk. Kettles were left in bowls of water, metallic objects used in the microwave, cupboards emptied, food scattered over the floor, and clothes draped across fires. Ivy was constantly on edge throughout the night
- Lack of joined up health and care packages meant that Joshua and Ivy were treated as individuals, not a couple. Different agencies asked the same information, failed to pass on information or include family members in information gathering, even though this was explicitly requested and written in instructions. For example setting up a procedure to get Joshua taken into emergency care if Ivy was omitted in to hospital in an emergency required at least two home visits and the completion of a 30 page booklet. Both lost their patience with the non-ending round of questions which different agencies were subjecting them to, and from which they were deriving little benefit.

Although Joshua accepted and understood the catheter and had been convinced that pulling it would do him irreparable harm, it caused many problems. It was left open, emptied at inappropriate times and locations, punctured and not positioned correctly on his leg. District nurses were repeatedly called out to deal with blockages and misuse. Ivy attempted to take control but did not understand/could not see all the component parts, but had to be constantly alert to Joshua emptying the bag in appropriate times or simply fiddling with it. Many homemade solutions were tried. The problem was confounded by the delivery of incompatible bags and the night time bag and bags which had different systems - the operation of which was never clearly explained to the couple. Night bags require careful management, preferably by someone who does not sleep with a dog and a partner, who lies still and who does not wander about all night. This meant that even with care workers twice a day to ensure that the bag was empty and set up properly, the catheter was misused resulting in wet bedding three or four times a week. Ivy had to remain vigilant throughout the night, check on its status, monitor Joshua's movements throughout the night. Hygiene and cleanliness became major concerns.

Separation

Obviously the situation with respect to Joshua was deteriorating. As well as memory problems he became verbally abusive when Ivy tried to take control or direct him. Going to day care centres twice a week did little alleviate the strain, and he could not remember going to them once he had come back. The case workers advised that the couple should consider their own needs as individuals.

Rather abruptly, Ivy decided that she could no longer carry on and requested that Joshua be immediately removed from the bungalow, which she would continue to inhabit for the short term and look after his dog. Although this had been predicted, it was still a shock and caused substantial upheaval. Being his only relative, Joshua moved in to my

home, with my partner becoming full time carer. Joshua was confused, irritable and abusive, not knowing where he was, or what had happened, but knowing that he should be in his bungalow, with his dog. After a week, respite care was arranged in a nearby residential home to see if this would be a suitable solution. In order to help him settle, his dog was brought over. This was a very big alteration in his life, and the residential home was initially optimistic. However, after 4 days they requested that he leave immediately as he was too disruptive– going into rooms, moving papers etc and becoming agitated and aggressive when he did not understand his situation

Keeping Joshua with us while we debated his future, it was clear that no amount of alteration would enable him to accept a move, and the quality of life for the rest of the family would deteriorate as he required constant day time attention and companionship and management during the night. Telecare and telehealth solutions were not considered as particularly helpful, as they would not stop Joshua rummaging through things, emptying food stuffs on the floor, or moving things, trying to dismantle things. Changing bed time routines did not help and sleeping pills were not recommended. Joshua remained adamant that he wanted to return to the bungalow and would be able to look after himself (*'I've been looking after myself for years', 'who do you think has been doing the cooking'*). Any attempts at suggesting that this was not the case were met with incredulity. At this stage he changed from being abusive about Ivy for deserting him, to simply not mentioning her.

As he had been judged not yet frail enough/unsuitable for residential homes. Ivy had to leave the bungalow and he returned to live there with his dog and 24 hour care provided by the family for two weeks. The suggestion of care workers attending 4 times a day was rejected as unworkable, because even if he did let them into the house and accept them, they would not be able to guarantee his safety between visits. Following more refurbishment of the bungalow, a care agency was found that provided live in care, and the case worker was convinced that Joshua's needs and wishes were being followed.

At the time of authorship, this arrangement has been going on for 5 weeks. We act as managers and co-ordinators, having found and briefed agencies and their staff. Carers live in for up to 2 weeks, they are paid directly with a premium going to the agency, given a float for the week to buy food, are met at the station and their travel costs covered. Joshua has been more tolerant of this relationship than expected. However, his confusion means that he does not know, recognise or remember that there are carers in his house, who try to direct his actions and look after him. This has resulted in the verbal and physical abuse of one female carer, who left after a week, and resulted in him being taken off their system. The second agency operates in a similar manner, requiring careful matching and initiating of carers. After another female carer claimed sexual harassment and feeling frightened, only male carers are now deemed suitable. As the 24 hour carers are finding it difficult to cope with a lack of sleep during the night, additional nigh time carers have also been arranged for two nights a week.

Joshua 'likes' being in his bungalow, in familiar surroundings, with his dog. It is not clear if he understands his relationship to the author and her partner. He knows that something is missing in his life, and that this is his memories. This makes him depressed. Although occasionally able to enter into a conversation, he asks the same questions repeatedly, perhaps out of politeness (such as '*do you have much work on', 'is my car alright'*, '*are the kids alright*') without registering the answer. He likes listening to music, going to the day centres and his garden. He does not know that anyone is living with him if they go out the room, and still takes umbrage at the suggestion that he cannot look after himself. However he is lonely, disconnected and craves the companionship of a female, which he has had all his life. The extent to which the current arrangements are sustainable is not known. They require constant management from us on a daily basis even with a carer, the co—operation of Joseph and his continued good health.

DISCUSSION

The case study raises a number of issues which may be termed as wicked problems. With the trend to smaller families, break up of family units and mobility patterns it becomes very hard to develop and maintain relationships with elderly relatives

Joshua is acutely aware of loss and does not understand what has happened to him – what he has lost or why. Providing photographs helps to bring back some memories, but in talking to him it seems that these memories only surface when he is looking at the pictures and even then he is unsure of what he is seeing or his relationship to it, without prompts. He is most affected by the loss of his ability to drive, his physical mobility and his memory ('*I can only think I have had some kind of mental breakdown'*). His self identity is bound up with being a home and dog

owner. This is evidenced in his repetition of his address, his army number, and his obsession over the whereabouts of his dog.

He has been able to deal, for the most part with the loss of autonomy and can be cheerful. He does not ask for help, but he has accepted strangers into his home who have to provide intimate care. Being at home brings anchorage and feelings of control (Nicholson et al, 2012) into his life and has enabled him to sustain connections with the past – through looking at ornaments and pictures As the situation evolves, new problems and challenges are set. Of these the most problematic are nightwakefulness (and dismantling/trashing of rooms), and recognizing how to deal with and reduce conflicts when Joshua feels that a stranger is trying to control him.

Given the desire to keep people in their own homes as long as possible, the caring profession, especially for older people is going to expand. Yet little is known about the qualities which such people should have, or the training they need. Indeed, the main experience for some of our carers has been that they have cared for a dying relative. Dewar and Nolan (2012) identified the need to develop compassionate care in hospital setting. In the private home care sector there is a similar need, i.e. to be aware of another's feelings, appreciate how they are affected by their experiences and to interact with them in a meaningful way. Although carers should not be expected to be on –call 24 hours a day there is a need for them to engage with the person they are caring for and to learn very quickly how to show compassion and to interact with them in a meaningful way- perhaps through photographs and music/television. This will help to reduce the sense of loss, isolation and loneliness that is felt and increase feelings of companionship. Each carer put into the home with Joshua is alone with him for two weeks. They usually have a mobile phone, some drive. Although we brief them for half a day, this is not standard practice. Each carer leaves a log book which identifies habits and routines. None have mentioned their sense of isolation or the strangeness of being in a different home every two weeks. As companions, the changes may have benefitted Joshua – who used to spend all day dozing in front of Sky news or worrying - as he experiences people with different interests, skills and conversations. Although exhausted by their stay the carers are keen to return and applaud Joshua's day time behaviour.

In conclusion, the ongoing case study is identifying specific areas which should be addressed in keeping the frail elderly living independently in the community; such as the better design and delivery of medicines; redesign of catheters; more joined up services in which the barriers between social and health care are removed. By studying the shift from independence and autonomy in the home, a new transition has been recognized, in which control is handed over, as well as the need for the type of skills needed by carers working as 24 hour live in companions.

Joshua used to say *'as I am now, so shall you become'* when referring to his physical deterioration. The speed of medical advances means that the current generation will suffer from similar issues to the ones related here. The question is, do we have sufficient understanding of what it means to grow old and are we prepared to make the high levels of investment and sweeping reforms needed to improve health products and services. Although much could be learnt from the respectful treatment and care of the elderly in non Western societies, family break up means that many will have to be resourceful and independent in later life. This may necessitate training of young older people to understand, accept and plan for life changes – for extended periods of old age- to ensure successful aging and coping strategies, and to improve health literacy.

Lastly, greater consideration needs to be given to the role played by informal circles of care; family, friends and partners. Not all people want to, or can draw on these resources. With a substantial increase in the number of elderly, new local, sustainable and transferable community based and led initiatives need to developed, where older citizens and their carers can support each other, and find advocates.

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