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7th International Conference on Applied Human Factors and Ergonomics

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Preface

Injury prevention is a common thread throughout every workplace, yet keeping employee safety and health knowledge consistently is a continual challenge for all employers. The discipline of Safety Management and Human Factors is cross-disciplinary concerning safety, health and welfare of the people engaged in work or employment. The book offers a platform to showcase research and for the exchange of information in safety management and human factors. Mastering safety management and human factors concepts is fundamental to both the creation of products and systems that people use and the design of work systems to avoid stresses and minimize the risk for accidents.

This book focuses on the advances in the safety management and its relationship with human factors, which are critical in the design of any human-centered technological system. The ideas and practical solutions described in the book are the outcome of dedicated research by academics and practitioners aiming to advance theory and practice in this dynamic and all-encompassing discipline.

A total of six sections are presented in this book. Each section contains research papers that have been reviewed by members of the International Editorial Board. Our sincere thanks and appreciation to the following Board members:

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We hope that this book, which is global and state of the art in safety management domain of human factors, will be a valuable source of theoretical and applied knowledge for global markets.

Guimarães, Portugal Pedro Arezes
July 2016

Contents

Part I
Safety Management

At What Age Is the Occupational Accident Risk High? Analysis of the Occurrence Rate of Occupational Accidents by Age

Akiko Takahashi and Takashi Miura

Abstract This study aims to analyze changes in the annual occurrence rate of occupational accidents by industry and by accident type, and to clarify the risk of occupational accidents by age. Based on the published number of casualties and number of employees, the annual number of casualties per 1000 workers was calculated. Although the occurrence rate of occupational accidents in the manufacturing industry and in the construction industry exhibited similar tendencies, risk for construction workers in their late teens was extremely high. The distributions of risk of falls and of cuts and abrasions differed greatly by age. In the future, we plan to make use of these data for safety management of sites and for improvement of workers' safety awareness.

Keywords Occupational accident statistics · Age · Occurrence rate of accidents · Industry type · Accident type

1 Introduction

According to the Ministry of Health, Labour and Welfare data, occupational accidents have been in long-term decline in Japan. However, 1057 workers were killed and 119,535 workers experienced absences of four days or more due to occupational accidents in 2014 (annual number of casualties per 1000 workers in all industries is 2.3) [1]. Thus, many occupational accidents still occur.

To consider appropriate safety measures in an effort to prevent occupational accidents, it is very important to determine the factors that affect the occurrence of occupational accidents using analysis of accident data and psychosocial methods.

Previous studies examined the relationship between occupational accidents and such factors as workers' profiles (e.g., gender, age, job tenure, industry, occupation,

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and type of employment), personality, health condition, lifestyle, workplace, and work contents [2–4]. Of those factors, the relationship between occupational accidents and workers' age has become a social concern that has been examined in many studies. In those studies, accident frequency, severity, and characteristics were used as indicators to evaluate occupational accidents, and the results indicated different tendencies by workers' age.

Focusing on occupational accidents among young workers, Salminen reviewed 63 studies of nonfatal accidents and 45 studies of fatal accidents. The results indicated that young workers had a higher injury rate than older workers, and young workers had a lower fatality rate than older workers [5]. However, Laflamme and Menckel reviewed 22 studies of age-related risks over three decades [6], and found various results on the relationship between accident frequency and workers' age. They classified occupational activities into four categories: age-impaired, age-counteracted, age-neutral, and age-enhanced. It was assumed that safety problems of older workers may be restricted to age-impaired activities. Furthermore, with regard to accident characteristics, it was concluded that older workers may have greater risk of injury to the back and lower limbs.

Thus, workers' age has been treated as a factor that predicts the risk of occupational accidents. Many studies that examined the relationship between occupational accidents and workers' age commonly divided workers' ages into several age categories and compared each characteristic among those categories. However, if we analyze changes in the occurrence of occupational accidents by age (i.e., at what age the occupational accidents begin to increase, or at what age the most occupational accidents occur), we can clarify the characteristics of occupational accidents. Then we can consider safety measures to prevent occupational accidents, based on these characteristics.

In our previous study [7], we analyzed and diagrammed the annual number of occupational accidents in Japan using the accident database published by the Ministry of Health, Labour and Welfare, in an effort to clarify changes in the occurrence of occupational accidents [8]. Results indicated that aspects of the distribution of occupational accidents by age (e.g., the age at which accidents began to increase and the age at which most accidents occurred) differed among industries and among accident types.

However, the number of occupational accidents at each age was affected by the number of employees at that age. Therefore, to understand the effect of workers' age more exactly, it was necessary to analyze the annual occurrence rate of occupational accidents.

The purpose of this study is to analyze changes in the annual occurrence rate of occupational accidents for some industries and some accident types, to compare them among those industries and among those accident types, and then to clarify the risk of occupational accidents by age. Here, the annual number of casualties per 1000 workers was used as an indicator to evaluate the occurrence rate of occupational accidents. These statistics are used in the field of occupational safety in Japan.

2 Method

To calculate the annual number of casualties per 1000 workers, the annual number of casualties and the annual average number of employees were calculated.

2.1 Calculation of the Annual Number of Casualties

To calculate the annual number of casualties, the accident database published by the Ministry of Health, Labour and Welfare [8] was used. This database randomly sampled a quarter of the individual reports each year in Japan. An individual report, written in a row on a Microsoft Excel sheet, included the month, time, and situation of occurrence, as well as the industry, accident type, object causing the accident, and age. In this study, data from 2006 to 2010 were analyzed. The data in 2006 included 34,156 cases, and the sampling rate was 25.4 % of all cases. Based on this sampling rate, the number of casualties in 2006 was estimated. Figure 1 plots the number of casualties in all industries in 2006. In a similar way, the annual number of casualties from 2007 to 2010 was also estimated.

2.2 Calculation of the Annual Average Number of Employees

To calculate the annual average number employees, the data of the Labour Force Survey published by the Ministry of Internal Affairs and Communications [9] was used. These data included the average number of employees in five-year intervals from 15 years old to 64 years old, and 65 years old or older every year. Using these data, the annual average number of employees from 15 years old to 79 years old was estimated. The upper age limit was 79 years, because the proportion of

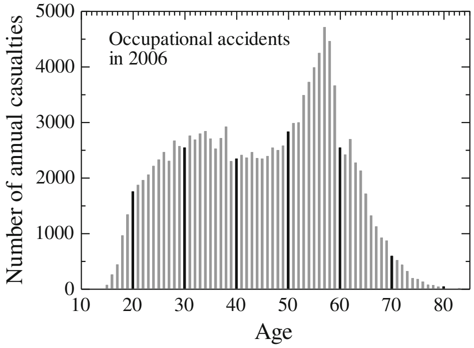


Fig. 1 Number of casualties in all industries in 2006

casualties of occupational accidents among workers 80 years old or older was extremely low (0.11 % of all casualties). The method of estimation was as follows. The cumulative frequency distribution was calculated in five-year intervals, and unknown values in one-year intervals were interpolated with a spline curve that passed each data point of this distribution. The difference between values in one-year intervals was treated as the annual average number of employees for each age.

2.3 Calculation of the Annual Occurrence Rate of Occupational Accidents (Annual Number of Casualties Per 1000 Workers)

Based on the annual number of casualties and the annual average number of employees, the annual number of casualties per 1000 workers was calculated from 2006 to 2010. Furthermore, the average of the five-year data was taken, and the annual distribution of casualties per 1000 workers was diagrammed. The estimated values for workers 17 years old or younger and for those 70 years old or older were excluded because the errors were too large. In this way, the occurrence rate of occupational accidents was calculated for such factors as industry and accident type.

3 Result and Discussion

3.1 Occurrence Rate of Occupational Accidents in All Industries

Figure 2 plots the annual number of casualties per 1000 workers in all industries. The annual number of casualties for workers in their late teens was comparatively high (3.0) and then fell for those in their early 20s. Although it remained low (2.0) for workers in their late 20s to the early 40s, it began to rise again for workers in their late 40s and remained high (3.5) up to age 60. Salminen [5] reviewed many studies of the relationship between occupational accidents and workers' age, and found that young workers had a higher injury rate than older workers. Simple comparison of Salminen's review with the data that we analyzed is impossible because our data included both non-fatal and fatal accidents; however, it is clear that the occurrence of occupational accidents in Japan was high for workers in their late teens and age 50 or older. Furthermore, the occurrence of occupational accidents began to rise again for workers in their late 40s.

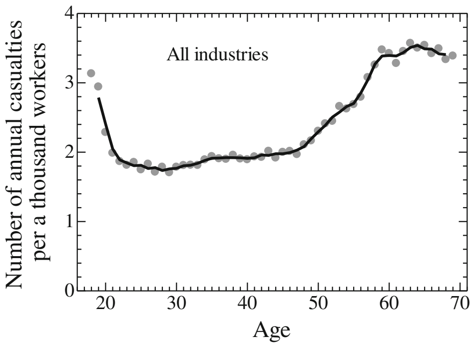


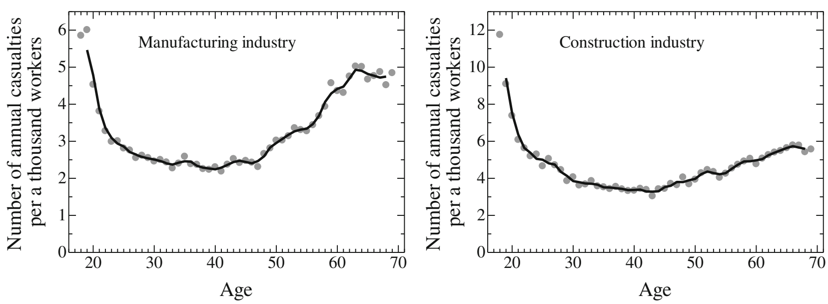
Fig. 2 Annual number of casualties per 1000 workers in all industries

3.2 Occurrence Rate of Occupational Accidents in Each Industry

The annual number of casualties per 1000 workers in each industry was calculated. Figure 3 plots the annual number of casualties per 1000 workers in the manufacturing industry and in the construction industry.

In the manufacturing industry, the annual number of casualties per 1000 workers in their late teens was high (6.0), but fell sharply for those in their early 20s and remained low (2.2) for those in their 30s. Subsequently, it began to rise again for workers in their late 40s, and the incidence for those in their early 60s reached the same level as that for 20-year-olds. The occurrence rate of occupational accidents for workers in their late teens and age 60 or older was higher in the manufacturing industry than in all industries (Fig. 2).

The annual number of casualties per 1000 workers in the construction industry was high overall. The annual number of casualties per 1000 18-year-old workers was especially high (12.0) and was four times higher than that for all industries.



a. Manufacturing industry

b. Construction industry

Fig. 3 Annual number of casualties per 1000 workers in all industries

Subsequently, it fell drastically to half for workers in their early 20s and remained low (3.5) for those in their 30s and early 40s. It began to rise again for workers in their late 40s and it reached 6.0 for those in their late 60s. The occurrence rate of occupational accidents for workers in their 60s was 1.7 times higher for the construction industry than for all industries.

In summary, the occurrence rate of occupational accidents in both the manufacturing industry and the construction industry was high for workers in their late teens and then fell, but began to rise again for workers in their late 40s and remained high for those 60 years old or older. Furthermore, the occurrence rate of occupational accidents for construction workers in their late teens was extremely high.

3.3 Occurrence Rate of Each Type of Occupational Accident

The annual number of casualties per 1000 workers by accident type was calculated. Figure 4 plots the annual number of casualties per 1000 workers involving falls and cuts and abrasions in all industries.

The annual number of casualties per 1000 workers involving falls was low (0.2–0.3) for workers 20–40 years old. However, it began to rise for those older than 40 years, drastically rising among workers in their late 40s. The incidence among workers in their 60s was three to five times higher than that among workers in their 20s and 30s. Therefore, this markedly high occurrence rate of falls for older workers indicates that workers 40 years old or older should take care to avoid this type of accident.

The annual number of casualties per 1000 workers involving cuts and abrasions was the highest (0.57) for 18-year-old workers, and drastically fell for those in their early 20s. It was lowest at 0.14 for workers in their 30s and early 40s, and gradually began to rise for those in their late 40s.

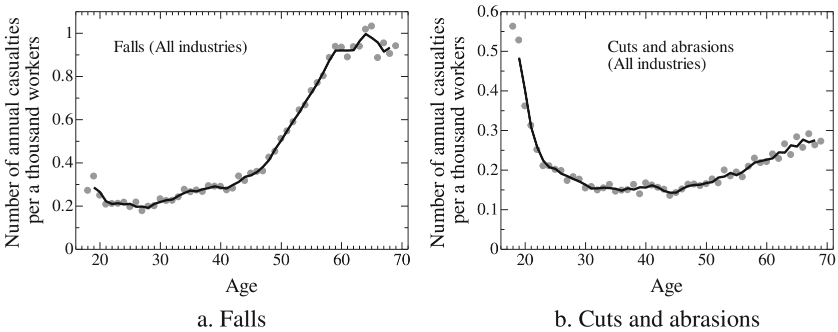


Fig. 4 Annual number of casualties per 1000 workers by accident type for all industries

In summary, the distribution of accident types differed by age. Therefore, it is important to consider safety measures suitable for each age. In addition, it is also desirable to take early safety measures focusing on the age at which accident risk begins to rise.

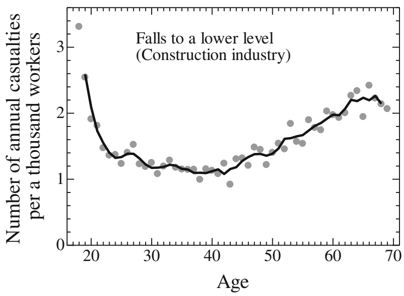
3.4 Occurrence Rate of Each Type of Occupational Accident in the Construction Industry

Analysis of the occurrence rate of each accident type is necessary to determine the relationship between accident type and age in the industry. Therefore, considering the overall high accident risk in the construction industry, the annual number of casualties per 1000 workers involving falls to a lower level (33.5–34.9 % of all occupational accidents in the construction industry from 2006 to 2010) [1] and involving cuts and abrasions (10.1–10.4 % of all occupational accidents in the construction industry from 2006 to 2010) [10] was diagrammed (Fig. 5).

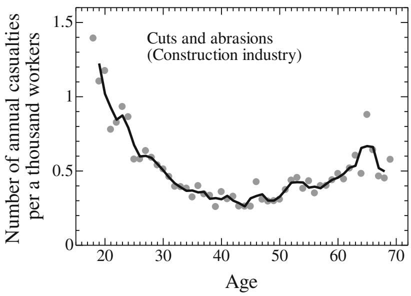
The annual number of casualties per 1000 workers involving falls to a lower level was the highest (3.3) for 18-year-old workers but fell to half for those in their early 20s. Although it remained low (1.2) for workers in their late 20s to 40 years old, it gradually rose for those in their early 40s and reached 2.4 for those in their 60s. Thus, construction workers in their late teens and in their 40s or older are at high risk for falls to a lower level.

The annual number of casualties per 1000 workers involving cuts and abrasions was also the highest (1.4) for 18-year-old workers, but fell to 0.28 for those in their late 30s. Although it gradually rose again for workers in their late 40s, the risk remained relatively low (0.5) for older workers. Thus, young construction workers (from late teens to early 30s) are at especially high risk for cuts and abrasions.

By subdividing factors of occupational accidents (e.g., industry and accident type) and comparing the occurrence rate among them, it was determined from what



a. Falls to a lower level



b. Cuts and abrasions

Fig. 5 Annual number of casualties per 1000 workers by accident type in the construction industry age we should take care to avoid the risk of each kind of occupational accident and what age is most at risk for each type of occupational accident. Furthermore, when objects causing accidents and work contents are considered, risk by age will be clearer.

In the future, we plan to share these data with managers and workers in an effort to improve safety management of the sites and increase workers' safety awareness. Furthermore, workers who estimate the risk of occupational accidents as less than the actual risk may take risky action. Therefore, we will study the difference between the objective risk that we analyzed in this study and the subjective risk that workers usually estimate.

References

1. Ministry of Health, Labour and Welfare.: Occupational accidents occurrences. Accessed 18 Jan 2016 (in Japanese). http://www.mhlw.go.jp/bunya/roudoukijun/anzeneisei11/rousai-hassei/
2. Frone, M.R.: Predictors of work injuries among employed adolescents. J. Appl. Psychol. **83**, 565–576 (1998)
3. Yoeh, H.T., Lockhart, T.E., Wu, X.: Non-fatal occupational falls om the same level. Ergonomics **56**, 153–165 (2013)
4. Gauchard, G.C., Chau, N., Touron, C., Benamghar, L., Dehaene, D., Perrin, P., Mur J.: Individual characteristics in occupational accidents due to imbalance: a case-control study of the employee of a railway company. Occup. Environ. Med. **60**, 330–335(2003)
5. Salminen, S.: Have young workers more injuries than older ones? An international literature review. J. Saf. Res. **35**, 513–521 (2004)
6. Laflamme, L., Menckel, E.: Aging and occupational accidents: a review of the literature of the last three decades. Saf. Sci. **21**, 145–161 (1995)
7. Takahashi, A., Miura, T.: Characteristics of occupational accidents by age. In: The Proceedings of the 19th Triennial Congress of the International Ergonomics Association, p. 317 (2015)
8. Ministry of Health, Labour and Welfare.: Occupational accidents database. Accessed 15 Feb 2016 (in Japanese). http://anzeninfo.mhlw.go.jp/anzen_pgm/SHISYO_FND.aspx
9. Ministry of Internal Affairs and Communications.: Labour force survey. Accessed 15 Feb 2016. http://www.stat.go.jp/english/data/roudou/index.htm
10. Ministry of Health, Labour and Welfare. 2015. Occupational accidents occurrences in each industry and each accident type. Accessed 10 Feb 2016 (in Japanese) http://anzeninfo.mhlw.go.jp/user/anzen/tok/anst00.htm

Human Factor in Occupational Risks Prevention: From Error Theories to Responsibility and Liability Theories

Ángel Crescencio Martínez Ortiz

Abstract The current hegemony of the mechanistic thinking, deeply rooted in the machine image, and the analysis procedure that involves breaking down complex things into simple ones in order to find their existing meaning, together with a great coincidence, have all led to talk about the human being exclusively, as a mere component or casual factor in risk situations. We make the human being responsible for a load that business managers and politicians would share equally. This is all due to an inadequate global security response. The individual is intentionally separated from the environment. Why? In order to make him causal factor and main subject in risk situations, especially in those with political implications. Our work involves understanding human participation in unwanted events from the ethic idea of responsibility and reliability in all organizations, instead of from the individual error thinking.

Keywords Human factors · Responsibility · Paradigm · Mechanistic · Systemic

1 Introduction

It is unavoidable to speak about human factor facts when we try to understand occupational risks prevention. As we see it, people's health is what moves such social practice. However, all human factor issues have been managed through theories that study accidents casualty.

Occupational risks prevention needs to be understood as one cooperative human activity aiming to achieve a goal that societies establish. Therefore, it is a performance that depends of its context of discovery. With all this being said, you will understand that we can't manage occupational risks prevention without taking into account its rational context.

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When we talk about rational context in risks prevention, we are saying [1] that risks prevention, as a certain type of social practice, can't be excluded from a context of intelligibility that is comprised of a way in which we understand Nature, in block capitals; a way of understanding the human being and a way of understanding business. Of course, we are always referring to risks prevention in workplaces.

Different worldviews have various ways to understand these elements. At the moment, there is also a dispute to achieve hegemony between the mechanistic worldview and the systemic worldview, which leads to two different patterns to understand occupational risks prevention and the human being.

2 Paradigm of Mechanism: The Illusion of Control and Security

In the sixteenth and seventeenth centuries, the medieval vision of the world based on the Aristotelian philosophy and Christian theology experimented a radical change. The vision of the world as a machine took over the organic, living and spiritual vision of the universe. The machine metaphor became a dominant principle of modern ages. It tried to explain how the universe, man, and later on the organizations functioned.

Several developments in the sciences of physics, astronomy and mathematics supported this radical change. Movements such as the Scientific Revolution where we find names like Copernicus, Galileo, Descartes, Bacon, and Newton, among others. All these authors were in fact heirs of the eighteenth century Enlightenment and nineteenth and twentieth centuries' empiricist philosophers. They all worked under the theme: "Given a system initial conditions and laws of nature, one can calculate its approximate movement" [2].

Life length for this theme will require a particular understanding of the concepts of Nature, human being and rationality. We cannot forget here the company organization as a must-have context for a productive activity and its risks.

2.1 Nature: One Geometric Space

The vision of Nature has influences on thoughts since it imposes a global vision of the world as a certain transformation in the different areas of knowledge and human action. Nature itself, without previous spiritual elements, or any type of purpose, is identified with the Euclidean geometric space and it is understood within the mathematical reasoning. As a consequence, Nature becomes one uniform space with underlying laws, such as the laws of Mathematics and various Mechanism and Dynamics abstract thinking frames, which will operate universally for all times and places.

The consequence for this Nature approach will be the emergence of the rationalist tradition of prevention.

3 Rationalistic Tradition in Prevention

Our idea is that the mechanistic thinking pictures will be specified in the field of risk prevention in a tradition that has dominated the twentieth century and that it should be put aside in order to achieve higher success levels in risks prevention. Without a doubt, one of this project's goals will be recovering the *res cogitans* that the individual had lost during the Enlightenment.

The main features of this rationalistic tradition in occupational risks prevention will be:

3.1 Risk Is an Objective Thing

From the epistemological point of view, we can say that Logical Empiricism realism would explain the rationality that will prevail in the science of prevention. This will mean to say goodbye to the perceptual in benefit of the conceptual, also the subjective gives way to the objective; which will also reach the risk scope.

In this preventive tradition there are many probabilistic statistics risk definitions based on scientific criteria, that is, positive quantitative science (such as engineering, statistics, physics or chemistry). Risk is an objective property of an event or an activity. It can be measured probabilistically to calculate its adverse effects. From this approach, risk is measured in figures measuring damage.

3.2 Technical Factors that Determine Risk

Occupational hazards are determined by the influence that working conditions has on workers' health. Studying the occupational risks only from the side of natural sciences will mean reducing the risk analysis to the study of the conditions that can be treated with the methods of these sciences (i.e. methods that can be translated into physical or mathematical language). We will leave out other aspects such as all psychosocial risks.

3.3 Quantitative and Analytical Risk Evaluation (One Workplace at a Time)

In this objective tradition, risk evaluation is seen as a highly technical diagnostic phase. There is a quantitative calculation of the human health risks that working conditions bring about. This approach understands risk as mathematically measurable, so it understands evaluation as a process of estimating magnitudes. Mechanistic epistemology is not only transferred to the quantification of risks but also will establish its analytical rationality to the procedure established for its evaluation. It will refer to a one workplace at a time rather than to global security response.

3.4 Only a Few Technicians Own Expert Knowledge

Objective analysis methods of working conditions that we just mentioned have the following features. Analyses are based on objective data and only experts can put them in practice with the application of scientific methods and techniques. In the analysis phase, such methods do without workers' participation. In this tradition, the concentration of expert knowledge in prevention belongs to small group of specialists who master the procedures and measuring instruments.

The rational tradition in risks prevention that we identify within the framework of a mechanistic paradigm, will add analytical rationality to help us understand risks prevention and accident rates in terms of factors, sources and human error.

4 Mechanistic Human Factor

The current hegemony of the mechanistic thinking, deeply rooted in the machine image, and the analysis procedure that involves breaking down complex things into simple ones in order to find their existing meaning, together with a great coincidence, have all led to talk about the human being exclusively, as a mere component or casual factor in risk situations. We make the human being responsible for a load that business managers and politicians would share equally. This is all due to an inadequate global security response [3].

The individual is intentionally separated from the environment. Why? In order to make him causal factor and main subject in risk situations, especially in those with political implications. It has happened so in railway accidents like in the Valencia Subway accident (2006) or the Ebola spread (2014). Within this mechanistic paradigm of the human being, we can find a long range of accident causation theories (Heinrich theory, H. W. (1950), domino theory, multiple casualty theory, and energy transfer theory). All these make use of an analytical rationality and a great coincidence in explaining how accidents happen. Workers or citizens would just become simple factors in a causal chain. The occurrence of an accident or an unwanted situation can be explained just by them (at least 80 % of the accidents).

From our point of view, this unfortunate management of human participation in the safety field is due to the fact that when we speak of "Human Factor" related to prevention, we speak from the mechanistic language that has been dominating scientific fields like Engineering, interested in quantifying (risk) and calculating probabilities (human error), Psychology, long dominated by the scheme S-R behaviorism, in its various forms, Ergonomics, focused for a long time in anthropometric figures that represented magnitudes, and Business Science, unable to break free from the classical theory of a bureaucratic and mechanistic organization vision.

This language enabled us to understand the human being as a mechanism whose behavior conforms to a certain structure and programming, developed by safety engineers. Everything that is far from this program becomes noise, deviation or individual error correctable with reprogramming or proper recycling:

«The insistence on human error is suspect of clouding other safety factors, especially design, organization and management limitations. There are "normal" accidents given the structure of the system» [4].

5 Systemic Paradigm

However, systemic thinking wants to address all those encrusted ideas and values, typical of the mechanistic worldview, from another perspective: «The vision of the universe as a mechanical system constructed with parts and governed by the laws of mathematics», «human body as a machine», «life in society as a conglomeration of individuals in a competitive struggle for existence» and «analytic rationality, one knowledge breaker»; that still survive to the consequences we already know in the field of prevention.

The Psychosocial Tradition, which we identify with the systemic paradigm, will add systemic rationality allowing to understanding prevention and accident rates in terms of organization, global security response and systemic reliability. As we see it, this is a better look at exactly what human factors involve. We need to look into the sustainability context where this psychosocial prevention tradition takes place before we study it.

5.1 Contextual Rationality

First, you must understand rationality from another point of view. According to the systemic vision, the essential features of an organism are features of all that no part has itself. They emerge from the interactions and relationships between the parts. Although we can discern individual parts in any system, these parts are not isolated. The nature of the whole is always different from the mere sum of the parts. Twentieth-century science has revealed that these parts' features are not intrinsic but can only be understood from a larger context. So it is that the relationship between the parts and the whole become reversed. It is then that we will understand parts can only be understood from the organization of the whole.

Systemic rationality becomes contextual, unlike the analytical nature of the mechanistic paradigm. Systems become the unit of analysis of the new paradigm.

This line of knowledge's keys lead to what we call the line of objectivity in brackets or hermeneutics. Two are the consequences: The existence of a reality constructed by the individual, as opposed to the objective reality of the mechanistic worldview, and the existence of a plural rationality.

In the mechanistic paradigm objectivity is achieved by its adaptation to an external and independent reality the individual knows. In the new paradigm, this external and independent to the individual reality no longer exists. It is constructed by the individual through the way they know reality: Establishing patterns in the relationships network that is reality. At the same time, this will mean that there will be as many realities as ways of existing knowledge.

Ontological and epistemological features of this worldview will bring about different ways of understanding the organizations and humans. In the field of prevention they will be specified in an emerging psychosocial approach.

5.2 The Human Being: Personality System

In psychology, the basic concept of behavior used to be the robot model. We had to explain behavior with the mechanistic stimulus-response scheme (S-R). On the other hand, human behavior will not be understood in the systemic personality theory without considering the pursuit of goals and the individual's intentions. Systemic thinking means that personality has system features where things and the whole itself emerge together, thanks to a slow gathering of learning processes and social, cultural and linguistic factors.

The social relations' system in which the actor is involved is not merely functional but it is constitutive of the personality itself. This systemic dependence will also have consequences for the way we understand action.

5.3 Holistic Theory of Action

The action is to be understood as a system where cultural, social and psychological components live. This systemic scheme extends the mechanistic action scheme. It finds a new source of intelligible individual action in rules provided by the social system or any of its institutions, such as the organization.

Action systems are structured around three focal points: the individual actor, the social system and a system of cultural patterns. The interest of the action must be maintaining the balance of relations between them and the environment in which they find themselves.

From our occupational risks prevention research side, the action that is of our interest is the one that should be explained by the system consisting of a worker whose personality is built as a result of belonging to a certain social community. This worker performs in a certain company context according to some corporate culture we still do not know. Next point will go over this in detail.

5.4 The Organization

Whether we are aware or not, the vision applied to business organizations today is a direct descendant of seventeenth century Newtonian physics. In the mechanistic paradigm, the machine metaphor and closed systems is the most appropriate figure to understand the company organization. From the systemic point of view, it is the figure of a most appropriate ethical company that will transform a physical space into symbolic that will allow the individual to own identity and it will add intelligibility to action. This company will be the citizen company.

5.5 The Citizen Company

Among the theories that understand the organization as a system, it will be the citizen company [5] model that best reconciles with our interests to understand the occupational risks prevention as opposed to the mechanistic frameworks. Therefore, it has potential to become a guide for individual action also in occupational risks prevention.

A citizen company is a type of organization that is not understood as one machine type, which goal is exclusively obtaining physical products. It is a human group that aims to satisfy the interests of all groups involved in their activity or stakeholders. This concern for all those affected by the productive activity equals to introducing the ethical question in business strategy.

A citizen company does not ignore its social and ecological environment. It is essential for its survival, and it assumes as its own responsibility to meet those demands of social and ecological nature, as well as economic, which its stakeholders make (either internal or external). This implies the assumption of the company as an economic but also social organization which incorporates economic and social balance. Consequently, it is through the theory of responsibility how we connect the company to the systemic thinking and the individual to the social system.

This addition made by companies on a voluntary basis of social and environmental concerns in their business operations and relations with its partners, is what is known as Corporate Social Responsibility. It is only a part of that larger sphere that is social ethics.

As we can see, this social responsibility represents the addition of ethical values to the company management. They will be put next to the traditional economic values of corporate management creating a certain organizational culture identity. Citizen companies are no longer conceived as moneymakers. They are now entities owning culture. The real backbone of the company is not material but it is now symbolic: one system of sharing meanings and interpretive schemes that create and recreate meanings.

This culture guarantees decision coherence with the key values and beliefs that give identity to the organization. It generates commitment and addresses individual behavior; also in occupational risks prevention. With this symbolic space that comes with business ethics, risk prevention is extended with the psychosocial aspects that it had lost during its mechanistic phase.

6 Psychosocial Tradition in Prevention

For many years, in risks prevention, the world has been written with the same mathematical language that Galileo spoke. Now the reality that risks prevention must work with is no longer perceived mechanistically, as a mere set of elements or risk factors that can be understood in isolation and that can predict their behavior. For instance, the damage caused by the application of a set of universal laws.

We will understand reality as a number of elements or factors that interact with each other and with the environment, resulting in one dynamic and unpredictable reality that cannot be reduced to the sum of its components.

Companies can no longer be understood as indoors, suitably parcelled areas with a perfect stable environment that predicts, with the use of some mathematical calculations, its future behavior in relation to risk. Companies need to be open; they need to count with their environment in order to survive. Preventers will have to deal with uncertain environments. In many cases, it will be impossible to reduce these environments to a small set of measurable and manipulable factors.

The human being cannot be explained with merely chemical and physical criteria anymore either. Their actions will not be understood just through their personal preferences. Now, the human being builds his identity by reference to social organizations that he is part of. He addresses his actions regarding to the values available in the culture where he is integrated.

This means that occupational risks prevention will not only require, in accordance with the traditional way, that limiting rationality that natural sciences bring. Risks prevention will also have a greater scope ethical/social rationality. This is a key feature in citizen companies that have a social risk perception.

6.1 Social and Ethical Risk Perception

When we refer to social risk perception we are referring to a certain level of acceptable risk, or what is the same, certain ethical standards that should work as reference for the citizens' protection and safety. It does not originate in the objective criteria of science but in the confidence, competence, independence, legitimacy, etc., relations that people are going to keep up with the institutions responsible for managing risk. It can also be associated with all criteria accompanying risks. Risks are so subjective: its catastrophic impact, immediate or retarded risk effects, new or existing risks, voluntary or involuntary exposition to risk, etc.

In our society today, risk has ceased to have clear boundaries and to respect borders. Prevention rationalist conservative approaches focused on limit values and conventionally stable scenarios should be expanded with an ethical responsibility vision. This will create some overall security response (governments, corporations and companies response). A part of a certain responsibility preventive culture will deal with the unpredictable.

Different theoretical approach models to this social perception of risk exist, such as the psychometric perspective, anthropologists and sociologists, cultural theory or social psychology, in general, they understand that the risks are social constructs. Our proposal in this work is the integrative perspective proposed by the psychosocial tradition. We have to understand occupational risks prevention from the broader context of social and organizational relationships in which workers' behavior takes place.

This proposal refers to a tradition that understands that the worker, business and society make some physical but also symbolic system where none of its constituent elements can be understood without referring to the other two. In the prevention and causation of accidents field, this approach will mean understanding human participation in unwanted events from the systemic idea of responsibility and reliability of the organizations and not from the mechanistic idea of individual performance and error. In short, we will understand human error as a result of certain systemic failures, and not as the cause that would explain the production of an accident by itself.

6.2 Systemic Theories of Accidents

If from the point of view of the rationalist tradition theories explaining the production of accidents they did from the linear rationality and strong causality, from the point of view of the psychological tradition, the accident to be analyzed from the point of view the reliability of systems. At the same time, the human factor will change its mechanical condition "of cause" by the "consequence" of a number of latent faults in the system. These systemic theories of human error, as proposed by Reason [6], warn us that human intervention, in many cases, is merely the trigger for an evil potion that for many years has been simmering.

7 Conclusions

In this paper we have tried to propose a change in perspective, from the dominant mechanistic thinking to a systemic approach in order to understand human participation in risk situations. This will not be achieved from the individual involvement that can be transformed into a source of disturbance or error, but from the responsibility that entails active participation in certain overall security response. As we see it, adopting the first option, means distorting reality to make it fit into a small number of factors that can be manipulated and controlled, including the human factor.

As we see it, if we take this approach for good, we are making the existence of unwanted events look simple and in an intentional way. We should rather face the responsibility of organizations and society itself. The mechanistic approach that reduces the production of unwanted events to the human factor, understood from the analogy of the human machine, means ignoring some broader reflection that should include organizations and society as a whole.

References

1. Martínez Ortiz, A.C.: Occupational risk prevention, also a matter of social corporate responsibility, Proteus, Barcelona (2013)
2. Gleick, J.: CAOS, One science creation, Seix Barral, Barcelona, p. 22 (1994)
3. Meliá Navarro, J.L.: Human Factor in Job Safety. Occupational Health And Safety Psychology. Lettera Publishers, Bilbao (2007)
4. Perrow, C.: Normal Accidents: Living With High-Risk Technologies. Basic Books, Inc., New-York (1984)
5. Cortina, A.: Citizens of the World. Towards a Theory of Citizenship. Alianza Editorial, Madrid (1997)
6. Reason, J.: Human Error. Cambridge University Press, New York (1990)

Management of Public Safety Artifacts Through Design

Walter F.M. Correia, Sérgio Ximenes da Silva, Fábio F.C. Campos and Marina L.N. Barros

Abstract The relationship between quantity and quality of what is produced and its creative processes do not always bring the desired responses for the end user. The objective of this work is to develop a project tool that can contribute in design methodologies for safety assessment of artifacts for restricted use in the activity of Public Safety through Risk Management and Vulnerability. Sought the insertion of the knowledge of an expert in the subject area working the risks and vulnerabilities present to get an artifact the best possible demand draft. Hence the importance of producing a range of values through a rational and practical tool.

Keywords Design · End user · Design methodologies · Security artifacts · Public safety · Risks · Vulnerabilities · Values scale

1 Introduction

The design techniques are grouped primarily in four phases outlined below: exploration of the problem, generation and selection of alternatives, assessment artifacts, presentation solution [1].

The needs of the modern man are usually in line with the development of their professional and private activities, family relationships, leisure, sports, not neces-

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sarily with security issues, lifetime warranty against direct attacks and indirect its existence, therefore, to ensure that there is the presence of the state, which has the obligation to ensure citizens a dignified and secure life.

Article 1 of the Brazilian Constitution of 1988 [2], in its sole paragraph, states: “all power emanates from the people, who exercise it through representatives or directly elected under this constitution”. The article in question distinguishes ownership of exercising power, exemplifying that the holder of the power is the people, but the exercise of that power is given by the representatives of the people towards the consecration of a democratic state and therefore of popular sovereignty.

It is precisely because of this, we have a bunch of different needs and aspirations that must be dealt with attention, arising from the activity of Public Safety, it is he who, nowadays, is responsible for the maintenance of peace and the resolution of chores, participating directly in combat of life and death.

It is within this framework that must serve the designer, seeking to meet the most demanding needs arising Sector Public Safety, to meet not only the large-scale production that standardizes end users as if they were all alike, but bringing fore concepts and procedures to the externalization of increasingly specific needs of the end user, which should be treated as unique.

Hence a new need arises within the design process: the use of expert knowledge in the process of data collection, trying to list the main features, resulting in an escalation of values that should be prioritized for achieving more specific and appropriate to demand from the activity of public safety.

This research seeks to gain an aspect of visual perception of real space of Pernambuco/Brazil, concerning the equipment for individual use in the activity of public safety, with a focus on police cars. Working the absence of proper methodology of analysis for the selection, procurement and distribution of them, analyzing them from different perspectives. The equipment’s are used in various operating environments that have the lowest and highest risk to the police. Understanding “risk” as the possibility of occurrence of an event that will cause more or less injury. Aspects such as ergonomics, usability and liability will be addressed.

2 Theoretical

There are specialties, the most different in design: interior design, fashion, industry etc. Another specialty is very relevant to the Design Vehicle concept presented by the Portuguese Donato Nappo and Stefania Vairelli in his book “Design of Vehicles” [3]: “It is the study of the formal and aesthetic evolution of vehicles, from its origins to the present day. It is a chronological narration that precedes and goes through the world of wheeled transport to join those who, with his ingenuity, managed to make history by determining the most significant developments and stages around the world”.

Public safety, on the other hand is a concept linked to the legal provision of security, properly allocated in the Constitution of Brazil, on Federal Constitution of 1988 [2] in the article 6 on social rights, together education, health, work, housing, leisure, social security, protection of motherhood and childhood as well as assistance to the destitute.

In light of the principle of Human Dignity that guides the concept of public security, the renowned versa right operator Greco [4]: "Even the vilest, most hateful man, the criminal is cruel and colder bearer of this value".

It is clear that in both concepts (design and public safety) is a common factor: a plurality of disciplines and related issues that act as automatons on an assembly line, in which each of the concepts and disciplines is responsible for a portion of the whole and on which have a direct influence on the final result if they relegated oblivion. Requiring so no special attention, but just as far right as applicable to each factor.

It is this diversity that makes up this design as an element of creation, adaptation and binding of artifacts to the specific needs of the users responsible for activity practice of public safety, it is classified the Design of Public Safety.

Through the Designer of Public Safety will be developed up-dormant potential.

3 Research Methodology

A Tool proposal has its beginning with the direct evaluation of a specialist in the area in question (as the end user, for example, police who constantly use the vehicles in different situations).

Must first be listed risks and vulnerabilities present then they should be explained, staggered and subdivided into groups by functionality and relevance.

From then applies the Likert scale and the GUT table. At the end there should be an intersection between the Likert Scale and table GUT applying markings most relevant values in Table Staggered.

Hence it will be a Guide Line for the functionality aspects of risks and vulnerabilities considered more important to be worked. With that reaches up the main goal: to get an artifact the best possible demand initially proposed.

Questions about financial viability and time must be treated in a secondary analysis therefore imply technical and administrative issues.

Some topics listed in the guide lines are specific to police cars and alone, since they are the focus of this case study. The fact that Tool Risk Management and Vulnerabilities can be used in any artifact public safety concerns that are listed new risks and vulnerabilities present in these other artifacts that need to be evaluated. This must be done using the knowledge of another expert in the field for that other object to be evaluated. The list of risks and vulnerabilities varies depending on the artifact being evaluated. For example, if the object is a building like Arts and Communication Center of Federal University of Pernambuco and demand for the relative safety organic through the tool can list the risks and vulnerabilities present through knowledge of security experts and end users, and in addition to determine which core values to be worked out, you can scale them and differentiate them, for example, on whether the students are more at risk than the teachers.

3.1 Development of the Tool Through the Case Study

Situation Map of Risks and Vulnerabilities. The police cars is using as a case studys, at first should be to list the risks and vulnerabilities listing them in a Location Map of Risks and Vulnerabilities. Risks and vulnerabilities listed must relate to the performance of the activity to be studied. They should be divided into groups by affinity. It is understood as affinity similar characteristics that individualize previously risks and vulnerabilities related items may relate precisely because they do not fit in any other existing group. The subdivision into groups allows for ease of observation and quantification when implementing the next steps of the tool. At this stage of application of the tool have been identified in the case study, six groups that have different components interconnected by functionality such as protection against external threats or availability of adequate allocation of artifacts or the possibility of interference with space to move (Table 1).

After preparation of the list of risks and vulnerabilities, all factors must be exemplified one by one as some examples below:

Humanized Compartment to Transport Detainees. It is what is usually called the "chess" in the car, only suitably adapted. Instead of transporting prisoners and detainees in the trunk of the vehicle or in the back seat without any containment structure that is not only the shackles, inmates can be transported safely (both for themselves and for the police who are conducting). In one case in 2005, two policemen carried a prisoner in the back seat properly handcuffed behind when stopped at a house to pick up the documents attached. While an officer was out of the car, the prisoner has his hands cuffed behind his legs and grabbed the gun from the officer who was in front of the driver's seat. After much struggle between both the police managed to retrieve his pistol and held the prisoner. He almost lost his life. No telling where accidents occur with the vehicle and that in them you are stuck in the boot will likely be hit hard.

Table 1 Location map of risks and vulnerabilities present on use of vehicles

Map location of risks and vulnerabilities gifts in use of vehicles		
Affinity groups	No. of requirements order	Risks and vulnerabilities
Group 1	1	Humanized compartment to transport detainees
	2	Radios communicators

This table is available with this step in the whole project

Likert Scale. For that we consider the risks and vulnerabilities related to a police vehicle, duly listed in the previous step development tool. Each aspect will be evaluated according to what the user considers it more or less important for the maintenance of life. After quantification of this perception of importance will be highlighted aspects considered more significant to be worked and taken as indispensable in daily intercourse. Such items marked with score level 5 will be related to the markings later GUT tool to be developed in the next step of managing risks and vulnerabilities.

Tool G.U.T. Considering the severity levels (damage wreaked by the situation), urgency (time resolution) and trend, the GUT tool actions regarding the risks and vulnerabilities by priority level will be listed.

The table is available with this step in the whole project (Table 2). Requirements to be prioritized through the tool GUT.

Data Analysis. This step is like a cross between the risks and vulnerabilities marked as most significant in the Likert Scale and GUT tool. Starting from such a real cross stratification considered more important aspects which will enable a concentration of values that result in a Guide Line Scheduling of priority values when assessing the quality of a police car to be worked on next step will terse-management of risks and vulnerabilities.

4 Results

4.1 Guide Line Scheduling Priority Values When Assessing the Quality of a Police Car

Following the proposed methodology have will result in Guide Line with a list of priority values when assessing the level of quality of a police car (object worked as a case study). The result is realistic about the needs of the object demanded as part of remarks made by an expert in the area and follows a logical process of development and correlation of data. The proposed model is not restricted to police cars, but can be used for other artifacts (Table 2).

Risks and vulnerabilities listed in the guide line end up resulting from the application of the management tool are to be considered when assessing the level of adequacy of a police vehicle to the desired activity. They should base the final decision on the response to the demand for police vehicles serving as guides for defining the artifacts to be worked primarily as they were defined as most important by taking up the knowledge base of experts in the field.

Table 2 Guide line scheduling priority values when assessing the quality of a police car

Guide line scheduling priority values when assessing the quality of a police car		
Affinity groups	No. of requirements order	Risks and vulnerabilities
Group 1	1	Humanized compartment to transport detainees

This table is available with this step in the whole project
Source The Author (2013)

5 Conclusion

5.1 Initial Considerations

We found no methodology for evaluating the effectiveness of equipment restricted the activity of public safety that takes into account the knowledge of experts in the phase of data collection in the design process. Somehow occurs submission methodological empiricism.

Not verified the existence of a process of individualization of equipment to adjust them to the professional and thus reduce the possibility of failure in the performance of their activities.

5.2 Compliance with the Objectives of This Study

Risks and vulnerabilities demonstrated to be an efficient means of development for applicability management tool for intervention in artifacts restricted activity in public safety, specifically in the police cars.

The methodological processes of the Design are benefited from the inclusion of expert knowledge in the development stage of the product, otherwise, may result in deficit of the end product.

The transfer of knowledge from experts in the form of guide lines for the design process proved to be of paramount importance for the proper intervention of the designer, or at least to a more appropriate tweaking the design of artifacts.

5.3 Contributions to the Design

The design methodologies usually do not fall into the phase of collecting data, expert knowledge on the subject that want to treat.

Regarding police cars, procedures allocated are arranged empirical studies and getting the assessment processes restricted to methodologies of manufacturers that are geared to the average consumer. With the proposed tool, there is a strengthening to the designer for the process of creation and development of artifacts focused on the activity of public safety, facilitating and strengthening the development of this professional activity.

5.4 Recommendations for Future Work

Because the dynamics of the theme worked, relevant aspects require further developments may eventually become part of a whole different composing proc-cedimentais important changes in the activity of public safety.

It is suggested for the development of future work to be worked aspects such as:

- Establishing NBR—Brazilian Standard Regulatory about specific aspects in police cars such as the control of sirens, lighting indicative and radio.
- The creation of a specific methodology, focused on the assessment of artifacts for restricted use in the activity of public safety.
- Test the tool on equipment that is not related to the activity of public safety.

5.5 Final

There are currently investments in public safety in the State of Pernambuco/Brazil, in respect of the acquisition of the latest equipment such as a thermal camera for use in helicopters, trucks Centre's Integrated Command and Control used in Cup of Confederations in 2013 and later to be used at the World Cup football in 2014, the anti-bomb robot fully automated, special vehicles used in tactical units, ships and helicopters, however, as regards police vehicles, in general, occurs submission to empiricism regarding the necessary adjustments, which are not made with its own methodological tool.

The proposed tool allows an allocation needs more efforts and resources resulting in savings in time and propciando better adaptation of artifacts to the user, as it should be, assuming an interaction where the user has to adapt itself to the minimum possible artifact to survive the hazards present in the workplace.

It was found that there was no in-depth studies on the causes that led to incidents of public safety equipment.

For the activity of public safety, comfort and security are interdependent and the link is the design. The process of adaptation and selection of artifacts is permeated by so many factors that can only be matched in number to the number of possible combinations of pieces of a chessboard. Hence the importance of producing a range of values through a rational and practical tool that will assist in developing safer artifacts.

References

1. Vasconcelos, Luiz A.L.: Uma Investigação em Metodologias de Design. Recife, 2009. Monografia (Graduação) – Universidade Federal de Pernambuco/Departamento de Design
2. Brasil.: Constituição. Constituição da República Federativa do Brasil. Brasília, DF, Senado (1998)
3. Nappo, D., Vairelli, S.: Design de Viaturas – a evolução do design dos veículos de estrada. Tradução Silvia Steiner, Lisboa. Casal do Marco, Lisma (2006)
4. Greco, R.: Atividade Policial: aspectos penais, processuais penais, administrativos e constitucionais, 4ª ed. Niterói, RJ: Impetus (2012)

A Case Based Approach to Assess Waiting Time Prediction at an Intensive Care Unity

Ana Quintas, Henrique Vicente, Paulo Novais, António Abelha, M. Filipe Santos, José Machado and José Neves

Abstract Waiting time at an intensive care unity stands for a key feature in the assessment of healthcare quality. Nevertheless, its estimation is a difficult task, not only due to the different factors with intricate relations among them, but also with respect to the available data, which may be incomplete, self-contradictory or even unknown. However, its prediction not only improves the patients' satisfaction but also enhance the quality of the healthcare being provided. To fulfill this goal, this work aims at the development of a decision support system that allows one to predict how long a patient should remain at an emergency unit, having into consideration all the remarks that were just stated above. It is built on top of a Logic Programming approach to knowledge representation and reasoning, complemented with a Case Base approach to computing.

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Keywords Waiting time · Intensive care unitlogic programming · Logic programming · Knowledge representation and reasoning · Case-based reasoning · Similarity analysis

1 Introduction

Intensive Care Units (ICUs) are responsible for the provision of medical care to any patient that arrives at the hospital in need of immediate care [1, 2]. Indeed, these departments stand for the interface between the emergency medical services and the hospital, and for some patients serve as the first or the only point of contact with the health system [2]. Undeniably, on the one hand, the ICUs nature has changed significantly over the last decade, on the other hand increasing visits has coincided with a decreasing numbers on the number of ICUs and a declining number of inpatient beds [3]. These constraints associated with an hour-to-hour variable and unpredictable workload, dependent on the number of patients and their diagnosis, may result in significant variations to Waiting Times (WTs) [4].

WT, after triage, is the measure of time that a patient spends until to receive treatment. The conventional prediction tools cannot guess with accuracy this time interval, even among ICUs that are quite similar in size and workload. Indeed, several factors can influence WT, like ones related with the time of day or night or the weekday. Another important factor is the triage process in itself [4]. Definitely, this process influences the WT due to the fact that the patients are not seen on a first-come, first-served basis, but based on the patient's health status [2, 4]. The triage process allows the adoption of a chart flow that reflects the patient's symptoms [4]. Moreover, the WT is conditioned by factors associated with the patient's profile such as age or gender [2].

The prediction of the WT requires a proactive strategy able to take into account all these factors. Thus, this paper addresses the problematic of waiting time at an emergency unity and reports on a computational framework that uses knowledge representation and reasoning techniques to set the structure of the information and the associate inference mechanisms [5, 6], anchored on a Case-Based Reasoning (CBR) approach to problem solving [7, 8].

This paper is organized into five sections. In the former one an introduction to the problem is made. Then the proposed approach to knowledge representation and reasoning is introduced. In the third and fourth sections is introduced a case study and presented a solution to the problem. Finally, in the last section the most relevant achievments are described and the possible directions for future work are outlined.

2 Knowledge Representation and Reasoning

Knowledge and belief are generally incomplete, contradictory, or even error sensitive, being desirable to use formal tools to deal with the problems that arise from the use of partial, contradictory, imperfect, ambiguous, nebulous, or missing information [5, 6]. Logic Programming (LP) has been used for knowledge representation and reasoning, representing a point of convergence in the disciplines of *Logic*, *Mechanical Theorem Proving* and *Computer Science*. It may be given in terms of elements of *Model Theory* [9, 10] or *Proof Theory* [5, 6]. In the present work the *Proof Theoretical* approach is followed in terms of an extension to *LP*. An *Extended Logic Program* is a finite set of clauses in the form:

$$\begin{aligned}
\{\ & p \leftarrow p_1, \dots, p_n, not\ q_1, \dots, not\ q_m \\
& ?\,(p_1, \dots, p_n, not\ q_1, \dots, not\ q_m)\ \ (n, m \geq 0) \\
& exception_{p_1} \quad \dots \quad exception_{p_j}\ \ (0 \leq j \leq k),\ \ being\ k\ an\ integer \\
\}\ & ::\ scoring_{value}
\end{aligned}$$

where "?" is a domain atom denoting falsity, the p_i, q_j, and p are classical ground literals, i.e., either positive atoms or atoms preceded by the classical negation sign ¬ [5]. Under this formalism, every program is associated with a set of abducibles [9, 10], given here in the form of exceptions to the extensions of the predicates that make the program. The term $scoring_{value}$ stands for the relative weight of the extension of a specific predicate with respect to the extensions of the peer ones.

In order to evaluate the knowledge that can be associated to a logic program, an assessment of the clauses`Quality-of-Information (QoI) is performed, and given by a truth-value in the interval 0…1, inclusive in dynamic environments [11, 12]. Thus, $QoI_i = 1$ when the information is known (positive) or false (negative), and $QoI_i = 0$ if the information is unknown. Finally for situations where the extension of $predicate_i$ is unknown but can be taken from a set of terms, $QoI_i \in\ ]0 \dots 1[$. Thus, for those situations, the QoI is given by:

$$QoI_i = 1/Card \tag{1}$$

where *Card* denotes the cardinality of the abducible or exception set for *i*, if the abducible or exception set is disjoint. If the abducible or exception set is not disjoint, the clause's set is given by $C_1^{Card} + \cdots + C_{Card}^{Card}$, under which the QoI evaluation takes the form:

$$QoI_{i_{1 \leq i \leq Card}} = 1/C_1^{Card}, \dots, 1/C_{Card}^{Card} \tag{2}$$

where C_{Card}^{Card} is a card-combination subset, with *Card* elements. The objective is to build a quantification process of QoI and measure one's Degree of Confidence (DoC) on the argument values or attributes of the terms that make a predicate's extension, taking into consideration their domains [13]. Thus, the universe of discourse is engendered according to the information presented in the extensions of such predicates, according to productions of the type:

$$predicate_i - \bigcup_{1 \le j \le m} clause_j \left(\left(QoI_{x_1}, DoC_{x_1} \right), \ldots, \left(QoI_{x_n}, DoC_{x_n} \right) \right) :: QoI_i :: DoC_i \quad (3)$$

where ∪ and *m* stand, respectively, for set union and the cardinality of the extension of $predicate_i$.

3 A Case Study

Aiming to develop a predictive model to estimate the waiting time at an intensive care unity a database was set. The data was taken from the health records of patients at a major health care institution in the north of Portugal. This section demonstrates briefly the process of extraction, transformation and loading. Moreover, shows how all the information comes together and how it is processed.

3.1 Extract, Transform and Load

To feed the *CBR* process it was necessary to gather data from several sources and carry out an *Extract*, *Transform* and *Load* (*ETL*) process to organize the information. The information was organized in a *star schema*, which consists of a collection of tables that are logically related to each other [14]. To obtain a star schema it was essential to follow a few steps. In the former one it was necessary to understand the problem and gather the parameters data, information or knowledge that may have influence in the final outcome. Based on literature [1, 4], the parameters that may influence the waiting time were *Age*, *Gender*, *Priority*, *Chart Flow Adopted*, *Accompanying Person*, "Via *Verde*", *Day of the Week*, *Part of the Day* and *Number of Patients*. "Via *Verde*" stands for the existence/non-existence of a special protocol for easy access to the ICU. The following stage was related with the dimensions that would be needed to define these parameters on the facts table. Finally, information from several sources was collected, transformed according the fact and dimension table and loaded to fact table.

The star schema conceived for this study (Fig. 1) takes into account the variables that influence the WT (Facts Table) where Dim Tables show how data were classified. For example, patients under 10 (ten) years old, aged in the range [10, 18], ranging between [18, 60] and over 60 years old, epitomize by the values 0 (zero), 1 (one), 2 (two) or 3 (three), respectively.

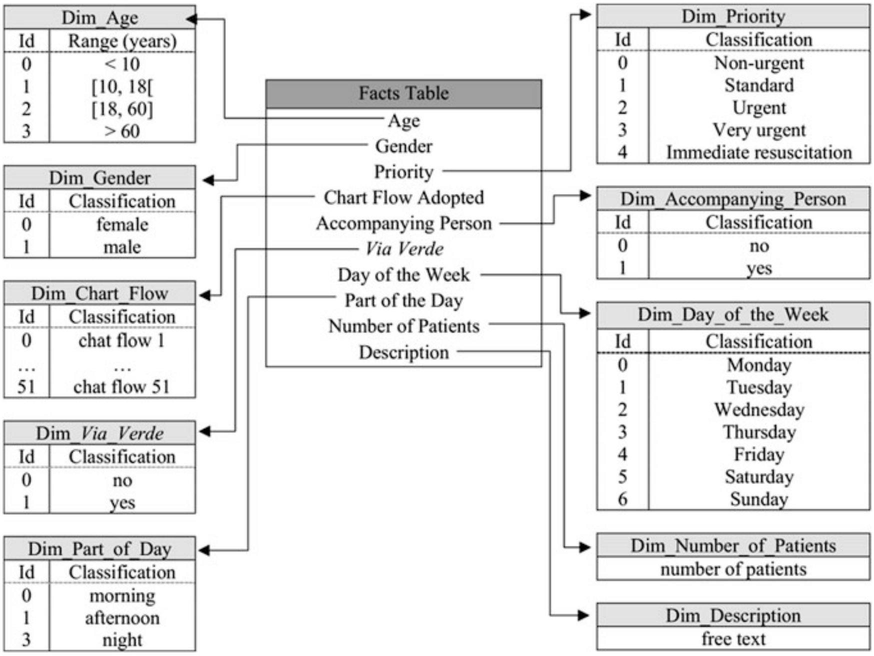

Fig. 1 An overview of the rational data model

3.2 *Data Processing*

Based on the star schema presented in Fig. 1, it is possible to build up a knowledge database given in terms of the table depicted in Fig. 2, which stand for a situation where one has to manage information aiming to estimate the waiting time at an intensive care unit. Under this scenario some incomplete and/or unknown data is also available. For instance, in case 1, the *Chart Flow Adopted* is unknown, which is depicted by the symbol ⊥, while the *Number of Patients* ranges in the interval [90, 100].

Applying the algorithm presented in [13] to the fields that make the knowledge base for Waiting Time prediction (Fig. 2), excluding of such a process the *Description* ones, and looking to the DoC_s values obtained, it is possible to set the

	Waiting Time Prediction										
Attributes of the Feature Vector:	#	Age	Gender	Priority	Chart Flow	Accompanying Person	*Via Verde*	Day of the Week	Part of the Day	Number of Patients	Description
Feature Vector Attributes:	1	3	1	4	⊥	1	1	1	2	[90, 100]	Description 1
	2	2	0	2	15	0	0	3	1	78	Description 2
	…	…	…	…	…	…	…				…
	730	1	0	1	34	1	⊥	5	0	[53, 58]	Description 730
Feature Vector Domains:		[0, 3]	[0, 1]	[0, 4]	[0, 51]	[0, 1]	[0, 1]	[0, 6]	[0, 2]	[0, 200]	

Fig. 2 A fragment of the knowledge base to assess waiting time at an ICU

arguments of predicate **w**ating_**t**ime_**pred**iction (wt_{pred}) referred to below, that also denotes the objective function with respect to the problem under analyze.

$$wt_{pred} : \text{Age} , Gen_{der}, Pri_{ority}, C_{hart}F_{low}, Acc_{ompanyPerson},$$
$$V_{ia}V_{erde}, D_{ay}O_{f}W_{eek}, P_{art}O_{f}D_{ay}, N_{umber}O_{f}P_{atients} \rightarrow \{0, 1\}$$

where 0 (zero) and 1 (one) denote, respectively, the truth values *false* and *true*.

Exemplifying the application of the algorithm presented in [13], to a term (case) that presents the feature vector ($Age = 2$, $Gen_{der} = 0$, $Pri_{ority} = 2$, $C_{hart}\ F_{low} = \perp$, $Acc_{ompany\ Person} = \perp$, Via $V_{erde} = 0$, $D_{ay}\ O_f\ W_{eek} = 5$, $P_{art}\ O_f\ D_{ay} = 0$, $N_{umber}\ O_f\ P_{atients} = [40, 50]$), one may have:

Begin %DoCs evaluation%,

%The predicate's extension that sets the Universe-of-Discourse for the term und observation is fixed%

$$\{\ \neg\, wt_{pred}\ \left((QoI_{Age}, DoC_{Age}),\ \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP})\right)$$

$$\leftarrow not\ wt_{pred}\left((QoI_{Age}, DoC_{Age}), \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP}\right.$$

$$wt_{pred}\ \underbrace{\left((1_2, DoC_2),\ \cdots, (1_\perp, DoC_\perp),\ \cdots,\ (1_{[40,\,50]}, DoC_{[40,\,50]})\right)}_{attribute's\ values} :: 1 :: DoC$$

$$\underbrace{[0,3] \qquad \cdots \qquad [0,1] \qquad \cdots \qquad [0,200]}_{attribute's\ domains}$$

$$\} :: 1$$

%The attribute's values ranges are rewritten%

$$\{\ \neg\, wt_{pred}\ \left((QoI_{Age}, DoC_{Age}),\ \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP})\right)$$

$$\leftarrow not\ wt_{pred}\left((QoI_{Age}, DoC_{Age}), \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP}\right.$$

$$wt_{pred}\ \underbrace{\left((1_{[2,2]}, DoC_{[2,2]}), \cdots, (1_{[0,1]}, DoC_{[0,1]}), \cdots, (1_{[40,50]}, DoC_{[40,50]})\right)}_{attribute's\ values\ ranges} :: 1 :: Do$$

$$\underbrace{[0,3] \qquad \cdots \qquad [0,1] \qquad \cdots \qquad [0,200]}_{attribute's\ domains}$$

$$\} :: 1$$

%The attribute's boundaries are set to the interval [0, 1]%

$$\{\ \neg wt_{pred}\ \left((QoI_{Age}, DoC_{Age}),\ \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP})\right)$$

$$\leftarrow not\ wt_{pred}\left((QoI_{Age}, DoC_{Age}), \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP})\right)$$

$$wt_{pred}\underbrace{\left((1_{[0.67,0.67]}, DoC_{[0.67,0.67]}), \cdots, (1_{[0,1]}, DoC_{[0,1]}), \cdots, (1_{[0.2,0.25]}, DoC_{[0.2,0.25]})\right)}_{attribute's\ values\ ranges\ once\ normalized} :: 1 :: DoC$$

$$\underbrace{[0,1] \qquad \cdots \qquad [0,1] \qquad \cdots \qquad [0,1]}_{attribute's\ domains\ once\ normalized}$$

$$\} :: 1$$

%The DoC's values are evaluated%

$$\{\ \neg wt_{pred}\ \left((QoI_{Age}, DoC_{Age}),\ \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP})\right)$$

$$\leftarrow not\ wt_{pred}\left((QoI_{Age}, DoC_{Age}), \cdots, (QoI_{Acc}, DoC_{Acc}), \cdots, (QoI_{NoP}, DoC_{NoP})\right)$$

$$wt_{pred}\underbrace{\left((1,\ 1),\ \ \cdots,\ \ (1,\ 0),\ \ \cdots,\ \ (1,\ 0.92)\right)}_{\substack{attribute`s\ quality-of-information \\ and\ respective\ confidence\ values}} :: 1 :: 0.78$$

$$\underbrace{[0.67,\ 0.67] \cdots \quad [0,\ 1] \quad \cdots\ [0.2,\ 0.25]}_{attribute`s\ values\ ranges\ once\ normalized}$$

$$\underbrace{[0,1] \quad \cdots \quad [0,1] \quad \cdots \quad [0,1]}_{attribute`s\ domains\ once\ normalized}$$

$$\} :: 1$$

End

4 Case Based Reasoning

CBR methodology for problem solving stands for an act of finding and justifying the solution to a given problem based on the consideration of similar past ones, by reprocessing or adapting their data or knowledge [7, 8]. In *CBR—the cases*—are stored in a *Case Base*, and those cases that are similar or close to a new one are used in the problem solving process. Indeed, and unlike other problem solving methodologies, namely those that use *Decision Trees* or *Artificial Neural Networks*, relatively little work is done offline. Undeniably, in almost all the situations, the work is performed at query time (Fig. 3). Really, the main difference between this new approach and the typical *CBR* one relies on the fact that it allows for the handling of incomplete, unknown, or even contradictory data, information or knowledge [15], i.e., in [8] the working data is merely nominal and nuncupative, does not allowing for the handling of incomplete, unknown and even contradictory data, information or knowledge. On the other hand, each attribute of a given relation or predicate is to be understood not only in terms of its data quality, but also subject to an assessment if its boundaries with respect to its domains are the more appropriate ones, considering the problem under equation, i.e., one has to have a confidence measure that a particular attribute, taken values in a given interval, fits into a given domain. It also contemplates a cases optimization process present in the *Case Base*, whenever they do not comply with the terms under which a given problem as to be addressed (e.g., the expected degree of confidence on the prediction was not attained, either using particle swarm optimization procedures [16] or genetic algorithms [6]).

When faced to a new case, the system is able to retrieve all cases that meet such a structure and optimize such a population, i.e., it considers the attributes *DoC*'s value of each case or of their optimized counterparts when analysing similarities among them. Thus, under the occurrence of a new case, the goal is to find similar cases in the knowledge base. Having this in mind, the algorithm given in [13] is

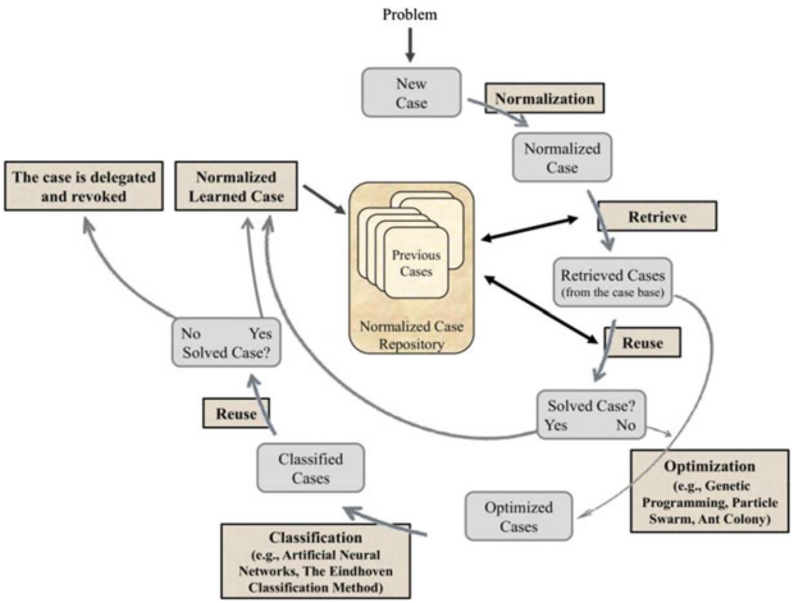

Fig. 3 An extended view of the CBR cycle

applied to the new case that presents feature vector (Age = 3, Gen_{der} = 1, Pri_{ority} = 3, $C_{hart}\ F_{low}$ = 42, $Acc_{ompany\ Person}$ = ⊥, Via V_{erde} = 0, $D_{ay}\ o_f\ W_{eek}$ = 4, $P_{art}\ o_f\ D_{ay}$ = 1, $N_{umber}\ o_f\ P_{atients}$ = [80, 120]), with the results:

$$\underbrace{wt_{pred_{new}}\big((1,1),\ (1,1), \ldots, (1,0),\ (1,1), \ldots, (1,1),\ (1,\ 0.98)\big) :: 1 :: 0.89}_{new\ case}$$

Then, the *new case* can be depicted on the Cartesian plane in terms of its *QoI* and *DoC*, and through clustering techniques, it is feasible to identify the clusters that intermingle with the new one (symbolized as a square in Fig. 4). The *new case* is compared with every retrieved case from the clusters using a similarity function *sim*, given in terms of the average of the modulus of the arithmetic difference between the arguments of each case of the selected cluster and those of the *new case*. Thus, one may have:

$$\underbrace{\begin{array}{l} wt_{pred_1}\big((1,1),(1,1),\ldots,(1,0),(1,1),\ldots,(1,\ 0),(1,1)\big) :: 1 :: 0.78 \\ wt_{pred_2}\big((1,1),(1,1),\ldots,(1,0),(1,0),\ldots,(1,1),(1,0.95)\big) :: 1 :: 0.66 \\ \vdots \\ wt_{pred_j}\big((1,1),(1,1),\ldots,(1,1),(1,1),\ldots,(1,0),(1,0.98)\big) :: 1 :: 0.88 \end{array}}_{normalized\ cases\ from\ retrieved\ cluster}$$

Assuming that every attribute has equal weight, the dissimilarity, in terms of *DoC*, between $wt_{pred_{new}}^{Doc}$ and $wt_{pred_1}^{Doc}$, i.e., $wt_{pred_{new \to 1}}^{Doc}$, may be computed as follows:

$$wt_{pred_{new \to 1}}^{Doc} = \frac{\|1-1\| + \cdots + \|0-0\| + \cdots + \|1-0\| + \|0.98-1\|}{9} = 0.11$$

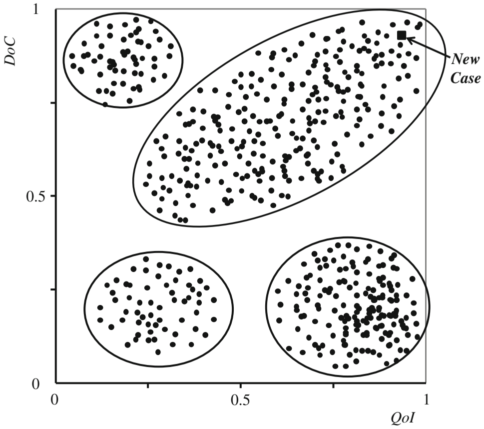

Fig. 4 A case's set divided into clusters

Thus, the similarity for $wt_{pred}{}^{Doc}_{new \to 1}$ is $1 - 0.11 = 0.89$. Regarding *QoI* the procedure is similar, returning $wt_{pred}{}^{QoI}_{new \to 1} = 1$. Thus, one may have:

$$wt_{pred}{}^{QoI,Doc}_{new \to 1} = \frac{1 + 0.89}{2} = 0.945$$

These procedures should be applied to the remaining cases of the retrieved cluster in order to obtain the most similar ones, which may stand for possible solutions to the problem.

In order to evaluate the performance of the proposed model the dataset was divided in exclusive subsets through the ten-folds cross validation. In the implementation of the respective dividing procedures, ten executions were performed for each one of them. To ensure statistical significance of the attained results, 20 (twenty) experiments were applied in all tests. The model accuracy was 89.9 % (i.e., 656 instances correctly classified in 730).

5 Conclusions

The decision support system to estimate the WT at an ICU, presented in this work, is centred on a formal framework based on Logic Programming for Knowledge Representation and Reasoning, complemented with a *CBR* approach to computing that caters for the handling of incomplete, unknown, or even self-contradictory information. It is able to provide adequate responses since the overall accuracy is close 90 %. Additionally, under this scenery the users may define the weights of the cases' attributes on the fly, letting them to choose the most appropriate strategy to address the problem (i.e., it gives the user the possibility to narrow the search space for similar cases at runtime). In future work is mandatory to specify and to implement an independent Decision Support System system to automatically choose which strategy is the most reliable to be followed with respect to a specific problem.

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References

1. Khangura, J., Flodgren, G., Perera, R., Brian, H., Shepperd, S.: Primary care professionals providing non-urgent care in hospital emergency departments. Cochrane Database Syst. Rev. **11**, CD002097 (2012)
2. Australian Institute of Health and Welfare: Emergency Departments: At the Front Line. In: Australia's Health 2014, Australia's Health Series, No. 14, pp. 394–405. Australian Institute of Health and Welfare, Canberra (2014)

3. Hing, E., Bhuiya, F.: Wait time for treatment in hospital emergency departments: 2009. http://www.cdc.gov/nchs/data/databriefs/db102.pdf
4. Canadian Institute for Health Information: Understanding Emergency Department Waiting Time. Canadian Institute for Health Information, Ottawa (2007)
5. Neves, J.: A logic interpreter to handle time and negation in logic databases. In: Muller, R., Pottmyer, J. (eds.) Proceedings of the 1984 Annual Conference of the ACM on the 5th Generation Challenge, pp. 50–54. Association for Computing Machinery, New York (1984)
6. Neves, J., Machado, J., Analide, C., Abelha, A., Brito, L.: The halt condition in genetic programming. In: Neves, J., Santos, M.F., Machado, J. (eds.) Progress in Artificial Intelligence, LNAI, vol. 4874, pp. 160–169. Springer, Berlin (2007)
7. Aamodt, A., Plaza, E.: Case-based reasoning: Foundational issues, methodological variations, and system approaches. AI Commun. **7**, 39–59 (1994)
8. Richter, M.M., Weber, R.O.: Case-Based Reasoning: A Textbook. Springer, Berlin (2013)
9. Kakas, A., Kowalski, R., Toni, F.: The role of abduction in logic programming. In: Gabbay, D., Hogger, C., Robinson, I. (eds.) Handbook of Logic in Artificial Intelligence and Logic Programming, vol. 5, pp. 235–324. Oxford University Press, Oxford (1998)
10. Pereira, L., Anh, H.: Evolution prospection. In: Nakamatsu, K. (ed.) New Advances in Intelligent Decision Technologies—Results of the First KES International Symposium IDT 2009, Studies in Computational Intelligence, vol. 199, pp. 51–64. Springer, Berlin (2009)
11. Machado J., Abelha A., Novais P., Neves J., Neves J.: Quality of service in healthcare units. In: Bertelle, C., Ayesh, A. (eds.) Proceedings of the ESM 2008, pp. 291–298. Eurosis—ETI Publication, Ghent (2008)
12. Lucas, P.: Quality checking of medical guidelines through logical abduction. In: Coenen, F., Preece, A., Mackintosh A. (eds.) Proceedings of AI-2003 (Research and Developments in Intelligent Systems XX), pp. 309–321. Springer, London (2003)
13. Fernandes, F., Vicente, H., Abelha, A., Machado, J., Novais, P., Neves J.: Artificial neural networks in diabetes control, pp. 362–370. In: Proceedings of the 2015 Science and Information Conference (SAI 2015), IEEE Edition (2015)
14. O'Neil, P., O'Neil, B., Chen, X.: Star schema benchmark. Revision 3, 5 June 2009. http://www.cs.umb.edu/~poneil/StarSchemaB.pdf
15. Neves, J., Vicente, H.: Quantum approach to case-based reasoning (in preparation)
16. Mendes, R., Kennedy, J., Neves J.: Watch thy neighbor or how the swarm can learn from its environment, pp. 88–94. In: Proceedings of the 2003 IEEE Swarm Intelligence Symposium (SIS'03), IEEE Edition (2003)

Safety Coordination in Large Construction Project (Completion Process of Unit 3 and 4, Mochovce Nuclear Power Plant, Slovak Republic)

Ivan Pekár and Ján Doni

Abstract Safety coordination is quite often underestimated in large construction sites with insufficient focus paid thereto. The problem lies primarily in the lack of the contractors' awareness to legal requirements, thereof concerning insufficient allocation of financial means to Safety and this not only on the side of the Owner, but also on the side of the contractors. All of the above stated points contribute to the high rate of incidents' occurrence in construction sites.

Keywords Safety coordination · Planning of activities · Risk assessment · Coordination of activities in common workplaces · Monitoring of activities at site · Proactive communication with subcontractors · Information flow evaluation

1 Introduction

BOZPO co. provides coordination of Safety in the largest construction site within Central Europe, i.e. completion process of Unit 3 and 4 of Mochovce Nuclear Power Plant, Slovak Republic. The activities have been launched in 2008 with the total number of man hours reaching at the moment number 50 million. The approx. daily estimation of workers at site is 5500, out of which approx. 4500 perform site based construction activities making the Safety coordination process quite challenging.

The tools used for the Safety coordination are as follows:

- Safety coordinator and his team
- Planning of activities including their scheduling—every week the schedule of works is prepared for the upcoming week consisting of all planned activities received within that particular week

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- Coordination meetings—representatives of contractors and subcontractors planning to perform activities in the upcoming week do take part on these meetings
- Risk Assessment and coordination of activities in common workplaces—identification of corrective and preventive measures with eventual restrictions to be applied to concerned activities
- Monitoring of site performed activities—contradictions between received time schedule and real conditions, efficiency of adopted measures, compliance with safety rules
- Proactive communication with subcontractors—alerts and notifications of identified shortcomings, assistance, suggestions for improvement of measures having a high risk potential

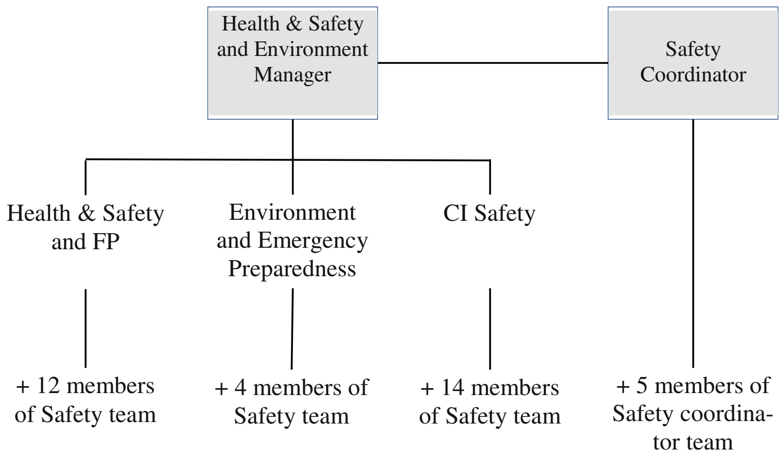
2 Safety Coordinator

The Owner is obliged to nominate, in accordance with relevant legislation, the Site Safety Coordinator.

This duty shall be mostly completed by the Owner; however, many times the Owner assumes the question of Safety at site is by nomination of the Safety Coordinator solved. And here comes up the first issue:

- Legislation does not define no. of Coordinators with regard to the size of the site and no. of workers
- Legislation does not define time period to be spent by the Coordinator at site

The completion process of Unit 3 and 4 of NPP Mochovce (MO34) is one of the only Projects where the Safety unit, Safety coordination and Safety Supervision are provided by a team consisting of 40 Professionals in the Safety field.



3 Planning and Time Schedule of Activities

Planning of civil activities in large construction sites is a very difficult process. On MO34 Project we do have a construction site divided into two parts – Nuclear Island and Conventional Island. Based on this division there are by the Owner (Safety Coordinator) managed two main coordination meetings for each Island separately. Representatives of the site based main contractors participate on these meetings.

The first part of the coordination meeting lies in performance of inspections and coordination of already planned activities summarized in the table and divided in terms of location and contractor.

Workplace	Contractor	Subcontractor	Activity description	Responsible person
A0001	XXXX	XXXX	Installation of penetrations and plates	
A0001	XXXX	XXXX	Installation of pipelines DPS 3.11.02	
A0003	XXXX	XXXX	Installation of small plates, pipelines and equipment (inspections)	
A0003	XXXX	XXXX	Installation of pipelines DPS 3.11.02	
A0004/1	XXXX	XXXX	Installation of pipelines DPS:3.11.02	
A0005	XXXX	XXXX	Revisions of ZHD and HD	
A001/1	XXXX	XXXX	Pulling of cables	
A001/1	XXXX	XXXX	Installation of secondary cable trays	
A001/1	XXXX	XXXX	Installation of NHPIR and IL	
A001/1	XXXX	XXXX	X-ray tests	
A001/1	XXXX	XXXX	Pulling of cables	
A001/1	XXXX	XXXX	Installation of penetrations and plates	
A001/1	XXXX	XXXX	Installation of pipelines (inspections)	
A001/1	XXXX	XXXX	DPS 3.14.01—Inspection of real conditions, EFD 841	

All activities are supplemented with further data as: number of workers, type of hazard, concerned Permits required also for specific activities including measures and notes. After verification and closing of all activities this plan is sent to all contractors.

The second part of the meeting consists of evaluation and verification of assigned tasks, issuance of new tasks, adoption of measures and information flow between the Owner and the contractors.

4 Risk Assessment and Coordination of Activities in Common Workplaces

One of the most important efforts during coordination of Safety is identification of hazards during performed activities. Risk Assessment is a significant tool defining measures which shall be adopted during particular works. On MO34 Project the Risk Assessments are part of the Technological procedures requested to be attached to all activities.

In large construction sites many activities are performed in common workplaces. To plan such activities, consistent coordination of Safety is very crucial and necessary. All of the activities on MO34 Project are planned into details, including their permanent monitoring since each such activity creates a specific hazard and if there are several types of hazards focused in one place, the risk of injury may be significantly increased.

5 Monitoring of Site Based Activities

Inspection of performed activities is an inseparable part of the Safety coordination process. 24 Safety Supervisors perform their daily inspections on MO34 Project. CSI system is used to monitor the site conditions as is seen in the table below.

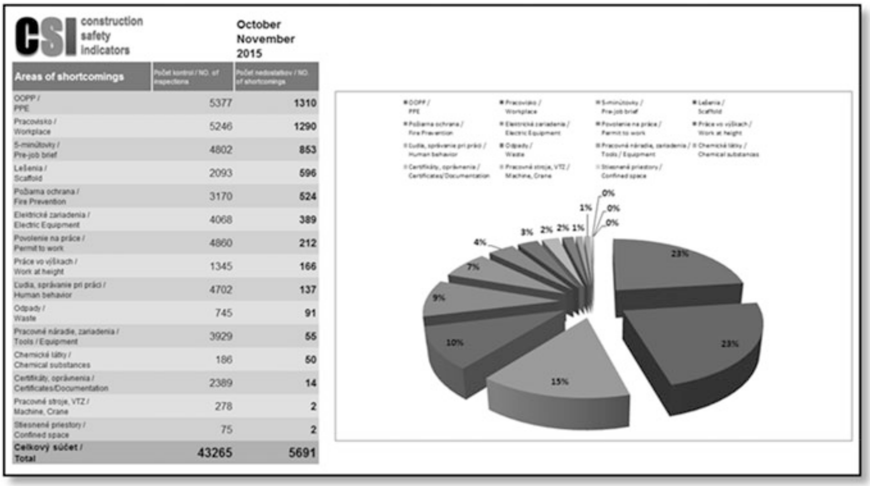
CSI construction safety indicators

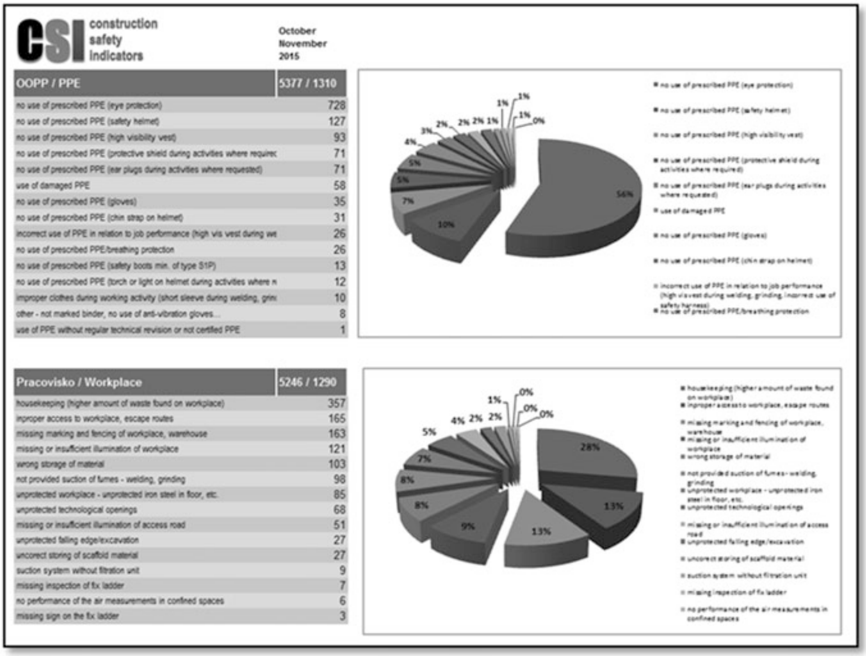
Project "NPP Mochovce"	2010	2011	2012	2013	2014	2015	SUMARY
Počet človekohodín (všetci) No. of man-hours	4 741 662	5 416 731	5 820 423	7 420 031	11 424 854	12 527 882	47 351 583
Smrteľný úraz / Ťažký úraz Fatal accidents / Severe accidents	0/0	0/0	0/0	0/0	0/0	1/0	1/0
Úraz s PN viac ako 1 deň / LTI injuries with sickness leave > 1 day)	5	5	4	2	6	5	27
Poskytnutie prvej pomoci / Firs aid cases	15	8	7	22	25	14	91
Skoroudalosť / Near misses	12	11	5	11	39	40	118
Nebezpečná udalosť / Dangerous occurences	1	2	4	2	2	0	11
Požiar / Fires	2	2	2	1	0	0	7
Sumár neodpracovaných dní / Lost day totally	97	183	124	115	148	143	810
ŽLTÁ KARTA / YELOW CARD	39	106	165	216	528	2 277	3 331
ČERVENÁ KARTA / RED CARD	2	5	7	11	17	72	114

CSI is a tool established to monitor, analyze and evaluate safe/unsafe behavior including safe/unsafe conditions at site.

The base of this system is to be found in permanent site monitoring, administration and evaluation of findings and according to these data there need to be adopted effective measures preventing hazardous situations and injuries at site.

CSI is a very effective tool for defining of specific hazardous activities, locations and areas of the most critical shortcomings found at site.





6 Proactive Communication with Contractors and Subcontractors

Important part of the Safety coordination process is also communication and information flow between the Owner and contractors. It happens many times that this communication does not function correctly what may have impact on occurrence of several dangerous situations.

Correct way of communication lies in information flow including all necessary data concerning Safety at Site in a way from the Owner towards the contractors, however, also from the contractor towards the Owner. These information are necessary to be always processed and forwarded to all those who are concerned.

7 Conclusion

Site Safety concerns all persons. If we are able to set up effective system of Safety in all management levels, this can be the only way to achieve the most difficult goal “Zero Accident Level”.

The Promotion of Software Applications as Important Part of Effective Management of Occupational Safety and Health at Work

Ján Donič

Abstract Demands are always made on the performance of qualified personnel. They have to deal with more issues for quality tasks fulfillment regarding its content and also the extent. The pre-requisite for a successful management of this stress without reducing the level of quality of provided service is the use of software applications. These, however, can be a useful tool only if they are purposefully and professionally appropriate but also simple to apply. The need for software equipment is on the daily programmes not only in office work. Even a simple administrative activity cannot be done without a computer not to mention employment e.g.: a security technician or a coordinator on construction sites, who use the software programmes for their job and a lot of information from the Internet. This information are linked mainly in areas of health and safety at work, fire protection, civil protection and environmental protection. The basic modules must be: (1) national legislation, (2) documentation, (3) risk analysis, (4) registry. In addition to the practical use of the software in practice, application must have a modern look and design, must be easily handled with simple orientation in the program and usability of comprehensive and extensive search. Work of a technician is flexible in time and in space. It often happens, that access is limited or there is no access to the internet in the field. Therefore is a necessity, the application has on-line, but also off-line version. The advantage of any software is the ability to backup data, In order to prevent possible loss of important data and information, quick access to legislation, documents, training, risks and other parts of the software.

Keywords Software applications · Safety—technical service · Regulations · Documentation · Risk analysis · Registry

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1 Introduction

Even simple administrative activity cannot be done without a computer and not to mention the professions e.g.: safety technician or safety coordinator on construction sites, who use software programs for their work and amount of information from the Internet. Regulations puts difficult requirements on employers and also to the performance of safety and technical service. Software applications help navigate technician in the law more simply and easy. These applications are effective help for professionals. They navigate technicians quickly and effectively in all necessary requirements need to carry out their activities.

2 Software Applications

It is important to have an overview about events from the perspective of practice or regulations for people working in safety and technical service. Every technician will appreciate the access to the latest information needed for his work. Using software applications saves time, helps navigate in the issues and also ensures efficient way of working.

3 Modern Software—Effective Help in Practice

Various modern innovative treated applications are on the market, which streamline and improve the working activity of people working in the field of work protection.

Create applications should participate (and constantly update and improve application) qualified professionals, who have long years of experience in the field of work protection and experience. Their attention should be focused on creating usable applications and practical not only for beginners, but also experienced safety technicians, fire protection technicians, occupational medical services, experts in the field of environment, in the area of civil protection and safety coordinators on construction sites and other people active in this issue.

Application should be user friendly and divided into these areas:

- health and safety at work,
- fire protection,
- occupational medical services,
- environmental protection,
- civil protection,
- coordination of safety on construction sites,

while the basic modules must be:

- regulations,
- documentation,
- risk analysis,
- registry.

In addition to the practical use of the software in practice, application should have modern design, users will please and the practicality of the program will satisfy simplicity of use the program, usability of comprehensive and extensive search in module regulations on the basis of various parameters (type, number, title, content). In the case of interest of printed regulations to paper form is a useful feature for generating text to PDF directly in the application (without the need for external program) with possibility of editing (font formatting, color highlighting). To run another card in one window related with open regulations is another useful feature. (If the open regulations refer to another section in the same text, or another provision from the field.) Finding information in laws becomes clearer and more controlled.

There is often limited or no access to the internet in the field. Therefore is a necessity, the application has on-line, but also off-line version.

In the on-line version of the software is necessary to have always the current regulations, where comes to updating of the related documents and other parts of the software and of course the off-line version. Comfortable using on-line version is not conditioned by the need to install applications and it is accessible from any device connectable to a network.

Off-line version should be usable without network connection and its user interface consistent with the environment on-line. The advantage of the software is the ability to backup data and to avoid the possible loss of important data and information, quick access to the regulations, documents, training, risks and other parts of the software. Part of the application is appropriate to have technical support.

Users should immediately see (after their entry into the application) information about updating and upcoming changes.

4 Module Regulations

- Comprehensive and extensive search (type, number, title, content),
- generate prescription in pdf format with editing directly in applications without the need for an external program (option to print with performed changes—e.g. highlighting text),
- To run another card in one window related with open regulations is another useful feature (if the open regulations refer to another section in the same text, or refer to another provision from this area—e.g.: Degree No. 508/2009 refers to Degree No. 124/2006),
- Module regulations should have parts containing European regulations and the selection of the most commonly used Slovak Technical Standard.

5 Module Documentation

Another practical part of the application should be module "Documentation", which is unified, clear, purposeful, updated according of law, marked by a single system (based on the ISO system—marking, coding) and ready for easy implementation. Documentation includes various forms, materials for easy manage documentation, documents to training, tests, presentations and summary index (reserved technical equipment, medical examinations…), area of coordination of safety on construction sites.

The European Union constantly creates and implements sets of regulations into practice to protect the safety and health of workers. Its aim is determine the obligations for employers and workers and to limit accidents and occupational diseases. Within the application can be useful overview of European regulations relating to health, hygiene and safety at work. These Directives of EEC Council, the European Parliament, etc. are further acceptance by legal acts for creating Slovak regulations.

6 Module Risk Assessment

Applications include identification of hazards and sources of hazards and PPE proposal under the heading "Risk assessment". It is simple, modern and efficient tool for risk assessment used and respected with possibility of finding evaluation of selected activities, or areas within individual sectors throughout the EU.

There should be opportunity to insert new dangers, threats, and of course measures. Output report also includes the characteristics proposal of PPE and with identifying their type. Main objective of health protection and safety of people performing the occupational activity is in the process of risk assessment at work. Objective of risk assessment is to identify all dangers and hazards for each of the activities, evaluate the severity of the risks, to propose measures to eliminate risks, perform compliance checks and establish procedures for the use of the results of risk assessment.

7 Module Registration

Module "Registration" is important of use documentation for reserved technical equipment, training, personal protective work equipment, accidents and others.

RTE/reserved technical equipment/	proper identification, classification, tracking deadlines, possibility of inserting a floor plan object indicating the location of the RTE and possibility to added photography of the RTE),

Familiarization/training	types of training, terms…,
PPE	records, allocation…,
Injuries	records, registration…

Existence of a simple backup of user data helps avoid their unwanted loss.

8 Using of Software Applications Through Mobile Devices

Employees not always can use the computer in the performance of their activities and also access to the necessary application, so there is new necessity to have applications for mobile devices.

9 Conclusion

Nowadays, the work of beginners as well as experienced safety technicians, fire protection technicians, occupational medical services, experts in the field of environment, in the area of civilian protection and safety coordinators on construction sites and other people operating in these issues is unimaginable without software applications, that simplify and improve their work. People from mentioned areas use modern and professional tools to keep their work, performances and fulfillment of work tasks in quality.

Innovative treated applications should offer an innovative approach to work.

Expected advantages of using software applications are:

- access to the application without installation,
- access from any device connectable to a network,
- quick access to regulations, documents, training, risks and other parts of the software,
- advice and technical support.

BOZPO, s.r.o. creates and submits on the market applications based on experiences according requirements mentioned in this article.

Safety Culture Development: The Gap Between Industry Guidelines and Literature, and the Differences Amongst Industry Sectors

Nektarios Karanikas, Pedram Soltani, Robert J. de Boer and Alfred L.C. Roelen

Abstract Reason's typology of safety culture (i.e. Just, Informative, Learning, Flexible and Reporting cultures) is widely used in the industry and academia. Through literature review we developed a framework including 36 markers that reflect the operationalization of Reason's sub-cultures and general organizational prerequisites. We used the framework to assess to what extent safety culture development guidelines of seven industry sectors (i.e. aviation, railway, oil and gas, nuclear, healthcare, defense and maritime) incorporate academic references, and are similar to each other. Gap analysis and statistics showed that the guidelines include 53–69 % of the safety culture markers, with significant differences across subcultures and industry sectors. The results suggested that there is a gap between the industry guidelines and literature, as well as variant approaches to safety culture across the industry. The framework suggested in the study might be used as reference for completing existing safety culture development plans and constructing safety culture assessment instruments.

Keywords Safety culture · Just culture · Informative culture · Learning culture · Flexible culture · Reporting culture

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1 Introduction

Over the last decades, different theories of organizational culture have been developed, various characteristics of organizational culture have been identified [1] and several definitions have been suggested based on the way people think (e.g., values, attitudes, beliefs) and/or behave [2]. Safety culture is an aspect of organizational culture, and was firstly introduced in the frame of the investigation of the Chernobyl nuclear accident in 1986. Since then, numerous studies have attempted to define, and conceptualize safety culture, thus leading "… to different ideas about the best means of developing a safety culture and thus also about the means of developing safety." [3]. Regardless the diversity of studies, it seems that there has not been a framework integrating the safety culture characteristics referred in the literature and providing a holistic approach to safety culture development.

Despite the lack of academic consensus on the precise definitions and conceptualizations, safety culture is seen as part of a safety management system. Authorities and organizations have recognized the need to plan for initiatives in order to foster safety culture, with the goal of reducing accidents and incidents. This is achieved by ensuring that employees pay attention to risks, are committed to safety, and openly discuss their views. Regional and international bodies of various industry domains have generated their own lists of safety culture dimensions—prerequisites, and regulators have included safety culture as a matter of concern when auditing organizations [3]. However, no study has been conducted about the extent to which guidelines of industry bodies embrace the academic body of knowledge, and how similar those guidelines are to each other.

The purpose of this paper is to present the results of a research project conducted for a European Nuclear Power Plant (ENPP) [4]. One of the main project objectives was to suggest a complete set of safety culture development prerequisites, and compare the relevant ENPP documentation with the guidelines published by the aviation, railway, oil and gas, nuclear, healthcare, military aviation and maritime sectors. The selection of the sectors was made upon request of the ENPP. As part of the study, a comprehensive literature review led to the development of an inclusive theoretical framework, and a gap analysis revealed the distance between industry guidelines and literature as well the differences amongst the industry sectors considered. The analysis framework presented in this paper can be used to establish a common cross-industry approach to the development of safety culture, which is important since professionals might work in different industry sectors during their career and a harmonized approach to safety culture will make the respective transitions more effective and will enable the sharing of good practices between industries. The framework can also function as basis for developing an instrument to assess and benchmark safety culture.

2 Theoretical Background

The safety culture decomposition most widely mentioned in the literature and used by the industry is the one suggested by Reason [5], who proposed that safety culture consists of five subcultures that must be concurrently in place in order to foster such a culture. Reason's concept was complemented by various authors, who elaborated on the scope of each subculture and provided more detailed guidance about their development and maintenance (Table 1).

In addition to the elements per specific subculture, general prerequisites for safety culture development are described in the literature [7, 10, 12, 13, 15, 16, 17]. The combination of the safety subculture elements and general organizational prerequisites form a set of 36 markers, which comprises the analysis framework presented in Table 2 and used in this study.

3 Methodology

The framework of Table 2 was used to analyze the safety culture development guidelines of seven industry sectors: nuclear, aviation, healthcare, maritime, oil and gas, railway and defense. The researchers consulted the documentation published by international agencies and organizations per industry sector. In cases that such documents or agencies were not identified, we considered the ones available for the European region, and in case of inadequate resources in Europe, the North American region references were utilized; this decision was made on the grounds that the whole research project regarded a European firm.

Table 1 Reason's safety subcultures (adapted from [5]) and further literature references

Reason's safety subcultures	Definition	Literature references
Just culture	A culture in which acceptable and unacceptable behavior is communicated and understood	[6]
Flexible culture	A culture that allows flexibility and reconfiguration when the variability of working conditions and goals cannot be captured by established procedures	[7, 8, 9, 10]
Reporting culture	A culture where staff from all organizational levels voluntarily report safety hazards and own errors, violations, and deviations	[6, 9, 11, 12, 13]
Informative culture	A culture that enables sharing of a variety of safety information across the organisation	[7, 11, 14, 15]
Learning culture	A culture that draws valuable conclusions from its safety information system, and drives changes in the organisation based on the lessons learned	[7, 9, 12, 14, 15]

Table 2 Analysis framework

Marker	Explanatory remarks
General prerequisites (*G*)	
G1. Management commitment	Changes start from the top. There is both written and visible commitment
G2. Leadership	Leadership is valued as a steering factor towards safety culture development. Leaders adapt and shift between target-oriented and transformational styles
G3. Clear responsibilities and accountabilities of all management areas towards safety	–
G4. Safety department visibly responsible and accountable for safety planning	–
G5. Employees' involvement	The companies engage employees to planning, monitoring and improvement activities. A broad workforce representativeness minimizes power distance. A bottom-up approach in decision making is preferred and planned
G6. Non-reliance on past success	There is no ceiling for safety culture and resilience under a constantly changing environment
G7. Risk management policy	Decisions about changes and plans are based on a risk management framework, tailored to each level of decision-making
G8. Planning for buffers	In addition to optimizing resources during planning, there is capacity to cope with the unexpected. This is not seen as resource waste
G9. Rewarding safety initiatives	Rewarding active and exceptional contribution to safety such as new ideas, voluntary participation in safety plans etc., but not daily performance
G10. Internal communication	Open communication, questioning attitude and effective conflict management
G11. External communication	Communication channels with the society, authorities and other sectors
Just culture (*J*)	
J1. Documented definition of "acceptable" and "unacceptable" safety behavior, accompanied by assumptions, examples, indications, required evidence etc.	Workers and managers know what acceptable and unacceptable behavior is about, although a clear line cannot be drawn
J2. The decision for attributing unacceptable behavior is made and agreed by a team including peers	–
J3. Practitioners know their rights and duties regarding occurrences	A list of indicative measures and the cases that these might apply is communicated to employees

(continued)

Table 2 (continued)

Marker	Explanatory remarks
J4. Prevention of practitioners' stigmatization	In cases of mistakes/errors (acceptable behavior) that caused adverse outcomes, support is provided to the actors regarding their reintegration
J5. Organizational support in legal disputes	In cases of "acceptable behavior" subject to police investigations, the organization provides legal, financial and psychological support
Flexible culture (*F*)	
F1. Recognize the inevitable gap between standard procedures and working practices	Rules and procedures assume ideal and constant conditions
F2. Control of variability. Policy for managing the efficiency—thoroughness trade-off	There is agreement on risk thresholds and boundary policies that delegate authority to employees for self-organizing. Emergency stop procedures are accessible when safety is compromised
F3. Emergency response and crisis management exercises	In addition to the planned exercises, the resilience of the system is assessed through unplanned diverse scenarios under different conditions and various actors
Reporting culture (*R*)	
R1. Clear policy about reporting	Definition of "who, what, when, where etc." regarding reporting; communication of potential implications of reporting
R2. Voluntary R3. Non-punitive R4. Protected (confidential) R5. User-friendly R6. Accessible (system close to work-station) R7. Timely feedback to reporter	Characteristics for maximum potential of a reporting system (*note: 6 aspects in total as mentioned in the right column*)
Informative culture (*I*)	
I1. A user-friendly safety information system in place with free access for all employees	–
I2. Content of safety information	Proactive and reactive type of information; internal and external topics
I3. Time for access to safety information is planned in working schedules	
I4. Information sharing across teams, units and departments	Dedicated meetings, workshops, safety days etc., tailored to local needs as means to stimulate discussions
Learning culture (*L*)	
L1. Learning from failures	Occurrence and voluntary reports; safety investigation reports and audits results
L2. Learning from success	Part of safety investigations; promotion of success by managers and leaders

(continued)

Table 2 (continued)

Marker	Explanatory remarks
L3. Safety training	Incudes general training about safety management in the organization and specific training about the job role
L4. Internal benchmarking	Lessons from internal comparisons across departments, units etc.
L5. External benchmarking	Lessons from external comparisons (e.g., similar companies, industry sectors, regions)
L6. Safety information used to initiate changes	Knowledge is transformed to learning. This is evident if lessons learned from all sources drive policy and attitude changes

If more than one document dedicated to safety culture was available per industry sector, it was decided to assess the one(s) most recently published. Also, wherever there were various documents referring to safety culture development and including references to each other, the researchers analyzed the whole set of such published guidance per sector. Table 3 for provides an overview of the documents consulted per industry sector.

For each set of documents per sector, the researchers assessed which safety culture markers of Table 2 were present (i.e. conducted a gap analysis). Only the guidance clearly and distinctly linked to safety culture was considered in the analysis; under this approach, general references to safety management were not considered if in the documentation these were not explicitly connected with safety culture. Following the gap analysis, percentages of markers' reference in the guidance per sector were calculated in overall and per safety culture area (i.e. safety subcultures and general prerequisites).

In order to provide a more concrete indication of the extent of alignment amongst industry sectors in overall and per safety culture area, we used the Cochran's Kappa for evaluating the differences amongst all sectors and the Cohen's

Table 3 Safety culture guidelines per industry sector

Industry sector	Documents consulted
Nuclear	[18, 19]
Aviation	[20, 21]
Healthcare	[22, 23, 24]
Maritime	[25, 26, 27]
Oil and gas	[28]
Railway	[29, 30]
Defense	[31, 32]

Kappa for assessing the degree of pair agreements. The former test shows if there is a significance difference amongst binary data sets (i.e. safety culture is referred in the guidance or not). The Cohen's Kappa takes values from 0.00 (complete disagreement) to 1.00 (complete agreement) and takes into account the effects of agreement by chance. The SPSS 22 software package was used, and the significance level was set to $\alpha = 0.05$.

4 Results

Due to space constraints, this paper only reports the percentages per safety culture area and industry sector, as well the results of the statistical tests in overall for the 36 markers. The statistical results for the differences amongst industry sectors per safety culture area are available to the reader upon request to the corresponding author. The industry sectors referred in the following Tables were coded (alphabetical order) as follows: *A* for Aviation, *D* for Defense, *H* for Healthcare, *M* for Maritime, *N* for Nuclear, *O* for Oil and Gas and *R* for Railway.

Table 4 presents the percentages of markers indicated in the guidance per sector and safety culture area.

The Cochran's test showed significant differences amongst the industry sectors when considering all 36 markers ($p = 0.000$); the same test indicated that the highest non-alignment amongst sectors concerned the general prerequisites ($p = 0.046$) and reporting culture ($p = 0.038$). The pair agreements for sectors (i.e. Cohen's Kappa values) for all markers combined are shown in Table 5.

Table 4 Percentages of safety culture markers across industry sectors

Sector	All markers (%)	Safety culture areas					
		General (%)	Just (%)	Flexible (%)	Reporting (%)	Informative (%)	Learning (%)
A	69	64	40	67	86	75	83
D	53	73	0	67	14	75	83
H	58	73	0	0	71	75	83
M	33	55	0	33	14	25	50
N	64	91	40	67	29	75	67
O	67	82	40	67	57	50	83
R	67	91	40	33	43	75	83
All	59	76	23	48	45	64	76

Table 5 Cohen's Kappa values for all safety culture markers

Sector	A	D	H	M	N	O	R
A							
D	0.43						
H	0.64	0.55					
M	0.36	0.51	0.42				
N	0.38	0.55	0.42	0.34			
O	0.55	0.49	0.35	0.30	0.45		
R	0.55	0.60	0.59	0.40	0.57	0.50	

5 Discussion

5.1 Planning for Safety Culture Development

Taking into account the definition and scope of each safety culture area and marker, it can be claimed that the set of general prerequisites is the ground on which the organizations can build their safety culture. Furthermore, when considering the five subcultures suggested by Reason, it seems that their operationalization must follow a specific order: Just, Flexible, Reporting, Informative and Learning. More specifically:

1. Just culture corresponds to an operational environment in which workers are dealt with fairness, and unwanted events are judged against predefined and agreed boundaries and not merely against the severity of their outcomes.
2. Given the establishment of a just culture, a flexible culture might be established and the inevitable variability of working conditions and human performance will be recognized. Procedures will be revisited when design assumptions are invalid and/or conflicting goals emerge repeatedly.
3. Flexible and just cultures not only might result to an increase of the amount of the voluntary reports, but they might boost the quality and traceability of such reports. In addition to hazards, staff will share their own errors and experiences sourcing from confrontation with competing objectives and inadequate working conditions.
4. When reporting becomes systematic, a broad range of local safety information will be obtained, that can be shared across the organisation in addition to the information collected through other sources (e.g., audits, safety reviews, safety investigations).
5. A consistent and effective sharing of safety related information will increase the possibility for the organisation to learn and proceed to targeted and substantiated changes.

5.2 Alignment Between Industry and Literature and Within Industry

The percentages of markers in overall suggest that, in average, the industry guidelines in overall refer to 59 % of the safety culture development elements suggested by the literature. In this context, aviation is the sector that includes most of the markers in its guidelines, while the maritime sector includes only one third of those and ranks last amongst the seven industry sectors examined. When considering the individual safety culture areas, in average, just culture is the area least discussed in industry guidelines, whereas the general prerequisites and learning culture are the areas mostly represented. It is interesting that the percentages of markers' presence vary from 0 to 91 % across the sectors and safety culture areas, indicating remarkable variances of alignment to the academic references.

The results of the gap analysis suggested that there has been a distance between the academia and the industry regarding safety culture markers, such a distance varying from moderate to large. The fact that this study identified in literature various tangible ways to realize safety culture denotes that academia might generate practical solutions for the industry but those might not be appropriately communicated.

The statistical tests regarding the agreement amongst the industry sectors, revealed that the guidelines of the industry differ highly in the safety culture markers considered. The highest disagreement regards the reporting culture and general prerequisites; it is noticeable that although the latter area is one of the most frequently represented in terms of average percentage of safety culture markers, the industry sectors differ significantly in the sets of general prerequisite markers included in their respective documentation. The pair comparisons revealed low to moderate agreement with Cohen's Kappa values varying from 0.30 to 0.64, where the lowest agreement was indicated between the oil and gas and maritime sectors and the highest agreement regarded the aviation and the healthcare industry sectors.

6 Conclusions and Recommendations

The framework used in this study was based on a comprehensive literature review and incorporates specific and tangible characteristics that organizations can use to operationalize their safety culture development. Although the researchers sought to build a collectively exhaustive and mutually exclusive list of safety culture markers, the framework might be adjusted based on new research and concepts, and will be re-evaluated in the frame of an on-going study about safety culture assessment.

Since organizations might already have a set of safety culture markers in place, and need to prioritize their additional efforts under limited resources, it is suggested that they ensure maintenance and valid assessment of the existing safety culture markers and proceed to developing the complete set of markets with a specific order as proposed in the discussion section: General prerequisites, Just, Flexible, Reporting, Informative and Learning cultures.

The gap between literature and industry signifies the need for initiatives in order to bridge theory and practice. This will ensure that the concepts and models developed by the academia serve the needs of the industry, and that research results are retrofitted with practical experience and enable scientists to refine their theories and models. Apart from the distance between professional practice and academia, this research also showed a distance amongst industry sectors. It seems that although safety is a top priority for all industries considered, the way safety culture development is guided differs much across these. Relevant initiatives, efforts, ideas, concepts, solutions and challenges must be shared amongst the various sectors, to establish a common language about safety and facilitate the sharing of practices and experiences across the industry. This becomes increasingly important as professionals work in various industry sectors during their career.

Lastly, in the frame of this study, it is noted that an absence of a safety culture marker in the guidance documentation in an industry does not provide evidence that the respective industry sector does not exploit this marker. There is always some distance between work-as-designed and work-as-done and the practice in individual companies will differ from the guidelines published by industry bodies.

References

1. Guldenmund, F.W.: The nature of safety culture: a review of theory and research. Saf. Sci. **34** (1), 215–257 (2000)
2. Cooper, M.D.: Towards a model of safety culture. Saf. Sci. **36**(2), 111–136 (2000)
3. Reiman, T., Rollenhagen, C.: Does the concept of safety culture help or hinder systems thinking in safety? Accid. Anal. Prev. **68**, 5–15 (2014)
4. Karanikas, N., Soltani, P., de Boer, R.J., Roelen, A., Dekker, S.: Prerequisites for Safety Culture Development. Technical Report X10910/B, Amsterdam University of Applied Sciences, Aviation Academy, Netherlands (2015)
5. Reason, J.: Achieving a safe culture: theory and practice. Work Stress **12**(3), 293–306 (1998)
6. Dekker, S.: Just Culture: Balancing Safety and Accountability. Ashgate Publishing, Ltd, Farnham (2012)
7. Fernández-Muñiz, B., Montes-Peón, J.M., Vázquez-Ordás, C.J.: Safety culture: analysis of the causal relationships between its key dimensions. J. Saf. Res. **38**(6), 627–641 (2007)
8. Hollnagel, E., Woods, D.D., Leveson, N. (eds.): Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, Farnham (2007)
9. Hollnagel, E.: Safety-I and Safety–II: The Past and Future of Safety Management. Ashgate Publishing, Ltd, Farnham (2014)
10. Saurin, T.A., Righi, A., Henriqson, E.: Characteristics of complex socio-technical systems and guidelines for their management: the role of resilience. In: 5th Resilience Engineering Association Symposium (2013)
11. Benn, J., Koutantji, M., Wallace, L., Spurgeon, P., Rejman, M., Healey, A., Vincent, C.: Feedback from incident reporting: information and action to improve patient safety. Qual. Saf. Health Care **18**(1), 11–21 (2009)
12. Parker, D., Lawrie, M., Hudson, P.: A framework for understanding the development of organisational safety culture. Saf. Sci. **44**(6), 551–562 (2006)
13. Wiegmann, D.A., Zhang, H., von Thaden, T., Sharma, G., Mitchell, A.: A synthesis of safety culture and safety climate research. Technical Report ARL-02-3/FAA-02-2. University of Illinois, Aviation Research Lab (2002)
14. Casey, A.: Enhancing individual and organizational learning a sociological model. Manage Learn **36**(2), 131–147 (2005)

15. Gordon, R., Kirwan, B.: Developing a safety culture in a research and development environment: air traffic management domain. In: Europe Chapter of the Human Factor and Ergonomic Society Conference, Delft, The Netherland (2004)
16. Sellers, R.: The influence, measurement, and development of organizational safety culture. J. Int. Soc. Air Saf. Invest. 16–19 (2015)
17. Nemeth, C.P., Hollnagel, E.: Resilience Engineering in Practice, Volume 2: Becoming Resilient. Ashgate, UK (2014)
18. IAEA.: Safety Culture in Nuclear Installations: Guidance for Use in the Enhancement of Safety Culture, IAEA-TECDOC-1329. International Atomic Energy Agency, Vienna (2002a)
19. IAEA:. Key Practical Issues in Strengthening Safety Culture INSAG-15. International Atomic Energy Agency, Vienna (2002b)
20. ICAO.: Safety Management Manual. International Civil Aviation Organization, Canada (2013)
21. CANSO:. Safety Culture Definition and Enhancement Process. Civil Air Navigation Services Organisation, Amsterdam (2008)
22. WHO.: Draft Guidelines for Adverse Event Reporting and Learning Systems. World Health Organization, Geneva (2005)
23. WHO.: Guidelines for Safe Surgery. World Health Organization, Geneva (2009)
24. EU.: Council Recommendation on Patient safety, Including the Prevention and Control of Healthcare Associated Infections (2009/C 151/01) (2009)
25. IMO.: Principles of Safe Manning, Resolution A.890(21). International Maritime Organisation, London (1999)
26. IMO.: ISM Code and Guidelines on Implementation of the ISM code. International Maritime Organisation, London (2014)
27. ISF.: Safety Culture Leaflet. International Shipping Federation, London (date unknown)
28. OGP.: Shaping Safety Culture Through Safety Leadership OGP Report No. 452. International Association of Oil and Gas Producers, London (2013)
29. ERA.: Application guide for the design and implementation of a railway safety management system: developing and improving safety culture in the organisation. European Railway Agency, Valenciennes (2013)
30. EU.: Directive 2004/49/EC on safety on the Community's railways. European Parliament and the Council (2004)
31. US Air Force.: The US Air Force Mishap Prevention Program, Instruction, pp. 91–202, Virginia (2011)
32. NATO.: Standard for Air Traffic Management Safety Management System, Edition A Version 1. North Atlantic Treaty Organization (2014)

Effects of Work Organization in the Health and Wellness of Seniors Workers

Luciana Gusmao, Catarina Silva and Filomena Carnide

Abstract The objective of this paper is to analyze the influence of work organization on the health and well-being of elderly workers in a water and sanitation municipal service at Lisbon metropolitan area. This study involved 31 male participants, included in the category of operational assistant, who work as shakers and plumbers. Data collection was conducted through interviews as well as direct and indirect observations of real work, with posterior application of the REBA method. After data collection, it was observed that the activities analyzed showed mostly medium to high level of risk for development of musculoskeletal disorders by age and seniority of the workers. However, as most workers are 45 years old or more, there was no statistical significance between the occurrence of musculoskeletal pain and age of the worker. The only variable found that was statistically significant to the occurrence of musculoskeletal symptoms was seniority, showing the painfulness of constraints which workers are exposed to.

Keywords Work organization · Aging of workers · Musculoskeletal disorders · Shift work · Water and sanitation municipal

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1 Introduction

Currently, there are many methods to analyze work conditions and their repercussion on the health of the workers. According to the results of European Inquires related to work conditions, it is observed that it is not possible to know all the phenomena related to the intensification of work only through simple measurement of labor rhythm.

Data has shown the increased pace of constraints to which workers are exposed, such as: (a) pressure of a client who puts urgency in the work to be done, often forcing to exceed the working hours; (b) the service planning, that sets goals and allocates resources without considering the reality of work; (c) the changing priorities, which require frequent interruptions of work in progress; among others.

These phenomena indiscriminately cut across socio-professional categories, industry sectors, ages and genders. They are often accompanied by other kinds of constraints, namely, physical, environmental, relational and autonomy related.

The repercussions in the health of older workers (from 45 years old) are felt in a more intense way as a consequence of a reduced capacity of auto-regulate themselves within narrow margins of maneuver. But in addition to the inability to preserve their health, the feeling of often putting themselves and others in constant danger is intensified.

Thus, this article aims to analyze the effects of work organization in the health and wellness of senior workers, through characterization of previously identified constraints; the analyses of methods of individual and collective regulation of the activity; and the association of constraints with the cumulative health effects.

2 Methodology

This study was conducted between October 2010 and October 2011 in a Water and Sanitation Municipal Service in Lisbon, which main function is to ensure the water supply and the provision of basic sanitation services to the population.

In Sanitation Division, the activities developed by *shakers*, whose duties included cleaning and clearing network collectors of domestic wastewater and rainwater, domiciliary extensions and manholes, were analyzed. Similarly, in Water Division, the activities developed by *plumbers*, whose duties included the implementation of water distribution networks and their branch lines, laying pipes and necessary accessories as well as other similar and complementary work, were analyzed.

Out of a total population of 41 operators, inserted into the category of operational assistants, 31 subjects (n = 31) participated in the study, all male, working in the Division of Water or Sanitation. The averages, medians, standard deviations and the following independent variables were analyzed: age, seniority and body mass index (BMI). The average age was approximately 49 years old (± 9) and the average seniority of 20 years (±11). It was also found that, in general, the subjects were overweight and the average BMI was 28 ± 4 kg/m^2.

The criteria for inclusion in the sample were to belong to the operating assistant category and to be responsible for services in the public network of water or sanitation, regardless of age. The assistants who, in practice, exerted functions of leader or supervisor, and those responsible for the service of home network were excluded from the study.

The results were initially collected in a screening phase, in the work of Costa et al. [1] and Silva et al. [2] in order to characterize the constraints to which workers were exposed, and their level of discomfort, and relate them with data found in work organization and biomechanical analysis of tasks.

Later, unstructured interviews were conducted by registering the verbal inputs of the division leaders and supervisors, in order to perceive the overall functioning of the service, such as work organization, particularly in relation to schedules, shifts and teams. Thus, the arrangements of individual and collective regulation of the activity were analyzed depending on the nature of the tasks and the age of the operators.

Next, the Nordic Questionnaire Musculoskeletal [3] was applied as a manner of evaluating the exposure to risk factors generators of musculoskeletal disorders, in order to identify the symptoms and relate them to the performed work activity.

The real work analysis was done through daily accompaniment of several teams, in order to verify, in the practice, the routine of the work of the operators. Each day, a different team was accompanied. Direct observations were realized, in loco, and indirect ones, through photographic and video records, with the help of a digital Fujifilm camera, model Finepix J40, 12.2 Megapixels.

From the video records, the biomechanical analysis of the tasks executed by operators were realized, through the Rapid Entire Body Assessment—REBA [4], that was developed to analyze unpredictable postures of work and it is sensitive to musculoskeletal risk factors, by analyzing the postures of the entire body [5]. The REBA evaluates the biomechanical risk level through the analysis of posture in the trunk, neck, legs, arms, forearms and wrists, combined to factors like load/strength, handhold and activity. Finally, the punctuation that indicates the level of risk and the necessity of intervention is achieved. This punctuation varies from 1 to 15, and it is split like this:

- Score 1—very low risk, unnecessary intervention;
- Score 2 or 3—low risk, possible intervention;
- Score 4 to 7—medium risk, necessary intervention;
- Score 8 to 10—high risk, necessary intervention as soon as possible;
- Score 11 to 15—very high risk, immediate action.

Lastly, the organizational variables (shift, department and work time) and individual (age, seniority and BMI) were associated with the occurrence of pain. And the statistical analysis was made from the non-parametric tests of

Mann-Whitney (U) and Chi-square (χ^2), using the IBM SPSS Statistics Data Editor, version 19.0.

3 Results and Discussion

3.1 Work Organization

It was observed that each division (Water and Sanitation) is organized in an independent way, with some differences and similarities among them. In both divisions, workers are distributed mainly in two groups: the permanent work shift (general), and the rotating work shift (picket). Both with similar workload, of about 35–40 weekly hours. The workers from the permanent group work from Monday to Friday, between 8 a.m. and 3 p.m., with days-off on weekends. Meanwhile, the rotating work shift varies between the morning shift, from 8 a.m. to 3 p.m., and the afternoon shift, from 3 to 10 p.m.. Most of the sample belongs to the work rotate shift (picket).

To better visualize the characteristics of each sector, Table 1 presents a comparative resume of the organizational characteristics of both studied divisions.

About the work organization, it was found that in the Sanitation division, the operators have worked most of the time in the morning shift, what is more advantageous compared to the afternoon because of the regular night and day rhythm of the body and to allow all family, leisure and community activities in the evening and night time [6].

In the Water Division, usually the permanent shift work was lighter and specific, while the picket work was normally heavier.

According to the information received, in both divisions the workers have been distributed in shifts for many years, both in a random way and according to their individual preferences. They were then divided between the ones who would like to be in the general work and the ones who preferred the picket work. This fact is consistent with the literature, as when talking about work shifts, it is recommended to consider the preferences of the older ones, since from the age of 40 they become more prone to sleep disturbances and health problems [6].

According to the schedules established in each sector, the shift rotations follow a clockwise scheme (forward), what is considered preferable. They should also include in the shift plan weekends with at least two consecutive days of rest [6]. However, as the breaks between the rotations was longer in the Sanitation department, the days off ended only happening every three and a half months, different form the Water department where the works had 2 days off, on Saturdays and Sundays, every three weeks, which was much more advantageous.

Another aspect in the work of the shakers and the plumbers was the direct contact with the public, that many times have demanded them to rush the conclusion of their work, which causes tension between them. That happened

Table 1 Comparative table of work organization (Water × Sanitation)

	Sanitation	Water
General activities (periodic maintenance)	Cleaning network, replacing covers and repair works	Temporary water connections for parties and construction sites, and installation of extensions for irrigation of public gardens
Picket activities	Cleaning and clearing of the network, domiciliary extensions and manholes (emergency services)	Replace counters, pipe replacement and repair works, in case of breakages
Rotation scheme of shifts	4 mornings (picket)—1 day off 4 afternoons (picket)—2 days off 4 mornings (general)—1 day off	3 mornings—1 day off 3 afternoons—1 or 2 days off Wednesdays—nobody is off
Work distribution of the permanent work shift	Based on the picket information, the leader analyzes the necessities for repairs and distributes the service according to the type of the activity. Generally, the heaviest work is attributed to the younger workers, while the technical and specialized work is attributed to the older and expert ones	The leader receives the demands from the call center and goes to the indicated location to check the situation (necessity of doing water connections for parties, etc.) and employs the work to the permanent work shift, usually to the following day
Work distribution of the rotating work shift	The call center receives the occurrence calls and passes the work order to the supervisor and the division leaders. Then, they plan the services based on priorities/urgency and distribute them to the teams in the pickets	When the leader of the shift receives the occurrence, he goes to the local in order to check the service necessity. In case of rupture, he will verify if it is enough closing the water clock or if workers will be needed there. If it is to replace counters, generally it will be scheduled to the next day

especially in some unexpected situations like the obstruction of a collector causing bad smell, or even the rupture of a pipe, culminating in the shutting of the water supply. Facing those situations, the work time was limited to the time necessary for the conclusion of the services, because usually the situation had to be solved even if it exceeded their normal work schedule and went over their meal breaks. According to the literature, these social-economical pressures, specifically relating to the unfavorable work rhythm and physical conditions, such as excessive cold our heat, are the main causes of stress in the work environment [7].

In relation the organizational context, it was found that during data collection, the activities of higher physical strain were usually attributed to the younger workers and with less wok experience. Otherwise, the work that demanded more expertise and know-how was delegated to the older and more experienced workers.

In the context of aging, the ergonomic action recommended as for the physical work conditions is the attempt of suppressing or reducing considerably the proportion of tasks that are overly harmful to the older workers, ensuring that the work organization favors their mobility, with gestures that are able to spare them physically, and strategies of mutual help and distribution of tasks [8].

3.2 Biomechanical Analysis of the Task

In the water division, the following activities were analyzed: (a) the clearance of the pipes in a residential building; (b) the changing of the valve; (c) the assembling of a pressure regulating valve; and (d) the installing of a temporary water branch on a construction site.

In order to clear the piping of a building, the “opening and closing of the valves” was necessary to cut the water supply; making an “opening of a ditch with pickaxe” and “revolving the dirt with a shovel”, to find access to the water linkage branch; and the “junction of valves”, attaching the connecting valve to the water branch.

Even though this activity is not recurrent, the gestures and embarrassments involved in it are also common to various other activities, thus happening more frequently. Among the mentioned tasks, the one with the higher risk involved is the “junction of valves”. However, apart from the physical effort and adequate posture demanded, it is a short-length task, with the possibility of breaks for physiological recovery.

The work organization is made informally, in a way that the older workers realize shorter and more specific tasks, as the “closing and opening of valves” and the “junction of valves”. Those longer and less specific tasks, as the “opening of a ditch with pickaxe” and “revolving the dirt with a shovel” are attributed to the younger workers.

The exchange of valves was an atypical service, requested by the plumber of the domiciliary network, that damaged the valve when trying to close it, in an operation of exchange of a timer. From this task, the “breaking of the plaster” that consists on hammering a stake into the wall, so that it breaks and the find access to the damaged valve.

The task was physically straining, repetitive, in painful posture and caused great noise. There was also the time pressure to conclude the service, imposed by the residents that frequently came with noise complaints and to ask how long the service would still take to be finished, which was an additional pressure factor.

The score of the REBA for this task showed elevated risk, taking into consideration the factors of risk of musculoskeletal disorders, as well as repetition, strength, inadequate posture and impact [9]. However, apart from the presence of the risk factors mentioned before, this task has a low frequency (sporadic) and a short length (not surpassing one hour), which helps minimize the risks. Besides, the task was alternated every 2 or 3 min with another operator, allowing a short break for the functional recovery of the muscles and prevention of fatigue.

The “assembly of the pressure regulatory valve”, performed in the headquarters of the municipal services, consisted basically of screwing bolts in inadequate postures, with the employment of strength and repetitive movements. Besides that, the activity was of short length (going just over one hour) and of low frequency, done sporadically, with a medium level of risk according to the final score on REBA.

Conclusively, the “installing of a temporary branch on a construction site” is one of the activities that involves all the tasks of “opening of a ditch with a pickaxe” and “revolving the dirt with a shovel” and “assembling of valves/screwing bolts”. Even though all these activities are considered of medium level, with a REBA score between 5 and 6, the tasks are more frequent and performed in inadequate postures and repetitive movements, what could lead to musculoskeletal lesions on the long term, since those factors have an accumulative effect (Table 2).

In the Sanitation Department, the activities analyzed were (a) clearing of the collector; and (b) checking of the “resources”.

The most frequent activity for the shakers is the “clearing of the collector”, performed under different conditions and in various locations, in which are included the tasks of “opening of the lid of the collector with a pickaxe”, “introduction of the hose into the collector” and “controlling the hose during the clearance”. From these, the ones with higher musculoskeletal risk, as the operation with the hose (introduction into the collector and control of it), are performed by the youngest operators, sparing the health of the older ones.

The activity of verifying the resources happens only on the months from April to September (summer in the north hemisphere), because it is when there is less rain. The work consists of lifting the lids, to verify the specific collectors that were made years ago, without worrying about separating the flow of the waste of domestic water from the rain water, being drained into the sea without previous treatment. This way, concrete barriers (resources) were built to deviate the domestic flux and stop it from following the rain course, in order to avoid contamination of the rivers and the beaches.

However, the barriers could not be overly high deviating all the water flux, not to overload the water treatment stations with the rain water during winter. These collectors must be verified as a preventive way during bathing season, because in case of clogging, the clearing is done immediately, preventing the sewage to surpass the barrier and getting drained into the sea.

Even though the activity demands the “lifting of the collector lid”, appointed by REBA as a elevated risk, this task was not performed frequently. In addition, many

Table 2 Classification of tasks as level of risk (Water)

Task	REBA score	Level of risk	Intervention
Opening and closing of the valves	4	Medium	Necessary
Opening of a ditch with pickaxe	5	Medium	Necessary
Assembling of valves/screwing bolts	5	Medium	Necessary
Revolving the dirt with a shovel	6	Medium	Necessary
Junction of valves	9	High	Necessary soon
Breaking of the plaster to change valves	9	High	Necessary soon

Table 3 Classification of the tasks as level of risk (Sanitation)

Task	REBA score	Level of risk	Intervention
Opening of the lid of the collector with a pickaxe	6	Medium	Necessary
Introduction of the hose into the collector	8	High	Necessary soon
Lifting of the collector lid	8	High	Necessary soon
Controlling the hose during the clearance	10	High	Necessary soon

collectors didn't need to be effectively open, sufficing only to look at the outcome or not of sewage by the tube designated to the rain water, in the margins of the river and the beach. Besides, this task was not performed every day by the same person, also minimizing the risk.

In Table 3, the tasks of sanitation department are shown with results of REBA methods.

In the sanitation department, the evaluated tasks showed medium to high levels of risk. The shakers, in the same way that the plumbers, also assume many painful postures, such as trunk flexion, among others. Besides, sometimes, they also need to lift weights (the lids) in those uncomfortable postures. This means an additional risk for the development of musculoskeletal symptoms, especially in the lumbar spine, once when a person bends until the superior part of the body is practically horizontal, the effects of lever impose a very high pressure on lumbar discs [6].

3.3 Musculoskeletal Symptoms

After analyzing the results of the Nordic Questionnaire [3], related to musculoskeletal symptoms, it was verified that from all the operators interviewed, 38.7 % presented pain complaints in upper limbs in the last 12 months, 29 % complaints of pain in lower limbs, while 51 % referred to lumbar pain in the last year. These musculoskeletal symptoms confirm the kind of the work, handwork realized in the ground level and inside ditches and manholes, obligating the worker to stand for a long time, or to keep himself crouched or bended, besides handling with loads (the weight of the hose, in the case of shakers). This also confirms the results of the REBA in the biomechanical analysis of the task that revealed medium to high risk to development of musculoskeletal disorders.

The level of discomfort showed by the workers indicates the difficulty of the work in question, compromising their capacity of realizing the same functions as they get older. Studies show that a set of environmental, social and psychological factors can cause fatigue or stress, that has cumulative effects in the organism and are able to cause several types of diseases. [7] Besides, the aging process starts around the 30s and 40s, and becomes faster from the 50s. This causes a progressive degeneration of the cardiovascular function, strength of the muscles, flexibility of the articulations, sense organs and cerebral functions [7].

4 Final Considerations

At the end of this study it was possible to perceive that the operators of the municipal services are often submitted to physical, environmental, postural and organizational factors that are able to cause musculoskeletal disorders, stress or fatigue.

Toward adopting preventive measures, it is important to consider that more than half of the operators are aged above 40 years, and most work for more than 20 years in the same function.

After the association between pain occurrence and organizational and independent variables, the statistical significance found between pain and seniority can be explained by the fact of the physical constraints having cumulative effects in the organism. This reaffirms the results of the REBA, that showed medium to high risk level to musculoskeletal disorders in most tasks analyzed.

The lack of significance among the other categories studied (age, BMI, shift work, work time and department) is because of the similar characteristics between the two groups, forming a sample relatively uniform to show significant statistical differences. Thereby, about the department, the physical and environmental constraints are very similar between shakers and plumbers. Besides, according to the biomechanical analysis of the tasks, both groups have the same medium to high level of risk for musculoskeletal disorders and they adopt forced postures.

For a more precise quantification of risk, it is suggested for a further work, a more in-depth quantitative analysis regarding the applied forces and the postures taken in the activities of the operating assistants. It is also possible to analyze the agents that modulate factors of risk like intensity, duration and frequency, in order to perceive how these factors contribute for the work-related musculoskeletal disorders and their effects in the quality of life of the workers.

References

1. Costa, C., Silva, C., Saraiva, D.: Monitoring of health-conditions of work relations in municipal water and sanitation service: results in the water sector. In: Azeres, P., Baptista, J.S., Barroso, M., Carneiro, P., Cordeiro, P., Costa, N., et al. (eds.) Occupational Safety and Hygiene—OSH 2011, pp. 206–210. Portuguese Society for Occupational Safety and Hygiene (PSOSH), Guimarães (2011)
2. Silva, C., Costa, C., Saraiva, D.: Monitoring of health-conditions of work relations in municipal water and sanitation service: results of INSAT inquires in the sanitation sector. In: Azeres, P.,

Baptista, J.S., Barroso, M., Carneiro, P., Cordeiro, P., Costa, N., et al. (eds.) Occupational Safety and Hygiene—OSH 2011, pp. 617–621. Portuguese Society for Occupational Safety and Hygiene (PSOSH), Guimarães (2011)
3. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sorensen, F., Andersson, G., et al.: Standardised nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. **18**(3), 233–237 (1987)
4. Hignett, S., McAtamney, L.: Rapid entire body assessment (REBA). Appl. Ergon. **31**, 201–205 (2000)
5. Castro, A.S.: Application of Ergonomics (Consulting in Ergonomics Course Handout), 3 edn. São Paulo, Brasil (2006)
6. Kroemer, K.H., Grandjean, E.: Fitting the Task to the Human. Taylor & Francis, London (2001)
7. Iida, I.: Ergonomics: Project and Production, 2nd edn. Edgard Blücher, São Paulo (2005)
8. Falzón, P.: Ergonomics. Presses Universitaires de France, Paris (2004)
9. Simoneau, S., Saint Vincent, M., Chicoine, D.: Better Understanding for the Better Prevention. IRSS; Maloine, Quebec (1996)

Occupational Health and Safety Practices and the Regulatory Regime: Evidence from the Infantile Oil Fields of Ghana

Olivia Anku-Tsede

Abstract The study examines OHS practices and the regulatory regime in the Ghanaian oil fields. Using the systematic content analysis, the primary qualitative method obtained data from regulators agencies, operators, sub-contracted companies of the upstream and other external opinions. Findings discovered that in the absence of solid OHS regulations, partners of the Ghanaian oil fields play collaborative role in promoting health and safety in their operations. Meanwhile, observation further revealed the country's legal provisions on crude production are bereft not because of no specific OHS legislations but are largely to the discretion of operators due to inadequate expertise, logistics, monitoring and surveillance. Owing to frail regulatory governance, operators are driven by reputational goals rather than external pressures in promoting OHS practices. The paper proposes for the Ghanaian regulatory frameworks to work as coercive pressures for the IOCs to be proactive in promoting health, social and environmental consciousness in the oil fields.

Keywords Occupational health and safety · Regulatory regime · Infantile oil fields · Ghana

1 Introduction

OHS research is a new and gradually developing field in Ghana, but there is no justification for depriving employees of their basic rights because of ignorance and apathy [1]. In Ghana, empirical findings have focused on the prevalence of occupational health and safety, hazards, risks and diseases in the construction, mining, agricultural and other commercial sectors [2, 3]. Whilst [1] revealed that the SMEs and the informal sectors are neglected, nothing is yet known about the relevance of OHS practices in the relatively young Ghanaian Oil Fields. This extremely hazardous

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industry employs thousands of people across the upstream, mid and downstream fields. In the upstream, where the exploration and production of crude is extracted albeit heightened possibility of worker injury and infirmity, the lack of in-depth expertise among especially the local workforce calls for the need to examine how OHS policies are enforced to meet the current standards in ensuring employee safety. Apart from the overly lack of political will, there is essentially low level of ratifications of ILO Conventions on OHS in the country; lack of comprehensive national OHS policy framework; ineffective OHS legislation and inspection; OHS capacity building, training and monitoring, etc., [1]. Poor occupational health and safety reduce working capacity of workers and may as well decrease economic gains by 10–20 % of the GNP of a country [4].

Whilst arguing that poor nations and organizations are unable to afford safety and health measures, [4] observed that in the Ghanaian growing workforce, employees are concerned with job security at the expense of quality work life. There is the need to reduce the unreasonably high risk of injury and suffering of occupational health diseases that in extreme cases result in high prevalence of work disability and premature death [5]. It is noted that although most of these infirmities and illnesses are preventable through modern occupational health and safety methods, they nevertheless go unattended and are needlessly incremented. In the oil production field which houses a significant number of foreign and local partners, it is imperative to conduct empirical analysis in exploring the extent to which worker safety and employee health is being protected. In fact, out of over 70 OHS related ILO conventions, only 10 have been ratified by the government of Ghana (Conventions 45, 81, 89, 90, 103, 115, 119, 120, 147 and 148) leaving some key OHS resolutions including; (Conventions 155, 161, 170, 174, 176 and 187) [6].

It is worth noting that Ghana has a defined regulatory framework governing the oil and gas industry [Ghana National Petroleum Corporation Act, 1983 (PNDCL.64); Petroleum Act, 1984 (PNDCL.84); Environmental Protection Agency Act, 1994 (Act 490); Petroleum Commission Act, 2011, (Act 821) and the 1992 Constitution of Ghana] with significant impact on crude production and development. These legislations including the UN Global Compact have sections with substancial bearing on the health and safety of employees. Nonetheless, to attain the globally accepted standards of providing for the safety, health and welfare of workers, the Ghanaian OHS statutes and frameworks must not only thoroughly reflect current needs and numerous problems confronting modern organizations but essentially carry resilient, firm and effortful message to investors and employers that the nation attaches supreme prominence to OHS. In the context of weak regulatory governance regarding occupational health and safety practices, this paper is motivated by [7] who undertook similar study on the pressures for sustainability practices in an oil and gas company in Sudan. The main research questions are: what are the main institutional factors that drive the Ghanaian oil exploration and production companies to be occupational health and safety conscious? Which category of stakeholders is seen to exert the most pressure on the operators, and how do the latter respond to such demands?

2 Theoretical Foundations

Theoretical perspectives from legitimacy theory and new institutional sociology (NIS) theory are used to investigate the institutional factors that drive Ghanaian oil exploration and production companies to be health and safety conscious, responsible, and the response of the companies towards such pressures [7]. It is argued that although there are overlaps of ideas between the theories, they provide varied and useful insights [8]. Organisations are said to depend not only on economic resources for growth and survival but also on societal acceptance legitimacy and acceptance within which they function [9, 10]. Some posit that there are three mechanisms of institutional isomorphism [11]. Coercive isomorphism results from formal and informal pressures exerted on organisations by other firms and institutions to which they owe allegiance [7]. For instance, national laws and regulations compel organisations to adopt and formulate certain policies and structures [12]. Besides, the normative isomorphism mechanism arises when norms and rules of society and other professional bodies and agencies influence the practices of organisations. Finally, organizations are described as mimetic isomorphism when they attempt to duplicate the practices of other successful organisations. Thus, firms that are uncertain of certain practices seek to emulate other successful reference groups [13]. In essence, the institutional theory explains how diverse institutional pressures nurture the structures and practices of organisations [14, 10]. In this context, the NIS theory helps identify and understand the institutional forces that drive the identified company to adhere to operational health and safety practices [7].

2.1 Occupational Health and Safety Practices in Ghana

Like many African countries, Ghana does not have a defined and comprehensive national OHS policy. This presents varied and monumental issues regarding OHS challenges and practices that are rampant in the Ghanaian economy. However, not only the policy frameworks are fragmented and limited in scope, the commonly observed challenge is that most of the policies of the African countries do not work [1]. Among others, the main challenges and drawbacks to effective OHS practices include; weak OHS infrastructure, lack of capital and human resource commitment; insufficient, untrained and inadequate professionals; overly insufficient education; and dolefully lack of proper monitoring and surveillances for occupational health and safety diseases and injuries [15]. In support, [16] investigated health and safety practices among construction SMEs and discovered inadequate government/ institutional support for regulatory agencies responsible for health and safety standards and inefficient institutional frameworks and lack of skilled human resources. For instance [17] observed that most of Ghana's legal provisions on OHS is impoverished as many industries, including agriculture and most of the informal sectors are not categorically covered. Nonetheless, few statutes, including; the

Factories, Offices and Shops Act 1970, Act 328 and the Mining Regulations 1970 LI 665 which have driven OHS implementation in the manufacturing, shipping and mining sectors inform the implementation of occupational health and safety. Other enactments with some appreciable bearing on OHS are the Workmen's Compensation Law 1987, PNDC Law 187, the Ghana Health Service and Teaching Hospitals Act 526, 1999 and the Environmental Protection Agency Act 490, 1994.

Other essential OHS issues involve the ceaseless exposure of workers and the unsuspecting general public to occupational health and safety risks, hazards, and diseases including all forms of industrial accidents. In Ghana, fire outbreaks in many institutions have repeatedly and considerably increased over the last couple of years. For example, Ghana's central medical store, and tens of markets were gutted by fire resulting in the destruction of hundreds of market stalls, and a significant amount of goods and cash. Interestingly, state agencies including the Ministry of Foreign Affairs and Land Commission were reduced to ashes with distressing effects. It is needless to emphasize the recent Goil Feeling Station fire explosion resulting in the destruction of property, homes, vehicles and taking about a hundred lives.

2.2 Overview of the Infantile Ghanaian Oil Fields

Although oil exploration dates back nineteenth century, i.e., before independence and during colonial times, but production in commercial quantities began in 2010. The major national players that regulate petroleum exploration and production in the country include; Ministry of Petroleum, Petroleum Commission, Environmental Protection Agency, Ghana National Petroleum Commission, National Petroleum Authority, and the Ghana National Gas Company. The Petroleum Commission in particular was established to promote, regulate and manage the efficient conduct of upstream petroleum operations in the country. Among others, the operators include; Tullow Oil, Kosmos Energy, HESS, ENI, etc. Besides, there are other oil field service companies that have been sub-contracted to participate and provide engineering services to the operators. They include Baker Hughes Ghana, Halliburton, Schlumberger, Oceaneering, Modec, etc. Just as other parts of the world, oil production presents a complex integration of state players from within and outside the country. As exploration continues and new wells are being discovered, statuses of some of the blocks have been relinquished, others are in various stages of appraisal and development. In Ghana, there are four sedimentary basins: Tano-Cape Three Points, Saltpond/Central, Accra-Keta, and the Voltaian Basins. The upstream oil and gas survives on heavy logistical support, requiring importation of materials and equipment through Sea Freight and Air Freight Shipments. Between 2009 and March 2010, there were 383 sea freights and 1590 air freights shipments for the Jubilee Field [6]. Since aviation plays enormous role in the supply chain, helicopters and fixed wing aircrafts are used to transport the workforce from and to the FPSO Nkrumah and the Rig as well as for replenishment on the offshore platforms. It was reported that, in the same period, there were 1023 helicopter flights which carried 9438 passengers, 648 fixed wing flights and carried 10,647 passengers. Besides, marine activities including vessels for short and long term charter are employed for supply of equipments to the Rig and disposing waste substances [18].

3 Research Design and Methodology

The study adopted the primary and qualitative approach using systematic content analysis for data collection and analysis. The sampling frame consisted of the major regulators, operators and other sub-contracted bodies in the upstream of Ghana's oil industry. The sample involves a total of 24 face-to-face semi-structured interviews with experts and officials responsible for regulating and ensuring the adherence to occupational health and safety practices in the working environment of the workforce in all the major oil exploration and production sites of the country. Senior managers were considered as a key source of rich information, as they were directly involved in sustainability [19] as well as other health and safety decision-making for their respective institutions. External views were represented from relevant government officials, such as those from the regulatory agencies, academics who worked as consultants to environmental impact assessment [7] and the local frontier communities and non-governmental organizations. This was conducted over a period of five months, from November 2015 to March 2016. It is argued that there is lack of published research that employs interview-related methodology in developing nations [10]. In response to this call and to provide a rich and thorough understanding of the phenomenon under exploration, interview approach was deemed appropriate. Compared to some scholars [14] who obtained insights from 12 interviews with one group of informants, i.e., senior officials from the identified organisation, this paper used much more representation from key informants from various organisational levels, providing richer insights. Conducting an interview, participants were informed of the aim of the study and guaranteed of absolute confidentiality in handling data. All interviews were tape-recorded and transcribed for data analysis. In addition to the interviews, casual and informal conversations and observations were conducted during visitations to the production area of the companies. Further, review of relevant documentary materials such as website analysis [7] and health and safety laws and regulations were obtained to support the data generated from the interviews and to address the psychometric issues of validity and reliability [20, 21].

4 Findings

Findings revealed that in the absence of sound and concrete OHS regulations, partners of the Ghanaian oil fields play collaborative role in promoting health and safety in their offshore and onshore operational activities. As a joint effort, reports from both regulators and the operators indicate there is a road map being adopted in reporting and controlling incidents regarding occupational health and safety. Further observation revealed that most of Ghana's legal provisions on the oil and gas production are bereft not because there are no specific legislations regarding OHS but that they are left to the discretion of the operators. Meanwhile, casual observations include the incessant exposure of workers and the unsuspecting public and the frontier communities on health and safety risks, hazards, and ailments.

Regarding preventive strategies, risk assessment, medical surveillance and control of hazards, the regulators offered: *[…] we have a monthly reporting template, that was implemented in 2014, … we did with the operators as well, the play, we all came together, … let's put our ideas together …we are requesting for this, ooh, this, we are requesting for this information, ok, let's add this thing, that kind of thing.*

So … again we all agreed as a regulator and operators have the reports are submitted monthly, so far all the activities that they do…like let's say, we are in March, so far all the activities they've conducted in February, they will submit it in the first week of March. I think we've agreed on the 4^{th}, 5^{th} of the succeeding month.

Some operators observed: *[…] so it covers the safety performance, any injuries, fatalities,* etc. *It also covers, the environmental aspects as well, so any […], it also covers security issues in terms of the fishermen […] veering into the safety zones, any breeches of the security zone, vandalism,* etc.

[…] I mean health and safety in the broad sense because operational health is just an aspect of what we do so we are working at what is happening in the working environment, we are looking at what they are, the flaring, what emissions, what is going out, what are the chemicals they are using and that kind of thing, so we are able to monitor […], even the helicopter incidents, road, marine, vessel collisions, all those things are covered in the report […]

Again some regulators remarked: *We also have plan audit and inspections that we conduct. And these ones are not just for the off-shore but also for activities on-shore so the service providers, we can even go to Tullow's office, their logistic base in Takoradi and conduct our inspections or audit to see how they are adhering to their own management systems in terms of health and safety.*

[…] And we also look at their report, like their own internal audit to see how they are following up with their remedial measures. Another thing we have established is that anytime there an incidence occurs, like a major incident or fatality or major near miss, they are to report to us immediately.

[…] And I mean if an incident occurs that sometimes it's not even directly linked to them but maybe one of their service providers. Because we hold the operator responsible, they are to report to us immediately and it's also a way of checking their activities.

It further came to light that the regulatory authorities do not work in isolation, and that although the departments from the regulatory agencies dedicated to ensuring health and safety are not always at the fields, other departments especially engineering, monitors operational activities of the operators on day-to-day basis, and perhaps capture reports of OHS issues for such units.

[…] Emm the audits too of course that's a major way of, but you cannot be there all the time and then as a Commission, we don't work in isolation or as a department, so together with the other departments like engineering, etc.*, if there is any help or need for occupational health issues, they capture it and report to us.*

Sometimes they send us the report from off-shore, like immediately if its major and when they come back, it's their reports that they submit so that we deal with all that as well, so we have our way of getting reports from the fields.

We in the Jubilee field and other exploration companies in the sedimentary basins view the crude resource in Ghana as the driver for heavy venture and significant investment in the country. Thus, although we are motivated by profits, it presents us the opportunity to ensure lives are protected and we work in collaboration with other stakeholders to promote safety of our workforce as well as the environment in which we operate.

[…] To ensure the adherence to safety regulations, one of the key policies is the buffer restrictions zone on the Oil Rig and the five nautical miles radius of no fishing around the Rig […]

Meanwhile, just as there is no national OHS policy, there appears no concrete health and safety regulation governing the exploration and production of light crude in Ghana. Whereas some operators opined that: *[…] Our obligations are vested under the contractual agreement which includes some form of safety practices.*

The company adopts workplace health and safety and environment health as a priority. So we have health and safety department with its own budget for CSR and other safety activities.

A regulator stated: *[…] And another thing that we have at the moment, we are drafting health, safety and environment regulations for upstream activities. For all the activities, explorations, development, production - all the petroleum activities upstream.*

A senior academic consultant remarked;

[…] In fact, government lacks the will to pass efficient health and safety laws since their goal is to encourage foreign investments at the expense of local businesses.

Thus, until OHS policy is passed and becomes law, the regulators are only trying to ensure the operators comply with the joint prescriptions. This provides ample room for the operators as such issues do not only become discretional but may prove overly difficult for the firms to be prosecuted in the events they are found culpable in regard to occupational health and safety. A key example is the fatal incident of the Ivorian oil rig service helicopter that crashed into the ocean around the Russia's Lukoil West Cape Three Points, killing three people in 2014 and injuring others [22]. To date, not an individual has been found liable to that fatality. This only emphasizes the assertion that not only the policy frameworks are fragmented and bereft in scope, the fundamental observed challenge is that most of the policies of the African countries do not work [1] hence the need for new learning and institutional support for regulatory agencies responsible for health and safety standards.

One thing I'll say is that the upstream petroleum industry is high risk. The risk is very high that even without the regulations we try to do everything possible to *reduce risk. Regardless of this, there are international obligations we have to meet. For instance, some of signed to the ISOs, IMF, IFC, and the World Bank regulations and their international standards that we comply with, so we are trying to comply …and as the money involve is huge, so health and safety is one of the priorities.*

[…] Nevertheless, there are some health and safety regulations to ensure that we execute our activities in a safe manner devoid of incidents, because it is a high risk industry, you cannot rule out incidents. But for now, I don't think there is any pressure. And relating to where we are, the stakeholders just fall on us if there is any problem to seeing the way forward and the ways of solving the issues.

[…] One, you talked of health and health is the human resource that you are working with, so one of the main drivers to make sure that health and safety is paramount is the name associated with the institution or agency that has the fatality.

There are internal pressures that drive our health and safety consciousness, regarding especially our parent company's audit pressure and the need to protect its reputation. The regular audit is a coercive institutional pressure with non-compliance affecting management executives, as many of them were seconded from the parent company.

There could be other drivers but since Ghana is a young oil producing country, we are doing our best to make sure that incidents are reduced to the barest minimum. We don't want to start with a bad name so that when we talk of health and safety, negatives are associated with Ghana. No! We don't want that!

Thus, the IOCs appear are driven rather by reputation i.e. the need to keep good public image. This, [23] described as paramount as it is a bankable asset which could be used by the company in its transactions with the stakeholders. They are therefore aware that any OHS and environmental incidents would negative effects on the company and the long-term costs. It suggests that coercive and normative isomorphism are largely missing hence the IOCs adopt the mimetic isomorphic institutional pressure, where they learn from others and promote some appreciable OHS norms or followed those of the foreign partners. It must be noted that although the regulators on daily basis ensure monitoring of these operators, there is lack of technical, logistic, human and financial resources to effectively promote OHS issues at the highest standards. Thus, one regulatory official contend that: *Monitoring, what the management of PC can do to ensure health and safety is monitoring. And monitoring comes with resource, financial resource, because one, they could regularly send their monthly reports to us, how do you verify that the report that they are sending to you represents the true picture on the ground? You can only ensure that through inspections and monitoring. These are huge and major challenges. He bemoaned!*

This corroborates such factors as lack of capital and human resource commitment; inadequate trained professionals; lack of education; and proper monitoring and surveillances for occupational health and safety diseases and injuries [15]. The revelation further means that many of these operators are not under pressure from any stakeholder groups regarding OHS at the Rig. As an official remarked: *[…]*

I think until the regulation is passed, we are not going to have such pressures from anybody because it is the regulations that we are going to use.

Thus, unlike elsewhere in the world, the situation seems quite different in Ghana as the industry faces some minimal pressure and inquiry from civil society groups and NGOs in influencing and pushing some appreciable amount of occupational health and safety consciousness. This contrasts the situation in Sudan where OICs are faced with coercive pressures to operate in sustainable manner as failure to do so amounts to the consequence of license withdrawal in the country [7]. The Ghanaian situation expands the argument that OHS remain desolate and abandoned in developing African economies due to competing national and sector challenges [24].

Another observed: *Maybe civil society could come in but as at now, no civil society has come around to say or ensure that health and safety issues are paramount in their industry. […] Even health and safety, they the operators themselves exert a lot of pressure on PC to ensure that is done. Because as we said, it all comes with reputational issues so they won't sit down for somebody and we as regulators ensure that the right things are done. […] but as I am speaking with you, we don't have pressures coming from outside to ensure health and safety. Maybe we have these people, factories and inspectors who should be in charge of health and safety but they don't because their law does not allow them.*

Of course, these observations are in sharp contradiction with [25] who remarked that due to their advocacy for the public good and not private self-interest, civil society groups possess symbolic power and legitimacy from the positive standing and conviction garnered from the community. In essence, their dealings and presence offer minimal force hence does not change and influence societal expectations of the organizations so as to significantly persuade their survival and legitimacy. For both the regulators and the operators, it appears NGOs and civil society are not exerting any pressure for health and safety issues at the oil fields and the frontier communities. Whilst a regulator offers that: *[…] but we don't have any particular NGO sitting on us, they are not interested in the community […], an operator conjectured;*

There are NGOs there but, emm, in the communities most of them are looking at the community relations, community avenues and for some of them, they just insight the community needlessly, because you go into a community and an NGO is telling them that the water is for them, the fish is for them, they should go all out there. But that is not how it is; it's about peaceful coexistence because you have safety zones around facilities for a reason.

It is surprising however that most of the participants including the chiefs and their people averred that the communities are inundated with issues of livelihood rather than health and safety. Whilst a native for instance remarked: *[…] At the moment health and safety is not an issue, it's more about the community, the livelihoods […].*

An operator observed: *The major coercive pressure we face is the high expectation of the local communities. They demand provision of services, facilities,* etc., *in compensation for the harmful effects of our operations on their resources and livelihood.*

Another operator on the other hand offered: *What happens in the communities are more of livelihood issues than health and safety. But we rather set the limit to ensure that their safety is taken care of in terms of canoe or boat fishermen getting closer to where the operations are. We have two zones, the advisory zone and the exclusive zones. We make sure that they don't go close to these areas. Because one, even the net that they use can entangle any part of a vessel or a rig …or even the platform,* etc. *… and that creates a major accident, not to the operations but even to the fisherman. So that is what we do, we rather put pressure on them to make sure that they don't get themselves into that trouble in the first place.*

As poverty stricken nation, the survival of the people in the oil production communities is knotted to fishing and farming hence the issue of safety becomes secondary. As a natural resource and a global commodity, crude production draws attention from key local and international stakeholders. It is therefore the responsibility of the regulators and civil society to work in the interest of these frontier communities. The euphoria and the high expectation of the catchment communities must serve as key pressure for the operating firms to be socially and environmentally conscious. Moreover, the issue of crude extraction is of significant interest to the traditional rulers, the chiefs, fisher folks, farmers and all others in the catchment communities. Just like gold in Tarkwa and Prestea, many fear the untold ramification of the negative and destructive effects it may pose to live and property if not well managed. Besides, many express concerns about the potential pollution of the sea endangering the lives of flora and fauna.

5 Discussion

Following the discovery of crude, the interest of world powers including the United States, United Kingdom, China, and some Asian giants in the Ghanaian economy have heightened with its associated injection of FDI and huge financial inflows from these nations and other oil rich organizations. Although it appears efforts are being made, there is the need to equip the operational readiness of the Navy as well as the regulatory agencies to respond effectively to the emerging occupational health and safety challenges posed by the production of oil at the Ghanaian waters. Notwithstanding the fact that oil production has the potential to create wealth and fundamentally transform the economy, generate growth, and reduce poverty, there is inherent tendency of adverse effects on the health, social and environmental life of the people. The OICs seem challenged by their own internal drivers regarding enhancing the reputations and image for health and safety and sustainability practices [26].

Considering the fact that oil seems to have brought the incidents of corruption, poverty, conflicts, etc., among many African nations, it is needless to emphasize the need for ensuring the health and safety of the workforce and the local frontier communities is not jeopardized. Coupled with the activities of the IOCs, the inundation of heavy duty trucks which are producing noise at high decibels thereby increasing the cost associated with OHS among the people. The incessant clash in the Niger Delta, Nigeria, arising between local communities and the oil producing companies over water pollution and land degradation should be a concern and serve as a great deal of lessons for us [27].

In so far, just as the operating companies do not perceive much pressure from the state agencies such as the PC, GNPC, MOEN, etc., these regulators do not also feel much demand from other stakeholders such as civil society and NGOs regarding health and safety practices at the oil fields. The finding is quite dissimilar similar to other studies conducted in emerging economies, which showed the essential role of civil society and NGOs, in pushing for improved corporate, social and sustainable reporting practices [21, 25]. In essence, prior research discovered that NGOs are one stakeholders groups, through their engagement, may create cognitive dissonance on the organisations, leading to unfreezing of established norms, and, therefore promote superior sustainable practices. In fact, [7] proved that, at the very least, NGOs and civil society is endowed with the power to exert influence for superior and healthy safety practices among organizations in the oil and gas industry. Besides, findings contrast earlier observations [19, 28] that the laws and regulations were the main driving force for institutional health and safety and environmental consciousness.

Knowing that as a result of the pressures in global competition, the international corporate policy is unfavorable for supporting health and safety practices in developing nations [29] and that it is undesirable for organisations to obtain competitive edge in such economies in the areas of health and safety and well-being of employees [30], there is the need to champion the course for safe working conditions for our people. This, considering the huge fiscal inflows the oil industry attracts into the economy, there should be concerns for policy makers and researchers and all other players of the industry that the need for sound working and efficient OHS regulation for the country's oil exploration and production can no longer be delayed.

The existence of occupational health and safety hazards, risks and diseases at the off-shore and on-shore corroborate the empirical reports of the prevalence of these occupational health and safety hazards, risks and diseases in Ghana [2, 3]. It is estimated that about 80 % of the workforce in developing nations work in the highest risk industries—mining, construction, agriculture, forestry and are mainly and unduly in high risk and one-fifth to one-third could suffer occupational disease or injury yearly, and in extreme cases leading to high prevalence of work disability and premature death [5]. Owing to the lack of national OHS policy, these OHS risks, hazards and diseases are prevalent not only in the mining, and construction sectors but particularly in the developing oil fields of the country. Critical observations from these IOCs revealed that not only do they not commit to the essentials of OHS policies, there appears immense and perpetual exposure of workers and the frontier communities to occupational health and safety risks, hazards, and diseases including all forms of industrial accidents.

6 Conclusions and Implications

In conclusion, it appears the focus of OHS off-shore is bigger that on-shore activities in Ghana. Whereas many have instituted environmental and other emergency response plans, staff training on firefighting, and evacuation procedures, etc., many of the operators contend that they have had risks of false alarms, that there is a lot more work to do. They underscored that since they have not been in operation for long and because of the nature of the tasks, staff is constantly being trained. As crude prices begin to reel from the loss in the international market, government must desist from putting pressure on the IOCs to increase production in her bid to attract foreign investment to attain economic development in the country. This can only be at the expense of OHS and other environmental sustenance efforts of the country. Instead, the laws and regulations must be allowed to work as coercive pressures that compel the IOCs to be proactive and socially and environmentally responsible, and the consequence for non-compliance being loss of operational license to operate in the country. Both the government and the operators must have nothing to hide but ensure the activities of the latter have minimum or zero adverse impacts on the health of the workforce and the frontier communities. Although there appears to be some appreciable level of public awareness and friendliness and tolerance towards the petroleum industry in the country, civil society and NGOs must be seen to exert enormous pressure in pushing for health and safety and sustainability practices in the Ghanaian oil enclaves. In the milieu of frail regulatory governance vis-à-vis poor occupational health and safety practices, operators are mainly driven by reputational goals of their foreign partners to promote health and safety of their workforce and the wider environment. There is the need for government to facilitate efforts on the health and safety regulations frameworks and improve capacity building of the regulatory agencies in order to achieve valuable working conditions and reduce the tendencies of fatalities in the oil blocks. Indeed, as several diverse stakeholders are affected by the operations of the exploration and production companies [31] it is crucial to obtain extensive array of perspectives from these salient groups with varied discipline and expertise.

References

1. Pupulampu, B.B., Quartey, S.H.: Key issues on occupational health and safety practices in Ghana: a review. Int. J. Bus Soc. Sci. **3**(19), 151–156 (2012)
2. Ackerson, O.B., Awuah, E.: Urban Agriculture Practices and Health Problems among Farmers Operating on a University Campus in Kumasi, Ghana. Field Actions Science Reports, vol. 1 (from: url:http://factsreports.revues.org/451) (2010)
3. Agbenorku, P., Owusu, D.J., Nyador, E., Agbenorku, M.: Traumatic injuries among printing press workers in Kumasi (Ghana). J. Med. Med. Sci. **1**(9), 426–432 (2010)
4. Amponsah-Tawiah, K., Dartey-Baah, K.: Occupational health and safety: key issues and concerns in Ghana. Int. J. Bus. Soc. Sci. **2**(14), 119–126 (2014)

5. ILO.: Occupational safety and health country profile: Ghana. Ratification of ILO Conventions (2012)
6. Tullow Ghana Limited (2011)
7. Abdalla, Y.A., Siti-Nabiha, A.K.: Pressures for sustainability practices in an oil and gas company: evidence from Sudan. Qual. Res. Account. Manage. **12**(3), 256–286 (2015)
8. Deegan, C.: Introduction: the legitimising effect of social and environmental disclosures—A theoretical foundation. Account. Audit. Account. J. **15**(3), 282–311 (2002)
9. Campbell, J.L.: Why would corporations behave in socially responsible ways? An institutional theory of corporate social responsibility. Acad. Manage. Rev. **32**(3), 946–967 (2007)
10. Yang, H.: Business implications of corporate sustainability in an emerging country: evidence from China. Int. Rev. Bus. Res. Papers **7**(1), 77–89 (2011)
11. DiMaggio, P.J., Powell, W.W.: The iron cage revisited: institutional isomorphism and collective rationality in organizational fields. In: Powell, W.W., DiMaggio, P.J. (eds.), pp. 63–82. The New Institutionalism in Organizational Analysis (1991)
12. Hussain, M.M., Hoque, Z.: Understanding non-financial performance measurement practices in Japanese banks: a new institutional sociology perspective. Account. Audit. Account. J. **15**, 162–183 (2002)
13. Hassan, M.K.: Management accounting and organizational change: an institutional perspective. J. Account. Organ. Change **1**, 125–140 (2005)
14. Islam, M.A., Deegan, C.: Motivations for an organization within a developing country to report social responsibility information: evidence from Bangladesh. Account. Audit. Account. J. **21**(6), 850–874 (2008)
15. Muchiri, F.K.: Occupational health and development in Africa: challenges and the way forward. Afr. Newsl. Occupa. Health Saf. **13** (2003)
16. Kheni, N.A., Dainty, A.R.J., Gibb, A.G.F.: Health and safety management in developing countries: a study of construction SMEs in Ghana. Constr. Manage. Econ. **26**(11), 1159–1169 (2008)
17. Clarke, E.: Do Occupational Health Services Really Exist in Ghana? A Special Focus on the Agricultural and Informal Sectors. Ghana Health Services, Accra, Ghana (2005)
18. Aratuo, I.Z.: Ghana's oil industry: the state, operators and local frontier communities. Unpublished thesis, University of Ghana, Legon (2012)
19. Rodrigue, M., Magnan, M., Boulianne, E.: Stakeholders' influence on environmental strategy and performance indicators: a managerial perspective. Manage. Account. Res. **24**(4), 301–316 (2013)
20. Creswell, J.W.: Qualitative Inquiry and Research Design: Choosing Among Five Approaches. Sage, London (2012)
21. Mzembe, A.N., Meaton, J.: Driving corporate social responsibility in the Malawian mining industry: a stakeholder perspective. CSR Environ. Manage. **21**, 189–201 (2014)
22. Reuters, http://ca.reuters.com/article/topNews/idCABREA470XH20140508
23. Kuruppu, S., Milne, M.J.: Managing reputation and maintaining legitimacy: understanding a company's responses to sustainability issues. University of Canterbury (2011). www.utas.edu.au/data/assets/pdf_file/0009/188406/Kuruppu_Milne.pdf
24. Nuwayhid, I.A.: Occupational health research in developing countries: a partner for social justice. Am. J. Public Health **94**(11), 1916–1921 (2004)
25. Deegan, C., Islam, M.A.: An exploration of NGO and media efforts to influence workplace practices and associated accountability within global supply chains. Br. Account. Rev. **46**, 397–415 (2014)
26. Belal, A.R., Owen, D.L.: The views of corporate managers on the current state of, and future prospects for, social reporting in Bangladesh: an engagement-based study. Account. Audit. Account. J. **20**(3), 472–494 (2007)
27. Imobighe, T.A.: Conflict in the Niger Delta: a unique case or a 'Model' for future conflicts in other oil-producing countries? In: Traub-Merz, R., Yates, D. (eds.) Oil Policy in the Gulf of Guinea; Security and Conflict, Economic Growth, Social Development, pp. 101–115. Friedrich-Ebert-Stiftung, Germany (2012)

28. Lozano, R.: A holistic perspective on corporate sustainability drivers. Corp. Soc. Responsib. Environ. Manage. **22**(1), 32–44 (2013)
29. Alhasan, M.R., Partanen, T.J.: Occupational health and safety programs in the less developing countries—A serious case of negligence. J. Epidemiol. **11**, 74–80 (2001)
30. Stiglitz, J.: Employment, social justice and societal well-being. Presentation at ILO Global Employment Forum, Geneva, Switzerland (2001)
31. Makki, M.: Evaluating arctic dialogue: a case study of stakeholder relations for sustainable oil and gas development. J. Sustain. Dev. **5**(3), 34–45 (2012)

Determining Empirical Donning and Doffing Times for Complex Combinations of Personal Protective Equipment (PPE)

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Abstract Personal Protective Equipment (PPE) is specialized clothing or equipment worn to minimize exposure to a variety of hazards. As an example, wearing multiple layers of work gloves is common in several industries such as food processing and healthcare. Despite the widespread use of gloves, there are no known published studies that have developed donning and doffing times for layers of protective work gloves. Each glove layer has a time associated with donning and doffing depending not only on the glove but also on the other layers being worn. We use Time Study to empirically develop standards for donning and doffing times of multiple layers of work gloves in four different combinations.

Keywords Personal protective equipment · Work gloves · Donning and doffing · Time study

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1 Introduction

In many occupations, workers must wear various types of PPE to protect multiple body parts or to protect one body part from multiple hazards. Wearing multiple layers of work gloves may provide simultaneous protection from cold temperatures, wet conditions, sharp cutting tools, blood or body fluid exposure, or other hazards. A literature review did not uncover any reports of studies conducted to determine times for donning and doffing multiple layers of work gloves. Each layer of glove that is worn has an associated time for donning and doffing, but the previous pair(s) of gloves that are donned and the pair(s) of gloves underneath the pair being doffed may affect the don and doff times. Statistically based techniques such as *Time Study* can be used to empirically develop standards for donning and doffing times, including those for multiple layers of work gloves. These techniques are well established within *Industrial Engineering* and two closely related sub-fields *Methods Engineering* and *Work Measurement*. This study describes the methodology and results of several experiments conducted to develop the methods and times for donning and doffing multiple layers of work gloves in four different combinations.

2 Time Study Experiments

Engineering students were trained on how to develop methods and conduct time studies including how to perform pace rating. The students were randomly placed into teams of 4–5 students and randomly assigned one of four glove layering methods, listed here in order from innermost to outermost layer: (1) Thermal (Cotton) + Rubber + Protective (Steel Mesh) (TRP); (2) Thermal + Rubber + Protective + Rubber (TRPR); (3) Thermal + Thermal + Rubber (TTR); and (4) Thermal + Rubber + Rubber (TRR). These combinations were chosen because they represent glove layering methods observed in industry by the researchers. One of the combinations (TRP) has been specifically referred to in documents related to litigation regarding the compensability of donning and doffing required PPE.[1] Each team was instructed to identify a donner/doffer, a timer, and the rest of the team members were assigned to be pace raters; therefore, each team had two-three pace ratings for each trial. These individually observed pace ratings were averaged to apply to the timed trial.

Information often missing in the literature when instructions are given and/or standard times are reported is the description of the method used to perform the

[1] Federal Litigation Update: Compensability of Pre-Shift and Post-Shift Duties, ABA 2009 Labor and Employment Law CLE Conference.

operation that is studied. When detailed methods are missing, it is not possible to determine if the standard times are accurate or to compare standard times from different researchers. For example, in the Centers for Disease Control (CDC) directions for nurses to don gloves when working with confirmed Ebola cases, the instructions read: "Put on first pair of gloves."[2] How to "put on" the gloves is not detailed. The importance of a detailed doffing process for PPE is addressed in a 2014 article in the Annals of Internal Medicine: "Despite its lethal nature, Ebola transmission can be interrupted with simple interventions and by focusing on basics. Improvement in basic health care infrastructure and providing an adequate supply of PPE along with a ritualized process for donning and doffing PPE are desperately needed to prevent further unnecessary infection and loss of life among the heroic health care workers who are on the frontlines of this war. Protection of health care workers in Ebola outbreaks does not happen by accident—it is achieved through the provision of adequate PPE and, more important, a focus on systems processes that enforce the safe use and removal of PPE."[3]

In this study, students were given detailed training in how to write work methods and were assigned several different donning/doffing time study experiments prior to this one. Methods Engineering teaches that when work methods are written, actions of the body parts (usually the right and left hands) are detailed. The students conducting these experiments were also instructed to "Minimize wasted motion. Minimize mistakes. Minimize awkward hand positions. … Make sure that you clearly describe the start and stop positions for donning and doffing, defining the position of the person, the person's body, and the gloves. The donner/doffer should be able to perform the method repetitiously and identically at "100 %" before the time study begins."[4] The number of practice trials conducted by each team was not prescribed and varied by team.

A representative sample of the work methods produced by this study before the time studies were conducted is quite different from the CDC instruction referenced above. The example contained here is for donning and doffing the TRP layers of gloves.

[2]Guidance on Personal Protective Equipment (PPE) To Be Used By Healthcare Workers during Management of Patients with Confirmed Ebola or Persons under Investigation (PUIs) for Ebola who are Clinically Unstable or Have Bleeding, Vomiting, or Diarrhea in U.S. Hospitals, Including Procedures for Donning and Doffing PPE, CDC guidance, August 27, 2015, http://www.cdc.gov/vhf/ebola/healthcare-us/ppe/guidance.html.

[3]Fischer WA, Hynes NA, Perl TM.: Protecting Health Care Workers From Ebola: Personal Protective Equipment Is Critical but Is Not Enough. Ann Intern Med. 2014;161:753–754. doi:10.7326/M14-1953.

[4]Sims, LuAnn, "Lab Instructions for INSY 3021, Layers of Work Gloves", Department of Industrial and Systems Engineering, Auburn University, Spring 2013.

2.1 Donning Thermal + Rubber + Protective (TRP) Layered Gloves

1. Begin: With all gloves lying flat on table. Left glove facing your left and right glove facing your right. Thumbs towards each other. Thermal gloves closest to you: followed by rubber gloves then protective gloves (Fig. 1).
2. With right hand grasp bottom cuff of left hand glove and lift upwards (Fig. 2).
3. 3A. Insert left hand into glove; slide hand towards fingertips while simultaneously pulling glove towards your wrist with your right hand. Continue sliding hand inside glove until fingertips of left hand reach the end of the fingertips of left glove (Fig. 3).
   3B. Right hand must non-simo regrasp and pull glove one time. Release cuff with right hand.

Fig. 1 Start position

Fig. 2 Begin don of left thermal glove

Fig. 3 Complete don of left thermal glove

4. With left hand grasp bottom cuff of right hand glove and lift upwards
5. 5A. Insert right hand into glove; slide hands towards fingertips while simultaneously pulling glove towards your body with your left hand. Continue sliding hand inside glove until fingertips of right hand reach the ends of the fingertips of right glove.
   5B. Left hand must non-simo regrasp and pull glove two times. Release cuff with left hand. Thermal gloves are now donned (Fig. 4).
6. Grasp bottom left rubber glove cuff with right hand and top left rubber glove cuff with left hand. Open up the cuff by pulling apart (Fig. 5).
7. Release glove cuff with left hand and insert left hand into glove. While sliding left hand in glove pull glove towards your body with right hand. Continue until finger tips reach the end of the glove (Fig. 6).

Fig. 4 Complete don of thermal gloves

Fig. 5 Begin don of left rubber glove

Fig. 6 Don left rubber glove

8. Grasp bottom right rubber glove cuff with left hand and top right rubber glove cuff with right hand. Open up the cuff by pulling apart.
9. Release glove cuff with right hand and insert right hand into glove. While sliding right hand in glove pull glove towards your wrist with left hand. Continue until finger tips reach the end of the glove. Rubber gloves are donned.
10. With right hand grasp bottom cuff of left hand protective glove and lift upwards.
11. Insert left hand into left glove. While sliding left hand inside glove, pull glove towards your wrist with right hand. Continue until finger tips of left hand reach the end of the left glove fingertips. Release cuff with right hand.
12. 12A. Hold left hand horizontally in front of body with palm facing downwards. 12B. Grasp button clasp tab with right hand and pull over to top of hand (Fig. 7). Push down on button tab until clasp snaps and is secure (Fig. 8). Release clasp with right hand.
13. With left hand grasp bottom cuff of right hand protective glove and lift upwards.
14. Insert right hand into right glove. While sliding right hand into protective glove pull glove towards your body with left hand. Continue until fingertips of right hand reach the ends of the fingertips of right glove. Release cuff with left hand.
15. 15A. Hold right hand palm down horizontally in front of body.
    15B. Grasp button clasp tab with left hand and pull over to top of hand. Push down on button tab until clasp snaps and is secure. Release clasp with left hand. End: All gloves are now donned.

Fig. 7 Begin fasten of left protective glove

Fig. 8 Fasten left protective glove

2.2 Doffing Protective-Rubber-Thermal Layered Gloves

1. Begin: All layers of gloves donned.
2. With right hand grasp left hand protective glove buckle with thumb and index finger and pull upwards to unbuckle and release strap with right hand.
3. Grab finger tips of left hand glove with right hand and pull away from body until glove completely slides off hand (Fig. 9).
4. Lie glove flat on Table
5. With left hand grasp right hand protective buckle with thumb and index finger and pull upwards to unbuckle and release strap with left hand.
6. Grab finger tips of right hand glove with left hand and pull away from body until glove completely slides off hand.
7. Lie glove flat on table: Protective gloves are now doffed.
8. Grab finger tips of left hand rubber glove with right hand and pull away from body until glove completely slides off hand.
9. Lie glove flat on table.
10. Grab finger tips of right hand rubber glove with left hand and pull away from body until glove completely slides off hand.
11. Lie glove flat on table: Rubber gloves are now doffed.
12. Grab finger tips of left hand thermal glove with right hand and pull away from body until glove completely slides off hand.
13. Lie glove flat on table.
14. Grab finger tips of right hand thermal glove with left hand and pull away from body until glove completely slides off hand.
15. Lie glove flat on table (Thermal gloves are now doffed). End: All gloves are now doffed and lying on table (Fig. 10).

Fig. 9 Begin doff of left protective glove

Fig. 10 Stop position

3 Results

The experiments were conducted over a two semester period with approximately 120 engineering students per semester conducting the time studies. All of the students were different from one semester to the next. The layering method experiments were repeated with different teams from 5 to 8 times each. The number of trials for each experiment was supposed to be 30 as directed by the lab assignment. The number of trials for each experiment actually varied from 15 to 50 but averaged 28. Some teams reported that they didn't have enough time to conduct 30 trials. The data were collected and aggregated for both years. A check for normality was conducted, and then the mean, standard deviation, and statistical outliers were identified. The resulting data representing the recommended standard time (based on the means) for donning and doffing layers of glove combinations is shown in Table 1. The ratio of doff time to don time for different combinations of glove layering is also shown in Table 1.

One experiment was also done for the TRP layering method to compare donning and doffing times of multiple layers of gloves to the times for donning and doffing single layers. If all three gloves are donned and doffed separately, the total don and doff times are 26.8 and 12.2 s respectively. For this experiment, donning multiple layers of gloves increases the time by 57 % and doffing increases the time by 42 %.

Table 1 Time study results in seconds

Layering method	Don	Doff	Ratio doff/don (%)
TRP	42.2	16.2	38.3
TRPR	66.2	23.6	35.6
TRR	35.7	18.7	52.3
TTR	34.9	24.1	68.9

MOST Calculation				
		Date: 3/1/2016		
		Engineer: LuAnn Sims		
Operation:		Study No.: Don TRP Glove		
No.	Method Description	No.	Sequence Model	Fr.	TMU
1	With all gloves lying flat on table. Left glove facing your left and right glove facing your right. Thumbs towards each other. Thermal gloves closest to you: followed by rubber gloves then protective gloves (Figure 1).	9	$A_1 B_0 G_1 A_0 B_0 P_0 A_0$	1	20
2	With right hand grasp bottom cuff of left hand glove and lift upwards (Figure 2).	4	$A_1 B_0 G_1 A_0 B_0 P_0 A_0$	1	20
3	3A. Insert left hand into glove; slide hand towards fingertips while simultaneously pulling glove towards your wrist with your right hand. Continue sliding hand inside glove until fingertips of left hand reach the end of the fingertips of left glove (Figure 3). 3B. Right hand must non-simo regrasp and pull glove one time. Release cuff with right hand.				
4	With left hand grasp bottom cuff of right hand glove and lift upwards	3A	$A_1 B_0 G_0 M_3 X_0 I_6 A_0$	1	100
5	5A. Insert right hand into glove; slide hands towards fingertips while simultaneously pulling glove towards your wrist with your left hand. Continue sliding hand inside glove until fingertips of right hand reach the ends of the fingertips of right glove. 5B. Left hand must non-simo regrasp and pull glove two times. Release cuff with left hand. Thermal gloves are now donned (Figure 4).	3B	$A_1 B_0 G_1 M_3 X_0 I_0 A_1$	1	60
6	Grasp bottom left rubber glove cuff with right hand and top left rubber glove cuff simo with left hand. Open up the cuff by pulling apart (Figure 5).	5A	$A_1 B_0 G_0 M_3 X_0 I_6 A_0$	1	100
7	Release glove cuff with left hand and insert left hand into glove. While sliding left hand in glove pull glove towards your wrist with right hand. Continue until finger tips reach the end of the glove (Figure 6).	5B	$A_1 B_0 G_1 M_3 X_0 I_0 A_1$	2	120
8	Grasp bottom right rubber glove cuff with left hand and top right rubber glove cuff with right hand. Open up the cuff by pulling apart.	6	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
9	Release glove cuff with right hand and insert right hand into glove. While sliding right hand in glove pull glove towards your wrist with left hand. Continue until finger tips reach the end of the glove. Rubber gloves are now donned.	7	$A_1 B_0 G_0 M_3 X_0 I_6 A_0$	1	100
10	With right hand grasp bottom cuff of left hand protective glove and lift upwards.	8	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
11	Insert left hand into left glove. While sliding left hand inside glove, pull glove towards your wrist with right hand. Continue until finger tips of left hand reach the end of the left glove finger tips. Release cuff with right hand.	9	$A_1 B_0 G_0 M_3 X_0 I_6 A_0$	1	100
12	12A. Hold left hand horizontally in front of body with palm facing downwards. 12B. Grasp button clasp tab with right hand and pull over to top of hand (Figure 7). Push down on button tab until clasp snaps and is secure (Figure 8). Release clasp with right hand.	10	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
13	With left hand grasp bottom cuff of right hand protective glove and lift upwards.	11	$A_1 B_0 G_0 M_3 X_0 I_6 A_0$	1	100
14	Insert right hand into right glove. While sliding right hand into protective glove pull glove towards your wrist with left hand. Continue until fingertips of right hand reach the ends of the fingertips of right glove. Release cuff with left hand.	12A	$A_1 B_0 G_0 M_0 X_0 I_0 A_0$	1	10
15	15A. Hold right hand palm down horizontally in front of body. 15B. Grasp button clasp tab with left hand and pull over to top of hand. Push down on button tab until clasp snaps and is secure. Release clasp with left hand.	12B	$A_1 B_0 G_1 M_3 X_0 I_6 A_0$	1	110
	End: All gloves are now donned.	13	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
		14	$A_1 B_0 G_0 M_3 X_0 I_6 A_0$	1	100
		15A	$A_1 B_0 G_0 M_0 X_0 I_0 A_0$	1	10
		15B	$A_1 B_0 G_1 M_3 X_0 I_6 A_0$	1	110
	Time in Seconds:	42.48		TMU	1180

Fig. 11 Most analysis don TRP

MOST Calculation					Date: 3/1/2016
					Engineer: LuAnn Sims
Operation:					Study No.: Doff Protective Glove-Rubber-Thermal
No.	Method Description	No.	Sequence Model	Fr.	TMU
1	Begin: All layers of gloves donned.	4	$A_0 B_0 G_0 A_1 B_0 P_3 A_0$	1	40
2	With right hand grasp left hand protective glove buckle with thumb and index finger and pull upwards to unbuckle and release strap with right hand.	7	$A_0 B_0 G_0 A_1 B_0 P_3 A_0$	1	40
3	Grab finger tips of left hand glove with right hand and pull away from wrist until glove completely slides off hand (Figure 9).	9	$A_0 B_0 G_0 A_1 B_0 P_3 A_0$	1	40
4	Lie glove flat on table.	11	$A_0 B_0 G_0 A_1 B_0 P_3 A_0$	1	40
5	With left hand grasp right hand protective buckle with thumb and index finger and pull upwards to unbuckle and release strap with left hand.	13	$A_0 B_0 G_0 A_1 B_0 P_3 A_0$	1	40
6	Grab finger tips of right hand glove with left hand and pull away from wrist until glove completely slides off hand.	15	$A_0 B_0 G_0 A_1 B_0 P_3 A_0$	1	40
7	Lie glove flat on table: Protective gloves are now doffed.				
8	Grab finger tips of left hand rubber glove with right hand and pull away from wrist until glove completely slides off hand.	2	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
9	Lie glove flat on table.	3	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
10	Grab finger tips of right hand rubber glove with left hand and pull away from wrist until glove completely slides off hand.	5	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
11	Lie glove flat on table: Rubber gloves are now doffed.	6	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
12	Grab finger tips of left hand thermal glove with right hand and pull away from wrist until glove completely slides off hand.	8	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
13	Lie glove flat on table.	10	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
14	Grab finger tips of right hand thermal glove with left hand and pull away from wrist until glove completely slides off hand.	12	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
15	Lie glove flat on table (Thermal gloves are now doffed).	14	$A_1 B_0 G_1 M_1 X_0 I_0 A_0$	1	30
	End: All gloves are now doffed and lying on table.				
	Time in Seconds:	17.28		TMU:	480

Fig. 12 Most analysis doff TRP

Seven experiments were conducted where the times were recorded for donning each layer in addition to the total times for the don. These experiments show that the don time of the second layer was similar for different gloves: an average of 10.82 s for a second thermal glove (TTR) and an average of 10.57 s for a second rubber glove (TRP, TRPR, and TRR). However, donning the third layer had much more variability, with average times of 8.70, 12.80, and 23.68 for TTR, TRR, and TRP/TRPR respectively. Additional data from this study directly compared the time to don a thermal glove as the first layer versus donning a second thermal glove over the first thermal glove. These times were 6.19 s versus 10.82 s, an increased time of 75 % for the same type glove.

3.1 *Sample Validation Using a Predetermined Time System (MOST)*

MOST (Maynard Operation Sequence Technique) was developed by Kjell B. Zandin in 1980. One of the researchers is an experienced MOST analyst who conducted a MOST study of one of the glove layering methods, TRP, for both donning and doffing as a validation of the time studies. MOST uses the concept of sequence models for manual work. Two sequence models were used in this study, General Move and Controlled Move. A General Move occurs when an object moves freely through space. In this study, this only happens at the beginning of the don, when the first glove is picked up. The rest of the moves were Controlled Moves, where the object that moves is constrained in some way during the move. In this case, the hand is constrained by the glove (and vice versa). The MOST analyses (shown in Figs. 11 and 12) is done using a standardized form where the steps are shown on the left hand side (the same steps as shown above for the methods preceding the time study) and the sequence models on the right hand side. Index values are chosen from a table depending on the move characteristics. A higher index value results in more time being given for a motion. When the index values are summed and multiplied by 10, the subsequent time is in TMU (1/100,000) of an hour or 0.036 s. MOST is based on 100 % pace, eliminating the need to pace rate an operator. The MOST analyses for this study result in a recommended donning standard for TRP of 42.5 s (compared to 42.2 average for all time studies) and a doffing standard for TRP of 17.3 (compared to 16.2 average for all time studies).

4 Discussion

This study shows that Time Study can be used to develop don and doff times for layers of work gloves. Several different sizes of each type of glove were made available to the teams. The teams selected a donner/doffer that had a reasonable fit to the first thermal layer in each layering sequence. Subsequent layers had to fit over previous layers without undue effort as well. As an aside, fit of gloves is a factor in the time it takes to don and doff, and some research was done in this set of experiments to define "fit" of gloves to hands. Further research may be done in this area, but for the purposes of this experiment, teams self-selected for proper glove fit without specific definition.

The instructions given to the teams specified that all layers were to be donned on each hand. However, it is common in industry for the layers on one hand to be different than on the other hand depending on whether the worker is right or left handed and what type of tool (such as a knife) will be used with each hand. Therefore, the don and doff times we found can be viewed as a worst-case scenario. We also know that gloves can become wet when worn for certain jobs. Only dry gloves and hands were used in these experiments; adjustments to don/doff times might have to be made for wet conditions. It is also very important to note that these experiments did not take into account doffing gloves in cases where the worker must be protected against contamination such as in the case of health care workers exposed to Ebola. Future work may include developing detailed methods and times for donning and doffing gloves and other PPE under different conditions.

5 Conclusions

The following conclusions can be reached from the study:

1. Classical time study can be used to empirically establish statistically sound donning and doffing times for personal protective equipment such as work gloves. MOST can be used effectively as validation for the time study experiments when the detailed methods performed in the time study are known.
2. There is evidence from this study that in general, doffing time is less than donning time for work gloves. Further research may result in the ability to provide useful models for the relationship between donning and doffing times so that researchers or practitioners may estimate the time for one if they know the other without performing separate time studies.
3. Donning and doffing layers of work gloves increases the time more than simply adding up times for donning and doffing one glove at a time by a significant amount, up to 75 % for donning and 42 % for doffing. Additional research may be done to model interaction effects of multiple PPE combinations.

Using Semantics to Improve Information Fusion and Increase Situational Awareness

Valdir A. Pereira Junior, Matheus F. Sanches, Leonardo C. Botega, Caio S. Coneglian, Natália Oliveira and Regina B. Araújo

Abstract Situational Awareness (SAW) is the ability of a human to perceive, understand and project the states of assets in a real-world environment. In the emergency management domain, SAW is developed by means of a range of information collected from several sources, typically in real time. With this amount of information to be observed by the human operator, the development of SAW is a very complex and dynamic task. To assist this process of developing SAW, several technological and informational approaches have been developed to support decision-making systems, bringing together situational assessment routines (e.g., acquisition, processing and presentation) for the human operator to build SAW based on the information at hand, which can be very quality-limited in many aspects, depending on their source. Since such systems employ concepts and techniques of data and information fusion to perform information integration, issues regarding synergistic information association emerge. In order to enhance and

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improve this process, it is proposed in this paper a new fusion approach using the concepts of data quality and semantics.

Keywords Situational awareness · Emergency management systems · Data and information fusion · Ontology-based information fusion

1 Introduction

Situational Awareness (SAW) is the cognitive process that describes the ability of a human to be aware of all the elements and contexts of an environment, in order to understand what they mean in the present and in the near future. For this reason, the concept of SAW is usually applied to situations of operational and critical areas, such as surgical procedures, emergency management, military operations, traffic control and others. Such domains need a human decision-making, and this should be the most accurate and appropriate to each situation being analyzed. However, to achieve SAW is a complex task, especially when situations are highly dynamic and built based on uncertain input information [1].

Aiming to assist the SAW process, decision-support systems were developed. Such systems typically include phases of acquisition, processing and graphical presentation of information related to a particular situation to be observed by the human. However, such systems have a high level of complexity, because they process a lot of data and information, observed from several sources, from which are required to present to the human the most faithful possible information about the situation that occurs in the real environment [2, 3]. The problem increases when data are derived from human sources, which are generally imperfect, bringing information quality issues to the process.

For this purpose of situational assessment, such approaches applied data and information fusion techniques as part of such systems, which have the capability of processing a great amount of data and infer the situation with the best possible quality outcomes. Such process becomes possible because the data fusion uses several techniques of handling and organizing data, making it possible to compare, to associate and to evaluate data, which may be acquired from various and heterogeneous sources.

However, even using data and information fusion techniques a major informational constraint may arise. Being the whole processing based on a syntactical construction of the information. Hence, the internal mechanisms of fusion are typically based on the syntax of words, instead of the real meaning assigned to a word or expression. Such issue reduces the processing capabilities, once different syntax may express the same information or have common connection points. It is clear that such limited approach increases the data quality issues and the associated uncertainties.

This process of assigning a context or meaning to information is well represented by semantic models, which can assign a meaning to information before and during the processing, allowing that situational information to be built in different ways but having the same context or meaning. Such new semantically associated information can be performed by fusion means, contributing to generate information with improved quality and more faithful to the real environment.

Thus, this paper proposes the development of a semantic approach for enhancing information fusion and mitigating information quality issues, in support of SAW systems and decision-making.

2 Related Work

Initially, data fusion systems have been developed in order to monitor, identify and characterize military entities, such as ground vehicles, aircraft, weapons systems and enemy troops, to reduce the large volume of data and promote simplified, converged measurements and more significant.

Traditionally, the first fusion systems promoting the exclusive use of physical sensors or from signals intelligence (SIGINT), such as radar, acoustic sensors, seismic, photosensors and range detectors. Thus, the approach was restricted to mining and association data from various combinations of data from such sensors.

In this context, the systems were designed from the perspective of Low-Level Information Fusion (LLIF), whose automated functional processes were limited to produce estimates of classification, identification and tracking of targets.

Currently, there is great interest in the use of non-physical sensors to promote a holistic view of the world. Among these sensors are: banks of various entities of data that holds the domain of interest data services arising from different communication networks (sub-systems or World Wide Web) and cloud computing (COMINT), remote sensing services by images (IMINT) and the use of human intelligence for the observation of a scenario (HUMINT) and include your account as qualitative source of data and information, directly or indirectly.

The HUMINT information is subject to trends, inaccuracies and omissions. Interpret and merge this information requires the deduction of semantic meaning, which often cannot be inferred by automated functions and requires human participation in the interpretation and use of information. Examples of these challenges include the interpretation of allegations made by witnesses to report to emergency call systems [4].

In this context, there is a gradual change of the role of passive image of the situation receiver to a perspective in which the human becomes an active participant of the process [5].

Thus, the community began to consider issues relating to High Level Information Fusion (HLIF) DFSs perspective that considers participatory human in search for patterns, relationships and behaviors inferred entities by physical sensors and not physical, in order to support inferences and high-level decisions.

Recently, semantic approach to data fusion emerged, with the use of ontologies as part of the representation and inference process. At work McGuinness [6], are presented classifications and ontologies organizations such as ontologies that can be kept inside in an application or domain, but also be external sources, but have a certain level of standard, i.e., controlled sources, as controlled vocabularies and glossaries, as Ontology Structured containing information of different classes, with restrictions on types and values, thus requiring a more specific processing to be able to use it and how they can collaborate in the process of merging information.

In addition to the evolution of the human role during the DFMs processes, has to consider the issues of quality of data and information [7], both as a single entry for a decision on data fusion, and to compose a set of multiple criteria of integration, which can be collected directly from the environment, an artificial intelligence and human input.

At the same time, there was evolution of models and fusion algorithms, new application areas started to make use of such approaches, especially those of critical context and require extremely reliable and representative information such as the domain management emergencies [8].

Carvalho [9] makes use of ontologies to represent critical areas characterized by the presence of uncertainty. To this end, this paper carries out a study on technical processes and ontologies, able to represent the complex semantics of these areas along with the uncertainty that these contain. As a solution, it is proposed the use of a Probabilistic Ontology (PR-OWL). The question raised during the development of this article, is to find a technique that is able to represent multi-entity relationships present in an ontology and still be able to represent the probability and uncertainty of the information. As a solution is proposed and analyzed one Bayesian Multi-Entity Network.

In order to validate the techniques mentioned above by the work itself, we conducted a case study in a critical area, which by its nature, requires a lot of information from various sources and presenting uncertainty rates, which is the detection area fraud in contracts in Brazil, where we analyze the possible sources of data and how they can be used to find the best possible application of a Probabilistic Ontology. And the fusion results can be favored by this technique in this field.

Costa [10] also uses a critical area to represent and justify the use of data fusion in this case are used highly expressive Bayesian models to be able to process HLIF. Moreover, they are compared LLIF and HLIF in several respects, including, fields, form capture and Classification of data. Reconnecting problems and positives among these, and how factors of uncertainty may arise and affect the data, considering that the role of human and how it will interact. Thus noting the relevance of this uncertainty in the data and information and how it interferes with the human ability to interpret the information submitted to it.

From this, techniques and methods that have the ability to interpret and represent this uncertainty of the data were analyzed and existing relationships between classes, when such data are arranged in an ontology. On top of this, the article analyzes the semantics HLIF considering the Bayesian Network techniques Multi-Entity, which is able to represent multi entities in an ontology and the various existing relationships between them, thus becoming a highly expressive technique and useful for areas that depend on a huge amount and diversity of data to make the data fusion process.

Another technical analyzed are probabilistic ontology may represent the formality and the same relationship between the data, however accomplishing probability calculations, which are capable of representing the uncertainty associated with a given or association determined. With this in, it developed a plugin to a graphical application developed by the University of Brasilia, to study the behavior and application of both techniques together and be able to analyze their results.

As a case study, such techniques were also applied to a critical area in this case, the Domain Sea along with Department of Defense. Being analyzed as Bayesian Networks Multi-Entity and Ontologies Probabilistic can contribute to the management of this area that also requires the interpretation of various data, stemmed from several sources, both physical sensors, as HUMINT data, thus proving again full capacity techniques together to represent all the semantics of a given to a human, together with the integrated uncertainty factor.

Kim [11], performs an analysis of data capture methods and web information, i.e., heterogeneous data sources or types and different classifications of data captured for that shows the concept of Linked Data, which enabled the connection between data through some context they have in common, ensuring maximum extent capture and recovery of data on the Web, along with this are also cited the RDF method that enables the classification of a document, i.e., structuring of data captured so that they can be reused by other techniques or methods as well as also mentioned SPARQL, which enabled the query execution on the RDF generated, allowing a larger processing and manipulation of data captured in the web.

These techniques allow the end user, this on the web, running highly complex questions and receive the best possible response in the context in which it was raised, that when using Data Fusion that by using the techniques mentioned above, allowing the query Connecting the metadata and data, thereby generating the best possible information for the response. However, the article does not cite detailed and technical information about shooting techniques, representation and processing of information, both in the Linked Data and in Data Fusion techniques, leaving unclear how many details mentioned are integrated. In addition to not consider any context or quality indices, the initial information or post processing.

3 The Process for Semantic Fusion with Information Quality Awareness

In order to fulfill the objectives proposed in this paper, it is proposed a process that specifies the information management for the assessment and acquisition of SAW, guided by the requirements and needs of decision-makers of São Paulo State Police (PMESP), in managing criminal situations.

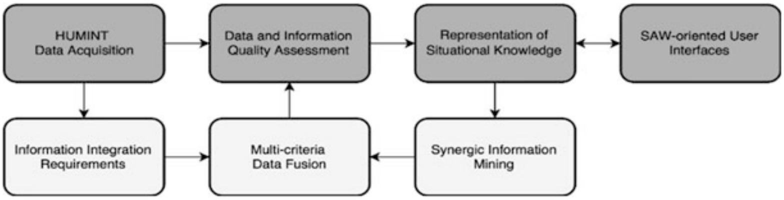

Fig. 1 Process for semantic fusion with information quality awareness

This process can be abstracted into four main sub-processes. The fusion one (highlighted in Light Gray in Fig. 1) is composed by: Information Integration Requirements for determining the rules and needs for information integration, Multi-Criteria Data Fusion responsible for associating the synergic information and the Synergic Information Mining, which is responsible for performing the search for synergic information and bring this to the current process.

The first step of the fusion process described here is the capture of a natural speech, in this case a crime report made to emergency answering services.

The report is then transcribed into words that is analyzed to find elements defined as important by the requirements elucidation. Then, the identified objects are encapsulated in a JSON object.

This JSON characterizes the main objects, their attributes and basic relationships between them, such as which attributes belong to each object, then these objects, are subjected to quality calculations to assess their initial quality scores.

The quality indexes are applied in a local and global contexts and recalculated every time an information is transformed (updated) or inferred by assessment routines, such as the information fusion [12]. The product of this phase is then a collection of objects that may or may not be related in some dimension.

Such collection of objects corresponds information of Level L1 of fusion, according to the JDL (Joint Directors of Laboratories) and other taxonomies [12], along with quality scores assigned to each object and attribute, according to the methodology for information quality assessment [7].

3.1 Performing the First Steps of a Semantic Information Fusion Using Quality Assessments

From the identified objects and attributes included in a the JSON object, a preliminary ontology is instantiated with the classes of *victim*, *criminal*, *robbed object* and the location/place, considered the fundamental objects to define a robbery situation, each with their respective attributes and relationship properties, representing the initial semantic meanings of the information, as shown in Fig. 2.

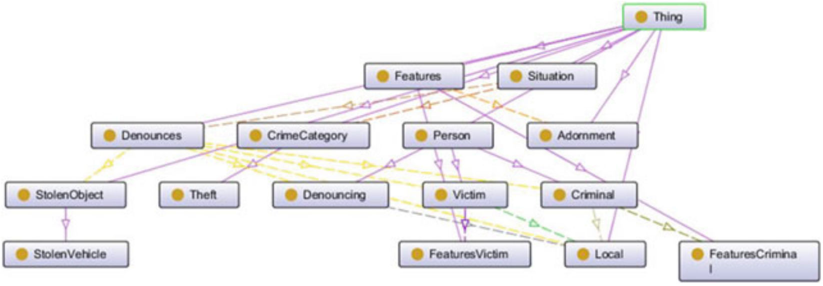

Fig. 2 Ontology of an emergency situation

With the instantiated ontology, the information set is once more transformed into a JSON object, now with the semantic meaning between objects and attributes. This semantic information is related by means of their present properties.

This JSON object is now the input of the fusion process. In addition, there will be other input parameters and criteria sets provided by the human operator, defined at runtime at the user interface, such as: which objects to specifically associate, which external sources to use, which properties must exist and a new threshold of minimum quality of the information, for example: “criminal: {“completeness”: 45, “clothes”:{“red shirt”, “black pants”}}”.

Once the fusion process is started, there is the synergy search among classes already present in the ontology, taking into account the objects, attributes, data properties, quality scores and their properties set into the semantic model.

After the synergy search among the information already stored in the ontology, a search on other sources of data is started in order to obtain new information about the associated objects, aiming to validate and build greater consistency to the already set information. Considering that the input of this process is isolated information or information already associated among objects, the output of this process is a L2 fusion information, i.e. information with a certain level of relationship.

This process will be carried out by an algorithm based on data mining techniques, using the Apriori technique, which infers the frequency of certain information when analyzed in relation to the rest of an environment (information of the situation and requested sources). This inference is made from a proposed calculation of the information support, according to Fig. 3, as follows.

```
foreach(resultSinergicSearch as oneResult){
  if(isArray(oneResult)){
    for(var iT = 0; iT < count(oneResult);iT++) fP = oneResult[it]/count(oneResult)
    oneResult[iT+1] = fP;}
  else{
  fP = oneResult/count(resultSearch);
  resultSearch[fT]+=fP;}}
```

Fig. 3 Part of the core of data mining algorithm

For the process herein proposed, it is used the principles of data mining in databases, but some changes will be made in order to analyze the frequency of such information by a single ontology knot or a proposed parameter, that is, it searches for the covariance between the data.

The result of this process is obtained through the initial information plus the new information with their respective attributes, quality scores, properties and the relationship score among such information.

This result is validated in the next step (multi-criteria association), which deals with the association between the information submitted to the fusion process and the synergistic information found. This association meets certain pre-defined criteria such as quality scores and pre-defined properties as satisfactory for each association or type of information. The following process inserts the new information found within the context of the original information submitted to the process, in order to achieve and meet the multi-criteria defined in the previous process.

Multi-criteria fusion generally obeys two requirement sources: an input of a human expert entry/interaction during system operation or based on well-defined criteria established during requirement elucidation conducted during project phase.

As a result, every initial information submitted to the fusion process is generated, however, with new attributes, properties and even new objects found during the fusion process, thus making results explicitly L2 level (Situation Assessment).

This result can be submitted again to the previous process of synergy search, increasing its capability to find new information and consolidate the information already available. In this manner, information increasingly specializes in the current situation, or in a single part of the situation, depending on the input. This cycle is performed when the result of the Multi-criteria Association, objects, attributes, indexes of quality and properties are not within the parameters required, defined by human input or delimited by the system.

If this second process is not carried out, the resulting information will be submitted to the quality assessment process, now scoring the new information found and reconsidering the general scores of information. After this process, the information re-evaluated by the quality assessment is re-instantiated in the ontology and represented in the system, according to the request of the operator.

In the primary fusion phase, in the automated process performed immediately after the acquisition and evaluation of the quality of information, it is made the most associations possible between objects, their attributes, properties and their rates of pre-determined quality and quality thresholds, considering the existence of two or more data sets available from the same source or from different sources.

The primary fusion meets informational requirements that are, the criteria of priorities defined the analysis of requirements, such as minimum levels of quality and main properties between information, which is useful to define what should be built first and consequently shown to the human expert. These informational requirements are based on an analysis questionnaire applied to several police officers of different positions, functions, and career time, thus ensuring a heterogeneous view of the subject, and also managing to validate the most important criteria to a given situation.

In the case of the fusion on the demand of the operator, the algorithm is activated once again, but the criteria for integration are entirely selected by the operator via interface, instead of all possible combinations of automatic objects, attributes and properties identified in the acquisition phase.

This association process, now manual, is operated via interface by the expert, and besides being based on objects and attributes, these associations is strongly supported in related quality scores, and suggest hypotheses about information relating to previously identified objects with other objects identified by other sources related to the real environment.

Since this input process is performed by the operator via interface, the criteria for the data fusion process can be chosen and changed by the same operator, who is able to add new features, as well as removing criteria pre-defined by the requirement analysis. This capability demonstrates the flexibility of the framework to receive and process different criteria for a given situation, and allows the agents to better interact with the system based on their experiences and knowledge, thus ensuring a process of construction and development of SAW very close to the real environment.

4 Case Study

To analyze the processing of the algorithms described in the previous section, semantic fusion techniques were adopted and a simulation was performed with an actual case using reports transcribed of the same crime, reported service 911 to PMESP. Such reports were submitted to the process of Fig. 1 and the results were compared with and without the use of the semantic approach.

With the first report no information fusion occurs, considering that its information is unique and there are no parameters for an integration. Hence, objects and classes are just listed, found on the possible occurrence and created as the first Situation.

Report 1: "**a crime has just happened** here on **domingos setti**. A driver was threatened and ordered to leave the vehicle without taking anything. **The robber fled toward the subway klabin**";

As there is no other occurrence or report in the database, only the objects present in the report, marked in bold, were identified, such as time, place, criminal, data about how the escape occurred and the new calculated quality scores. This process will have the same result, regardless of fusion as it is done through the process of acquisition and classification of incoming information, best explained in Sect. 3 of this paper.

At the following moment, a fusion between the Situation 1 and a new report occurs, considering the moment a second report reaches the system. Such report goes through the process of acquisition and classification of the information normally. By this moment, the differences between the syntactically fused information and the semantic information fusion arise.

Report 2: "**a guy was robbed** in front of me by **someone armed.** It happened so fast and was in **domingos setti near the restaurant don paladino. The thief had a gun was tall and had tattoos on his arms.** He hit **the man and he looks very hurt**".

In the second report, we have more information on the occurrence, such as: the victim, the place and the criminal.

Again without the use of semantics, a fusion of the situation already instantiated in the system, with the new report 2, occurs, generating the Situation 1:

Situation 1: "**just happened** a crime here on **domingos setti** a driver was threatened and ordered him to leave the vehicle without taking anything **the robber fled toward the subway klabin**";

In this situation already instantiated, we find the following objects: time, place, stolen object and criminal. The fusion examines the objects that are already instantiated in the situation and their quality scores, places of each object and the overall situation. Thus, there is a Boolean and syntactic analysis and parsing operation between objects of Situation 1, with data from the new report, validating which are present and if the information has some level of similarity, considering minor syntactic variations, also with the quality indexes, validating if both are sufficient and will contribute to better quality of general information.

Depending on the result, new possible situations are generated, filled with the information present in both previous objects. The quality indexes are not yet updated, but only kept together with the information for future usage as calculation parameter.

In this example, the only objects with some similarity are those regarding the location information, "domingos setti", this result is obtained by a syntactic analysis. As the result from this information, we have the update of the criminal information, the update of the location information and the addition of a victim object. The result is shown in Fig. 4.

After this fusions process, the quality indexes are not updated. This resulting situation is resubmitted to the quality assessment process, which will re-evaluate the quality scores considering the new information presented.

This was the syntactic fusion process information using quality indices which presents the information and the situation as a general and generic context.


```
"criminal":{
    "sex":"male",
    "status":"fleeing",
    "escapeTo":"Klabin subway",
    "height":"tall",
    "weapon":{"armed", "pistol"},
    "tattoo":`{"arms"},
    "completeness":42.85,
 },
 "object":{
    "completeness":9.09,
 },
"victim":{
   "sex":"male",
   "condtion":"bruised",
   "wordReference":{"a guy", "man"}
   "completeness":42.85,
},
"place":{
   "street":"domingos setti",
   "reference":"restaurant don paladino ",
   "gps":{"-22.2208"," -49.9486"},
   "completeness":41.66,
}
```


Fig. 4 Objects after syntactic fusion with quality score

The fusion between the first situation, as instantiated in the system, with the new report received, which has passed through the process of acquisition, classification and evaluation of information quality, will again be performed using ontologies techniques to improve the results of the process, making the semantic fusion of information.

At this point the synergistic search process and association between the information not only occurs in a Boolean form, evaluating the presence information, and syntax, considering word constructs, with minor variations and quality scores assigned to information and the complete situation. The semantic process considers the meaning of the word that regards an information and not only its structure.

Considering the synergistic search algorithm and applying the techniques of semantic proposals, it is possible to have a wider search and more possibility of synergy points between the existing situation and new reports obtained.

At this stage, using semantics we may obtain a bigger and better synergistic amount of information between the situation and the new objects.

This synergy, in this case, also gives the location because it matches the exact description of it (“domingos setti”) but looking at the two reports, it is clear that they refer to the criminal as “the robber” while other treats they as “a thief” and “someone armed”.

In the conventional synergistic search process, these data were not related. They have a very distinct syntax, however, the terms have the same meaning, which is the criminal of this situation. The synergistic information is highlighted.

Report 1: “a crime has just happened here on **domingos setti**. A driver was threatened and ordered to leave the vehicle without taking anything. **The robber** fled toward the subway klabin”;

Report 2: “a guy was robbed in front of me by **someone armed**. It happened so fast and was in **domingos setti** near the restaurant don paladino. **The thief** had a gun was tall and had tattoos on his arms. He hit the man and he looks very hurt”.

This process is possible because the ontology proposal already has a basic knowledge, listing the main and most common terms, such as thief, bandit, criminal and other variations of these words, which express the same meaning when fusing the analyzes, generating a situation with much more complete and accurate information (Fig. 5).


```
"criminal":{
    "sex":"male",
    "status":" fleeing",
    "escapeTo":"Klabin subway",
    "height": "tall",
    "weapon":["armed", "pistol"],
    "tattoo":["arms"],
    "wordReference":["the thug", "the
thied", "armed someone"],
    "completeness":42.85,
  },
  "object":{
    "completeness":9.09,
  },
"victim":{
    "sex":"male",
    "status":"hurt",
    "condtion":"bruised",
    "wordReference":["a guy","man"],
    "completeness":42.85,
},
"place":{
    "street":"domingos setti",
    "reference":"restaurant don paladino ",
    "number":null,
    "gps":["-22.2208"," -49.9486"],
    "completeness":41.66,
}
```


Fig. 5 Objects after semantic fusion with quality score

In Fig. 5, the information highlighted was considered synergistic semantic information during the fusing process. This demonstrates the algorithm's ability to interpret contexts and situations, which expands the search and integration of data using semantics. Current inferred information feeds the knowledge about situations (aka situational knowledge) represented by the ontology, which is updated every cycle and reused to perform new inferences.

Before this resulting information is presented to the operator, it can be once more submitted to the fusing process in case they are not within the related criteria or submitted to the quality assessment, which will re-evaluate the quality scores based on new information found. After the quality re-assessment, this information will be set in a new ontology that represents the current situational knowledge and then it will be presented to the operator via interface.

5 Conclusions

This paper presented an approach for including semantics into the fusion process by feeding the inference routines with the awareness of information quality and using their indexes as part of the multi-criteria fusion algorithms. Such approach was presented initial steps of a new solution that process may be coupled into situation assessment systems for specialists to reason about information of lower dimensionality and better quality.

For such, this work also presented methods for information fusion, natural language processing, information quality assessment and knowledge representation to be employed in such process.

The application of the process and associated methods generated valid results regarding the obtaining of expected information useful for developing SAW, according to the requirements defined by the domain specialists. Such information was successful incrementally built using syntactical and semantical input. The use of multi-criteria information fusion empowered the assessment of situations by generating several integration possibilities of synergic information for the analysis of a specialist. Also, the specialist has the possibility to define the criteria (through user interfaces) and the information quality threshold for the parameterization of the fusion algorithm.

Subsequently, the comparisons made between the simple data fusion with the semantic information fusion show that new components, such as Semantic Web technologies, can bring improvements to the processes, making more efficient the discovery of information. This comparison makes explicit the need to insert mechanisms that bring greater intelligence to processes dealing with fusion and SAW.

Finally, with the establishment of new relations empowered by semantics and information quality, authors stated that the situation awareness of decision-makers may be improved once uncertainty about situations and their assets can be mitigated.

As future work, the authors intend to expand and optimize the techniques of acquisition and natural speech processing, as well as methods that make fusion engine, expanding the ability to search and synergistic association data. Also, study and improve the data-mining algorithm from semantic data, as well as the power of its association of multiple criteria, increasing the power to process different inputs, given the multitude of criteria, linguistic or quantitative.

References

1. Kokar, M.M., Endsley, M.R.: Situation awareness and cognitive modeling. IEEE Intell. Syst. **27**(3), 91–96 (2012)
2. Blasch, E.: Information fusion for decision making. In: Computer and Systems Science, vol. 198 (2005)
3. Bossé, E., Paradis, S., Breton, R.: Decision support in command and control. In: Computer and Systems Science, vol. 198 (2005)
4. Vincen, D., Stampouli, D., Powell, G.: Foundations for system implementation for a centralised intelligence fusion framework for emergency services. In: 12th International Conference on Information Fusion. FUSION'09, IEEE, pp 1401–1408 (2009)
5. Nilsson, M., Van Laere, J., Susi, T., Ziemke, T.: Information fusion in practice: a distributed cognition perspective on the active role of users. Inf. Fusion. **13**(1), 60–78 (2012)
6. McGuinness, D.L.: Ontologies for information fusion. In: Proceedings of the Sixth International Conference on Information Fusion, pp. 650–656 (2003)
7. Souza, J. Botega, L., Santarém Segundo, J.E., Berti, C.: Conceptual framework to enrich situation awareness of emergency dispatchers. In: 17th International Conference on Human-Computer Interaction, Los Angeles. Lecture Notes in Computer Science (LNCS) (2015)
8. Blasch, E., Steinberg, A., Das, S.: Revisiting the JDL model for information exploitation. In: Information Fusion (2013)
9. Carvalho, R.N., Laskey, K.B., Da Costa, P.C.G., Ladeira, M., Santos, L.L., Matsumoto, S.: Probabilistic ontology and knowledge fusion for procurement fraud detection in Brazil. URSW **527**, 3–14 (2009)
10. Costa, P.C., Laskey, K.B., Chang, K.C., Sun, W., Park, C.Y., Matsumoto, S.: High-level information fusion with bayesian semantics. In: Proceedings of the 9th Bayesian Modelling Applications Workshop (2012)
11. Kim, H., Son, J., Jang, K.: Semantic data fusion: from open data to linked data. In: Proceedings of the European Semantic Web Conference (2013)
12. Llinas, J., Bowman, C., Rogova, G., Steinberg, A.: Revisiting the JDL data fusion model II. In: 7th International Conference on Information Fusion (2004)

A New Proposal of Lighting Design Layout for Workplaces

Cristina Caramelo Gomes and Sandra Preto

Abstract Contemporaneous life encourages individuals spending too much time indoors. Workplace environments are changing due to new methods of work, technology and the need to answer to user's requirements and expectations. Interior environments are supported by natural and artificial light. It is widely accepted that natural light has a significant impact in individual sense of comfort and well-being; artificial light does not present the same positive impact in individuals. For organizations energy efficiency is the main goal, neglecting the impact on human well-being and performance. There is a multidisciplinary approach to lighting design research but the gap between the results and their application in practice still exist. This paper aims to raise the discussion around lighting design in working environments and the need to improve the contribute of natural light and the need to study carefully artificial light solutions towards the management of its effects in human visual and non-visual systems.

Keywords Natural light · Artificial light · Visual and non-visual human system · Workplace environment · Lighting design layout

1 Introduction

This paper aims to raise the discussion about the impact of lighting design in workplace environs. There is an array of multidisciplinary data that establish technical parameters impact in human sense of comfort and well-being, and professional performance. Scientific areas such as neuroscience, optics, psychology, architecture, lighting design for example produce knowledge, disseminate results but there is no

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solid connections between them. Despite the multidisciplinary possible to find in the available information, the relationship between data, studies and results is scarce or inexistent. The relationship between academia and industry, grieves from the excessive theorizing disregarding practice purposes and the practice without being supported by the theoretical knowledge. Thus, the specific objective of this piece of research is to give a new approach to the conception of workplace's lighting design, by the understanding of the impact of light in human visual sense, body functioning and sense of well-being, environment perception and tasks accomplishment. Workplace environs are changing due to the introduction of new methods of work, the increase of technological equipment and the need to respect human dignity throughout the guaranty of user dignity and inclusivity. Working hours are increasing as increases the time that we spend indoors. The use of technological gadgets such as computers, laptops, tablets, mobile phones, etc.… change and challenge the workplace lighting design. If ergonomics features of furniture and equipment are answering to this trial lighting design remains frozen in standard and inadequate solutions supported by spatial configurations, stereotyped suspended ceilings and technical parameters of lighting fixtures. Natural and artificial light are complementary subjects but with different parameters and impact on human beings. Interior environments, particularly the ones conceived to work, depend considerably from artificial light, which produce a significant effect on human visual and non-visual systems, which can be confirmed by the discovery of the third photoreceptor in the retina, ipRGC (intrinsically photosensitive retinal ganglion cells). It seems crucial to produce knowledge supported by multidisciplinary approaches and start to suggest informed solutions that can be implemented in order to build up pilot studies updated with human requirements and expectations, technical development and the tasks performed despite its traditional, new or adapted way to be performed.

2 Literature Review

2.1 Visual and Nonvisual Systems

The light influences the human sense of comfort and well-being in a biological, physiological and psychological way [1, 2]. Interior environments and their natural and artificial light contribute to our sense of awake and somnolence once the lighting level influences our circadian rhythms [3, 4]. Beside visual photoreceptors, cones and rods, the human eye also contains non-visual photoreceptors, the ipRGCs, which affects the circadian rhythm. The intrinsically photosensitive retinal ganglion cells (ipRGCs), recently discovered, stimulate sections of the brain that influence the human cognitive functions. The suprachiasmatic nucleus (SCN), located within the hypothalamus (Fig. 1) through the light perception, guides our sympathetic and parasympathetic systems and informs the human body when to regulate multiple functions such as body temperature, sleep patterns, cognitive

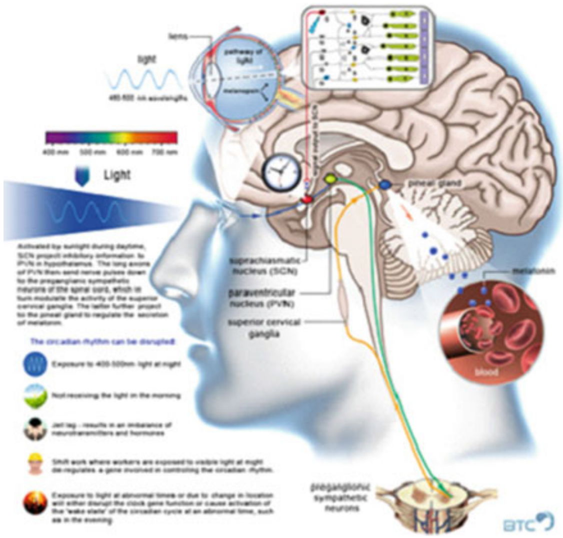

Fig. 1 Circadian rhythm [8]

performance, mood, well-being; it influences also the release and production of hormones like melatonin (in the absence of light, by the pineal gland) and cortisol [1, 5, 6] in the morning making us alert stimulating the production of serotonin, by the pituitary gland, which make us feel vigorous and active [6, 7].

The insufficient exposition to natural light during the winter season contributes significantly to the development of seasonal affective disorder (SAD) [9, 6]. There is an inversely proportional balance between the production of the pituitary hormones and the pineal gland. When the production of pituitary hormones increases the production of the pineal gland decreases and vice versa. The individual exposition to unsuitably high intensities of light in late afternoon disturbs the circadian rhythm, stimulating energetic states and challenging sleeping patterns [10, 11]. Supported by previous statement it is important to have a particular attention about the light that we expose ourselves along the time of the day and the seasons of the year; moreover, human beings exhibit different levels of retinal sensitivity. Thus, some lighting design' features allow and improve our visual acuity but they can be inadequate to our biological system [12].

2.2 *Differences Between Daylight and Artificial Light*

To discuss how the light, despite its natural and artificial character reveal indoor environs it is important to discuss the differences between them and its relation with human biological, physiologic and psychological requirements. Natural light connects us to natural world allowing the perception of time, weather conditions, seasons and geographic position. The advent of artificial light by opposite is

Fig. 2 Illuminance recommended for the optimization of the workplace environment and the synchronization of the circadian rhythm [15]

controlled by human requirements and expectations [13]. The disadvantages of artificial light rely on the temperature and glare produced by the use of incorrect sources of energy. Natural and artificial light are the two sides of the same coin which complement each other [3, 9]. Natural light can reach a higher intensity when compared with artificial one; daylight can achieve 100,000 lx with direct sunlight and 10,000 lx on a cloudy day [10, 14]. Indoor lighting design can reach levels of intensity which endangering human biological needs. The light levels for the biological effectiveness must be lower than 1000 lx (Fig. 2), its colour temperature must be similar to daylight and whenever possible it must be dynamic too [3].

The recent research results show that the non-visual effects of lighting design are gradually considered at the conception process of interior environs at physiologic and psychologic levels [5]. At workplace environs the fluorescent lamps are the most common in spite of new types of lamps with different forms, dimensions and effectiveness [14]. The flicker phenomenon, it is another parameter that can endanger our sense of comfort and wellbeing. As an example, if the fluorescent lamp has high-frequency electronic ballasts (around 30 kHz) the occurrence of headaches and eyestrain is less than with magnetic ballasts (50 Hz). As an alternative to fluorescent fixtures, LEDS are becoming more popular and this type of lamps allow to save energy reducing the carbon footprint, they need less management/replacement [6, 7, 14] although they can also produce the flicker phenomenon [9, 2]. However, the advantages of the LEDS are contradicted by the emission of blue light (400–500 nm) once this colour temperature is harmful to the eye since it impairs the retina and cellular DNA [16]. Beside lighting parameters, it is important to consider human nature, and this implies to look carefully to the chronological age of the user, once along human life cycle the requirements for light and the sensitivity to luminous differences and glare effects. This is a pattern in human nature, and beside this pattern it is important to consider any visual impairments that the individual can exhibit. Added to human requirements (Fig. 3) are the function and tasks requirements [11]. Lighting design is a complex art which demands more than technological knowledge. Changes in the ageing eye challenge the amount of light that reaches the retina demanding more light to perform individual and professional tasks. From the age of 35, there is a tendency to the decreasing of the pupil size and lens become thicker promoting light scattering in the eye which might raise human sensitivity to glare and impair the brightness

Fig. 3 Office worker put styrofoam around his desk in order to reduce the noise and light [19]

Fig. 4 3 harbour exchange [20]

adjustment (Fig. 4). The yellowing of the crystalline difficult the distinction of analogous colours which can be compensated by a light of cooler colour temperature [17, 18].

Individual requirements of light—due to personal or function parameters—can be provided by separately switched luminaires and task lights [9], individualised solutions can contribute to individual satisfaction as well as individual mood and productivity improvement [19]. Possible disturbs of mood can be encouraged by sleeping problems as a consequence of deficient exposure to daylight; this situation can be minimized by the exposure to artificial light with 1000 lx with a cool colour temperature of 4000 K or 5000 K between 9 am and 6 pm, since it is similar to daylight and stimulates the healthy functioning for the circadian rhythm [2, 19, 10]. At workplaces environs, the use of cool white light (blue light, 460 nm) it is very common once its features activate individual concentration [3, 18], however it is important to consider that this type of light has the capacity to suppress melatonin and increases dopamine, serotonin, and cortisol [10]. To minimize such disadvantage the solution can be the use of a dynamic lighting system, which could integrate changes in illumination level and light colour during the course of the day, and by consequence, similar to daylight, stimulate the human body. [6, 19].

2.3 Workplace

Offices' workplace design is based on the formal configuration of the building and the trends of the times in which they are built or rehabilitated. Technological equipment, furniture, finishing and lighting design depend on financial budget and author preferences—designer, architect, builder, owner, etc.…—disregarding the requirements of users and the tasks to perform. Although the lack of knowledge towards particular features of users (physical, behavioural, psychological) and tasks there are standard solutions concerned with technical as well as Ergonomic and Environmental Psychology for Design concepts which are commonly documented and recognised. The overlook of human and tasks heterogeneity leads to standard environments; new methods of work presents different requirements as the traditional one and despite this reality and designers' awareness the lighting outlines are incorrectly planned according to its location, type of light, orientation, intensity and colour temperature. Usually, the lighting design considers predominantly the illuminance on the working plan (horizontal surface) disregarding the illuminance that affects the vertical plan (particularly at the eyes level). A healthy light considers visual comfort while answering to users' visual and non-visual requirements [1, 3]. Workplaces are enlightened by natural and artificial light; users become more tired when they are exposed to lower levels of vertical illuminance. The ceilings and walls with glossy finish can be used as reflectors to affect positively the ipRGCs [3]. Workplace lighting design is based on general and task light switching from the illumination over a large area to particular areas such as desk or an area of it (Figs. 5, 6 and 7). The task light can be oriented to a local, allowing the user to adjust and control its direction and area of incidence where required or desirable [1, 6, 19]. This type of light is more important with the use of computers and other technical gadgets, once these equipment screens are self-illuminated. An arrangement of general and local lighting systems emerges as the best solution for increase our wellbeing through visual and non-visual comfort [1, 18].

The parameters such as illuminance and colour temperature are quantitative indexes used to calculate and assess office design lighting. The constancy of illuminance level affects human visual perception and mood [21]. Office spaces must offer finishing materials to arrange for different levels of luminance, once this is the parameter that allows the user to perceive the bright and glare on the visual field [2]. Traditional methods of work encouraged as a main goal the visibility on desk's surface; the intensive use of computers oriented the main goal to the required visibility of the digital equipment's screen. The IESNA Lighting Design Guide do not consider anymore the horizontal illuminance as the main goal when conceiving

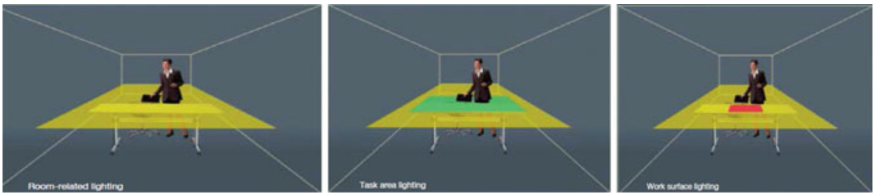

Fig. 5 Room-related lighting. Task area lighting. Work surface lighting [14]

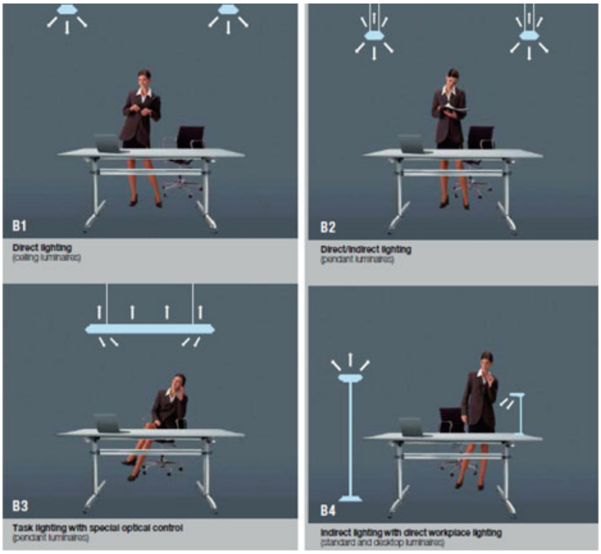

Fig. 6 *B1* Direct lighting (ceiling luminaires). *B2* Direct/Indirect lighting (pendant luminaires). *B3* Task lighting with special optical control (pendant luminaires). *B4* Indirect lighting with direct workplace lighting (standard and desktop luminaires) [14]

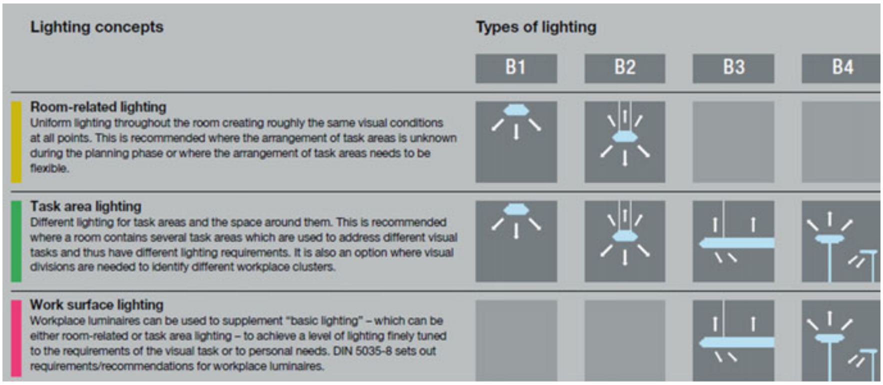

Fig. 7 Lighting concepts/types of lighting [14]

workplaces lighting design. The change of working methods from paper to computer encouraged to reduce horizontal illuminance levels [2], although the regular use of both and so, the required adjustments that this switch implies for user's visual comfort [22]. The objective of workplace lighting design needs to be rethought. Usually, lighting design is based on an invisible grid at the ceiling level in which the fixtures are located and illuminates uniformly all the space below. All the information delivered about lighting design impact on users' performance and

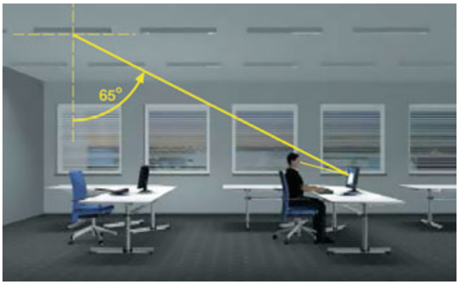

Fig. 8 Depending on the class of VDU, the mean luminance of luminaires which could be reflected on the screen needs to be limited to 200 cd/m2 or 1000 cd/m2 above a threshold angle of radiation of $\gamma \geq 65°$ (calculated at 15° intervals all around the vertical axis) to avoid disturbing reflections [14]

Fig. 9 The UGR method takes account of all the luminaires in the system which contribute to the glare sensation as well as the brightness of walls and ceilings [14]

wellbeing and the development of lighting components demands a new approach to the office lighting design idea [14]. A lighting reflection on a screen influences user visual acuity (Fig. 8); the presence of glare (Fig. 9) causes a psychological impact increasing the sense of tiredness and decreasing the concentration levels; this situation induces a lower visual performance and consequently increases the possibility of error. There are two types of glare, the direct and the reflected one, the first occurs when a bright point of light is positioned in the user's visual field; the reflect one occurs as the result of disturbing reflections from screens and glossy finishing from, walls, pavement, furniture or paper [14].

2.4 Window

Windows work as an escapement that enable the refreshment of the eyes and the de-stress of the mind, and these restoring experiences contribute to promote the sense of wellbeing [22, 23]. The natural human need to interact with natural world is caused by the feelings of serenity and optimism resulting from this interaction which decreases the psychological stress, aggressive behaviour and feelings of

Fig. 10 Interior showing sky gardens. Organic Grid + /Sean Cassidy & Joe Wilson. Image Courtesy of Metropolis Magazine [26]

depression. The windows encourage the interaction between users and nature (Fig. 10) and allow the natural light to invade interior spaces [24]. To control the amount of natural light, solar radiation, glare as well as shadows the windows can have devices such as blinds, light shelves, light reflectors, etc… [25].

The light that illuminates an interior space through a vertical window reveals a vertical illumination component as opposed to a ceiling-basic artificial down-lighting system, which is characterised by a horizontal-light component. The lighting design layout based on visual criteria for adequate light on the horizontal working surface does not guaranty a healthy working area lighting layout. To achieve the objective of a healthy lighting design layout both vertical and horizontal illuminance should be used as lighting design parameters [22]. Standard solutions reveal that the levels of illuminance are higher when a window is close and the illuminance level decreases significantly when the windows are distant (Fig. 11). Thanks to weather conditions, geographic location, season, time of day, and spatial location, and particularly the position and dimension of the windows, interior spaces can reveal a lack of light due to a lower illuminance level; this fact can be minimised by the support of artificial light [27].

2.5 Lighting Layout

Contemporaneous offices facilities consider the solution of suspended ceilings to hide and protect wiring and technical equipment. Repeatedly the stereotomy of the suspended ceilings are based on squares with 60 cm width (Fig. 12), which implies and support the position and distribution of fixtures [11]. Lighting design solutions must consider a multidisciplinary approach (such as neuroscience, chronobiology, architecture, lighting design, just to name a few), and achieve intelligent and effective solutions to lighting design. Pilot studies must be encouraged and good practices must be documented and information must be delivered [12].

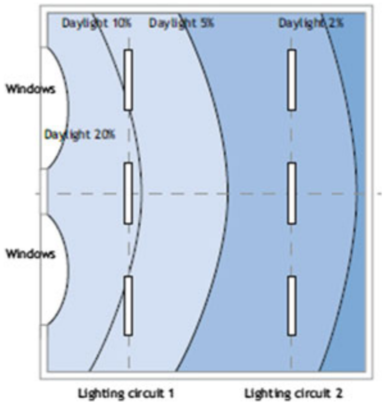

Fig. 11 Relation between daylight and window distance [11]

Fig. 12 Office renovation [28]

Less is more is a slogan linked to Mies van der Rohe, but it is also applicable at users' visual field at workplaces. Too much stimuli are not required nor desirable; when workplace environment encourages relaxation, satisfaction and good mood contributes to enhance the concentration and consequently the performance of more complicated tasks. An irregular fixture pattern on the ceiling blurs spatial layout and orientation, once the irregular solution attracts the users' attention. By opposition, a patterned fixture solution minimises the required effort to recognise the spatial layout and orientation. By consequence, lighting designer are simultaneously ceiling designers, and lighting design drawings must consider also fixtures' location, sprinkler heads, air diffusers, return grilles, smoke detectors, loudspeakers, and so forth. To prevent visual chaos, these ceiling elements are organized in an invisible grid [29]. The ceiling is an important part of the indirect lighting system once by its properties it must reflect the incident light that reached back into space. The ability of a ceiling to reflect light is indicated by its Light Reflectance or LR value. The LR values range from 0.00 to 1.00 and represent the percentage of reflected light. For example, an LR of 0.75 value means that the panel reflects 75 % of the light reached it. High light reflectance or Hi-LR ceilings have an LR of 0.83

or higher, these solutions increase the reflectance of a ceiling, allowing to increase the distance between fixtures and promoting a better management of the use of building's light and energy [30]. The common use of lay-in acoustic tiles ceiling allow the easy relocation and management of recessed fluorescent light fixtures and the access of all the area to manage technical equipment. Other solutions beyond lay-in acoustic tile ceilings exist such as drywall soffits. The relationship between the ceiling and the lighting design is always critical. In the large majority of offices environs, mechanical and electrical equipment and distribution pipelines are not exposed to give an aesthetical ceiling's appearance. Alternative solutions to the basic lay-in acoustic tile ceiling are limited, but several are viable, even with low budgets. Vertically positioned acoustic baffles and snap-on aluminium slat systems pops up in a pronounced range of colours and finishes. Suspended or floating panel solutions are available and have a particular impact when a dramatic effect is required and/or desirable. Translucent and luminous ceilings are quite popular in workplace environments; the use of materials with glossy finishing demands a diffuse ambient light. The office lighting design is always a compromise between the ideal solution, the real boundaries of the budget, the stereotomy of the ceiling and the trends and standards of the marketplace. In the large majority of the buildings, despite functions, standard solutions are suggested unless there is no constraint about financial budget; this reality has a direct impact on standard solutions in spite of the functions and formal configurations of the building [31].

3 Discussion

Lighting design boosts the architectural experience by reinforcing architectural elements and improving visual and psychological experiences throughout the space. Lighting design projects aim to create ambiences trough spatial identity or just to provide a visual performance to the user that interacts with the space. The user interaction with the space and the others is supported continually by functions and tasks performance. Beyond iconic ambiences and functional oriented solutions, lighting design tends to forget individual needs and expectations. Working environments are inhabited by dissimilar individuals, functions and ways of performing which require different types of light. However, reality illustrates standard solutions which are based on formal configuration of the space, suspended ceiling stereotomy, fixtures technical parameters, trends and tendencies and financial budget. Despite the information available about the lighting impact on human visual and non-visual system, this item is repeatedly neglected by lighting design professionals. Work environments should benefit from natural light which must be complemented by artificial light whenever other levels of light are desirable beyond the ones provided by sunlight. The importance of natural light features to human body demands artificial light with similar properties. The use of digital technology in working environments change and challenge the lighting design solutions. Parameters of artificial light such as intensity and colour temperature should change along the day alike natural light. An arrangement between ambient light and task light, which increase individual solutions oriented to tasks and individual's requirements, emerge as a model to follow. Standard solutions must be avoided once they do not give identity to space or contribute to a better performance of the function and much less for the well-being of the individual. A closer relationship between academia and industry is required and desirable. Innovative solutions are needed to be implemented to be studied, documented and disseminated. Sustainable solutions do not concern exclusively to an effective saving of energy, but to responsive environments that contribute to human sense of comfort and well-being.

References

1. Aries, M.: Human lighting demands—healthy lighting in an office environment. http://alexandria.tue.nl/extra2/200512454.pdf
2. Newsham, G.R., Veitch, J.A., Reinhart, C.F., Sander, D.M.: Lighting design for open-plan offices. https://www.nrc-cnrc.gc.ca/ctu-sc/files/doc/ctu-sc/ctu-n62_eng.pdf
3. Osram.com: light in its third dimension—the biological aspect of lighting design for better quality of life. https://www.osram.com/media/resource/hires/333819/light-in-its-third-dimension.the-biological-aspect-of-lighting-design-for-better.pdf
4. Cajochen, C., Zeitzer, J., Czeisler, C., Djik, D.: Dose-response relationship for light intensity and ocular and electroencephalographic correlates of human alertness. http://www.chronobiology.ch/wp-content/uploads/publications/2000_12.pdf
5. Boyce, P.: Human Factors in Lighting. CRC Press, Boca Raton (2003)
6. Licht.de—licht.wissen 19: Impact of light on human beings. http://www.lightingeurope.org/uploads/files/CELMA-ELC_Health_WG(SM)007_lichtwissen19_Impact_of_Light_on_human_beings.pdf
7. Boyce, P.R.: The impact of light in buildings on human health. http://sllp.org/bbs/data/file/csheb_Symposium/1226372677_dTXEituG_Peter_R_Boyce.pdf
8. ThePaleoMom.com: The new science of sleep-wake cycles (and how to improve yours!). http://www.thepaleomom.com/2015/08/the-new-science-of-sleep-wake-cycles.html
9. Walerczyk, S.: Human centric lighting & technology. http://nmaee.org/images/meeting/011513/STAN_WALERCZYK/stan_walerczyk___human_centric_lighting__technology_nm_ies_1_1_13.pdf
10. Rensselaer Polytechnic Institute: Human eye sensitivity and photometric quantities. http://www.ecse.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/Sample-Chapter.pdf
11. The Carbon Trust: Lighting—bright ideas for efficient illumination. https://www.lbhf.gov.uk/Images/J7802_CTV049_Lighting%20Overview_AW_Print_tcm21-179778.pdf
12. Wirz-Justice, A.: Light, health and wellbeing: implications from chronobiology for architectural design. http://discovery.ucl.ac.uk/1361488/
13. Russell, S.: The Architecture of Light. Conceptnine Print, California (2008)
14. Iesanz.Org: Good lighting for offices and office buildings. http://www.iesanz.org/_r328/media/system/attrib/file/971/lichtwissen04_offices_office_buildings.pdf
15. Tralau, B.: human centric lighting. http://www.ibe-biv.be/media/pdf/Studiedag_2014/06_Tralau.pdf
16. Lighting Global: LED lights and eye safety. http://global-off-grid-lighting-association.org/wp-content/uploads/2013/09/Issue_2_LEDLightsandEyeSafety_EcoNotes_final.pdf
17. Figueiró, M.: 24-Hr lighting scheme for older adult. http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab092627.pdf

18. Sleprojects.com: Smart lighting engineering—human centric lighting. http://www.sleprojects.com/data/files/HUMAN%20CENTRIC%20LIGHTING%20%28english%29.pdf
19. Walerczyk, S.: Task ambient lighting focus on DOE & California's new title 24 with tunable task lights. http://lightingwizards.com/wp-content/uploads/2014/03/TASK-AMBIENT-LIGHTING-fn.pdf
20. Maris Interiors LLP: 3 harbour exchange. https://www.google.pt/url?sa=i&rct=j&q=&esrc=s&source=imgres&cd=&ved=0ahUKEwj9_efUx9fLAhXI7hoKHbfxAEkQjxwIAw&url=http://www.maris-interiors.co.uk/building-expertise/3-harbour-exchange/&psig=AFQjCNH1CMWeOZW9JPRZkNdh73NLpROIfA&ust=1458848328876273http://www.maris-interiors.co.uk/building-expertise/3-harbour-exchange/
21. Lee, J.-H., Moon, J.W., Kim, S.: Analysis of occupants' visual perception to refine indoor lighting environment for office tasks. Energies **7**, 4116–4139 (2014)
22. Dodo, Y.A., Kandar, M.Z., Ossen, D.R., Jibril, J.D., Bornoma, A.H., Abubakar, A.I.: Importance of a view window in rating green office buildings. Adv. Mater. Res. **689**, 180–183 (2013)
23. Persky, E.C.: Biophilia and corrections: bringing nature into correctional environments. http://www.aia.org/aiaucmp/groups/ek_members/documents/pdf/aiab101434.pdf
24. Phillips, D.: Day and light—natural light in architectures. http://www.gbv.de/dms/bs/toc/377410780.pdf
25. Ochoa, C.E., Aries, M.B.C., van Loenen, E.J., Hensen, J.L.M.: Considerations on design optimization criteria for windows providing low energy consumption and high visual comfort. Appl. Energy **95**, 238–245 (2012)
26. ArchDaily.com: Workplaces of the future to abandon the open plan and feed employees with sky gardens. http://www.archdaily.com/591039/workplaces-of-the-future-to-abandon-the-open-plan-and-feed-employees-with-sky-gardens
27. Tregenza, P., Wilson, M.: Daylighting: architecture and lighting design. Routledge, London (2011)
28. eOffice.London: Week two of eOffice Holborn renovation. http://www.eoffice.london/post/109394046266/week-two-of-eoffice-holborn-renovation
29. Gordon, G.: Interior lighting for designers. Wiley, New Jersey (2003)
30. Armstrong.com: Health care—high light reflectance ceilings—energy savings and environmental benefits of high light reflectance ceilings. http://www.armstrong.com/common/c2002/content/files/38652.pdf
31. Karlen, M., Benya, J.: Lighting Design Basics. Wiley, Hoboken (2004)

Testing the Effect of Audio, Visual, and Heat Stimuli on Pilots Generated by an Aircraft Bird Strike Collision Avoidance System

Blake Abrecht and Jeffrey Newcamp

Abstract An experiment tested the effects of audio, visual, and heat stimuli on pilot performance during high cognitive workload (critical) phases of flight. The experiment tested pilots flying a flight simulator while performing tracking tasks and secondary cognitive tasks with external audio and visual stimuli present. The results of this study indicate that with the tested combination of audio, visual, and heat stimuli present, the change in pilot tracking task performance was not statistically significant. However, pilots' secondary cognitive task performance decreased with the presence of these external stressors. Although these results indicate that the presence of the tested combination of external stimuli adversely affected pilots' secondary task performance in a laboratory setting, because of the drastic difference in experimental conditions versus actual flight conditions, it is concluded that the tested combination of stimuli is safe to utilize in any bird strike countermeasure system intended to be implemented on an aircraft.

Keywords Collision avoidance · External stimuli · Task performance

1 Introduction

Given the frequency of bird strikes that contribute to aviation incidents and the high cost of aircraft repair and potential loss of life when these incidents occur, various attempts have been made to design external systems to lower the occurrence of bird strikes. While much focus has been on designing and fielding systems for use on the ground, other recent efforts have considered integrating bird strike collision

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avoidance systems onto airframes. Such efforts could allow for a wider range of system effectiveness to include regions well beyond the airport environment; however, the integration of such a system onto airframes poses a potential human factors problem for the pilots in command of these aircraft. The same elements that are used to alter avian flight trajectories are considered external stressors in the aviation environment that could degrade pilot performance.

The effect that external stressors have on human operators has been studied extensively over the past sixty years, yet, many of the previous studies have only assessed the effect of single stressors. Although some studies have analyzed the combined effects that multiple external stressors have on human task performance, there has been no previous study that has assessed the combined effect of flashing lights and noise in an aviation cockpit environment.

The first study to test the effects of noise on human performance was conducted in the late 1950s. Participants completed various tasks under quiet noise conditions (roughly 80 dB) and the same tasks under loud noise conditions (roughly 115 dB). Researchers concluded that "it is clear that noise produces readily measurable changes in human performance; [however], the effects of psychological stress may have been more important than noise" regarding the change in human performance [1]. In 1989, a study was conducted to assess how pilot performance could be affected by biodynamic stressors. Having participants perform dual psychomotor tasks in a centrifuge, researchers determined that "biodynamic stressors, such as noise…can adversely affect subjective operator workload without affecting objective task performance" [2]. However, it is important to note that the presence of multiple stressors, which included acceleration, heat, cold, noise, and vibration, was not tested.

Because these past experiments only tested the effect of single stressors, other experiments that tested the effect of combined stressors were studied. In a 2007 experiment, researchers tested participants' ability to read characters on a computer screen while in a mobile driving environment. Measuring vehicular vibration and noise levels, researchers determined that "noise has a significant negative effect on the performance of a readability task in a mobile driving environment" [3]. Similarly, when experimentation assessed the physiological function and performance of pilots in the Air Combat Maneuvering environment in the Naval Air Development Center's Human Centrifuge while under a combination of stressors, researchers found that combined stressors "resulted in a significant decrease in tracking accuracy" [4].

As previous literature suggests, studies have been conducted to test the effect of stressors on users during various task-involved situations. Yet, a deficiency exists in that no study has expressly addressed the combined effect of flashing lights and noise in an aviation cockpit environment. While certain research suggests that the presence of some stressors do not affect objective task performance, other research suggests that human performance can in fact decrease while being exposed to various stressors.

Finding an answer to this question is vitally important. Research is currently being conducted to produce a viable and effective bird strike collision avoidance system that utilizes a combination of light and sound stimuli on the aircraft to deter birds and prevent bird strikes in the air environment. It is thus paramount to determine whether a pilot's flying performance or cognitive workload will be degraded in an aircraft that is operating near a bird strike collision avoidance system that utilizes such stimuli.

2 Method

2.1 Experimental Design

The experiment that was designed to test the effect of the combined external stressors was a within-subjects design, meaning that pilots were assigned to both the experimental condition and to the control condition, with the order of execution being randomized. During the experimental condition, pilots were exposed to the audio and visual stimuli while performing a sinusoidal tracking task and were asked logic and mathematics questions by a researcher. The control condition was identical; except that pilots were not exposed to the audio and visual stimuli. Each pilot completed four, 90-s trials, with two trials being under the experimental condition and two trials being under the control condition. The independent variable was the condition stimulus present versus no stimulus present. The dependent variables were the accuracy of the sinusoidal tracking tasks (SOS Task) and the number of logic and mathematics questions that the pilot answered correctly.

2.2 Participants

There were 31 pilots, both male and female, who participated in this experiment. These pilots were active duty military officers, civilian faculty members, and military academy cadets of all four classes (freshman through senior) from the United States Air Force Academy in Colorado. Participation was limited to pilots who had a minimum of 10 logged flight hours over the past year and who had no history of epileptic seizures based on self-reporting.

2.3 Apparatus

The aviation cockpit environment is quite an interesting study location because pilots can easily become task saturated with flying, navigating, and communicating tasks. The cockpit is a difficult environment to mimic on the ground and care must be taken to ensure an experimental setup is analogous to the flying environment. This experiment utilized the Calspan Genesis 4000 Flight Simulator System. The

Table 1 Sinusoidal tracking task parameters

Description	Value
SOS pitch task gain	2
SOS roll task gain	15
SOS fade-in time (s)	2
SOS fade-out time (s)	2
SOS task duration (s)	95
SOS random phases (1 = Random)	1
Delay until scoring starts (s)	5
Scoring duration (s)	90
Pitch desired tolerance (°)	0.5
Pitch adequate tolerance (°)	1
Roll desired tolerance (°)	3
Roll adequate tolerance (°)	7

flight conditions of the Genesis 4000 were set to straight and level flight prior to the beginning of the experiment. Pilots participating in the experiment used the simulator's center stick to control the simulator. The Genesis 4000 was programmed to run a sinusoidal tracking task program. The parameters of the sinusoidal tracking task are shown in Table 1.

To create the audio stimuli, a PSAIR12 300-W amplified speaker with a PSCBL-RCU-10 ten foot remote control cable, a PSCBL-DC-10 ten foot power cable, and a PS-BAT-28 PB 28-V battery were used. The speaker system played an audio file that combined a Canada goose distress call and background aircraft engine noise with a frequency range of 0–11,000 Hz at 90 dB.

To create the light stimuli, a General Electric 600-W Airbus A320 landing light was connected to two 12-V batteries with an average voltage of 24.43 V per trial. This landing light was connected to a custom-built flashing unit programmed to flash at 0.75 Hz. The landing light increased surface temperature of the pilots' skin by 11° Fahrenheit over each 90-s trial, as measured by a laser temperature meter.

There were four sets of 15 mathematics and logic questions, which included addition, subtraction, multiplication, division, definition, and short answer questions. Each set was equivalent in difficulty, as determined by the research team. A generic stopwatch was used to record the time for each 90-s trial.

2.4 Procedure

To begin the experiment, each pilot was given 2 min of free flying with the Genesis 4000 simulator so that they could become familiar with the sensitivity of the control stick. Once the free flight period ended, the test began. The order of conditions was randomized; therefore, some pilots began the first 90-s trial with the stimulus present while other pilots began the first 90-s trial without the stimulus present.

Once the pilot indicated that they were ready to begin the trial, the sinusoidal tracking task was turned on (the stimuli were turned on as well for the experimental condition).

Five seconds into the tracking task, a researcher began asking mathematics and logic questions. The next question was not asked until the pilot either gave an answer or indicated that they wished to pass on the question. No feedback was given regarding whether the pilot answered the question correctly. Each trial contained a different set of 15 questions of equivalent difficulty.

Once the first 90-s trial was complete, the tracking task performance and number of questions that the pilot answered correctly was recorded. A 30-s break was given before the next trial began. Pilots completed four, 90-s trials, with the condition alternating between each trial, resulting in the pilot completing two control trials and two experimental trials.

For the experimental condition trials, the aircraft landing light and PSAIR12 speaker were set five feet to the pilot's right side at a 45° angle. These apparatuses were turned on when the sinusoidal tracking task began and stayed on for the entire 90 s of the trial.

3 Results

Before the experiment began, it was determined that any pilot who was unable to perform the sinusoidal tracking task at the desired level for at least 5 s would be excluded from the data analysis. Of the 31 pilots who participated in this experiment, the data from two pilots were outliers. These outliers were excluded because the pilots met the preset desired performance parameters on average less than 5 s per trial for each of the four 90 s trials. Excluding these outliers, 29 pilots performed adequately and their performances were subsequently analyzed.

Using the John's Macintosh Program (JMP) software developed by the JMP business unit of the SAS institute, multiple multivariate analyses of variance (MANOVA) statistical tests were used to analyze the collected data. A probability of 0.05 was used to determine significance. Trials were split into two test conditions, with one condition signifying that the first and third trials had the stimulus present and the second and forth trials did not have the stimulus present. The second condition signified that the first and third trials did not have the stimulus present while the second and fourth trials did have the stimulus present.

After performing each trial, pilots were assigned their Theta Root Mean Square (RMS) Error, which assessed pitch performance, and the Phi RMS Error, which assessed roll performance in the sinusoidal tracking task. The lower the error, the better the pilot performed regarding the tracking tasks. A MANOVA test was conducted on the Theta RMS Error between the two conditions. It was found that the ($F(1,3) = 9.37$, $p < 0.05$) for the trial number and ($F(1,3) = 0.60$, ns) for the trial number versus the condition. This showed that there was no interaction between the trial number and the condition, meaning that the presence of the stimulus did not have an effect of the ability of the pilot to perform the tracking tasks throughout all trials. However, there was an interaction between trial numbers, meaning that a learning effect occurred for pilots as the experiment progressed through the trials. Running a MANOVA test on the Phi RMS Error yielded similar results, ($F(1,3) = 5.00$, $p < 0.05$) for the trial number and ($F(1,3) = 0.34$, ns) for the trial number versus the condition.

However, although a learning effect occurred across all trials analyzed together, when the Theta RMS Error and Phi RMS Error across Trial 3 and Trial 4 were analyzed, there was no learning effect present. The trial number analyzed across Trial 3 and Trial 4 resulted in ($F(1,1) = 0.01$, ns) for the Theta RMS Error and ($F(1,1) = 4.15$, ns) for the Phi RMS Error. Figures 1 and 2 show the graphical analysis of these results.

These data indicate that no significant interaction existed between the second set of trials and no significant learning effect was present during the final two trials of the experiment. The trial number versus the condition resulted in ($F(1,1) = 0.24$, ns) for the Theta RMS Error and ($F(1,3) = 0.03$, ns) for the Phi RMS Error, indicating that although no learning effect was present, the presence of the stimuli still did not affect pilot performance regarding the sinusoidal tracking task across the last set of trials.

Because it was determined that a learning effect was no longer present between Trial 3 and Trial 4, these two trials were analyzed regarding the secondary cognitive task. Calculating a MANOVA test that assessed the number of questions answered

Fig. 1 Theta RMS error versus trial across Trial 3 and Trial 4

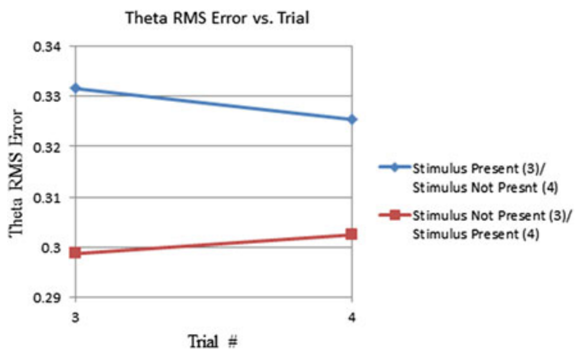
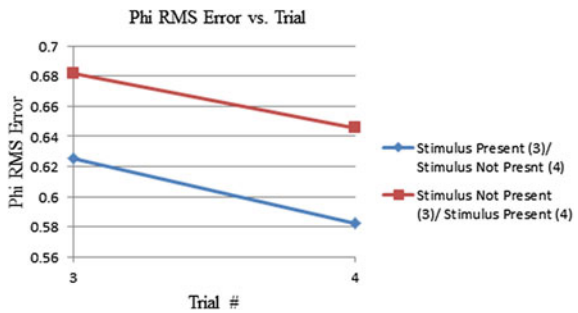


Fig. 2 Phi RMS error versus trial across Trial 3 and Trial 4



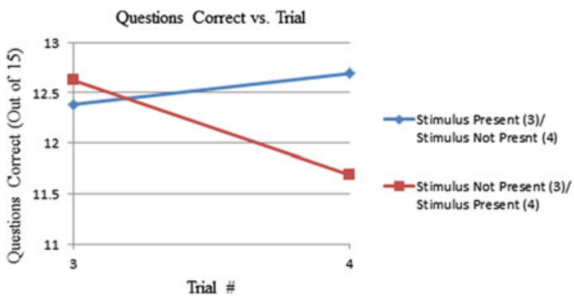


Fig. 3 Questions answered correctly versus trial across Trial 3 and Trial 4

correctly out of 15 between Trial 3 and Trial 4, it was found that ($F(1,1) = 1.24$, ns) for the trial number (confirming that no learning effect was present) and ($F(1,1) = 4.87$, $p < 0.05$) for the trial number versus the condition. Figure 3 shows the graphical analysis of this result. This result showed that an interaction did occur between conditions and that pilots performed worse on the secondary cognitive task with the external stimuli present.

In summary, after analyzing the results, it became apparent that even with measures in place to eliminate a learning effect, a learning effect did occur during the first two trials; however, the last two trials did not experience a learning effect. Assessing Trial 3 and Trial 4 for the Theta RMS Error and Phi RMS Error showed that the presence of the external stimuli did not affect pilot performance regarding the sinusoidal tracking task. However, analyzing the questions answered correctly between Trial 3 and Trial 4 showed that the external stimuli did negatively affect the secondary cognitive task performance.

4 Discussion

As a result of this experiment, it was concluded that when conducting a sinusoidal tracking task on a flight simulator, pilots' performance was not degraded when the combination of audio, visual, and heat stimuli were present. However, when assessing the secondary cognitive task performance of the pilots, their performance was worse when this combination of stimuli was present.

These results support the conclusions found in previous stressor experiments. Based on the audio stressor study conducted by Jerison in [1], it was concluded that participants in that study performed worse in various tasks when louder levels of volume were present. While pilots in our study were able to maintain their level of tracking performance, this came at the expense of the secondary cognitive task. This further supports the results found in [2] which concluded that noise can adversely affect workload without affecting the primary task that is being conducted. It also supports the results found in [3] which concluded that noise had a significant negative effect on reading ability while driving, a secondary task that increased the cognitive workload of the participant. Our experiment did differ from results found in [4] which concluded that when presented with a combination of stressors in a centrifuge, participants' ability to track objects was degraded.

The main difference in this research compared to previous research on external stressors is the specific combination of stressors that were involved. Many previous experiments have tested the effect of audio stimulus, visual stimulus, or heat stimulus; however, the combination of these three stressors has not previously been tested regarding the effect on tracking tasks and secondary cognitive tasks of pilots. It may be that any one of these three stressors, or the combination of all three stressors affected the outcome of this experiment. Further research is necessary to determine how each stimulus affected the performance of the pilot participants.

This experiment was initially designed to test the effect of audio and visual stimuli and how this combination of stimuli affected a pilot's tracking performance and secondary cognitive task performance. The presence of the heat stimulus arose due to the experimental set-up and was not initially intended to be a part of the experimental design. A fielded bird strike avoidance system is unlikely to cause a rise in temperature near a pilot.

The inspiration for this study came from research that is being conducted to create a bird strike collision avoidance system that is intended to reduce or eliminate airborne bird strike occurrences. If it could be shown that the combination of audio and visual stimuli did not adversely affect a pilot's performance in an aircraft near a plane that utilized such a countermeasure, then the safety of such a system could in part be validated. However, it is important to note that the experimental condition differed drastically from actual flight conditions. First, if such a system were to be utilized on an aircraft, passing aircraft would only be exposed to the audio and visual stimuli from the system for a matter of seconds at a remote distance. However, the experimental condition tested the effect of the stimuli when it was five feet from the pilot participants. Based on the results of this study, it can be concluded that a bird strike collision avoidance system that utilized this combination of stimuli would not negatively affect pilots in nearby aircraft.

Certain limitations exist that affect the conclusions that can be drawn from this study. It was found that the combination of audio, visual, and heat stimuli did not affect the pilot's tracking performance while it did affect the secondary cognitive task performance. However, the secondary cognitive task was only assessed based on the number of questions that pilots answered correctly. A more in-depth cognitive workload analysis, such as the NASA-TLX is required to draw a more detailed conclusion regarding cognitive workload. Furthermore, the application of this study is intended for pilots in a flying environment. Actual flight conditions vary considerably from flight simulator conditions, which could affect the application of this study. Lastly, because this experiment was conducted in a controlled environment, pilots could have focused mainly on the primary tracking task while disregarding the secondary cognitive task. In a real-world environment where radio communication or other flight related tasks are critically important, the workload distribution could be altered, resulting in the external stimuli affecting the pilot differently.

5 Conclusion

When exposed to a 600-W landing light flashing at 0.75 Hz set at a 45° angle 5 ft from the pilot, with the light increasing the surface temperature by 11° over a 90-s period and a 90 dB audio signal present, pilots flying a flight simulator were able to consistently perform sinusoidal tracking tasks. However, pilot performance regarding a secondary cognitive task was degraded. This research validates the safety of any bird strike collision avoidance system seeking to utilize this combination of stressors. However, further research is necessary to fully understand how this combination of stressors affects tracking tasks and secondary cognitive tasks.

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Disclaimer The views expressed in this article are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.

References

1. Jerison, H.J.: Effects of noise on human performance. J. Appl. Psychol. **43**(2), 96–101 (1959)
2. Armstrong, H. G.: The effect of sustained acceleration and noise on workload in human operators. Aviat. Space Environ. Med. **60**(10.1), 943–948 (1989)
3. Khan, I.A., Mallick, Z., Khan, Z.: A study on the combined effect of noise and vibration on operators’ performance of a readability task in a mobile driving environment. Int. J. Occup. Saf. Ergon. (JOSE) **13**(2), 127–136 (2007)
4. Bowman, J.S., Von Beckh, H.J.: Physiologic and performance measurements in simulated airborne combined stress environments. Aviat. Space Environ. Med. **50**(6), 604–608 (1979)

The Importance of Ergonomics Analysis in Prevention of MSDs: A Pilot Study

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Abstract The ergonomics industry contributes to improve the efficiency, reliability and quality of industrial operations, the aim being to prevent rallying this study, in order to implement working conditions which prevent the onset of MSDs. This study was developed in Swedwood Portugal. The company has its own production lines in jobs that require intervention in order to reduce the risk of developing MSDs. To quantify the level of risk and an ergonomic elaboration of an action plan for preventive and corrective measures to be implemented, the company proceeded with the application of ergonomic evaluation methodology and analysis of anthropometric data. The research was conducted in three phases: (1) application of methodology Checklist OSHA, allowing you to prioritize more detailed evaluations and adapt the methodology of level 2, (2) workload assessment with the methodology RULA (classification integrated risk of MSDs) and Equation NIOSH (calculation of the recommended weight limit). Results suggest that it is imperative to ascertain and make immediate modifications in 65 % of jobs (e.g. First post battens receipt of PAUL; mounting frames; Assembly Sandwich BOF; Packaging Genax 2

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rank 1), 25 % may need a few changes (e.g. Inspection of parts lacquering; Placement in HDF glue machine; Packaging Genax 2 position 0) and in 10 % of the posts it is urgent to further analyse and make the respective changes (e.g. Mount honeycomb; supply station assembly honeycomb). The results indicate the need to implement preventive and corrective measures, using tools of ergonomics and engineering, such as interventions based on anthropometry, organization of working time, changes in the working methods, reorganization of production layout and equipment introduction aid to the implementation of tasks.

Keywords RULA · Ergonomic analysis · Swedwood-Portugal

1 Introduction

Ergonomics is the scientific study of the relationship between man and his means, methods and workspaces. Its purpose is to develop, through the creation of several scientific subjects that make up a body of knowledge, that within a perspective of application, should result in a better adaptation of man to technology and work environments and life.

Makes the overall analysis of work situations, promoting their improvement and thereby ensure the best working conditions for employees, while also taking into account the efficiency of the system [1].

The ergonomic interventions not only concur in the management and control of negative events for workers health but also in achieving advantages in terms of lower costs and greater productivity [2].

Comprising a set of actions, including, study and work transformation, helping to optimize the relationship between the physical involvement, work processes and the activity of the individual carrying out their activities in accordance with the characteristics of the individual and the type of relationship that is established at the level of individuals versus machine interfaces [3], work organization and improvement of working conditions [4]. As by analyzing the activity it is possible to reflect on human activity [5], the modification is recommended to improve the health status of workers. Industry contributes to improve the efficiency, reliability and quality of industrial operations [4]. Through the data collected in private companies of different size, in this extensive industrial “sofa area” there is an emphasis to the importance of prevention through adequate ergonomic solutions and the need to improve training programmes covering the whole area [6]. The initial stage of an ergonomic evaluation of a unit of industrial production must be taken into consideration and to distinguish between prescribed and real work.

The prescribed work comprises the objectives set by the company to carry out a particular activity (e.g. number of parts to be produced; defects to avoid) and the actual work that is carried out concretely in the production unit independently of performances held [5, 7] so the non-fulfilment of the objectives set by management may lead to human errors.

This assessment provides information regarding the etiological mismatch between the prescribed work and real work, such as the human idiosyncrasies, work organization, the man-machine binomial and the activities preparation context. Observation is the preferred method by an Ergonomist to analyse the activity. Through which are observed the movements, gestures, glances, the use of technical devices and the interactions between people. Significant information is collected, related to the activity, such as the production itself, errors and defects to understand the strategies developed by the workers. Additionally, physical or chemical parameters registration that evolve over time and reflect, sometimes very faithfully, the workers' intervention.

The industrial production of upholstered furniture exposes workers to significant risk of occupational disorders due to ergonomics-related problems, such as repetitive strain and movements of the upper limb, manual load lifting, prolonged static postures [2]. In industrial reality, working conditions rarely meet the needs of the workers; therefore it urges to explore the interactions in the Man-Working system and intervene to prevent potential negative impacts, such as the appearance of musculoskeletal injuries related to work (MSDs). These type of injuries are a frequent consequence of occupational diseases and have been increasing with the implementation of new methods and models of work organization. Nowadays it is an important issue to study Health and Safety at Work. Being defined as a set of inflammatory and degenerative diseases of the locomotive system which has its origin on occupational risk factors, such as repeatability, overload, posture maintained rhythms of intense work, exposure to vibration, manual handling, static or inadequate postures, insufficient breaks, low temperatures and organizational factors, high demands and low job control [8–11]. Individual factors such as age, sex, muscle strength, anthropometric characteristics also contribute to the development of risk factors [12, 13]. Affecting one or more regions of the body, with the neck and upper limbs being the most affected areas, which occur in the course of professional activity with repetitive movements, postures maintained and manual load handling [14].

1.1 Method of Risk Analysis MSDs-Rapid Upper Limb Assessment (RULA)

The legislation in Portugal, regarding the prevention of MSDs, doesn't specify any method for risk assessment. It is of particular assistance in fulfilling the assessment requirements of both the European Community Directive (90/270/EEC) on the minimum safety and health requirements for work with display screen equipment. The RULA method, seeks to assess the risk of work related musculoskeletal disorders of the upper limbs (hand, wrist, elbow, shoulder) [15], but also the neck and low back (due to trunk postures). It provides an objective measure of the MSD risk caused by tasks where the demands on the upper body are high but the whole body demands (i.e. the back and legs) are relatively low.

This method is used to assess posture, strength and movements associated with sedentary tasks, such as the use of computers, manufacturing or other where the worker is sitting or standing without walking, and should then be used as a first analysis to assess the level of exposure of the upper limbs to risk factors such as posture, muscle contraction, static repetition and strength and to determine the factors that contribute most to the risk associated with the task. To do a complete RULA analysis, the user decides which postures or parts of the work cycle need to be assessed. It is important for the user to look at the postures used over a full task cycle. After this they can select the posture to be assessed. Often those postures that are held the longest and/or considered to be 'the worst' are assessed [16].

It is then necessary to decide whether the left, right or both sides of the body should be assessed. RULA is actually designed to look at the left and right hand sides separately. A coding system is used to generate an action list which indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator [15]. If both sides are assessed, RULA will provide a score for each side. Determining, for each zone, ranges of posture and describing a score in accordance with the overload level. Similarly, evaluates whether the job is static (postures maintained for more than a minute) or repeated (frequency of movement of the segments ≥4 per min) and the force or load requirements. Its application consists in recording different working postures observed, classified by as coring system, using diagrams of body posture sand tables that assess the risk of exposure to factors external load [16].

2 Materials and Methods

2.1 Sample Characterization

This work was performed at Swedwood Portugal, registered with the CAE activity 31091—Manufacture of Wooden Furniture for other purposes. Its facilities occupy a total area of roughly 370,000 m^2, of which about 175,000 m^2 correspond to a covered area and the remaining as an open area, divided into 4 blocks. Daily, the factory manufactures more than 30,000 pieces of furniture for the IKEA Group. The plant operates 5 days/week, 24 h/day, in three shifts (8 h each). It has about 1300 employees (47 % women and 53 % men), 50 % of which come from a radius of 10 km and 80 % live within a radius of 20 km. There are different production technologies in this complex business. This study focuses on the analysis of the production process of the Board on frame. This sector is divided into 5 areas (Cutting, Frames and Cold press; Edge banding & Drill; lacquering and Packing), each with different tasks of the overall production process.

In the Cutting area, the melamine and HDF board is cut according to the specifications of the final product. This process is realized through integrated automatic machines (machines cutting discs, rollers mats, etc.). In the Frames section, more elaborate cuts are made to the pieces from the Cutting, supplements are mounted (Frame) via a hot glue system. HDF boards are then mounted to the produced Frame.

The Cold press is where the Frames are compressed by hydraulic presses. In Edge banding & Drill melamine boards and BOF pieces are hemmed, cut and perforated by automated machines. In Lacquering, the BOF pieces are lacquered through rolls by lacquering machines. In Packing, the various components of the final product are gathered and packed.

2.2 Ergonomic Assessment Tools

This research used the following two approaches to assess the MSD risks at the Cutting and Frames area.

Baseline Risk Identification of Ergonomic Factors (**OSHA Checklist**). This checklist includes questions on working postures of the back and neck, arms and hands, legs during sitting and standing tasks. It also gives examples of the type of action at a technical, organizational and individual level that can be put in place to prevent or reduce the risks caused by awkward postures.

The main risk factors evaluated by the OSHA Checklist tool are force, posture, repetitiveness, and work duration. Tasks associated with other risk factors, such as exposure to vibration, mechanical pressure, and low temperature, should be referred to professional personnel for further analyses.

The results show that the OSHA Checklist is an effective and rapid screening instrument to monitor the potential ergonomic risk for upper arm and the results from this checklist in examining the neck, shoulder and back symptoms were identical with that of the questionnaire survey.

Rapid Upper Limb Assessment (**RULA**). This method was applied to identify postural stress of upper limbs. The risk is calculated into scores and classified into four action levels. A RULA sheet consists of body posture diagrams and scoring tables. Based on the RULA method, the human body is divided into two parts, which are part A for Arm and Wrist analysis while part B for Neck, Trunk and Leg Analysis. A scoring system is used to assign scores at every step, depending on the body position, with the higher scores for more awkward postures. RULA method is widely used in ergonomic field (Table 1).

The ergonomic risk evaluation process included a formal meeting and a tour of the shop floor (onsite inspection). In the meeting, the chief inspector first introduced the ergonomic risk evaluation process and then dialogued with the employers and major

Table 1 RULA: score and indication

Score	Indication
1 and 2	Acceptable posture
3 and 4	Changes are recommended
5 and 6	Changes are soon required
7	Changes are immediately required

crewmembers to gather an overview of the work and the key problems experienced by the studied company. During the tour, researchers collected field data of specific tasks by talking with individual operators, taking photographic and video evidence of manual materials handling tasks, and measuring task demands and physical dimensions of inspected workstations. OSHA Checklist and RULA tools that enabled the quantification of ergonomic risk were then used for explaining potential causes of MSD's. Some weeks later, the researchers drafted and sent the company an inspection report with improvement suggestions, and a follow up meeting was arranged afterward to discuss the efficacy of the ergonomic interventions.

2.3 Ergonomic Practices: Operation Statement

In cutting area, during task 1 (Fig. 1) the worker's receipt of material from the cutting and forwarding the same to Foil, using a manual trolley. Pieces are forwarded to the trolley through automatic rolls and then the employee takes the trolley up to the destination rolls. The cargo withdrawal from the trolley is performed manually resorting to the operator's labour). In task 2 (Fig. 2) (set of two tasks performed by two employees), the operator receives the pieces from the PAUL rollers. The task consists in the reception and orientation of parts on the baseboard. The baseboard height is adjustable with a sensor that adjusts the height depending on the height of the load. In task 3 (Fig. 2) (set of two tasks performed by two employees), the operator receives and supports the pieces orientation on the baseboard. The height of the baseboard is adjustable via a sensor, which adjusts the height depending on the height of the load. The operator receives the slats above the PAUL's output elevator.

Fig. 1 Transport of the in parts manual car for the foil

Fig. 2 Stations receiving the slats

Fig. 3 Frames supply to assembly stations and frames assembly

In Frames area, task 1 (Fig. 3) is performed by an operator who is collecting the car carrying the slats, positioned next to the operators that perform the frames assembly. The operator takes the car to the supply area, where the slats needed for mounting the frame that is being produced are unloaded, in the trolley and then back, forwarding the car to the mounting area of the frames. Task 2 (Fig. 3) is performed by mounting the frames with hot glue. The mounting of this piece is performed by an operator who has at his side (right or left depending on the job) the slats, which are placed at its disposal by another operator in a trolley. Also, underneath the assembly panel are containers from where pieces for the assembly are taken. There is also a stand where to rest the hot glue gun in order to facilitate access to it. The assembly is held in pairs, i.e. two pieces at a time. The assembly of these pieces is performed by a collaborator throughout the entire work shift with an average production of 89 pieces/h worked per collaborator.

3 Results and Discussion

In Table 2 is a summary of the assessment made in the area of Cutting and suggesting: in task 1 (receipt of material from the cutting and forwarding the same to Foil, using a manual trolley. Pieces are forwarded to the trolley through automatic

Table 2 Summary of evaluation of tasks performed in cutting area

Task	Anatomic region	Posture	Muscles	Strength	Result	Final result	Observations
1[a]	Arm/Forearm/Pulse/Pulse rotation	5	0	3	8	7	Level of action 4[d]
	Neck/Torso/Legs	5	0	3	8		
2[b]	Arm/Forearm/Pulse/Pulse rotation	4	1	0	5	7	
	Neck/Torso/Legs	5	1	0	6		
3[c]	Arm/Forearm/Pulse/Pulse rotation	5	1	0	6	7	
	Neck/Torso/Legs	5	1	0	6		

[a]Task 1—transport with car parts manual for the Foil
[b]Task 2—first place of receipt to the slats PAUL
[c]Task 3—second post of receipt to the slats PAUL
[d]Action level 4—it is imperative to conduct investigations and immediate modifications

rolls and then the employee takes the trolley up to the destination rolls. The cargo withdrawal from the trolley is performed manually resorting to the operator's labour), the trolley replacement for mechanical cart maneuverer by the worker; in task 2 (set of two tasks performed by two employees. In this station, the operator receives the pieces from the PAUL rollers. The task consists in the reception and orientation of parts on the baseboard. The baseboard height is adjustable with a sensor that adjusts the height depending on the height of the load), a plan of rotation of workers (decreasing exposure time); Gymnastics; Changes to the machine the position in which the employee receives the slats requires an impractical approach, in this sense is proposed a change to the machine in order to improve working posture; in task 3 (set of two tasks performed by two employees. In this station, the operator receives and supports the pieces orientation on the baseboard. The height of the baseboard is adjustable via a sensor, which adjusts the height depending on the height of the load. The operator receives the slats above the PAUL's output elevator.), a Plan of rotation of the workers (decreasing exposure time); Gymnastics, training and awareness; Changes to the machine the position in which the employee receives the slats requires an impractical approach, regarding this situation is proposed that the machine is modified in order to improve working posture.

Table 3 is a summary of the assessment made in the Frames area and suggests: in task 1 (is performed by an operator who is collecting the car carrying the slats, positioned next to the operators that perform the frames assembly, the operator takes the car to the supply area, where the slats needed for mounting the frame that is being produced are unloaded, in the trolley and then back, forwarding the car to the mounting area of the frames). Gymnastics, training and awareness; Limiting the number of pieces by handle; Changes to the trolley-adaptation to anthropometric measures of the Portuguese population; in the second task (this task is performed by mounting the frames with hot glue. The mounting of this piece is performed by an operator who has at his side, right or left depending on the job, the slats, which are placed at its disposal by another operator in a trolley. Also, underneath the assembly panel are containers from where pieces for the assembly are taken. There is also a stand where to rest the hot glue gun in order to facilitate access to it. The assembly is held in pairs, i.e. two pieces at a time. The assembly of this pieces performed by a

Table 3 Summary of evaluation of tasks performed in area frames

Task	Anatomic region	Posture	Muscles	Strength	Result	Final result	Observations
1[a]	Arm/Forearm/Pulse/Pulse rotation	5	1	1	7	7	Level of action 4[c]
	Neck / Torso/Legs	5	1	1	7		
2[b]	Arm/Forearm/Pulse/Pulse rotation	7	1	0	8	7	
	Neck / Torso/Legs	4	1	0	5		

[a]Task 1—frames supply to assembly stations
[b]Task 2—frames Assembly
[c]Action level 4—it is imperative to conduct investigations and immediate modifications

collaborator throughout the entire work shift with an average production of 89 pieces/h worked per collaborator), labour Gymnastics, training and awareness; rotating workers Plan (decreased exposure time); adaptation of the piece to the worker it is proposed to adopt measures in the sense that the distribution of frames to assemble are made according to the height of employees, i.e., for the assembly of smaller frames, this should be done by workers of smaller stature. For larger frames, the assembly should be carried out by employees of higher stature; Work platforms placement (elevation of the worker).

Table 4 is a summary of the assessment made in the area of Cold Press and suggests: task 1 (is the introduction of two sheets of HDF in glue machine, the operator, prior to introduction into the machine, turns one of the sheets so that they stay "face to face", allowing the glue to be applied to the "back" of the sheets). Gymnastics; Training and awareness raising on task 2 (consists in the introduction of the combs in the frames); task performed by two operators "face to face" for each assembly line. The operator at this work station receives the frame through the mat assembly line, usually in batches of 10 into the carriers that are divided into two lots. The combs are received by operators through the platform output wikoma (cutting machine comb). The operator picks up the comb, with the fingers inside the cells and inserting it into the frame, tilting it slightly forward so that the furthest part from the collaborator is introduced first. At the end the comb is pressed towards the mat in order to verify that it is uniformly distributed within the frame). Gymnastics labour; Training and awareness; Plan rotating workers (decreased exposure time), task 3 (this task is performed to transfer the frames to the mat). The elevation of frames is performed via a lift in order to flatten the rolls with the carpet.

Table 4 Summary of evaluation of tasks performed in the area cold press

Task	Anatomic Region	Posture	Muscles	Strength	Result	Final Result	Observations
1[a]	Arm/Forearm/Pulse/Pulse rotation	2	1	0	3	3	Level of action 2[e]
	Neck/Torso/Legs	2	1	0	3		
2[b]	Arm/Forearm/Pulse/Pulse rotation	4	1	0	5	6	Level of action 3[f]
	Neck/Torso/Legs	4	1	0	5		
3[c]	Arm/Forearm/Pulse/Pulse rotation	4	1	0	5	5	
	Neck/Torso/Legs	3	1	0	4		
4[d]	Arm/Forearm/Pulse/Pulse rotation	5	1	0	6	7	Level of action 4[g]
	Neck/Torso/Legs	5	1	0	6		

[a]Task 1—placing the HDF glue machine
[b]Task 2—mounting honeycomb
[c]Task 3—supply of gas fitting honeycomb
[d]Task 4—assembly sandwich BOF
[e]Action level 2—it is necessary to investigate and there may be changes
[f]Action level 3—it is urgent to investigate and make changes
[g]Action level 4—it is imperative to conduct investigations and immediate modifications

The operator pulls out approximately once every 10 frames to the mat after the initial portion of frames are supported on the carpet. The operator, via a pedal, lowers the lift and frames are pulled by carpet. After the carpet is being held inside the marking according to the team and is visually inspected. This task is carried on until the end of the pallet, with the last frames, the baseboard is sent together with these). Gymnastics, training and awareness; Plan rotating workers (decreased exposure time) and task 4 (one of the collaborator removes the frame off the carpet while another collaborator places two HDF sheets on the upper part of the frame, after the pieces are joined together, the collaborators do the final adjustments to the assembly. During assembly, the collaborator for the lower part regulates the height of the freight elevator until 70 pieces per pallet (two lots of 35 pieces), after which the collaborator forwards the pieces to the entre the next line, Gymnastics labour; Training and awareness, Plan of rotation of workers (decreased exposure time); changes to the freight elevator—changes should be made to the freight elevator in order to optimize access. The freight elevator shall be adjustable (not only in height) but at length, to improve access to the load during the assembly of small frames. As were to be placed work platforms that are adjustable to the freight elevator.

Table 5 is a summary of the assessment made in the area of lacquering and suggests: Task 1 (in quality inspection of parts, through various quality parameters. The inspection is performed visually, with the parts going through the production line, using inspection equipment and by removing random parts of the line for further inspection. When parts are not according to the parameters established the collaborator removes the parts of the line, putting them on a pallet positioned here for parts to be reworked). Gymnastics labour; Training and awareness.

Table 6 is the summary of the assessment made in the field of Packing suggests: task 1 (the collaborators remove the piece located on the baseboard, inspect all sides of the piece, making it spin between them and put the piece in the package located on the assembly line), task 5 (consists on the handle of two pieces of the pallet, the operator joins them, inspects them and puts them in the packaging placed on the line. Afterwards the furniture pieces are put together, the operator places a filling carton per packaging), task 6 (the operator removes the work piece from the pallet, turn it for the purpose of inspecting, then put into the packaging element situated in line. Once the part is placed in the package, the collaborator inserts in the same package one protective sheet) and task 7 (the number of pieces to be placed in the package is sandwiched, in other words, a collaborator puts a piece in the box and in the next two, and so on, successively. When removing the part(s) of the pallet,

Table 5 Summary of evaluation of tasks performed in the lacquering area

Task	Anatomic region	Posture	Muscles	Strength	Result	Final result	Observations
1[a]	Arm/Forearm/Pulse/Pulse rotation	3	1	0	4	4	Level of action 2[b]
	Neck/Torso/Legs	3	1	0	4		

[a]Task 1—inspecting parts lacquering
[b]Action level 2—it is necessary to investigate and there may be changes

Table 6 Summary of evaluation of tasks performed in the area of packing

Task	Anatomic region	Posture	Muscles	Strength	Result	Final result	Observations
1, 5, 6 and 7[a]	Arm/Forearm/Pulse/Pulse rotation	4	1	2	7	7	Level of action 4[g]
	Neck/Torso/Legs	5	1	2	8		
2[b]	Arm/Forearm/Pulse/Pulse rotation	4	1	0	5	4	Level of action 2[f]
	Neck/Torso/Legs	2	1	0	3		
3[c]	Arm/Forearm/Pulse/Pulse rotation	6	1	2	9	7	Level of action 4[g]
	Neck/Torso/Legs	5	1	2	8		
4 and 8[d]	Arm/Forearm/Pulse/Pulse rotation	3	1	0	5	4	Level of action 2[f]
	Neck/Torso/Legs	2	1	0	3		
9[e]	Arm/Forearm/Pulse/Pulse rotation	3	1	3	7	7	Level of action 4[g]
	Neck/Torso/Legs	5	1	3	9		

[a]Task 1—packaging Genax 1; Task 5—packing Genax 2 position 3; Task 6—packaging Genax 2 position 4; Task 7—packaging Genax 2 position 5
[b]Task 2—packaging Genax put 2 0
[c]Task 3—packaging Genax 2 rank 1
[d]Task 4—packing Genax 2 rank 2; Task 8—packing Genax 2 position 6
[e]Task 9—housekeeping baseboards and pallets
[f]Action level 2—it is necessary to investigate and there may be changes
[g]Action level 4—It is imperative to conduct investigations and immediate modifications

visual inspection is taken upon). Gymnastics; Training and awareness; Plan rotating workers (decreased exposure time); Changes to production layout, Automation of packaging process (under study); task in 2 (a collaborator receives the carton from the machine that mounts the packaging, after being in the production line, a sheet of protective paper is applied on the base of the pack). Gymnastics, Training and sensitization, in task 3 (removal of a piece from the pallet, rotate it for the purpose of inspecting, and then place it in the package located on the line. Thereafter, each of the collaborators put a piece of cardboard filler). Gymnastics; Training and awareness; Plan rotating workers (decreased exposure time); Changes to production layout; Automation of packaging process (under study), in task 4 (consisting in the packaging of fittings (assembly accessories) cards and placing a sheet of protective paper, both placed inside the packaging, placed in the line. The parts are placed in a box where its height is adjustable by the collaborator), and task 8 (the cardboard lid is placed on the packaging in this task). Gymnastics; Training and awareness; Plan rotating workers (decreased exposure time); Changes to production layout; Automation of packaging process (under study), and the task 9 (the operator arranges for the baseboards and pallets coming from the packaging and makes the separation of waste (plastic, paper, etc.)). Gymnastics labour; Training and awareness; Plan rotating workers (decreased exposure time); Replacing baseboards (study)—currently the baseboards have a substantial weight, not compatible with the cadence of the task. With the replacement of baseboards for ones with a lower weight ensures a substantial gain in working conditions, contributing significantly to the viability ergonomic workstation.

4 Conclusion

With this study it was possible to intervene in reducing the risk for MSDs in two ways. On the one hand, intervening in the workplace through the layout reorganization, adapting the machinery, the equipment and tools used, among others, on the other hand, when these changes were not enough, it was possible to intervene at the level of employee turnover and implementation of gymnastics program.

Although the proposed measures do not stand training as a key factor, this is a tool of great importance as it regards the promotion of safety in the workplace. There are various movements made by workers who may be regarded as unnecessary, eliminating these movements through training and awareness result in a significant gain reduction in MSDs development. The training, however, is not the solution to all problems, especially if one has in mind specific aspects such as workers' age, their seniority in the company, the type of functions or even their perception of risk. The differences found in various jobs, pointed out that the training of workers for the perception of risk needs to be designed for each situation, and not to be carried out by a generic training that would suit all situations.

A properly designed job takes advantage of human capabilities as it considers the limitations and power efficiency of the system, if this is not achieved, the system performance is limited and it can pose a risk to the worker.

This consideration becomes relevant due to the increasing complexity of systems that often leads man near their limits. The need of the perfect knowledge of the workers physical characteristics becomes evident, therefore, to consider the machinery and equipment as an extension of the worker himself so that it operates with maximum efficiency and comfort. This is only possible if the design for the future user is analysed and considered.

References

1. Montmollin, M., Darses, F.: A Ergonomia. 2ª ed. Instituto Piaget, Lisboa, p. 144 (2011)
2. Nicoletti, S., Castoro, V., Iacobellis, M., Loizzo, N., et al.: Upper limb work-related musculoskeletal disorders (UL-WMSDs) in a large factory of the upholstered furniture industry: risk management. Med. Lav. **99**(4), 297–313 (2008)

3. Bento, A.: Ergonomia: Contributos para a Gestão de Recursos Humanos: Gestão de Recursos Humanos Contextos, Progressos e Técnicas, in: Caetano A.Vala J., Editors. Editora RH: Lisboa (2007)
4. Iida, I.: Ergonomia - Projeto e produção. Editora Edgard Blucher LTDA, São Paulo (2000)
5. Montmollin, M., Darses, F.: A Ergonomia. Instituto Piaget, Lisboa (2011)
6. Di Leone, G., Carino, M., Nicoletti, S., Trani, G., et al.: Manufacture of upholstered furniture and work-related upper limb musculoskeletal dis-orders: an industrial sector prevention project. Med. Lav. **99**(4), 250–261 (2008)
7. Rabardel, P., Carlin, N., Chesnais, M., Lang, N., et al.: Ergonomie: Concepts et Methods, ed. Pages. C.C. Octares Editions, Toulouse (2002)
8. Uva, A.S., Carnide, F., Serranheira, F., Miranda, L.C., et al.: Lesões Musculoesqueléticas Relacionadas com o Trabalho - Guia de Orientação para a Prevenção, ed. Ministério da Saúde. Direcção-Geral de Saúde - Programa Nacional Contra as Doenças Reumáticas. Lisboa (2008)
9. Bernard, B.P.: Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back. US Department of Health and Human Services, Cincinnati, OH (1997)
10. Forde, M.S., Punnett, L., Wegman, D.H.: Pathomechanisms of work-related musculoskeletal disorders: conceptual issues. Ergonomics **45**(9), 619–630 (2002)
11. Malchaire, J., Cock, N., Vergracht, S.: Review of the factors associated with musculoskeletal problems in epidemiological studies. Int. Arch. Occup. Environ. Health **74**(2), 79–90 (2001)
12. Armstrong, T.J., Buckle, P., Fine, L.J., Hagberg, M., et al.: A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scand. J. Work Environ. Health **19**(2), 73–84 (1993)
13. Punnett, L., Wegman, D.H.: Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J. Electromyogr. Kinesiol. **14**(1), 13–23 (2004)
14. Baxter, P., Aw, T.C., Cockcroft, A., Durrington, P., et al.: Hunter's Diseases of Occupations. CRC Press, London (2010)
15. McAtamney, L.: Nigel Corlett E.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl Ergon. **24**(2), 91–99 (1993)
16. McAtamney, L.: Rapid Upper Limb Assessment (RULA). In: Stanton, N., et al. (eds.) Handbook of Human Factors and Ergonomics Methods. CRC Press, London (2004)

Key Parameters of Occupational Safety for Sustainable Manufacturing Units: A Review

Vikramjit Singh, Arshveer Singh and Prabhdeep Kaur

Abstract Occupational safety remains a challenge to each and every nation and also it plays a vital role. The same is ignored in India, which causes intolerable effects resulting in medium to fatal accidents at the workplace. The focus of review paper is to explore the impact of occupational safety with the aid of data taken from industries on national and international level. Different researchers have pointed out various parameters that could be the possible requirement in view of occupational safety for the workforce especially in manufacturing industries. The study is carried out in two phases. First phase caters the collection of data from various sectors such as private industries, industry department offices, official government sites, different government policies, internet and national data analysis. Second phase is to analyze and pinpoint the critical parameters which require immediate attention to slow down the accident rate in Indian industries. It is concluded from the studies summarized in this paper that there should be stringent procedures drafted and implemented as far as occupational safety of workforce is concerned. The studies revealed that the parameters needs attention and should be deliberated in more meaningful manner such as management involvement, worker safety, training, personal protective equipment, workplace layout, fire fighting arrangement, workplace environment, welfare and medical facilities. The rate of accidents in Indian industry can be lowered with proper training programs in the form of worker training camps, conferences, workshops that can be initiated time to time for the workforce which should be industry specific.

Keywords Occupational safety · Industrial accidents · Risk factors

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1 Introduction

Occupational safety is a term that concerned with safety of the workers, employers and workplace environment. Every person has a right to be safe and secure. Workplace is in risk around the globe as the budget deposits incredible burden. Occupational safety focused on following factors:

(a) Advancement and maintenance in worker's safety and work capability;
(b) The advancement in working condition in accordance to worker's safety
(c) Development of new lawsuits helps to create a positive working environment that further boost the output of the workers.

"The worldwide battle to the down" which affects emerging and settled economies as an intercontinental corporation ramble the domain, examining for the nethermost grosses, the furthermost vulnerably susceptible workforce, and the tiniest instruction of occupational safety and prevention. In 2002, International Confederation of Free Trade Unions (ICFTU) declared that there are 3300 deaths per day on the work (two million fatalities per year) and 1.6 billion fresh lawsuits of occupational bugs.

In nation's development, there is major role of occupational healthiness and care. Work-related safety policies and physical exertions are not entirely influencing with progresses in technical awareness, but then again also by improvements in laws and in the collective back-and-forth between firms and workforces.

"An unplanned event, which mostly results in personal injuries, the machine's and equipment's' taking the knock or the ceasing of production for some time" is recognized as an occupational accident, according to World Health Organization (WHO). World Health Organization (WHO) evaluates industrial safety threats as the causative root of morbidity. The load of sickness from particular occupational threat influences amounts to 1.5 % of the universal encumbrance in statuses of disability adjusted life years (Fig. 1).

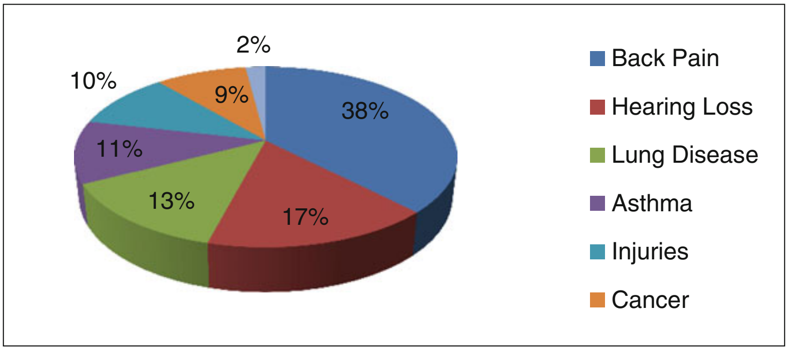


Fig. 1 Worldwide morbid circumstances according to WHO

Table 1 Occupational accidents in different countries

Years	2003	2004	2005	2006	2007	2008
Canada	73,526	69,479	65,903	61,233	53,906	47,812
Finland	16,769	15,977	16,211	16,343	15,965	
Germany	278,572	261,539	248,536	249,406	257,961	259,587
Hong Kong	4009	4258	4110	4228	3946	3587
Japan	32,433	31,192	29,973	29,597	29,316	28,259
India	16,432	57,839	49,904	43,676	33,990	
Italy	190,298	180,179	171,078	167,146	159,919	145,137
Singapore	1755	1799	1830	3401	3389	3279
United Kingdom	37,231	33,267	30,396	27,780		
United States	226,220	226,553	209,523	201,426	187,600	65,351

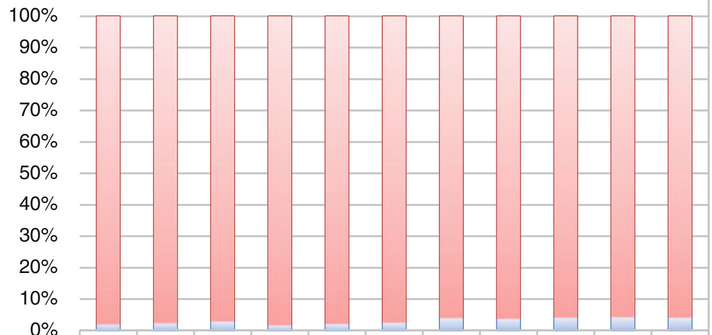
The manufacturing innovativeness is most hazardous branches in light of the rate of recurrence of occupational accidents. Occupational harms keep on being a worldwide challenge. International Labour Organization evaluated that nearby 2.3 million workforces pass away every year for the reason that of work-related coincidences and diseases near about 358,000 fatal occupational mishaps every year. The number of occupational accidents occurred from 2003–2008 as shown in Table 1.

2 Occupational Safety in India

India is a massive South Asian nation with a superficial zone of around 3.288 million km^2. The aggregate inhabitants of India, conferring to the World Bank, United States of America 2013 was 1.252 billion. About 67.97 % in 2013 of the inhabitants live in the rural country [1]. Expanding population is the foremost worry and assured as primary barrier to the economic progression of the country. According to the report of DGFASLI (2011), about 325,209 listed industrial factories near about 271,085 working factories [2]. In manufacturing plants, about 11.7 million persons are used. Directorate General of Factory Advice Service & Labour Institutes (DGFASLI) reports (2011) reveal that there are 7464 Medical Officers, 3587 Safety Officers, and 1715 Factory Inspectors in the state. There is a classification of different size of industries by the Ministry of micro, small& medium enterprises of India and European Union (Table 2).

Table 2 Classification of industry

Industry category	Employees	Investment
Micro	1–10	≤25 lakh rupees
Small	11–50	≥25 lakh ≤ 5 crore rupees
Medium	51–250	≥5 crore ≤ 10 crore rupees



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
TOTAL INJURIES	28364	20453	16432	57389	49904	43676	33990	33939	33093	31505	31270
FATAL INJURIES	627	540	525	1081	1142	1201	1464	1369	1509	1459	1433

Fig. 2 Number of total and fatal industrial accidents in India

The number of industrial accident occurs every year in India. The Bhopal Gas Heartbreak (1984) was the whirling opinion in the antiquity of safety in India. According to DGFASLI, the number of fatal and non-fatal accident is showing in Fig. 2.

3 Government Policies for Improvement in Occupational Safety

The primary target of the policies is to assure passable safety events and to progress the wellbeing of the workforces engaged in place of work to care for the employees in counter to industrial work-related threats. The different policies seek to take the nation-wide intentions into emphasis as a footstep on the way to enhancement in safety, well-being and atmosphere at place of work. The purposes are to reach the unremitting reduction, awareness, standardization and improvements in the prevalence of labour interrelated injuries, fatalities. The policies are intend to deal accommodations to the workforces from oppressed and arrange for perfection of the at work conditions within the factory locations [3]. In that respects, different patterns and acts are ground for proper safety and health in industry:

1. The Industrial Disputes Act, 1947
2. The Factory Act, 1948
3. The Minimum Wages Act, 1948
4. Punjab Factory Rules, 1952
5. The Companies Act, 1956
6. The Dock Workers Rules, 1986

According to national policy, The Constitution of India conveys proper detail of every right of workers. Some of directive principles are:

(a) Safeguarding the wellbeing and strong point of workforces;
(b) Affectionate years of youngsters are not mistreating;
(c) Inhabitants are not ambitious by financial stipulation to cross the threshold occupations unqualified to their age or martial capability;
(d) Government shall receipts footsteps, by appropriate legislature or in any additional way, to ensure the contribution of worker in the supervision of ventures, formations or other officialdoms employed in at all industry.

4 Need of Occupational Safety

There are insufficient methodical assessments of occupational wound prevention method that target small and medium enterprises. Safety is an elementary requirement, when an association is not gathering an employee's rudimentary desires, it is questionable that operative will be enthusiastic to pursue organizational goalmouths such as significant improvement.

In his review article, Rantanen examined that even though exhaustive improvements for consolidation legislature, exploration, and training accepted out during the previous years, one-third of workforces still graft beneath regular safety hazards. More than a few occupational in addition to non-occupational threat concerns cumulate into equivalent high-risk inhabitants. Coincidence hazard remains the most dangerous variety of exposure in the workplace [4]. Australia has undergone a rapid transformation within the area of work-related health and safety strategy and tactics. This change has highlighted the significant part of job-related health and safety in national growth and the importance of this matter to Australians [5]. The ILO has its great role in fortification of workers in contradiction of bad health, ailments and wounds due to workplace hazards and ergonomics.

Varonen and Mattila stated an imperative connection between the arrangement of protection climate as supposed by workforces on one-hand and welfare observes of the enterprise, level of safety of workplace and industrial mishaps on the other [6]. Das et al. [7] studied that a linear connection between disconnected and excellence endings. As when an employee is challenging with a condition where their awareness of their identifiable shelter at work diverge from the sensitivities and arrangements, workforces will answer back in conducts that to be expected to amended the strong point and superiority of their works. Lundberg et al. [8] find out overcoming strategic for opposition change equally important to avoid further strategies for determining and analysing cause.

Papadopoulos et al. examined the essence time of work, an age of employment, workplace, type of usage indentures and operative circumstances on work environment. These include the distraction of humanoid biological cadences, escalation of employee exhaustion due to amendments in patterns of time of engagement, employment uncertainty and working hassle, which grounds a grievous impression on workforces' safety and consequence in rise in occupational fates [9]. There are substantial perfections in specific disputes such as weakness to biological and physical agents, smearing engineering panels, and work-related services [10].

It is clear that requirement for supplementary resourceful ways and means to overwhelmed struggle to shift, in accumulation to a mandatory for further trustworthy methods to illuminate accidents. The workers in India are frequently ignorant and it is ordinary to instruct health edification to them, to instruct them of the unfavourable possessions of job and educative agencies. Responsiveness platforms and native group consultations are indispensable for enlightening the wellness prestige of these operational groups [11].

5 Risk Factors in Occupational Safety

The risk is higher but able to control is lower. Exploring ergonomics, operative throughput in factories compound progress of a specification that contained within queries regarding: company's demography, ergonomic concerns, issues correlated to management, environmentally friendly factors, and output and concerns related safety [12]. Nordlof et al. [13] analysis of safety culture through five main categories: (1) Communication importance (2) Concern of Specific for safety, (3) exterior conditions (4) Hazards acceptance, (5) trade-off between output and safety.

Ma et al. [14] examined different influences are: attentions, assessment of threats, communication, organisational atmosphere, safety wakefulness and proficiency, supervision care, and training. Lu and Tsai [15] are identified six dire safety macroclimate extents: safety insolence, trade safety and assistants' safety practices, management safety performs supervisor welfare practices, safety preparation.

The primary components for work safety scale are (a) controller safety, (b) contentment with the protection program, (c) work safety, (d) management, safety observes, and (e) workfellow safety [16]. Noweir et al. [10] evaluate the parameters for occupational safeties are: (a) Electric control and apparatus, machinery and tools; (b) Environment cleanliness and industrial discarded dumping; (c) Type of work action and occupied power; (d) Workplace health facilities; (e) Fire avoidance items; (f) Ecological conditions and existing health facilities. Nenonen [17] identified what kinds of accidents happen, when employees performed outsourced manufacturing operations and analyse the genes leading to these accidents by considering different factors. Ghahramani and Khalkhali investigated the content validity by application of the quantitative method also examined the construct validity of the scale by the application of EFA and CFA. Further, the inner consistency reliability of the scale was also satisfactory and it includes the different safety factors [18]. Saric et al. [19] examined of forklift misfortune trends within the Victorian industrial region (Australia).

The infesting industries expose both workforces and the atmosphere to precarious affluences. These enterprises regarded as by scarce and perilous use of mission and an extravagant role of expected capitals [20]. Exposure to noise significantly increased systolic blood pressure [21]. The eco-efficiency (i.e. air pollution) of the manufacturing sector in Malaysia by taking into account both economic and ecological factors [22]. Nyirenda et al. [23] identified the key factors as :Accident type, Age of the worker, Gender of the worker, Industrial activity of enterprises, Length of service or experience, Part of body affected, Occupation of worker (in enterprises), Primary sources of injury, Time of day accident happened.

6 Need of Training in Occupational Safety

We are find that mandate to advance the adjacent involvement of communal associates to take on the encounters in the prime in the valuation and regulator of place of work menaces by rallying native assets and proposing sanctuary to such operational inhabitants. Cheng and Wu [24] suggest that factories should heighten the safety and wellness training and offer safety and defending gear for the workplace and apparatus to make sure occupational protection by bearing in mind different unsafe acts and dangerous conditions. Sar [25] indicated that methodical training platforms organized for the workers in their peculiar place of work will be precise footsteps occupied for this willpower and these steps will guide us to silhouette healthier workforces. Mital [26] observed that there is a desperate prerequisite to train workforces in manufacturing organisations and in that way ameliorate the generally strong point and proficiency of such systems.

Work-related misfortunes can be diminishing through operative preventative processes by capitalising in safety equipment, preparation, and cultivating the workers, progression design, and technology [27]. Miller and Haslam [28] concluded that employee health and safety investments in many organizations from side to side-superior quantification of impact on throughput and repute threat. A larger apprehension of the complete elements, intricate in mining mishaps, and observes those organizational and superintendent disappointments that are projecting of subnormal concert at operative level [29].

In China, in order to stability financial advance and attain defensible development, the administration is now speedy up developed reshuffle prudently under the direction of “carefulness, neatness and protection” principle. The government has accomplished many policies on enlightening workers’ discrepancy provincial safety management and wellbeing input policies should be completed [30]. In Europe, safety at the workplace is a matter of the body politic and is governed by the Constitution, Labour protection in schools aims to cater the best working conditions, prevent accidents and the spread of disease among students, teachers and non-teaching staff as well as maintaining up with progress in science and technology [31]. In that respect are different issues observed in fifth India-EU seminar on employment and social policy: (1) Expansion of an appropriate scheme of endorsement of safety authorities; (2) Improvement of training and evidence materials; (3) Demeanour of seminars, workshops [32].

7 Conclusion

Although it is notified that there is high demand to educate workers in manufacturing industries to improve overall strength and efficiency. Prophylactic is an elementary requirement for every employee and if organization is not conforming that then it will definitely affect organizational goals such as superiority improvement. Many researchers find the different ingredients of safety like administration support, safety alertness and proficiency, organisational atmosphere, hazard assessment, safety communication, safety attentions and safety training as a major concern. Implementation of government policies for improvement in occupational safety can play crucial role. According to other study, researchers found that there are few additional parameters which are necessary for safe and tidy environment in manufacturing industry: Create and support safe work environment, Apply safety rules, act and discipline, Provide Personal Protective Equipment, Develop safe work measures and guidelines, Deliver safety keeping fit, Conduct continuous workplace inspections.

References

1. Census India. https://censusindia.gov.in/
2. Safety statics. https://www.dgfasli.nic.in/info1.htm
3. Statistics of Factories.: Labour Bureau Ministry of Labour & Employment Government of India, Chandigarh/Shimla (2009)
4. Rantanen, J.: Occupational health and safety in Finland Scandinavian. J. Work Environ. Health **9**(2). In: Proceedings of the Second US-Finnish Joint Symposium on Occupational Safety and Health: Helsinki, 24–26 May 1982, pp. 140–147, April 1983
5. Emmett, E.A.: Occupational health and safety in national development—the case of Australia. Scand. J. Work Environ. Health **23**(5), 325–333 (1997)
6. Varonen, U., Mattila, M.: The safety climate and its relationship to safety practices, safety of the work environment and occupational accidents in eight wood-processing companies. Accid. Anal. Prev. **32**, 761–769 (2000)
7. Das, A., Pagell, M., Behm, M., Veltri, A.: Toward a theory of the linkages between safety and quality. J. Oper. Manage. **26**, 521–535 (2008)
8. Lundberg, J., Rollenhagen, C., Hollnagel, E., Rankin, A.: Strategies for dealing with resistance to recommendations from accident Investigations. Accid. Anal. Prev. **45**, 455–467 (2012)
9. Papadopoulos, G., Georgiadou, P., Papazoglou, C., Michaliou, K.: Occupational and public health and safety in a changing work environment: an integrated approach for risk assessment and prevention. Saf. Sci. **48**, 943–949 (2010)
10. Noweir, M.H., Alidrisi, M.M., Darrab, I.A., Zytoon, M.A.: Occupational safety and health performance of the manufacturing sector in Jeddah Industrial Estate, Saudi Arabia: A 20-years follow-up study. Saf. Sci. **53**, 11–24 (2013)
11. Tiwary, G., Gangopadhyay, P.K.: A review on the occupational health and social security of unorganized workers in the construction industry. Indian J. Occup. Environ. Med. **15**(1) (2011)
12. Shikdar, A., Sawaqed, N.M.: Worker productivity, and occupational health and safety issues in selected industries. Comput. Ind. Eng. **45**, 563–572 (2003)

13. Nordlof, H., Wiitavaara, B., Winblad, U., Wijk, K., Westerling, R.: Safety culture and reasons for risk-taking at a large steel-manufacturing company: investigating the worker perspective. Saf. Sci. **73**, 126–135 (2015)
14. Ma, Q., Yuan, J.: Exploratory study on safety climate in Chinese manufacturing enterprises. Saf. Sci. **47**, 1043–1046 (2009)
15. Lu, C., Tsai, C.: The effects of safety climate on vessel accidents in the container shipping context. Accid. Anal. Prev. **40**, 594–601 (2008)
16. Hayes, B.E., Perander, J., Smecko, T., Trask, J.: Measuring perceptions of workplace safety: development and validation of the work safety scale. J. Saf. Res. **29**(3), 145–161 (1998)
17. Nenonen, S.: Fatal workplace accidents in outsourced operations in the manufacturing industry. Saf. Sci. **49**, 1394–1403 (2011)
18. Ghahramani, A., Khalkhali, H.R.: Development and validation of a safety climate scale for manufacturing industry. Saf. Health Work, 1–7 (2015)
19. Saric, S., Hadiashar, A.B., Hoseinnezhad, R., Hocking, I.: Analysis of forklift accident trends within Victorian industry (Australia). Saf. Sci. **60**, 176–184 (2013)
20. Mukul.: Polluting industries, environment and workers' health: a case for intervention. Econ. Polit. Wkly. **32**(35), L37–L44 (Aug. 30–Sep. 5, 1997)
21. Ismaila, S.O., Odusote, A.: Noise exposure as a factor in the increase of blood pressure of workers in a sack manufacturing industry. Beni-Suef Univ. J. Basic Appl. Sci. **3**, 116–121
22. Ramli, N.A., Munisamy, S.: Eco-efficiency in greenhouse emissions among manufacturing industries: a range adjusted measure. Econ. Model. **47**, 219–227 (2015)
23. Nyirenda, V., Chinniah, Y., Agard, B.: Identifying key factors for an occupational health and safety risk estimation tool in small and medium-size enterprises. IFAC-PapersOnLine **48**(3), 541–546 (2015)
24. Cheng, C., Wu, C.: An investigation and analysis of major accidents involving foreign workers in Taiwan's manufacture and construction industries. Saf. Sci. **57**, 223–235 (2013)
25. Sar, F.O.: Effects of employee trainings on the occupational safety and health in accommodation sector. Procedia Soc. Behav. Sci. **1**, 1865–1870 (2009)
26. Mital, A., Pennathur, A., Huston, R.L., Thompson, D., et al.: The need for worker training in advanced manufacturing Technology (AMT) environments: a white paper. Int. J. Ind. Ergon. **24**, 173–184 (1999)
27. Beriha, G.S., Patnaik, B., Mahapatra, S.S., Padhee, S.: Assessment of safety performance in Indian industries using fuzzy approach. Expert Syst. Appl. **39**, 3311–3323 (2012)
28. Miller, P., Haslam, C.: Why employers spend money on employee health: Interviews with occupational health and safety professionals from British Industry. Saf. Sci. **47**, 163–169 (2009)
29. Lenne, M.G., Salmon, P.M., Liu, C.C., Trotter, M.: A systems approach to accident causation in mining: an application of the HFACS method. Accid. Anal. Prev. **48**, 111–117 (2012)
30. He, X., Song, L.: Basic characteristics of work safety in China. Procedia Eng. **26**, 1–9 (2011)
31. Rusu-Zagar, G., Iorga, I., Anghel, S.O., Rusu-Zagar, C.: Occupational safety and health in national education. Procedia Soc. Behav. Sci. **92**, 832–837 (2013)
32. Fifth India-EU Seminar on Employment and Social Policy.: Occupational Safety and Health, New Delhi, 19–20 Sept 2011

Anthropometric Measurements of the External Auditory Canal for Hearing Protection Earplug

Wen Ko Chiou, Ding Hau Huang and Bi Hui Chen

Abstract Occupational noise still remains one of the most prevalent occupational health and safety problems. Hearing protectors are very important in providing proper protection for workers' hearing ability in noisy working environments. The protection efficiency of wearing hearing protectors such as earplug depends heavily on whether it is fitting inner the ear. Three-dimensional (3D) surface anthropometry enables us to collect key dimensions to fit between ear canal and earplug. However, few studies explore the relationship between hearing protectors and 3D canal data. Therefore, this study employs an ear impression injection and 3D scanning of ear impression to measure the external auditory canal size of Taiwanese adult, and find the key dimensions of EAC to provides a reference for hear protecting earplug design. 220 ear canal impressions were taken from both side ears of 110 adults. The portable 3D Camera was used to collect 3D auditory canal data from the ear impression models. The results of the study show that the key dimensions of external auditory canal for hearing protection are the length, width, depth of cavum concha, the ear aperture length and width, the canal isthmus, and the length of from ear aperture to first bend and second bend. In addition, we find the differences in ear canal size between men and women. The results of this study can give references for designing and choosing earplugs, achieve the objective of hearing protection for workers.

Keywords External auditory canal · Anthropometric · Hearing protection

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1 Introduction

Occupational noise still remains one of the most prevalent occupational health and safety problems. If workers long tern expose to noise environment will damage their hearing ability and even become deaf [1, 2]. Therefore, hearing protectors are very important in providing proper protection for workers' hearing ability in noisy working environments. Hearing protection could reduce sound entering ear canal, prevent middle ear damage and provide appropriate protection [3]. Noise-induced hearing loss can be prevented by avoiding excessive exposure to noise and using hearing protection such as earplugs and earmuffs [4, 5]. However, due to the discomfort of wearing hearing protection, workers in noisy work environments often do not wear them [6]. For instant, ear plugs generate pressure and heat, and are also body-intrusive. Ear plugs may cause irritation of the ear canal. The fitness and comfort issues reduce the workers' willingness to wear earplugs, thereby causing earplugs to lose their hearing protection effects. Moreover, existing earplugs in Taiwan are generally a poor fit for the ear canal size of domestic workers or are even too large because of these earplug are primarily imported. However, because they have no other choice, domestic workers are forced to wear earplugs that are too large and sometimes cause discomfort because the wall of the ear canal is squeezed by excessively large earplugs [7].

The protection efficiency of wearing hearing protectors such as earplug depends heavily on whether it is fitting inner the ear. Three-dimensional (3D) surface anthropometry enables us to collect key dimensions to fit between ear canal and earplug. However, few studies explore the relationship between hearing protectors and 3D canal data. Therefore, this study employs an ear impression injection and 3D scanning of ear impression to measure the external auditory canal size of Taiwanese adult, and determined the key dimensions of EAC to provides a reference for hear protecting earplug design.

2 Method

2.1 Participants

110 pair ear canal with normal hearing functions were collected. Their ages are between 20 and 40 years old. 220 ear canal impressions were taken from both side ears participants.

2.2 Ear Canal Data Collection

Ear canal is a complex geometry. In order to collect ear canal data, we using conventional hearing aid fitting methods, binaural closed-jaw impressions of the

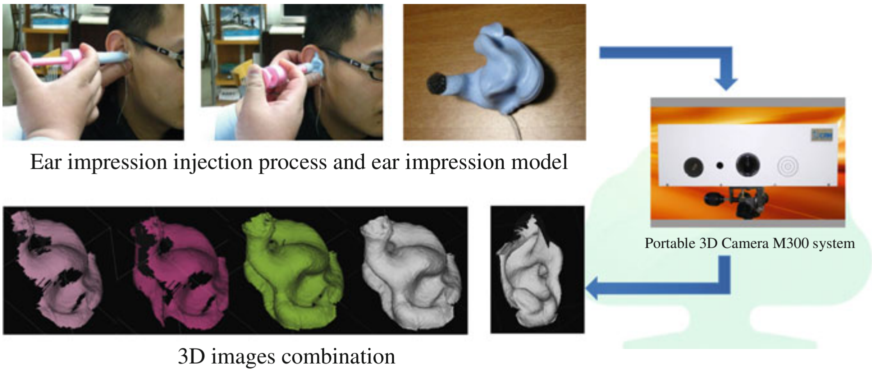

Fig. 1 3D ear canal model collection process

participants' ear canals were took using vented foam ear dams, a cartridge impression gun, and silicone impression material. Solid impression molds of both ears of each subject were fabricated. The steps of the ear canal collection process are briefly depicted in Fig. 1. Each impression was examined to be sure that its surface was smooth with no gaps, the canal portion clearly extended beyond the second bend of the ear canal, the concha portion was full and well-defined, and anatomical landmarks such as the first and second ear-canal bends were clearly visible. After collecting the ear impression model, each solid mold will also used 3D scan technique as the outer ear. Each model was taken 10 photos from different angels through 3D camera and use Beauty 3D software to automated merging all 3D images and filling the holes.

2.3 Definition of Ear Canal Landmarks

There are 19 landmarks (See position in Figs. 2 and 3, and definition in Table 1). The descriptions of these landmarks were through the anatomy features. These landmarks are important for the ear canal-related product [8, 9], and the most commonly applied in hear aid devices [9–13]. According these landmarks 13 dimensions were conducted (See Table 2).

3 Result and Discussion

In Table 3 shows the average and percentiles of all the collected ear canal dimensions. The obtained data indicates that the man's ear canal openings have an average 5 to 95 ‰ of height from 9.25 to 13.99 and width from 6.15 to 9.86 mm, respectively. The longest first bend length is anterior part and range from 5.10 to

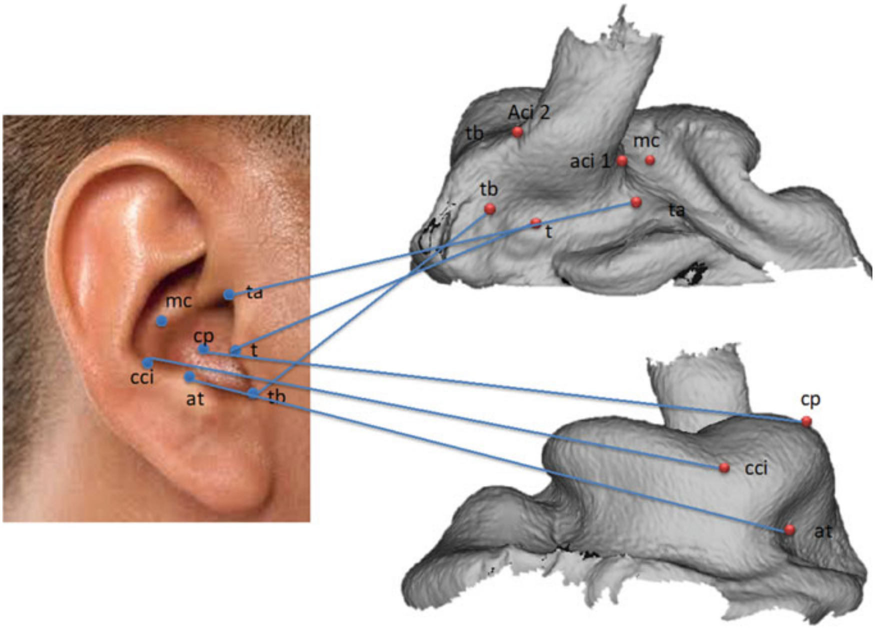

Fig. 2 The landmarks position on the ear and ear canal (I)

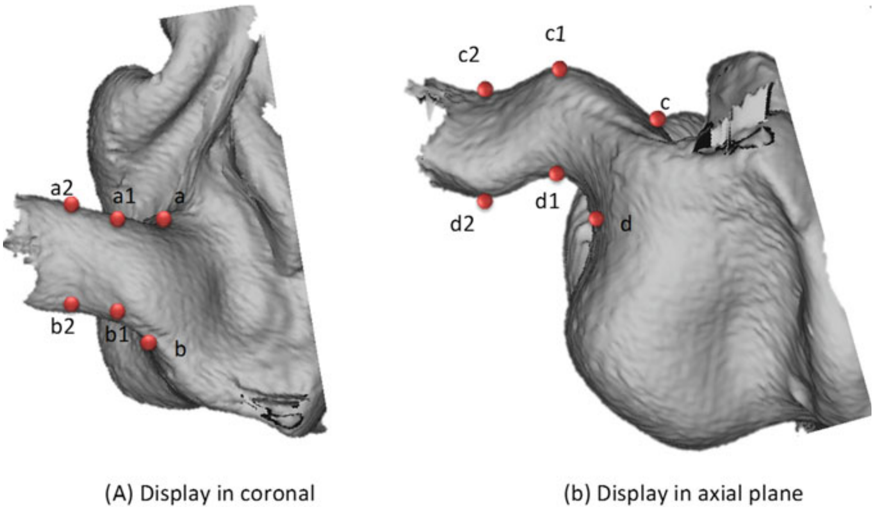

Fig. 3 The landmarks position on the ear and ear canal (II)

Table 1 Definition of ear canal landmarks

Items	Landmark	Code	Items	Landmark	Code
1	Tragus	t	11	The posterior points on the aperture	d
2	Incisura anterior auris posterior	ta	12	The superior points on the first bend	c1
3	Incisura intertragica inferior	tb	13	The inferior points on the first bend	d1
4	Crus-concha interaction	cci	14	The anterior points on the first bend	a1
5	Anti-tragus	at	15	The posterior points on the first bend	b1
6	Center of crus	mc	16	The superior points on the second	c2
7	Concha peak	cp	17	The inferior points on the second	d2
8	The superior points on the aperture	a	18	The anterior points on the second	a2
9	The inferior points on the aperture	b	19	The posterior points o on the second	b2
10	The anterior points on the aperture	c			

Table 2 Definitions of ear canal dimensions

Items	Dimensions	Definitions	Items	Dimensions	Definitions
1	Concha length	tb-mc	8	Superior second bend length	a-a1
2	Concha width	t-cci	9	Inferior second bend length	b-b1
3	Concha height	cp to t, at, mc plan	10	Anterior second bend length	c-c2
4	Ear canal opening length	au-as	11	Posterior second bend length	d-d2
5	Ear canal opening width	al-ar	12	Superior second bend length	a-a2
6	Anterior second bend length	c-c1	13	Inferior second bend length	b-b2
7	Posterior second bend length	d-d1			

9.02 mm. The longest second bend length is anterior part and range from 7.39 to 12.18. These two dimensions could be the reference of earplug length for Taiwanese male workers.

Table 3 Ear canal dimensions of males

Dimensions	Mean	SD	Percentile						
			5	10	25	50	75	90	95
Concha length	20.14	1.65	17.74	18.09	18.89	20.00	21.00	22.18	23.24
Concha width	17.48	1.51	14.94	15.49	16.52	17.39	18.61	19.44	19.87
Concha height	17.48	1.51	14.94	15.49	16.52	17.39	18.61	19.44	19.87
Ear canal opening length	11.50	1.29	9.45	9.73	10.59	11.45	12.27	13.26	13.99
Ear canal opening width	7.89	1.07	6.15	6.40	7.12	7.99	8.57	9.34	9.86
Anterior first bend length	6.95	1.19	5.10	5.43	6.04	6.91	7.68	8.59	9.02
Posterior first bend length	4.79	0.94	3.41	3.66	4.12	4.68	5.26	6.05	6.64
Superior first bend length	5.84	0.87	4.47	4.72	5.14	5.90	6.38	7.08	7.24
Inferior first bend length	6.65	1.06	5.01	5.47	5.98	6.55	7.05	8.15	8.91
Anterior second bend length	9.84	1.37	7.39	8.11	8.96	9.74	10.78	11.72	12.18
Posterior second bend length	7.64	1.27	5.67	6.08	6.75	7.66	8.27	9.36	10.12
Superior second bend length	8.72	1.17	6.78	7.27	7.91	8.73	9.57	10.37	10.68
Inferior second bend length	9.67	1.35	7.70	7.93	8.78	9.49	10.67	11.65	12.09
Height	172.42	6.11	164.10	165.00	168.00	172.00	175.00	180.00	188.30
Weight	67.49	9.97	50.00	55.20	62.00	66.00	72.00	79.60	89.50
BMI	22.72	3.30	18.16	18.59	20.81	22.41	23.86	27.00	30.77

In Table 4 shows the average and percentiles of all the collected ear canal dimensions. The obtained data indicates that the women's ear canal openings have an average 5 to 95 percentiles of height from 9.43 to 13.08 and width from 5.87 to

Table 4 Ear canal dimensions of females

Dimensions	Mean	SD	Percentiles						
			5	10	25	50	75	90	95
Concha length	19.72	1.51	17.16	17.65	18.79	19.74	20.61	21.81	22.43
Concha width	16.51	1.73	14.00	14.19	15.29	16.48	17.67	18.58	19.57
Concha height	16.51	1.73	14.00	14.19	15.29	16.48	17.67	18.58	19.57
Ear canal opening length	11.12	1.16	9.43	9.69	10.20	11.09	11.95	12.52	13.08
Ear canal opening width	7.52	1.15	5.87	6.03	6.68	7.47	8.11	8.99	9.90
Anterior first bend length	6.59	1.14	4.69	5.00	5.73	6.54	7.42	8.14	8.53
Posterior first bend length	4.76	0.90	3.61	3.75	4.17	4.51	5.35	5.85	6.31
Superior first bend length	5.60	0.82	4.26	4.42	5.00	5.57	6.20	6.78	6.98
Inferior first bend length	6.40	0.98	4.75	5.12	5.74	6.33	7.06	7.58	8.30
Anterior second bend length	9.54	1.44	7.46	7.73	8.41	9.41	10.60	11.43	11.95
Posterior second bend length	7.80	1.47	5.90	6.21	6.89	7.60	8.44	9.33	11.60
Superior second bend length	8.57	1.22	6.67	6.98	7.74	8.57	9.33	10.20	10.75
Inferior second bend length	9.42	1.26	7.41	7.91	8.62	9.39	10.29	10.87	11.61
Hight	158.55	5.04	148.00	153.00	156.00	158.00	162.00	166.00	168.00
Weight	51.68	10.06	42.00	44.90	48.00	50.00	54.00	60.00	72.00
BMI	20.64	4.24	16.33	17.53	19.13	20.08	21.89	23.77	26.67

9.90 mm, respectively. The longest first bend length is anterior part and range from 4.69 to 8.53 mm. The longest second bend length is anterior part and range from 7.46 to 11.95. These two dimensions could be the reference of earplug length for Taiwanese female workers.

Table 5 reveals the difference between males and females. The result indicated that most of all ear canal dimensions of males are longer than females unless the length between ear opening to first bend and second bend.

Overall, the results of the study show that the key dimensions of external auditory canal for hearing protection are the length, width, depth of cavum concha,

Table 5 The difference of ear canal dimensions between males and females

Dimensions	Gender	Mean	SD	t	p
Concha length	Male	20.14	1.65	2.02	0.045
	Female	19.72	1.51		
Concha width	Male	17.48	1.51	4.527	0.000
	Female	16.51	1.73		
Concha height	Male	17.48	1.51	4.527	0.000
	Female	16.51	1.73		
Ear canal opening length	Male	11.50	1.29	2.358	0.019
	Female	11.12	1.16		
Ear canal opening length	Male	7.89	1.07	2.571	0.011
	Female	7.52	1.15		
Anterior first bend length	Male	6.95	1.19	2.358	0.019
	Female	6.59	1.14		
Posterior first bend length	Male	4.79	0.94	0.203	0.839
	Female	4.76	0.90		
Superior first bend length	Male	5.84	0.87	2.157	0.032
	Female	5.60	0.82		
Inferior first bend length	Male	6.65	1.06	1.85	0.066
	Female	6.40	0.98		
Anterior second bend length	Male	9.84	1.37	1.606	0.110
	Female	9.54	1.44		
Posterior second bend length	Male	7.64	1.27	-0.879	0.380
	Female	7.80	1.47		
Superior second bend length	Male	8.72	1.17	0.954	0.341
	Female	8.57	1.22		
Inferior second bend length	Male	9.67	1.35	1.48	0.140
	Female	9.42	1.26		
Height	Male	172.42	6.11	15.58	0.000
	Female	158.55	5.04		
Weight	Male	67.49	9.97	9.956	0.000
	Female	51.68	10.06		
BMI	Male	22.72	3.30	3.447	0.001
	Female	20.64	4.24		

the ear opening length and width, the canal isthmus, and the length of from ear aperture to first bend and second bend. In addition, we find the differences in ear canal size between men and women. The results of this study can give references for designing and choosing earplugs, achieve the objective of design more fitting hearing protection for Taiwanese workers.

References

1. Brookhouser, P.E.: Prevention of noise-induced hearing loss. Prev. Med. **23**, 665–669 (1994)
2. Sanders, M.S., McCormick, E.J.: Human Factors in Engineering and Design. McGRAW-HILL, New York (1993)
3. Canetto, P.: Hearing protectors: topicality and research needs. Int. J. Occup. Saf. Ergon. **15**, 141–153 (2009)
4. Phoon, W., Lee, H.: Hearing protection plans require proper ear plug selection, usage. Train workers on noise hazards and motivate them to wear hearing protectors. Occup. Health Saf (Waco, Tex.) **62**, 98 (1993)
5. Rabinowitz, P.M.: Noise-induced hearing loss. Am. Fam. Physician **61**, 2759–2760 (2000)
6. Hsu, Y.L., Huang, C.C., Yo, C.Y., Chen, C.J., Lien, C.M.: Comfort evaluation of hearing protection. Int. J. Ind. Ergon. **33**, 543–551 (2004)
7. Yu, J.F., Lee, K.C., Wang, R.-H., Chen, Y.-S., Fan, C.C., Peng, Y.C., Tu, T.-H., Chen, C.I., Lin, K.Y.: Anthropometry of external auditory canal by non-contactable measurement. Appl. Ergon. **50**, 50–55 (2015)
8. Baloch, S., Melkisetoglu, R., Flöry, S., Azernikov, S., Slabaugh, G., Zouhar, A., Fang, T.: Automatic detection of anatomical features on 3D ear impressions for canonical representation. In: Medical Image Computing and Computer-Assisted Intervention–MICCAI 2010, pp. 555–562. Springer, Berlin (2010)
9. Sickel, K., Baloch, S., Melkisetoglu, R., Bubnik, V., Azernikov, S., Fang, T.: Toward automation in hearing aid design. Comput. Aided Des. **43**, 1793–1802 (2011)
10. Ahmad, I., Lee, W., Binnington, J.: External auditory canal measurements: localization of the Isthmus. Oto-Rhino-Laryngologia Nova **10**, 183–186 (2001)
11. Alvord, L.S., Farmer, B.L.: Anatomy and orientation of the human external ear. J. Am. Acad. Audiol. **8**, 383–390 (1997)
12. Alvord, L.S., Morgan, R., Cartwright, K.: Anatomy of an earmold: a formal terminology. J. Am. Acad. Audiol. **8**, 100–103 (1997)
13. Smelt, G., Hawke, M., Proops, D.: Anatomy of the external ear canal: a new technique for making impressions. J. Otolaryngol. **17**, 249–253 (1988)

Development of a User Interface for the Enrichment of Situational Awareness in Emergency Management Systems

Natália Oliveira, Fábio Rodrigues Jorge, Jéssica Souza, Valdir Pereira Júnior and Leonardo Botega

Abstract The individual's perception and understanding obtainment on events that transform an environment and their real critical contexts, is named Situational Awareness (SA). This process assists emergency management situation, allowing experts on SA acquisition and maintenance process, and provide subsidies for an assertive decision making. Specialized SA User Interfaces (UI) may facilitate the knowledge acquisition, allowing the perception and dynamic comprehension. The UIs design of SA-oriented systems in critical scenarios, as emergency management is a challenging issue, considering the presence of multiple heterogeneous data source, the information about situation that's in constant transformation and quality limitations associated every new inference. Known approaches seek to present specifically solutions to their application domain and are inevitably limited as the described needs in this paper. This paper presents the UI development to promote the visualization and situational information evolution follow-up, information quality aware, driven to a case of study in emergency management, which includes new challenges like the data presentation from human intelligence.

Keywords Situational awareness · User interface · Emergency systems assessment

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1 Introduction

Endsley [1] defines Situational Awareness (SA) as a process based on perception and comprehension development about what is happening in the environment inside of a volume and space of time, and the projection of its status in the near future.

The decision making systems, as emergency management systems, are recognized by experts as base provider to support the situational perception.

In critical scenarios, such emergency calls domain, a SA poor may harm the situation comprehension, compromising the allocation of resources, the heritage and the environment preservation. Furthermore, the SA process improvement may support operational process, assisting on the strategic actions planning, improving decisions quality and allowing better scenario comprehension.

Define a graphic representation process for critical situation management domain, is a challenge issue on Situation Assessment community, given the dynamics and complexity of information representation [2]. Moreover, provides data to experts about information's quality, to acquire a better comprehension about what is happening on the environment, are factors that assists the decision making process [3].

The data quality in assessment of emergency situations is also one of the critical factors in the decision making process [4], whereas situation awareness process may be impaired, have reduced effectiveness when imperfections information is input into the process, contributing negatively with the formation the operator mental model to respond to emergency calls.

In this paper is introduced the UI development dedicated to support of emergency situation data and information representation and management, quality aware, produced by emergency management system. A case of study addressing the analysis an emergency management domain is characterized, in order to illustrate as the use of UI can contribute to the situation assessment process.

2 Interfaces for Emergency Management

This section presents the state-of-the-art for SA-oriented interfaces. Existing solutions typically aim to empower the operator and the system by intensifying their relationship with information to build a more feasible representation of situations.

Yu et al. [5] presented a new visualization context through the UI, which has an interpretation engine for the operator's needs, defining which information must be presented. For the improvement of the operator's comprehension, a mechanism of fuzzy control was proposed to perform a diffuse search based on specific keywords of the application domain by operators' interactions.

Feng et al. [6] developed a decision support system that incorporates shared SAW among agents that extract relevant information about entities and represent them to the operator. These agents have the following set of goals and strategies for each SAW level: missions, plans, actions and physical attributes. Then, they are responsible for generating recommendations about the scenario. The UI deals with the spatial-temporal aspects of the evolution of missions.

Besides being efficient solutions for the specific application domains, such solutions are limited regarding the management of information being propagated through-out the cycle of situation assessment. Our approach innovates on promoting a full control of the information that is produced on each phase, using uncertainty representation and refinement methods as a resource to control the knowledge that is created, represented and used to assess situations.

The next chapter presents the interface development applied the Endsley [9, 10] guidelines, as well each item choices justifications.

3 The Development of the User Interface for Situational Assessment Systems

Situation Assessment has as the primary responsibility produce subsidies to assists the human operator's SA and consequently generate knowledge to the decision making process. A situation assessment complete process in complex scenarios it is intended to acquire, process and present parts of information, can contribute with situation understanding.

The process starts on Data Acquisition module, where the transcript of audio reported to the São Paulo State Police (PMESP) via emergency calls, and the social network posts acquisition is made. At this, a grammatical analysis to identify relevant objects, attributes and properties in sentences is performing, process called Natural Language Processing (NLP). A set of objects, attributes and properties called Situation, is produced and subject to the following module to the data and information quality assessment.

Data and Information Quality Assessment module determines a sequence of activities to quality data presents. Herein, situation is submitted to following dimensions' analysis: describing data or attributes completeness; currency, helps determine the information "age"; and uncertainty, a generalization of others dimensions in a single quality measure (set of data). Thus, each object has its completeness score, and in case of failure, time and uncertainty scores are applied [7].

On Situation Knowledge Representation Module, the goal is present semantic information, owing to flexibility present, object's relations in each class, called Object Propriety.

The Data and Information Fusion Module, performs search among the synergic information between present classes on ontology, that may hold object, attributes, proprieties and quality scores information's which have matching. As result, submitted information to fusion process are analyzed to find synergies, hierarchically, resulting new situational information [8].

Ultimately, SA-oriented User Interface Module, aims determines a sequence of activities to assists critical situations management process. This work, acts in this situational assessment stage. The UI, aims allow experts to SA acquire, maintain, and recover. This stage should present acquire, process, if necessary fused and present situations significantly.

The next chapter, the UI development is present and a case of study applied. This, refers to an urban robbery situation, related to PMESP's central monitoring complains, and the information inclusion on critical situations management process.

The case of study, guides this work development, describe an urban robbery complains input and process occurred in São Paulo/Brazil. The complains arrives to PMESP central, across emergency calls or social network posts. Each new complains, the system operator receives situational graphic representation actualization starting objects which comprise interest environment (the victim, the criminal, the stolen object, and event spot) and complainants present attributes and identified by the tool.

For the UI development lifting requirements, guidelines to SA design, introduced by Endsley [9, 10] were adopted. Thus, in this section are presented the development guidelines for each UI component and state of the arte design choices. Highlights up advantages and disadvantages each design choice for urban critical scenario.

In order to starts interface with information, our case of study will be addressing the following situation: "To stop the car on Domingos Setti avenue with Luis Vives street, at 2 PM, Luciano was surprised for an armed individual by an unidentified object. He was forced to out of the car with his hands up, but due to his age and walking difficulties, Luciano took some time to perform the robbery order, and in this way was assaulted hard head. Injured, Luciano get out of the car and tall individual, using light blue jeans and yellow t-shirt, run away with Luciano's black Porshe direction west of the city to Klabin subway. To be a little traffic local, they weren't registered many reports related to this incident."

3.1 Organize Information According to the Goals

The goal is analysis and evaluate situations from emergency management situations domain, to assists experts SA acquire using collated and processed information starting assessment systems.

For that, the information presentation was structured around goals to build a faithful situation presentation and follow the evolution, thus, it's necessary that UI do not totally goal-driven oriented, aiming SA contribution. Hence, the interface was divided into three different but inter-connected views. Fig. 1 presents the UI completed visualization for the acquisition of SA.

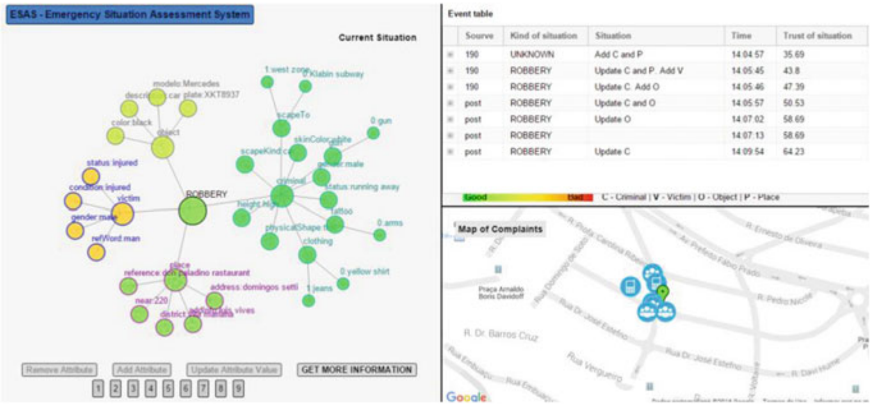

Fig. 1 UI presentation to emergency management

The first view (top right) in the UI is an object's table for incoming events, containing: information source, type of situation, objects found by acquisition and fusion, added time in-formation and the information quality (0–100) assessed. In this table was specificity the transformations, like: object data actualization.

Fig. 2, a report that occurs at 2:04 p.m. is exhibited: "*just happened a criminal here in domingos setti a driver was threatened and ordered he come out of vehicle with nothing the robbery run away toward the Klabin subway*" this are identified the information source, being an emergency call, type of situation that so far it is unknown, and could be add objects types: criminal and event spot, because ate the report this information was provided, feeding the situation.

The second view (bottom right) is a map-based, with visualizations as overlays geo-located according to the location of the acquired data. The use of georeferenced map overlays, is used in emergency management operations, because there is

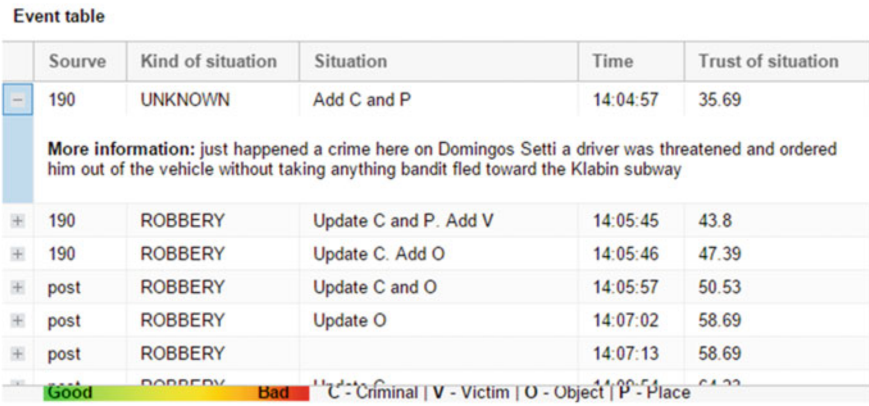

Fig. 2 First view, presentation of object's table for incoming events

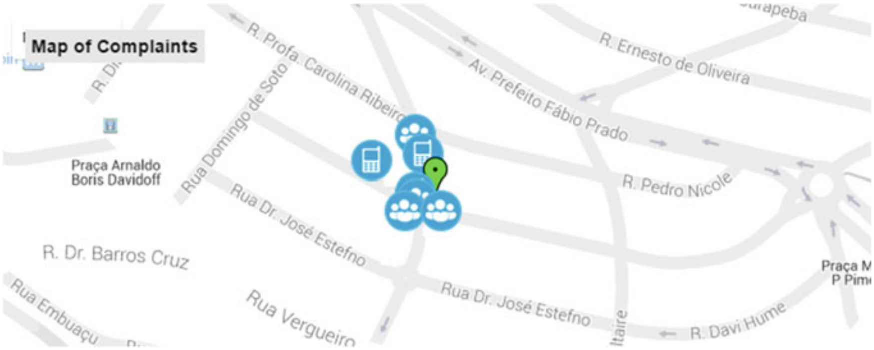

Fig. 3 Second view, map presentation

localization dependence to determine the attendance of the event, as shown in Fig. 3.

Based on case of study, ate the map are present the event spot approximated localizations identified in reports. The red marker presents the average found localization, and the blue glyphs presents de made reports localizations, differentiated by types, like: social network or emergency calls.

The third view (left) comprises for a relational graph, justified by the need of information hierarchical knowledge. Situation is present by the central node, with relations between objects and attributes.

The node size presents your importance; the biggest node presents the situation. The next level presents the set of objects (entities) identified on inference (ex: local). The smaller node leaves present the objects attributes (ex: reference points, descriptions, status), As show in Fig. 4.

3.2 Presenting Level 2 of Awareness Directly

The goal is to present necessary information into a second SA level that support directly understanding of minimum processing, as a first indication that a situation is probably happening. The idea is to present some figures already calculated instead of relying experts calculation on the Level 1 SA data.

Some situations (composed by objects and attributes) can be calculated and prioritized to reduce operator's mental calculation. For example, the automated part can perform information fusion from multiple objects "object" identified in the acquired information.

Fig. 5a shows a case of robbery, but refers something unidentified. By means of new reports, it is identified that a car was stolen, according to (b), is identified the car's color which is black (c) and the car's brand that is a Mercedes (d).

So, instead of displaying the input information separately information merged with low dimensionality and more meaning can be adopted.

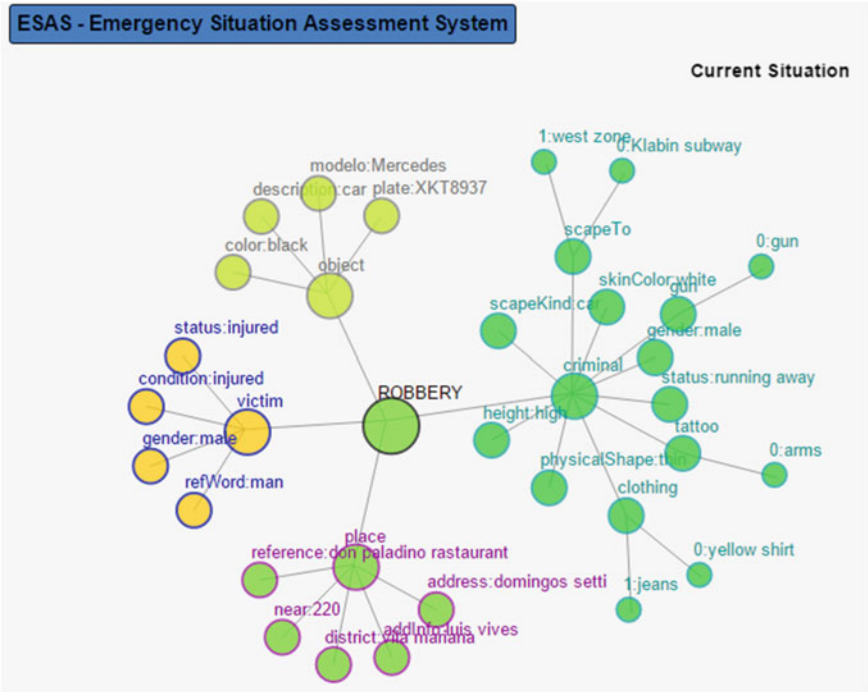

Fig. 4 Third view, hierarchical graph situational presentation

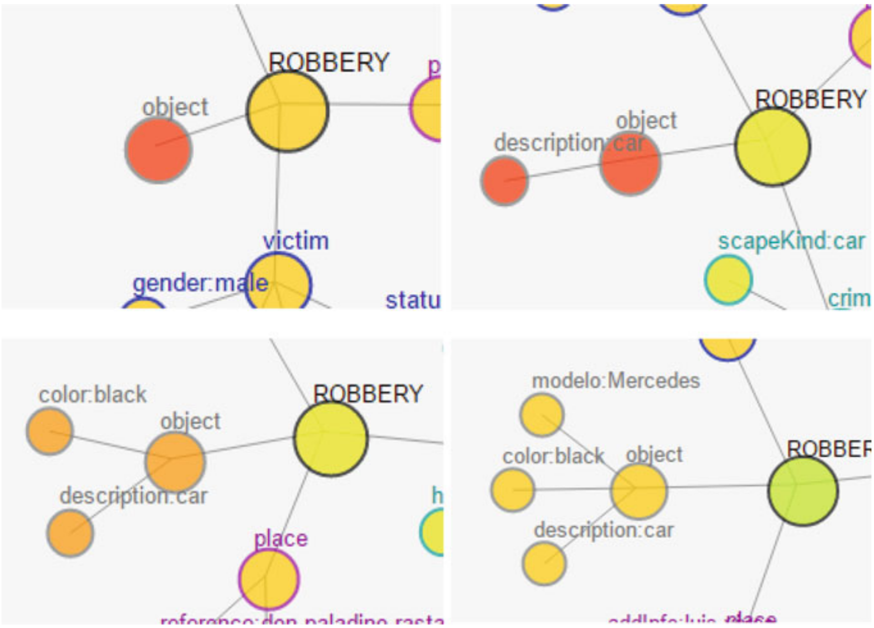

Fig. 5 Presenting level 2 of awareness directly

3.3 Supporting Global Situation Awareness

The "situation picture" should always be available. Global SA is the overview of the whole situation in a high level language and according to experts objectives. It is the data information and information apparently useful to the situation added to apparently not useful information.

In most Situation Assessment systems, global SA is always visible and can be crucial to determine what goals have high priority. In the development scenario of this UI, the overall SA can be represented by the map display, as shown in Fig. 3.

The permanence of these objects and attributes in the situation formation is important because according to the situation and information, the operator can be guided or not in the decision-making process.

3.4 Information Filtering

To avoid overloading not SA-related information should be filtered. The UI should only provide crucial information for the purposes of each task. Therefore, an interactive filter was developed.

This filter is useful to reduce search space and determines fusion candidates through visual analysis. However, SA does not occur instantaneously. Humans take time to orient themselves in relation to situations and critical attributes. To this end, the object table can be expanded on demand to expose and hide information on the report of a certain insertion of objects, textually, as shown in Fig. 2.

Furthermore, when a relation candidate has been detected, indicated by humans or the system, the table and the graph object provides a new graphical link indicating a probable relationship that may or may not be accepted by the skilled person.

3.5 Support the Reliability Verification of Information

It is known that in the context of data usage of human intelligence (HUMINT) as input, there is a great chance that the acquired data present some kind of quality problems.

To infer and represent the data source reliability local quality indices were adopted. The better the quality of the generated information, higher the data source reliability. Although the values reliability can be displayed numerically, Ware [11] states that the use of luminance levels is advised (lighter for more reliable).

Thus, the UI shows alternative forms of representing quality. The lower the information quality, the faster the human operator decision (high, medium, low) and they tend to better accept the lowest rates. The numerical data uses analog and in classification tend to generate slower decisions.

For UI, it is employed the use of colors and shapes, plotting relevant dimensions to the domain and generalization sure of the situation. The closer the node approaches the green color higher the data quality. The closer the red worse the data quality, according to Ware [11] on the perception of color in the representation of information.

3.6 Explicitly Identify Absence of Information

Humans deal with the absence of metadata as something positive. If there are positive readings, they find a lost reading is also positive when in fact, they can be extremely conflicting and inaccurate. Human beings act differently when they know if there is a likelihood of something going wrong. The lack of information is usually treated as correct and entrust level.

There are two variations of the problem: the inexistence of danger, which is when the information was analyzed and there is no threat; and when there are no known dangers when there are some places that were not covered or sensory limitations.

In addition, stress and workload can lead people to not pay attention to the lack of information. Some humans are dependent on visual information others only rely on their experience.

In that UI nodes have updated their internal color every time the information quality is corrected, mainly due to completeness, presented as the main information quality problem of information in this area, as Fig. 1.

The central node color in the graph represents certainty in the situation, calculated based on completeness and timeliness dimensions of objects. The color of the nodes of the first level is the quality level of each object, calculated based on completeness and particular object of the present time. The second nodes level of coloration follow the color of the first level, because it is a specialization of the object data.

Visual coloring techniques were used where the red-green scale and its hues qualify information. These are generally used to represent errors and information gaps. In this case, used to classify certain index thereof, as shown in the topical support and check the reliability of information.

The node size was used to represent information hierarchy, the highest (status) to the smallest (attributes), as shown in Fig. 5.

In the map, the use of glyphs happens due the abstraction the operator may have about the representation composed by objects in the formation of such display. In this case, a location marker was used to represent the median location in relation to other glyphs situation, as the colors techniques were employed. Glyphs with representation phones and social networks have been used to facilitate understanding of the origin of the information.

The site map was created in white and shades of gray to avoid operator's mental confusion in relation to relief and other information. Their choice is justified by better application grating staining of the glyphs, as shown in Fig. 3.

3.7 Representing Historical Events to Follow Up Information Evolution

In order to move forward and return to the situation evolution the UI displays graphic and interactive access to historical information on a timeline. A timeline was implemented in order to allow users to move along the situation and rediscover how it was at any given time.

In our approach, the situation is something that evolved over time. Past situations can also be restored through access buttons. When triggered, these buttons allow the user to navigate the situation, knowing how it behaved at any given time. The navigation is based on the reports where each number is the entry of a new report.

Thus, there is a possibility of returning in the past and also to monitor events in real time and move directly to a specific time. As a downside, there is a possible loss of focus on relevant current events and confusion about the reality of events.

3.8 Support Quality of Data and Information Level and Uncertainty Management

As experts need evaluate the utility of situational information, might have a manner for them be able to adapt such information to the necessities of their tasks. In this context, need the human act reflects on the information quality, it is inferred and presents by automation.

Once situational information was previously granted, the attributes referring to information quality are also measured and presented at the UI, together qualified information, in the visual suggestions form (cues) that shows such qualification. In this context, data and information quality not only assists experts to establish a trust level that they need deposit on information, but also guide them to seek resources to improve information quality, complementing the performed automation, but possibly cannot have been sufficient to arouse the human trust and stimulate the SA process.

In this approach, the expert is able to insert and remove parts of situational information, in this way, it is possible that expert insert, update or remove objects and attributes that compose situational awareness directly. The graph allows SA support allowing insertion and removal of news attributes that experts judge relevant for the situation as show in Fig. 6.

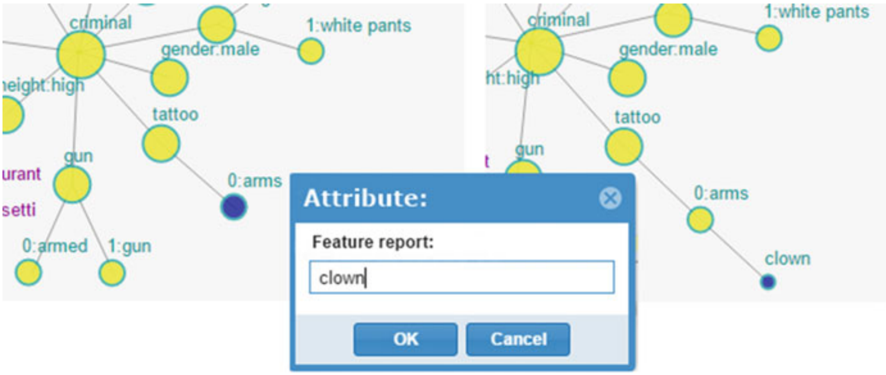

Fig. 6 Attributes insertion example. The clown attribute been inserted at tattoo attribute. Reference to the existence of a clown tattoo on the criminal arm

With this option at the tool, the UI expert have the possibility to manipulate the UI generated information, adding a new attribute that judge relevant for the situation or removing an attribute according your necessity.

Acting directly on situational knowledge, entered, updated or removed information reflect in others situational assessment process stages and may be considered for the Assessment, Fusion, Semantic Presentation and Graphical Interface.

4 Conclusion

During all Situation Assessment process, the situational information it is advertising, evolves and may be compromised because suffered transformations over time. The information quality in turn may be evaluated throughout the evolution process In this way, the user interface utilization to assists information management control helps the process to acquire, maintain and recover SA.

The UI, is responsible to allow the Situation Knowledge Presentation, where information presentations mechanisms do not interfere information semantically, but allow increment the situation knowledge relation process stages.

Both information has the goal to support SA-oriented UI, which is the situational information management and the contributed process for your formation.

With the information presented, concludes that is possible insert an SA-oriented UI on the emergency situation assessment process, because as shown at case of study the application had satisfactory results, assisting the experts acquire, maintain and recover SA process at UI. This conclusion, is based on the developed assessment and the UI development guidelines.

References

1. Endsley, M.R.: Designing for Situation Awareness: An Approach to User-Centered Design, vol. 56, pp. 727–728. CRC Press, Boca Raton (2011)
2. Kokar, M.M., Endsley, M.R.: Situation awareness and cognitive modeling. IEEE Intell. Syst. **3**, 91–96 (2012)
3. Llinas, J., Bowman, C., Rogova, G., Steinberg, A., Waltz, E., White, F.: Revisiting the JDL data fusion model II. Space and naval warfare systems command, San Diego, CA (2004)
4. Baumgartner, N., Gottesheim, W., Mitsch, S., Retschitzegger, W., Schwinger, W.: BeAware!—situation awareness, the ontology-driven way. Data Knowl. Eng. **69**(11), 1181–1193 (2010)
5. Yu, S., Deng, L., Zhang, Y.: Visualization user interface for decision support systems. In: Ninth International Conference on Hybrid Intelligent Systems, 2009, HIS'09, vol. 1, pp. 63–66. IEEE, August 2009
6. Feng, Y.H., Teng, T.H., Tan, A.H.: Modelling situation awareness for context-aware decision support. Expert Syst. Appl. **36**(1), 455–463 (2009)
7. Souza, J. Botega, L., Santarém Segundo, J.E., Berti, C.: Conceptual framework to enrich situation awareness of emergency dispatchers. In: 17th International Conference on Human-Computer Interaction, Los Angeles. Lecture Notes in Computer Science (LNCS) (2015)
8. Junior, V., Sanches, M., Botega, L., Souza, J., Saraiva, Caio., Fusco, E., Campos, M., Araújo, R.: Multi-criteria fusion of heterogeneous information for improving situation awareness on military decision making system. In: 17th International Conference on Human–Computer Interaction, 2015, Los Angeles. Lecture Notes in Computer Science (LNCS) (2015)
9. Endsley, M.R.: Designing for Situation Awareness: An Approach to User-Centered Design, vol. 365, pp. 19–21. CRC Press, Boca Raton (2012)
10. Onal, E., Craddock, C., Endsley, M.R., Chapman, A.: From theory to practice: how designing for situation awareness can transform confusing, overloaded shovel operator interfaces, reduce costs, and increase safety. In: ISARC 2013, pp. 1517–1525 (2013)
11. Ware, C.: Color sequences for univariate maps: theory, experiments and principles. IEEE Comput. Graph. Appl. **8**(5), 41–49 (1988)

Semi-visible Face Detection for Safety in Unconstrained Crowd Environment

Shazia Gul and Humera Farooq

Abstract Face recognition has gained interest due to largely growing public concerns for safety, specifically due to many terror activities around the world. These problems of terror increased the demand of suitable face recognition system in security applications. Face detection is the initial step for face recognition and it has been widely researched and examined. Numerous methods have been proposed with high detection rates in restricted scene. However, in unrestricted scene those method failed to perform accurate detection. The main challenges to deal in uncontrolled scene are detection of multiview, illuminated, occluded and blur faces. This research paper has studied the issues of face detection in unconstrained scene. More specifically, it has discussed the existing occluded face detection methods. Based upon the survey of different face detection methods, a half occluded face detection method is proposed. In order to deal with half occluded faces, new type of image features are proposed.

Keywords Unconstrained · Crowd · Occluded faces · Face detection safety · Free rectangular features

1 Introduction

At Present, along with the increasing use of panic activities around the world, safety problems is becoming more serious in public places and crowded areas. To increase the safety of people in the dense areas a robust method for people face identification is needed for many applications such as surveillance and other security systems. Most of the criminals use objects (accessories such as glasses or mobile phone) or

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mask to hide their face or some of them hide themselves intentionally to block their view from camera. Therefore a face identification method need to be developed to work in unconstrained crowd images and identify the people who are not properly visible in an image or video frame. Unluckily, identification of faces in crowded scene are too challenging [1]. In particular, identification of those people who try to conceal their faces in a crowded scene should be accurately detected.

Face detection algorithms are used in many real-time application such as surveillance system to detect individual of interest when enters in a secure area. Face detection is the primary phase for locating the face region and recognition concern with the identification of located region. The literature review shows that most of the existing work for face detection in crowd are based on the ideal situation [2–7]. Several studies has been shown considered for detection of frontal faces. However, those existing methods fail to perform detection in scenario where faces are captured with large number of variation in poses, illumination and occlusion.

In addition, most of the work has been done in face detection to processed frontal holistic faces and it achieved acceptable performance. Though, the face detection challenges such as; poses, illumination and occlusion are un-resolved issued in uncontrolled situations. The main challenge in detecting a face is to identify the person with semi visible face i.e. individuals who are trying to hide themselves behind someone or by their own body parts.

In order to construct a robust face identification system an occluded or semi visible face detection method is needed having high detection rates under uncontrolled environment. Development of such solution will be helpful in improving security environment, scientific research and help in the safety of sensitive areas as well as for general public places.

Existing literature shows that a numerous work has been done for detection in unconstrained crowd [8–13]. Each researcher aim to solve a single issue in crowd environment such as detection of individual movement, detection of crowd behavior, anomaly detection in crowd, calculating the crowd density, size or detection of frontal faces. However, it was noted that challenges associated with face detection is not solved in these techniques. It was also observed that the existing techniques [14, 15] of face detection in unconstrained environment achieve good results in some scenario such as detection of holistic faces, multi view faces but could not achieve good results if the face is occluded or illuminated.

In presented research work the emphasis is on solving problem related to security issues in unconstrained crowd environment. The detection of semi-visible faces in a crowd. For this purpose, different approaches of face detection have been studied. The purpose of this study to investigate the existing face detection methods in single face images and crowded images and to propose a technique for detection of occluded faces in unconstrained environment is the main focus of the proposed approach.

The rest of this paper is organized as follows. In Sect. 2 related work is reviewed. Section 3 describes about the proposed semi-visible face detection methods. Section 4. Determine experimental results Sect. 5. Finally, conclusion are drawn.

2 Related Work

As indicated in a recent survey done by [16] face detection methods are dived into four categories knowledge-based approach, feature-based approach, template matching approach and appearance based approach. Knowledge based approach capture knowledge based on faces and translate that knowledge to construct a set of rules. However, this method has many limitation; for example creating a proper set of rules can be difficult. If the rule is too general, there can be many false negative and false positive in case, if the rule is too detailed. This method is ineffective if the image is too complex with many faces [17]. Feature base approach is used to detect features in an image using pre-define features. It is used to localized human face using its features, for example eyes, nose, mouth and skin color. Unfortunately feature base method also failed to detect faces if the background is complex with different illumination condition and occlusion because features can be easily confused by the occluded region. Template matching approach used standard face pattern to detect faces. Several different pattern are stored and compare to the input image and detection is based on correlation between pattern and input image. Template matching approach is very simple but it is not proven strong for face detection because the detection is purely based on template and it cannot handle face effectively with variation in scale and positions. As shown in a survey of face detection methods, appearance based method is the most standard method and gained significant amount of popularity in last few years due to great efficiency and accuracy [18]. This machine learning approach is broadly used for learning of positive and negative images.

In 2001, Viola and Jones [19], implemented appearance based method and presents frontal face detection system. They proposed to use simple features in place of using pixel information, unlike state-of-the-art face detection methods which is use to boost classifier based on pixels [20]. The idea of these simple features were drive from haar wavelet. Haar wavelet are simple squared shape functions which are used from 1910 proposed by a mathematician Alfred Haar [21]. Several methods have been developed modifying Viola-Jones algorithm and concentrating on creating different cascade structure and extracting features [22–24]. Lienhart and Maydt [22] proposed an expansion of the haar-like feature for detection of the inclined face 45° and improved detection of holistic faces. Later Viola and Jones modified algorithm and used detector for multi view faces and represented additional haar like rectangular features [25].

As it is explained, there are several face detection methods [26, 27] in literature each method is design specifically to handle each challenge of face detection such as multiview and holistic face alone. However, the main challenge of face detection such as occlusion were not considered simultaneously in these approaches. On the other hand, several research papers had dealt face detection with occlusion [28–31] but these existing method limit themselves to detect occlusion in a single face image. Hence, these techniques are not useful if the background have more than one faces. As shown a face detection should be robust to detect concealed or occluded faces in unconstrained crowd environment, which is still an unsolved challenging problem in face detection.

In this proposed approach new type of rectangular features for semi visible or half occluded face detection is developed. The proposed features called free rectangular features unlike haar like features. Secondly a single cascade classifier has been developed to handle semi visible faces effectively. Skin color detection module is use to detect noise in an image and removed from the background based on the discriminative property of skin color.

3 Methodology

The literature review shows different techniques and methods of face detection and each category of the method performs well in certain criteria and also a drawbacks as well. Keeping in view those limitation, following high level diagram is proposed for half occluded face detection.

The complete procedure of the proposed approach has been outlined in Fig. 1. The first step is the detection of half faces and holistic faces. Firstly, half face detection module detects half right and half left faces in an image and holistic face detector module detect holistic faces in an image. Secondly, updating half face candidate is performed. The half face classifier also detects full faces right half and left half face area, therefore those images need to be removed for that purpose, those half faces which are basically full faces are detected using this step and removed. At the end detection of skin region is performed. Face region is confirmed through human skin color detection module because there are many false detection by the classifier, in order to remove those false detection, the skin color model is applied to verify the face area and remove other regions which are non-face.

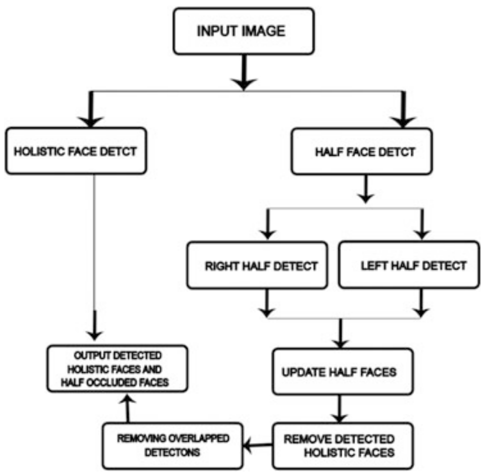

Fig. 1 Proposed semi visible face detection high level diagram

Furthermore, the execution of holistic face detection module depends on the Viola-Jones framework incorporated in OpenCV [32]. The classifier stored in OpenCV as haarcascade_frontalface_alt.xml is incorporated for holistic face detection. According to [33], the author describe this detector as the best holistic face detector, which works under variable conditions.

3.1 Half Occluded Face Detect

In the first stage, semi-visible or half occluded face detection is succeeded by detecting areas that indicate a half concealed human face. Face detection is based on Viola-Jones algorithm along with free rectangular features. Viola-Jones state-of-the-art method used four types of haar-like feature and Adaboost to select relevant features and discard non relevant.

However, The proposed half occluded face detection method use free rectangular features instead of haar like features, these features calculate only the difference between the two panes agreement pixels and it does not require branch operation according to the mask therefore it is fast.

Training Data for Half Occluded Faces. Positive examples are needed in order to train the classifier for positive examples (such as faces). Many face databases are available over the internet, among them the face images from LFW [34] database is selected. LFW is Labeled Faces in the Wild is the database containing unconstrained images. Figure 2 shows the example of images used for training of half occluded face, each face is trained by manually locating the half right and half left side of the face and the negative images such as non-face used in the implementation of proposed work.

Free Rectangular Features. Free rectangular are individual rectangles features. These features are separable rectangular unlike haar-like features which are composed of two or more rectangles with complex mass structure. The example of free rectangular features is illustrate in Fig. 3. Free rectangular features follows similar procedure like haar features as shown in Eqs. (1) and (2).

Fig. 2 Half face training examples and non-face images example

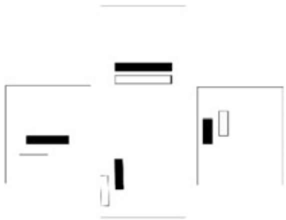

Fig. 3 Free rectangular features example

$$W_{sum} = \sum_{n=1}^{M} \sum_{x=W_{nx}}^{W_{nx}+W_{nw}-1} \sum_{x=W_{ny}}^{Wny+W_{nh}-1} i(x, y) \tag{1}$$

$$B_{sum} = \sum_{n=1}^{M} \sum_{x=B_{nx}}^{B_{nx}+B_{nw}-1} \sum_{x=B_{ny}}^{Bny+B_{nh}-1} i(x, y) \tag{2}$$

In Eqs. (1) and (2) $i(x, y)$ specify the brightness of each square area and n and m represents the number count. W represents the white square and B represents the Black square area and each of the x and y indicates x-axis and y-axis with vertical and horizontal lengths

$$f(x) = |W_{sum} - B_{sum}| \tag{3}$$

Equation (3) is indicated the absolute value of the difference of the each sum of black square area and each of the sum of white square rectangular area.

The proposed features seem very strong resistance to the brightness difference in color of the illumination change or race that utilizes the difference value between the respective regions as shown in Fig. 4.

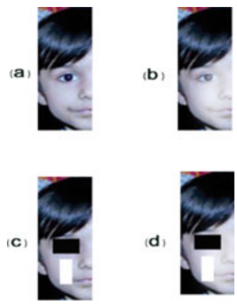

Fig. 4 Example of **a** lighted image and **b** non-lighted image. **c** Free rectangular feature applied to non-lighted image. **d** Free rectangular feature applied to lighted image

Fig. 5 Detection of half faces in an image

3.2 Update Half Face Candidate

The half occluded faces classifier is trained on half face images, therefore it detect half the face in the image, as the result some holistic faces are also detected by the classifier because holistic faces also contain half face areas (see Fig. 5).

Among all the faces put together including half occluded faces and holistic faces. In order to Find the center point, width and height of each face and compare them with each other, a threshold will be applied, which is equal to half face width. If there is similar distance between center and width of the face then this is surely a holistic face detected by the half face classifier. Holistic faces are also re-confirmed by the histogram of each half occluded face. If the histogram of two half faces are similar then these two half faces comprise of a holistic face. These holistic faces is removed using this module.

4 Experiments

In the following accuracy of proposed algorithm is analyzed through different experiment to observe its outcome at an optimal or sub-optimal solution. The main idea of proposed approach is to find all half occluded faces in the crowd image. The performance of the proposed approach will be evaluated based on the successful detection of half occluded faces and holistic faces in unconstrained crowd images. This evaluation will be carried out through these sets of experiments.

4.1 Evaluation Through FDDB Dataset Images

The FDDB [35] database is Face detection dataset and Benchmark which is mainly designed for studying and identifying the problems frequently occur in unconstrained environment. The proposed detector is mainly design for detection of semi visible faces therefore a subset of images containing semi visible faces are taken and tested. Figure 6 shows the example of FDDB dataset results by the proposed

Fig. 6 Detected half occluded and holistic faces from FDDB data set

Table 1 FP and TP rate of semi-visible faces [36]

Threshold	Average false positive	Average true positive rate
1	0	0.1
2	0.011111	0.19
3	0.155556	0.301667
4	0.195652	0.33

detector. Semi visible faces in each image are effectively detected which indicates that the method is capable to detect various type of occlusion in unconstrained image such as faces concealed by an object, glasses or another face. Table 1 summarize the results of proposed semi-visible face detector. The results has been collected manually for each image and based on the collected parameters average true positive rate and average false positive rate is calculated for different threshold values and Fig. 7 shows the graph based on these values.

Fig. 7 Accuracy curve of semi-visible faces [36]

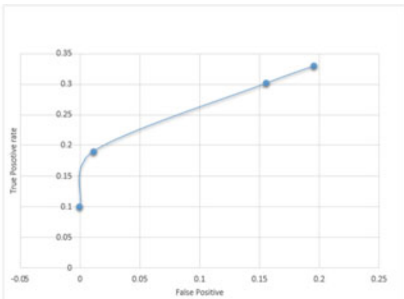

Fig. 8 Detected faces in the internet (crowded and group of people) images

4.2 Evaluation Through Crowded Images

Few images collected via internet has been tested and measured the performance of the proposed detector. Figure 8 displays the detection result of those images. Most of the faces in the image has been detected successfully, which proves that proposed method is effective method to work in these situations (See Fig. 8a) illustrate the image of huge crowd scene. The faces which are near to the camera such as foreground and mid ground are successfully detected but the background faces which are blur and too far away from focal point are ignore by the detector.

4.3 Evaluation Through Un-crowded Images

In order to check the effectiveness of the proposed algorithm on the uncrowded images. The images containing less than three faces are collected and tested. Some of the images were personal images and most of them are taken through internet. Figure 9 shows the result of the uncrowded images. The results shows that the proposed method prove successful on uncrowded faces. All of the uncrowded images tested on the proposed algorithm are detected successfully.

The proposed algorithm proves effective in other scenario as well such (see Fig. 9b), displays a women face occluded by a veil is successfully detected by algorithm. Moreover faces occluded by mobile phone and hands or another person are also detected. At the end another type of occlusion is investigated that is caused by non-uniform illumination for example (see Fig. 9e), those faces are not properly visible as one side of the faces is dark that is cause by a non-uniform illumination,

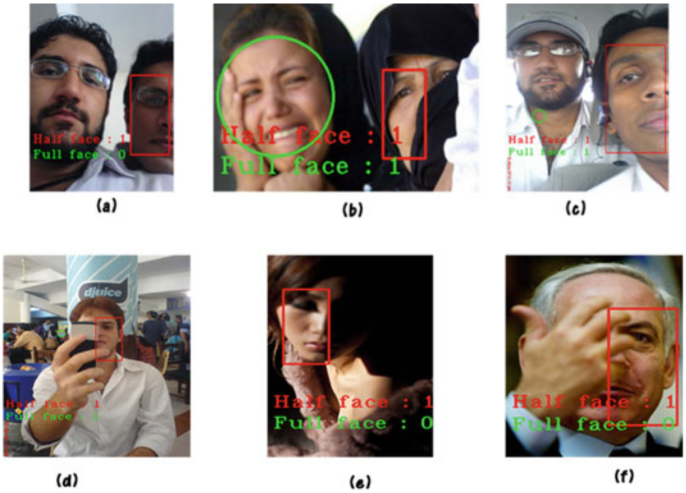

Fig. 9 Detected faces in un-crowded image

which is also a challenging problem in face detection. The proposed algorithm also detect those faces effectively and proved to be effective in non-uniform scenario a well.

5 Conclusion

This research paper has studied the issues of safety in unconstrained crowd environment. More specifically, it has discussed semi-visible face detection system in the crowd, where faces are obstructed and the detection system does not localize the occluded face region. Based upon the studies of chapter reviewed in literature an occluded face detection method is proposed. Furthermore, proposed method demonstrate that free rectangular features are more robust to occlusion. The skin color detection method is incorporated for more robust detection and removal of noise. Differentiation between holistic and occluded faces are effectively performed and removal of the overlap detection. The proposed method showed high detection rates and effectively deal with half occluded faces in the image. The experiments performed with the proposed detector effectively deals the half occluded faces which shows that it has ability to perform efficiently. However, it is also concluded that the performance of proposed method depend on the camera focus. The faces which are near to the camera are effectively detected but when it is far away from camera focal point (those faces which small size and blur) then the proposed detector is unable to detect those faces. The problems and limitation which needed to be research and examine in future are detection of those faces which are not near to the camera and detection of other type of occlusion (mouth occluded, both eyes occluded faces). These problems can be explored in future to address the problems of detection in un-constrained environment.

References

1. De Chant, T.: The Limits of Facial Recognition. PBS NOVA Next (2013)
2. Singh, A.R., Suganya, A.: Efficient tool for face detection and face recognition in color group photos. In: 2011 3rd International Conference on Electronics Computer Technology (ICECT) (2011)
3. Viola, P., Jones, M.J.: Robust real-time face detection. Int. J. Comput. Vision **57**(2), 137–154 (2004)
4. Saber, E., Tekalp, A.M.: Frontal-view face detection and facial feature extraction using color, shape and symmetry based cost functions. Pattern Recogn. Lett. **19**(8), 669–680 (1998)
5. Kotropoulos, C., Pitas, I.: Rule-based face detection in frontal views. In: 1997 IEEE International Conference on Acoustics, Speech, and Signal Processing, ICASSP-97. IEEE (1997)
6. Heisele, B., et al.: Component-based face detection. In: Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2001. CVPR 2001. IEEE (2001)
7. Hsu, R.-L., Abdel-Mottaleb, M., Jain, A.K.: Face detection in color images. In: 2001 Proceedings OF International Conference on Image Processing, 2001. IEEE (2001)
8. Andersson, M., Rydell, J., Ahlberg, J.: Estimation of crowd behavior using sensor networks and sensor fusion. In: 12th International Conference on Information Fusion, 2009. FUSION'09. IEEE (2009)
9. Arandjelovic, O., Zisserman, A.: Crowd detection from still images. In: BMVC. Citeseer (2008)
10. Bade, A.: Analysis of crowd behaviour theories in panic situation. In: International Conference on Information and Multimedia Technology, 2009. ICIMT'09. IEEE (2009)
11. Mahadevan, V., et al.: Anomaly detection in crowded scenes. In: 2010 IEEE Conference on Computer Vision and Pattern Recognition (CVPR). IEEE (2010)
12. Mazzon, R., Tahir, S.F., Cavallaro, A.: Person re-identification in crowd. Pattern Recogn. Lett. **33**(14), 1828–1837 (2012)
13. Wang, L., Dong, M.: Real-time detection of abnormal crowd behavior using a matrix approximation-based approach. In: 2012 19th IEEE International Conference on Image Processing (ICIP). IEEE (2012)
14. Barr, J.R., Bowyer, K.W., Flynn, P.J.: The effectiveness of face detection algorithms in unconstrained crowd scenes
15. Liao, S., Jain, A.K., Li, S.Z.: Unconstrained face detection. 2012, Technical Report MSU-CSE-12-15, Department of Computer Science, Michigan State University
16. Yang, M.-H., Kriegman, D.J., Ahuja, N.: Detecting faces in images: A survey. IEEE Trans. Patt. Anal. Mach. Intell. **24**(1), 34–58 (2002)
17. de Carrera, P.F.: Face recognition algorithms. Master's thesis in Computer Science, Universidad Euskal Herriko (2010)
18. Leibe, B., Schiele, B.: Analyzing appearance and contour based methods for object categorization. In: Proceedings of 2003 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2003. IEEE (2003)

19. Viola, P., Jones, M.: Rapid object detection using a boosted cascade of simple features. In: Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2001. CVPR 2001. IEEE (2001)
20. Pavlovic, V., Boosted detection of objects and attributes (2001)
21. StankoviĆ, R.S., Falkowski, B.J.: The Haar wavelet transform: its status and achievements. Comput. Electr. Eng. **29**(1), 25–44 (2003)
22. Lienhart, R., Maydt, J.: An extended set of haar-like features for rapid object detection. In: Proceedings. 2002 International Conference on Image Processing. 2002. IEEE (2002)
23. Mita, T., Kaneko, T., Hori, O.: Joint haar-like features for face detection. In: Tenth IEEE International Conference on Computer Vision, 2005. ICCV 2005. IEEE (2005)
24. Li, S.Z., et al.: Statistical learning of multi-view face detection. In Computer Vision—ECCV 2002, p. 67–81. Springer, Berlin (2002)
25. Jones, M., Viola, P.: Fast multi-view face detection. Mitsubishi Electric Research Lab TR-20003-96, 3: p. 14 (2003)
26. Wu, B., et al.: Fast rotation invariant multi-view face detection based on real adaboost. In: Proceedings of Sixth IEEE International Conference on Automatic Face and Gesture Recognition, 2004. IEEE (2004)
27. Huang, C., et al.: High-performance rotation invariant multiview face detection. IEEE Trans. Patt. Anal. Mach. Intell. **29**(4), 671–686 (2007)
28. Charoenpong, T., Nuthong, C., Watchareeruetai, U.: A new method for occluded face detection from single viewpoint of head. In: 2014 11th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON) (2014)
29. Chen, J., et al.: Modification of the adaboost-based detector for partially occluded faces. In: 18th International Conference on Pattern Recognition, 2006. ICPR 2006. IEEE (2006)
30. Hongxing, S., et al.: Facial area forecast and occluded face detection based on the YCbCr elliptical model. In: Proceedings 2013 International Conference on Mechatronic Sciences, Electric Engineering and Computer (MEC). IEEE (2013)
31. Ichikawa, K., et al.: Component-based face detection method for various types of occluded faces. In: 3rd International Symposium on Communications, Control and Signal Processing, 2008. ISCCSP 2008. IEEE (2008)
32. Bradski, G.: The opencv library. Doctor Dobbs J. **25**(11), 120–126 (2000)
33. Hassaballah, M., Murakami, K., Ido, S.: Face detection evaluation: a new approach based on the golden ratio ϕ. SIViP **7**(2), 307–316 (2013)
34. Huang, G.B., et al.: Labeled faces in the wild: a database for studying face recognition in unconstrained environments. Technical Report 07-49, University of Massachusetts, Amherst (2007)
35. Jain, V., Learned-Miller, E.G.: FDDB: a benchmark for face detection in unconstrained settings. UMass Amherst Technical Report (2010)
36. Gul, S., Farooq, H.: A machine learning approach to detect occluded faces in unconstrained crowd scene. In: 2015 IEEE 14th International Conference on Cognitive Informatics and Cognitive Computing (ICCI* CC). IEEE (2015)

Part II
Construction Safety

The Psychological Contract of Safety: The Missing Link Between Safety Climate and Safety Behaviour in Construction Sites

Mohammad Tanvi Newaz, Peter Davis, Marcus Jefferies and Manikam Pillay

Abstract The causal relationship between safety climate and safety behavior is examined in numerous studies, however the pathway that mediates this relationship is still unclear. Viewing safety through the lens of the 'Psychological Contract' it is argued that 'Psychological Contract of Safety' (PCSaf), could be a vital factor for improving safety performance. Previous research suggests that (1); safety climate is based on perception of workers regarding safety and (2); PCSaf is based on perceived mutual obligations between workers and supervisors, as a result, if PCSaf or mutual obligations between workers and supervisors are fulfilled, then safety behavior of the workers will be positively influenced. A proposed model of Psychological Contract of Safety (PCSaf) as an alternative intervention in the understanding and management of safety practice is presented. A final model will deepen understanding and reveal relationships between safety climate and safety behavior on construction sites.

Keywords Psychological contract of safety · Safety climate · Safety behaviour · Construction · Workers' perception toward safety

1 Introduction

Despite technological developments and the implementation of robust safety management systems, the construction industry's chronic level of fatalities, serious injury and ill-health appears resistant to change. This has led researchers and practitioners to focus on organizational and social factors, including safety climate, to induce positive change to the industry's poor safety performance [1]. Safety

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climate is considered a sub set of organizational climate and is believed to shape workers' behavior through their expectations about an organization's value and reward safety [2]. Desired safety values and behaviors should be enacted across different hierarchical levels of an organization. First-level supervisors play a key role in translating top management commitment to safety into safety values and practices within workgroups [3]. Although the importance of supervisors to worker safety behaviour has been well-established, specific behaviors most likely to support subordinate safety performance are less clear, especially in the construction industry [4]. Another area that has received little attention is the influence that organizationally based social exchanges between workers and supervisors may have on safety [5]. Blau [6], while discussing social exchange theory, argues that when one party acts in ways that provide benefits to other party; an implied obligation is generated for future reciprocity. Therefore, 'psychological contract' which is assumed as a consequent of social exchange theory can be introduced to capture the momentum between supervisors and workers to explore their relationships in terms of safety [6]. Psychological contracts of safety can be conceptualized as the beliefs of individuals about reciprocal safety obligations inferred from implicit or explicit promises [7]. Sully proposed the psychological contract as means of exploring this relationship, arguing that safety was already based on reciprocity involving a duty of care on the part of the employer and a reciprocal obligation to uphold safety standards on the part of the employee [7]. This research paper argues that the concept of psychological contract of safety could provide the cognitive basis for the development of workers safety behavior arising from supervisor's safety behaviour. This is a significant feature of safety climate in construction. Hence, a proposed framework, which explores the relationship between safety climate and safety behavior mediated by psychological contract of safety in a construction setting is suggested. The paper commences with an explanation of safety climate and safety behaviour in construction and their relationship and consequently introduces psychological contract of safety to explain the link between safety climate and safety behaviour.

2 Safety Climate in Construction

In the context of the construction industry, a number of notable safety climate studies have been conducted, please see; [8–14]. Consistent with research in other industries, there is empirical evidence to support a positive link between safety climate and the safety performance of construction organizations [15]. The relationship between safety climate and safety behaviour has been well established in safety research and its consequence are recognized as safety outcomes, which are crucial indicators for improved safety on construction sites. Despite this, researchers continue to explore different factor structures to study safety climate. Never the less, there is a movement to develop industry specific safety climate factor structures for ease of understanding the prime causes of positive and negative outcomes of safety initiatives. Hence, this paper identifies a common factor structure through a meta-analysis of safety climate studies in construction and proposes a factor structure to examine and explore the opportunity to obtain a common safety climate factor structure appropriate for construction industry.

Given the diversity of safety climate measures and indicators of safety performance within the safety literature in construction, the current study has used a meta-analysis to summarize these results and provide core dimensions of safety climate factors. A systematic search of the published literature was conducted using the SCOPUS database from 1980 to 2015. The keywords in the search being: safety climate; factors and dimensions of safety climate; construction safety; workers' perception; and safety management in construction. Following a literature review, 76 published articles of safety climate studies in the construction industry were identified. The reports were selected based on three main criteria: (1) the studies have a factor analysis of safety climate measurement; (2) the sample size of all the selected surveys is greater than fifty; and (3) the reports are published in English. Out of the 76 safety climate studies in construction across the globe, 16 studies met the criteria.

2.1 Factors of the Proposed Safety Climate Structure in Construction

Zohar described what he called a 'climate for safety' in 20 Israeli industrial organizations. This measure of safety climate was a summary of perceptions employees shared about their work environment and the relative importance of safety behaviour [16]. Based on questionnaires completed by over 400 employees, Zohar concluded 8 factors of safety climate following organizational practices, procedures, and rewarded behaviours were linked to an organization's safety level. Whereas Flin et al. [16], summarizes safety climate studies across several industries and through a meta-analysis, determined a set of 5 most common factors. However, as discussed previously, researchers have identified different factor structures contingent on respective industries and more recently they are focussing on the development of an industry specific common factor structure. In order to add insight into this endeavour, this research provides a meta-analysis of safety climate studies in construction and identifies a number of factors. Following Flin et al. [16], this research selected the 5 most common factors, described below, to capture the basic elements of workers' perception toward safety and utilize them as a safety climate factor structure set for future research. In addition, this research proposes to merge the 6th factor labelled as 'Communication' and the 7th factor labelled as 'Training' with the 2nd factor, renamed as 'Safety System', to strengthen the safety climate factor structure which would cover a comprehensively the workers' perception.

Management Commitment. Management commitment to safety is defined as the extent to which the general contractor management and safety personnel are perceived to place a high priority on safety, and communicate and act on safety issues effectively. Management commitment to safety has been identified as a core indicator of safety climate, which has been linked to increased safety behaviours and decreased injury severity in the construction industry [8, 10, 15, 17].

Safety System. The second factor identified in the majority of surveys was labelled as safety management/safety system. Generally respondents in the respective surveys were asked to indicate their satisfaction with the safety system or to indicate agreement/disagreement with statements relating to system performance. Out of 16 studies identified, 12 studies included some elements of safety system and safety management. In addition to the dimensions captured in this factor, this research includes 'Communication' and 'Training' within the factor 'Safety System' as these factors are influenced by the safety rules, regulations and activities of safety committee members involved in safety system.

Supervisor. Construction work is largely non-routine, necessitating the exercise of supervisory discretion in the interpretation of formal safety policies/procedures. In this context, the role of supervisors in shaping subordinates' safety behaviour is likely to be considerably greater than in work contexts with routine production processes [18]. First-level supervisors' responses to safety are a key determinant in the creation of subordinates' beliefs about the importance of safety to the organization [19].

Workers' Involvement. The next important theme is labelled as workers' involvement in safety. This label is provided due to indicators of worker's physical risk perception that defined the third factor of the Brown and Holmes [20] model in this study with indicators of workers' perceptions of control. This association led to speculation that worker perceptions of risk and control may be highly related to workers' involvement or responsibility for safety.

Co-workers/Workgroup Involvement/Support. Given the characteristics of construction work, which is undertaken within small workgroups, and in which members exercise considerable discretion in the interpretation of organizational safety policy and procedures, the role of first level supervisors and co-workers in shaping group-level safety climates is likely to be significant. Arguably, the group safety climate should be a stronger predictor of safety performance than organization level safety climate, especially in large organizations, because most workers have little contact with top management and are more likely to be influenced on a day-to-day basis by interactions with members of their immediate workgroup, including the supervisor and co-workers [21].

3 Safety Behavior in Construction

Choudhry [22] argues behavior is simply anything someone does or says. Psychologically, behaviors are actions or reactions of persons in response to external or internal stimuli. Work behaviors relevant to safety can be conceptualized in the same way as other work behaviors that constitute work performance. In this way, models of performance can be applied to safety performance in the workplace [23]. Derived from behavioral safety, the use of proactive measures of workers' perception of safety is thought to be one of the most useful indicators of safety performance (e.g., Borman and Motowidlo [24]; Broadbent [25]. Borman and Motowidlo [24] and Broadbent [25] identified two types of safety behavior: compliance and participation. 'Safety compliance' refers to the core activities individuals need to carry out to maintain workplace safety. These behaviors include adhering to standard work procedures and wearing personal protective equipment (PPE). 'Safety participation' describes behaviors that do not directly contribute to an individual's personal safety but which help to develop an environment that supports safety [26, 27]. Figure 1 shows the two types of workers' safety behaviour.

4 Influence of Safety Climate on Safety Behaviour

Researchers in various industries [for example; offshore oil drilling, forestry processing, machine manufacturing, healthcare, and construction [23, 28, 29] have found that safety climate has a significant affect on safety behaviour [4]. However, in construction, few studies have examined the mechanism through which organizational factors influence individual safety behavior at work [23]. For example, researchers have examined factors associated with safety climate (e.g. Mohamed [10]) within construction organizations and have suggested the need for a fundamental shift in our understanding of how safety is to be managed [30]. The generally positive and significant relationship between safety climate and various aspects of safety performance indicates that safety climate is a useful concept. In particular, the emergence of evidence from longitudinal studies permits researchers to make inferences about the direction of the causal relationship, i.e. safety climate shapes safety performance rather than the other way around. This evidence suggests that organizations should focus upon the strategic development of positive organizational safety climates as part of their occupational health and safety management activities [14].

What emerges from existing research is the proposition that important variables or characteristics of an organisational-level nature can lead employees to behave in particular ways in the context of safety. Currently, there is a lack of empirical evidence to inform the factors that influence how individuals attach meaning to, and interpret, elements of safety climate. This raises the question, how do the various elements of safety climate influence safety behaviours? [31]. Previous studies on supervisors' influence on worker safety behavior in construction is limited, and in the studies undertaken in construction and other industries, the interpretation of paths arising from supervisory behavior impacting worker safety behavior tends to be simple and not detailed [4]. Despite the importance of safety climate in the promotion of construction safety, previous studies have not focused on how to apply safety climate to accident prediction [32]. Therefore, it is clearly evident that there is a lack of understating of how different factors of safety climate influence the safety behaviour of workers. Hence, this research highlights this extant gap (Fig. 2) and argues certain mechanisms should be developed and tested to capture these missing phenomena between safety climate and safety behaviour in construction.

5 Psychological Contract and Safety

The influence of a supervisor in a construction setting is quite distinctive as described above. Considering the distinction and recognising the influence of supervisors and their relationship with workers, this research proposes, instead of using safety knowledge and safety motivation as determinants of safety performance, psychological contract of safety, which is based on the reciprocal relationship between worker and supervisor can be introduced to recognize the relationship between workers and supervisors in terms of safety. It is suggested that the concept of psychological contract of safety inherently endorses safety knowledge and safety motivation since psychological contract of safety is based on mutual obligated relationship between supervisor and workers. Accordingly it is assumed that if supervisors cannot develop the mutual and obligated relationship with workers in general then it would be difficult for them to improvise safety knowledge among workers nor can they motivate employees to promote safe behaviour in construction site. As a result this research supports and tests the concept of psychological contract of safety to address the gap between safety climate and safety behaviour and endeavours to develop a model to explain the mechanism by which safety climate factors influence safety behaviour in a construction setting.

The psychological contract of safety is defined as the beliefs of individuals about the reciprocal safety obligations between employer and employee inferred from implicit or explicit promises [7]. Employees form expectations about workplace safety that lead them to believe that certain actions will be reciprocated. These expectations constitute a psychological contract when employees believe that perceived employer safety obligations and perceived employee safety obligations are contingent on each other [33]. Seminal work of Rousseau [34] on psychological contracts in the organizational literature found two underlying contract dimensions characterized by the type of employment relationship perceived between the two parties: transactional and relational. Transactional contracts are short-term contracts that have an economic focus. They are observable and explicit in nature. Characteristic of transactional type contracts are performance-related pay and career development in exchange for longer working hours and multiple work roles. Relational contracts, on the other hand, are longer-term contracts with a socio-emotional focus. These types of contracts are subjective and implicit in nature, with traits such as hard work and loyalty being exchanged for job security [35]. Figure 3 illustrates the two elements of psychological contract of safety: employer safety obligations and employees safety obligations and two aspects of obligations: relational and transactional.

Before proceeding to the next section, it is important to address the gap that has been presented in Fig. 2 by adapting the concept of 'psychological contract of safety' coined by Walker and Hutton [7]. This research argues, since safety climate is basically the perception of workers regarding safety initiatives of management, supervisor and surrounding environment and psychological contract of safety is based on perceived mutual obligation of workers about safety, there should be a strong link between safety climate and psychological contract of safety. It is suggested that elements/factors of safety climate have strong impact on the formation of psychological contract of safety. Moreover, the level of fulfilment and breach of psychological contract of safety does have strong influence on worker's behavior that leads to safety outcomes [33]. In Walker's [33] model, injury is assumed as an antecedent of employee and employer obligation and how it influences safety behavior and safety climate. This research proposes a prospective view, where safety climate will be considered as an antecedent, psychological contract of safety (employee obligation and employer obligation) as determinant and safety behavior (compliance and participation) as component of safety performance.

As Lingard et al. [1] suggest, safety climate is theoretically positioned as an antecedent (rather than a consequence) of safety performance. In addition, Mohamed [10] examined the relationships between safety climate and safe work behavior in construction site environments using a structural equation model, which showed that safe work behavior was a consequence of safety climate. Since the pathway that safety climate influences safety behavior is unclear and specific behaviors of supervisor that influence safety components are not explicitly researched, this research proposes the concept of psychological contract of safety would be a strong platform where safety researchers can develop new models and test them explicitly in a construction setting. Subsequently, the relationship between fulfilment or breach of psychological contract and safety behavior is already proved [33], hence this research addresses the hypothetical gap and develops a framework (Fig. 5), which will be tested by the authors in a construction setting.

The relationships shown in Fig. 4, are used to extend the concepts via the below model (Fig. 5). In order to get an extended view and create a link among the Figs. 1, 2, 3, 4 and 5; all the above figures are merged into one (Fig. 5) and express

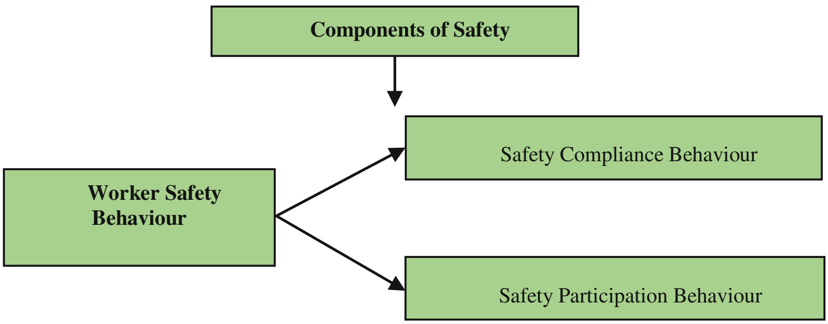

Fig. 1 Components of safety performance model adapted from Griffin and Neal [23]

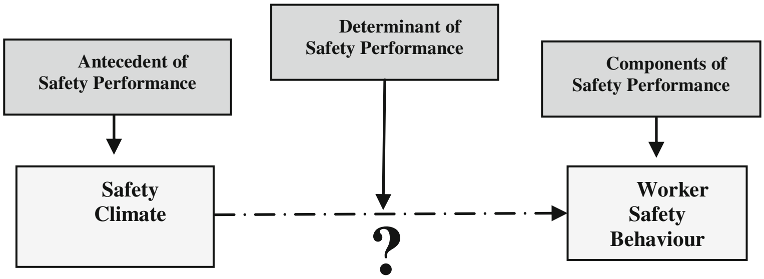

Fig. 2 Missing link between safety climate and behavior

Fig. 3 Model of psychological contract of safety adapted from Walker [35]

Fig. 4 Psychological contract of safety: the missing link between safety climate and behavior

the relationships between different components of the model. The new model adopts the model of Neal, Mark and Peter [27] concerning safety climate and safety behavior, along with Walker's [35] model of psychological contract of safety. However, as an alternative of using safety knowledge and safety motivation as determinants of safety performance as the Neal et al. [27] model, a psychological contract of safety is offered as a determinant of safety performance. Walker's [35] tested model of psychological contract of safety is brought into capture the dimension of relational and transactional aspect of employee and employer safety obligation to reveal a comprehensive analysis of safety obligations from the employee's point of view and their impact on safety performance (worker's safety

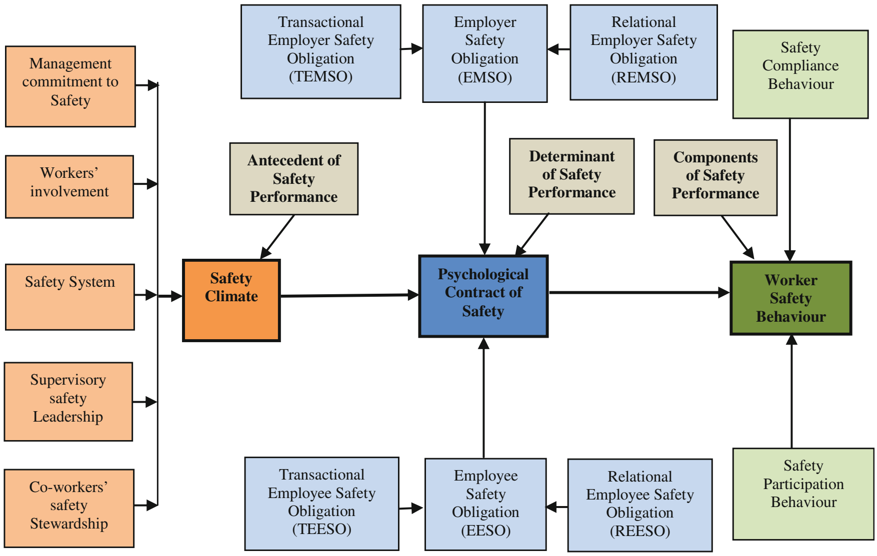

Fig. 5 Hypothetical model of psychological contract of safety

behaviour) in a construction background. It is crucial to decide the factor structure of safety climate considering the effect of the factors on psychological contract of safety and safety behaviour. As a result a factor structure emerged from a meta-analysis and was identified as the most common safety climate factors explored from safety climate studies in construction.

6 Implications of the Model

This hypothetical model has number of implications. This is the first model to explain the relationship between safety climate and safety behavior mediated by psychological contract of safety (PCSaf) in a construction setting. The factor structure developed from the meta-analysis will be examined to reveal how the factors of safety climate influence psychological contract of safety. In addition the research will identify how psychological contract of safety is formed from safety climate. The association between safety climate and psychological contract of safety will also express the strength of relationship between safety climate factors and elements of psychological contract of safety (employer and employee safety obligation). The influence of safety climate factors will also be assessed to relate the transactional and relational aspects of employer and employee safety obligation, which will be a significant development for both researchers and practitioners. In addition, the association between safety climate and safety behavior will be examined through this model. The connection between different factors of safety climate and components of safety performance (compliance and participation behavior) will be identified along with their strength of implication. In terms of relationship between psychological contract of safety and safety behavior new dimensions for safety research intervention are added. The association between two components of psychological contract of safety (employer and employee safety obligation) and two components of safety performance (compliance and participation behavior) will guide practitioners, together with academics on how workers' behavior is shaped by psychological contract of safety.

7 Conclusion

After more than 30 years of safety climate research, it is still unclear how safety climate influences the safety behavior. To address this, this research argues, psychological contract of safety (PCSaf) could be the key to explain the dynamics between safety climate and safety behavior. In addition, this research identifies the formation safety climate and proposes a framework to examine the mediated relationship of safety climate and safety behavior by psychological contract of safety in a construction setting. The implications of this research can be very useful for the managers, supervisors, safety advisors and workers on construction sites, helping to understand how safety activities should managed and factors that shape the worker safety behaviour. The next stage of the research planned is to test the proposed safety climate factor structure on a mega-construction project in New South Wales, Australia. While exploring the safety climate studies, this research proposes a model of psychological contract of safety (PCSaf) for construction industry and emphasizes that an examination of this model can lead researchers and practitioners to attain a better understanding of the relationship between safety climate and safety behavior through PCSaf. The next stage of the research will propose to test the interrelationships amongst each other in major construction projects of New South Wales, Australia.

References

1. Lingard, H.C., Cooke, T., Blismas, N.: Safety climate in conditions of construction subcontracting: a multi-level analysis. Constr. Manag. Econ. **28**, 813–825 (2010)
2. Zohar, D., Luria, G.: A multilevel model of safety climate: cross-level relationships between organization and group-level climates. J. Appl. Psychol. **90**, 616–628 (2005)
3. Lingard, H., Cooke, T., Blismas, N.: Do perceptions of supervisors' safety responses mediate the relationship between perceptions of the organizational safety climate and incident rates in the construction supply chain? J. Constr. Eng. Manag. **138**, 234–241 (2012)
4. Fang, D., Wu, C., Wu, H.: Impact of the supervisor on worker safety behavior in construction projects. J. Manag. Eng. 04015001 (2015)

5. Hofmann, D.A., Morgeson, F.P.: Safety-related behavior as a social exchange: The role of perceived organizational support and leader–member exchange. J. Appl. Psychol. **84**, 286–296 (1999)
6. Blau, P.M.: Exchange and Power in Social Life. Wiley, New York (1964)
7. Walker, A., Hutton, D.M.: The application of the psychological contract to workplace safety. J. Saf. Res. **37**, 433–441 (2006)
8. Dedobbeleer, N., Béland, F.: A safety climate measure for construction sites. J. Saf. Res. **22**, 97–103 (1991)
9. Glendon, A.I., Litherland, D.K.: Safety climate factors, group differences and safety behaviour in road construction. Saf. Sci. **39**, 157–188 (2001)
10. Mohamed, S.: Safety climate in construction site environments. J. Constr. Eng. Manag. **128**, 375–384 (2002)
11. Siu, O.-l., Phillips, D.R., Leung, T.-w.: Safety climate and safety performance among construction workers in Hong Kong. Accid. Anal. Prev. **36**, 359–366 (2004)
12. Fang, D., Chen, Y., Wong, L.: Safety climate in construction industry: a case study in Hong Kong. J. Constr. Eng. Manag. 573–584 (2006)
13. Choudhry, R.M., Fang., D., Lingard., H.: Measuring safety climate of a construction company. J. Constr. Eng. Manag. **135**, 890–899 (2009)
14. Lingard, H.C., Cooke, T., Blismas, N.: Group-level safety climate in the Australian construction industry: within-group homogeneity and between-group differences in road construction and maintenance. Constr. Manag. Econ. **27**, 419–432 (2009)
15. Gillen, M., Baltz, D., Gassel, M., Kirsch, L., Vaccaro, D.: Perceived safety climate, job demands, and coworker support among union and nonunion injured construction workers. J. Saf. Res. **33**, 33–51 (2002)
16. Flin, R., Mearns, K., O'Connor, P., Bryden, R.: Measuring safety climate: identifying the common features. Saf. Sci. **34** (2000)
17. Pousette, A., Larsson, S., Törner, M.: Safety climate cross-validation, strength and prediction of safety behaviour. Saf. Sci. **46**, 398–404 (2008)
18. Cooke, T., Lingard, H., Blismas, N.: Multi-level Safety climates: an investigation into the health and safety of workgroups in road construction. In: Proceedings of CIB W099 International Conference on "Global Unity for Safety and Health in Construction", Beijing, China (2006)
19. Zohar, D., Luria, G.: Climate as a social-cognitive construction of supervisory safety practices: scripts as proxy of behavior patterns. J. Appl. Psychol. **89**, 322–333 (2004)
20. Brown, R.L., Holmes, H.: The use of a factor-analytic procedure for assessing the validity of an employee safety climate model. Accid. Anal. Prev. **18**, 455–470 (1986)
21. Lingard, H.C., Cooke, T., Blismas, N.: Properties of group safety climate in construction: the development and evaluation of a typology. Constr. Manag. Econ. **28**, 1099–1112 (2010)
22. Choudhry, R.M.: Behavior-based safety on construction sites: a case study. Accid. Anal. Prev. **70**, 14–23 (2014)
23. Griffin, M.A., Neal, A.: Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. J. Occup. Health Psychol. **5**, 347 (2000)
24. Borman, W.C., Motowidlo, S.M.: Expanding the criterion domain to include elements of contextual performance. In: Personnel Selection in Organizations, p. 71. Jossey-Bass, San Francisco (1993)
25. Broadbent, D.G.: Maximizing safety performance via leadership behaviors. In: In Invited presentation at the 28th World Congress of Psychology, pp. 11–14 (2004)
26. Neal, A., Griffin, M.A.: Safety climate and safety behaviour. Aust. J. Manag. **27** (2002)
27. Neal, A., Mark, A.G., Peter, M.H.: The impact of organizational climate on safety climate and individual behavior. Saf. Sci. **34** (2000)
28. Varonen, U., Mattila, M.: The safety climate and its relationship to safety practices, safety of the work environment and occupational accidents in eight wood-processing companies. Accid. Anal. Prev. **32**, 761–769 (2000)

29. Neal, A., Griffin, M.A.: A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. J. Appl. Psychol. **91**, 946–953 (2006)
30. Choudhry, R.M., Fang, D.: Why operatives engage in unsafe work behavior: investigating factors on construction sites. Saf. Sci. **46**, 566–584 (2008)
31. Garavan, T.N., O'Brien, F.: An investigation into the relationship between safety climate and safety behaviours in Irish organisations. Ir. J. Manag. **22**, 141–170 (2001)
32. Zhou, Z., Goh, Y.M., Li, Q.: Overview and analysis of safety management studies in the construction industry. Saf. Sci. **72**, 337–350 (2015)
33. Walker, A.: Outcomes associated with breach and fulfillment of the psychological contract of safety. J Saf. Res. **47**, 31–37 (2013)
34. Rousseau, D.M.: New hire perceptions of their own and their employer's obligations: A study of psychological contracts. J. Organ. Behav. **11**, 389–400 (1990)
35. Walker, A.: The development and validation of a psychological contract of safety scale. J Saf. Res **41**, 315–321 (2010)

Resilience Engineering: A State-of-the-Art Survey of an Emerging Paradigm for Organisational Health and Safety Management

Manikam Pillay

Abstract Resilience engineering has been suggested to represent a new strategy for improving health and safety management. However, what resilience engineering is, and/or how it is different to organisational resilience is unclear. This paper provides a survey-of-the-art of RE in its widest context, based on a review of 46 articles published between January 1988 and December 2012. The state-of-art suggests that (i) a significant portion of literature comes out of work done in aviation, healthcare, nuclear and petro-chemical industries; (ii) there is no clear definition of OR, or of RE; (iii) RE lacks a clearly defined theoretical framework, and (iv) the gap between work as imagined and work as performed is an important reference point for research and practice in RE. The paper provides a working definition of RE and identifies a number of areas for advancing research and practice in this area of organisational health and safety management.

Keywords Health and safety management · Resilience engineering · Organisational resilience · Review

1 Introduction

Resilience engineering (RE) has been suggested to represent an innovative approach to improving organisational health and safety management [1, 2]. However, RE is relatively new to many human factors, safety practitioners and safety engineers, so its ability to deliver any improvements has been questioned [3]. In addition, compared to other strategies such as regulations, managements systems, safety culture or risk management; published research on RE appears patchy and disconnected. For example, publications on the topic frequently uses organizational resilience (OR) and RE interchangeably, suggesting they are one and the same. The language used in some of the published works refers to a multitude of

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characteristics and properties, making it a "semantically overloaded term in the sense that it means somewhat different things in different fields" [4]. Hence trying to develop a nuanced understanding of what it is (or not), can be a significant challenge for academic and researchers seeking to conduct research in RE, and for practitioners seeking to translate it into practice. This is a significant gap in the literature, which this paper aims to address, through a review of the state-of-the-art. The paper is organised as follows. First, the research method used for informing this reviews are discussed. Next, the landscape of RE is presented, followed by an analysis of published research in terms of industrial context, definitions, and dimensions/factors/measures. The paper concludes with a summary of main gaps in the literature, proposes a working definition and identifies a series of areas can for advancing research and practice.

2 Research Method

The search and selection of the literature, adapted from Hale et al. [5], included four (4) stages as illustrated in Fig. 1.

The first involved a systematic exploration of three electronic databases; Psyc INFO, Social Science Index (SSCI) and CINAHL, through the EBSCOHost platform, using *organisational resilience* and *resilience engineering* as key search terms, for publications between January 1988 and December 2012. The initial search resulted in 4 and 98 publications. The next included screening the titles and abstracts of the 103 articles to identify those that did not focus on health and safety management. The 66 articles removed at this stage focused on resilience in communities, psychological, children and youth, climate change, ecology and sustainability being removed. At the third stage, the remaining 37 full-articles were used as the basis for searching for further book chapters, conference proceedings and reports through *Google Scholar* using the titles or first author as keywords. An additional twenty (20) articles were added at this stage resulting in a sample of 57 papers for selection. The fourth and final stage involved applying the inclusion criteria of (a) peer-reviewed, (b) publications in English language, and (c) include one or more of the following: (i) definitions of the terms, (ii) measures, dimensions/factors or key concepts. A total of forty-six papers were included in the final review.

The next section charts the development of RE as a field of research and practice.

3 The Landscape of Resilience Engineering

The development of any new approach for improving organisational health and safety management has generally followed major catastrophes, and RE is no exception. The Columbia space shuttle disaster has been suggested to be a good

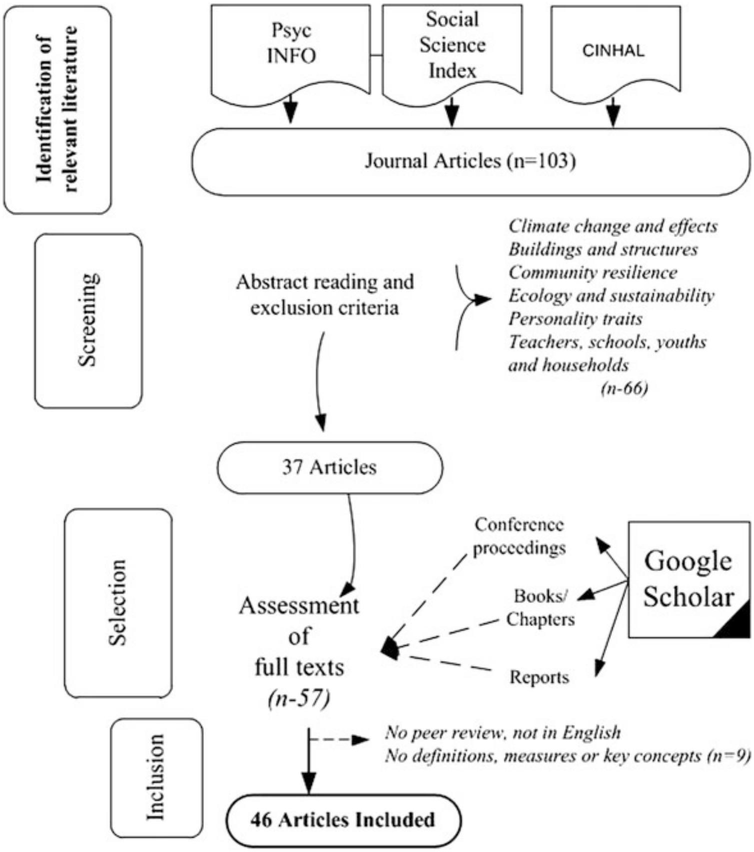

Fig. 1 Literature search and selection process

starting point [6]. On February 1, 2003 Columbia disintegrated upon re-entry to earth, killing all seven crew members [7]. RE emerged as a natural strategy to address a number of shortfalls in organizational behaviour in industries operating with similar cultural and organizational environments as Columbia. Following the release of the final report on the Columbia disaster, the first international symposium on RE was held in Sweden, and this acted as a catalyst for *Resilience Engineering Concepts and Precepts* [8]. This represents the seminal work in this field. Since then RE has gained momentum, with a steady stream of research being published from a range of domains. It is still relatively young as a field of research and practice [9] with a lot of scope for new and emerging academics, practitioners and researchers.

However, while RE is new, the ideas and concepts that it builds on have been part of the organizational and risk management literature for over two decades. The notion of resilience was first discussed by Wildavsky [10], who extended the ideas of ecological resilience into the safety domain. It has also been associated with high reliability organizations [11, 12], and more recently with the fifth age [13] or era; hence represents an evolution of health safety management practice.

3.1 Industries Contributing to Research

The review identified 37/46 articles included an industrial context, and a summary of the industries is illustrated in Fig. 2. The industries that were most represented included healthcare and petro-chemical, followed by aviation and nuclear; with a few articles also published from manufacturing, construction, electricity distribution and railways. The industries which have been highly represented include those who are very complex and technical in terms of their operations and processes, and they generally employ highly skilled personnel. Such organisations have been generally regarded as ‘tightly coupled and interactively complex’ [14].

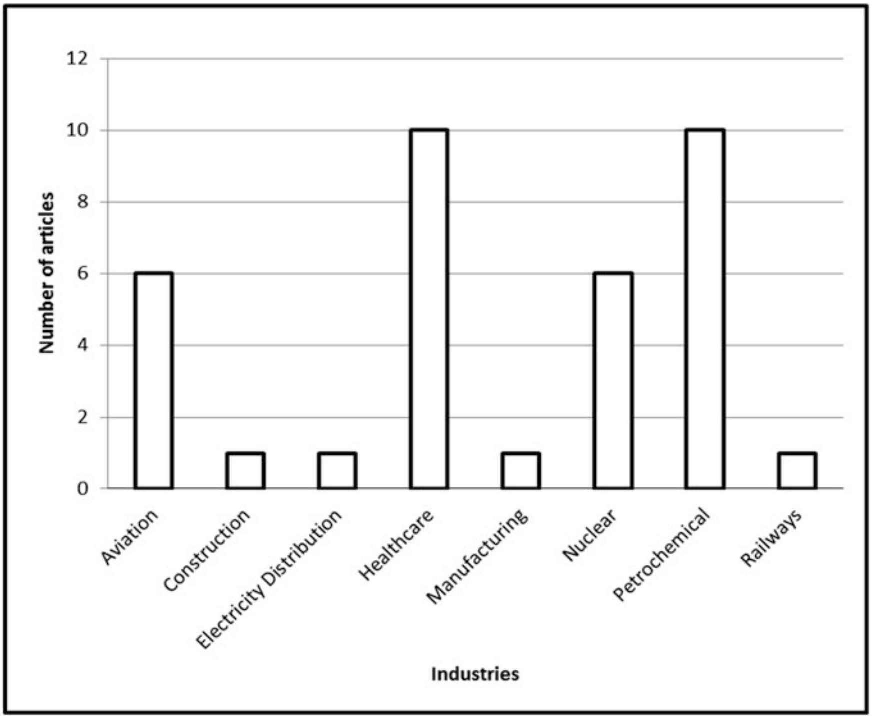

Fig. 2 RE Publications by Industry 1998–2012

This analysis by industry reveals one significant gap; there is very little in terms of published research on RE from traditional industries such as manufacturing, construction and mining; although propositions for the latter two have been suggested [15, 16].

3.2 Definitions

Being a relative new field of study in health and safety, it could be assumed that there is a common understanding of resilience, or of resilience engineering. A close examination of the literature surveyed suggests variations in the way different researchers have interpreted resilience, organisational resilience and resilience, with many using the terms interchangeably. One would tend to agree with it being described as 'confused consensus' [17]; in spite of the increased number of peer-reviewed publications on organisational resilience and resilience engineering, there is no single way in which these terms have been defined. The explanations appear to vary between the contexts in which they have been investigated. The next section looks at resilience as it relates to organisations.

Organisational Resilience. The literature surveyed suggests there are at least *seventeen* definitions of organisational resilience (OR). Sheridan captures the concept best as 'a family of ideas' [3]. Most of these suggest it is an ability, capability or capacity which is associated with being able to recover size and structure [18], withstanding major disruptions [19], absorbing disturbances and change [20], maintaining function and structure [21], bouncing back from adversity [10], handling disruptions and variations [22] and recovering to a stable state [23]. These notions of resilience, however, are restrictive and tied to reactive models of organisational health and safety. Moreover, they soften the importance of resilience, considering its influence in achieving 'nearly accident free performance' in highly-hazardous organisations [24, 25]. Safety efforts in these groups of 'high-reliability organisations' was not simply about bouncing back from adverse events; instead, it extended to guarding against potential minor mishaps and performance variations in normal operations escalating into major breakdowns of organisational processes. This ability enable organisations to 'anticipate and circumvent threats' [26, 27], with the recovery occurring very early in the process [28]. In addition to being reactive, it also has a proactive side [29], in that resilient organisations see safety both as a non-event (i.e. success) such as near-misses, and events such as failures, incidents or disasters [30]. This is an important distinction between organisational resilience and many other safety management approaches such as management systems, regulations or safety culture.

The above are all useful definitions, and the outcomes they seek to achieve are desirable, in fact required, if organisations are to survive in the current times of turbulence and uncertainty. However, all organisations should be able to bounce back from adversity. Current organisational theory suggests that organisations are complex adaptive systems [31], which could then mean that all organisations would be deemed resilient, at least to some degree.

However, two things appear to set resilient organisations apart from non-resilient ones.

The first is their ability to continue performing well without being affected significantly by threats and disturbances, and second is their ability to deal effectively with more than normal, every-day threats, and disturbances. This involves going beyond past experiences and preparing for unknown events, threats, and/or hazards; dealing with black swans or 'unexampled hazards' [32]. Instead of relying on successful experience of strategies, approaches and interventions previously deployed, these organisations continue to devote efforts in anticipating and preparing to deal better with hazards and threats they will face in the future. This ability is born out of a firm conviction that "unexpected trouble is ubiquitous and unpredictable, and thus accurate advance information on how to get it is in short supply" [10].

The discussion above suggests that organisational resilience covers a wide range of concepts, ranging from abstract to concrete facets, with each reflecting different solutions in terms of being reactive, proactive and adaptive, not only to prevent negative outcomes but also to support and strengthen outcomes of processes. There is also a great deal of uncertainty surrounding the notion, and the key 'challenge facing researchers is to achieve a consensus on the definition' [33]. However, whether such a consensus is necessary is questionable, because resilience itself is context-specific. Some organisations may be resilient in some aspects in comparison to others, and some sections of an organisation may display a propensity for resilience more than others. For this reason no attempt has been made to provide a unified definition.

Resilience Engineering. Similar to OR, there is no single definition of RE, largely because 'it exists more as a conceptual framework than a tight knit knot' [29]. The literature suggests four related but somewhat different definitions.

The first by Woods and Hollnagel [34] refers to RE as a 'paradigm for safety management.' This suggests it is a conceptual framework for safety management similar to human error [35]; systems, normal accidents [14] or high-reliability [21].

The second by Chialastri and Pozzi [36] suggests it involves adaptations to variations occurring beyond the design envelop of systems. This involves making temporary adjustments to an organisation's process by responding, monitoring, anticipation, and learning from disturbances, changes, major mishaps, or continuous stressors [37]. From the previous discussions on organisational resilience, this requires (i) responding to regular, irregular and 'unexampled' threats (ii) monitoring what was going on; (iii) anticipating risks and opportunities over the longer term, and (iv) learning from experience. Because an individual was not expected to possess all these four abilities, these were characteristics of organisations which are comprised collectively of groups, systems and processes [31].

The third suggests that RE involved 'developing an organisation's behavioural and cognitive capability such that it is able to effectively adjust and continue performing optimally near its safe operating envelop, in the presence of everyday threats and environmental stressors at all levels of the organisation' [16]. Behaviours are well known and well researched in health and safety, they largely comprise of actions taken by people at different levels of the system. Following rules/procedures or violating them can be observed through behaviours. Cognition involves a mental process of thinking, attending to information, processing and ordering that information to create meaning; and is closely associated with sense-making [38].

The fourth, Heikkila et al. [39], refers to it was a new way of thinking about the management of safety, pointing out what was different in RE: 'Whereas conventional risk management approaches are based on hindsight and emphasize error tabulation and calculation of failure probabilities, resilience engineering looks for ways to enhance the ability of organisations to create processes that are robust yet flexible, to monitor and revise risk model, and to use resources proactively in the face of disruptions or ongoing production and economic pressures.'

This brief analysis suggests that, similar to OR there is no universally accepted definition of RE. What is apparent is that it represents a sophisticated way for managing safety and risks. The sophistication is not so much in the technology, but more in the way one thinks about safety, and how it can be better managed through existing tools but in more innovative ways. This also involves a shift in perspectives, or way of thinking, about health and safety and how can be managed. These tenets can be used to formulate a unified understanding of RE. However, before doing this, it is useful to understand how RE has been theoretically conceptualised in previous research. This is discussed in the next section, by examining dimensions, factors and measures.

3.3 Dimensions, Factors and Measures

The analysis of RE definition pointed to a magnitude of dimensions, factors and measures which can be useful in informing research and practice. These include culture, cognition, behaviours, levels and the gap between work-as-imagined and work-as-performed.

Culture and RE. The first connections between resilience and culture was proposed by Reason [40], who integrated Mintzberg's (1989) three drivers of commitment, competence and cognisance with principles, policies, procedures and practices into a Checklist for Assessing Institutional Resilience (CAIR); a questionnaire for assessing organisational resilience quantitatively. The tool was further developed and used to measure resilience in aviation [41] and healthcare [42]. Flin [26] introduced 'managerial resilience culture' where commitment to safety was guided by a firm belief that when safety and production goals conflicted, managers ensured that safety predominated, and a climate of (i) workers and managers being more able to speak up when they were concerned about safety, (ii) workers being assured of not being penalised when they challenged their superiors, stopped production or expressed their concerns about safety risks. Wreathall [43] provided an initial set of 'themes of highly resilient organisations' which included (i) top-level management commitment, (ii) just culture, (iii) learning culture, (iv) awareness, (v) preparedness, (vi) flexibility and (vii) opacity; arguing there was a 'need to tie these approach to the concepts of resilience'. The first three of these can be associated with Flin's managerial resilience. Skogdalen [44] suggested these dimensions could be mapped into an organisational-human and technical factors model, the OMT method, while Bracco et al. [45] integrated these into a skills-rules-knowledge (SRK) framework for examining resilience in healthcare organisations.

Cognition and RE. Apart from culture, another dimension that has been published involves cognition. Back et al. [46] linked cognitive resilience with reflective management practice, arguing that identifying those strategies that people used to support performance in everyday situations was useful in identifying behaviours that enabled people to recognise and adapt to changes, disruptions and surprises created by the system. Back et al. [47] decomposed these at five levels of granularity, including (i) individual, (ii) small team, (iii) operational, (iv) plant and (v) industry. Bracco et al. [48], on the other hand, decomposed at the levels of skill (S), rules (R) and knowledge (K) suggested by Rasmussen (1983). Similar to culture, most of these papers are largely conceptual in nature, so more empirical investigations are necessary to clarify the relationship between RE and cognition.

Behaviors and RE. The idea that resilience is a behavioural characteristic arises from the work of Vogus and Sutcliffe [49], who linked this with the ability to make adjustments, through a hierarchical integration of behavioural systems whereby earlier structures and integrated incorporated into later structures in increasingly complex forms. Another set of behavioural indicators, decomposed according to vulnerabilities experienced across individual, small team, operational, plant and industry levels has also been suggested by Back et al. [47]. These papers are also conceptual, so more empirical investigations are necessary to clarify the relationship between RE and behaviours.

Levels of RE. The above section discussed three dimensions of RE that have been used for RE research. Implicit in the discussion of behavioural and cognitive RE is that it is distributed across a number of levels. This associated with the way it impacts a system at the different levels. One way of describing level is 'granularity,' suggested by Reason [40] who posited that resilience manifested at operational, management and organisational levels. McDonald [50] provided a similar decomposition at three layers, including operational, organisational and industrial. Reason's CAIR has been applied in a limited context in aviation and healthcare, while decomposition of RE suggested by McDonald has not been the subject of any empirical studies.

The Gap between Work as Imagined and Work as Performed. The preceding sections considered a range of measures and factors that have been used to inform RE research and practice. One important factor which has also been suggested to be important involves the gap between work as imagined and work as performed [2, 17]. This is the distance between operations as management imagines they go on and how they actually go on in practice, and has been suggested to one of the most important factors. There have been some attempt to operationalise this [51, 52] with some level of success. However, very few studies have made an attempt to integrate the key dimensions, factors and measures and the concept of this gap into a unifying theoretical framework.

4 Summary, Research Gaps and Implications

The following points can be summarised based on this review. First, there is no universally definition of RE; hence there is no uniform way of assessing, examining, or observing it. Second, it is a theoretical construct, not a concrete element, substance, or entity which can be touched, felt or smelt. Third, it is multi-factorial and common factors used for exploring and/or measuring it includes culture, cognition and behaviour. Fourth, it is multi-dimensional, and some of the more common dimensions for investigating it include individual, small teams, operational, plant, industry. Fifth, it is linked in some way with balancing safety and performance. And sixth, the gap between work as imagined and work as performed is important for RE.

"In order to advance research and practice in RE, it is important to develop some consensus on what it actually is. The following working definition is proposed: Resilience engineering is a sophisticated way of managing organisational safety through the development of cognitive, behavioural, and cultural abilities to enable organisational members at all levels to actively anticipate, respond, monitor and learn to operate close to the boundary of safe operations as part of normal work, by narrowing the gap between work as imagined and work as performed."

By framing this definition as above makes a number of things clear. One, RE is about organisational safety, not individual safety. Two, it incorporates cognition, behavioural and cultural aspects of an organisation. Three, although an individual can have all these attributes, it is only when they are collectively distributed across all levels of the organisation that these play a role in RE. Four, the cognitive, cultural and behavioural collectively enable the organisation to anticipate, respond, monitor and learn. Five, it is about operating as close as possible to the boundaries of failure as part of normal work. And six, the gap between work as imagined and work as performed is an important facet of resilience engineering.

The review also identified a number of gaps in research.

First, an analysis by industrial domains suggests current studies have mostly concentrated on complex organisations such as healthcare, petrochemical, aviation and nuclear. Missing is research from traditional high-risk industries such as construction, mining and manufacturing, and addressing this will be important in understanding where RE has a role to play in improving organisational health and safety management in these high-risk industries.

Second, an analysis of factors suggests that culture, cognition and behaviours play an important role; the specific mechanisms by which this is expected to occur, or what impacts they have (if any), is unclear. Third, analysis by dimensions and/or levels suggest that number of most research has been limited to examining single units or levels, even though current research in fields such as human error suggests that, at least on the level where work is done, risk and its management are likely to be influenced by other higher levels, such as managers, supervisors, associations and government.

And fourth, while the published papers provide a rich source of information on concepts, ideas and notions, many of these lacks a conceptual and theoretical framework which unify the complex constructs being investigated. In particular, theoretical framework that will be useful for examining the gap between work-as-imagined and work-as-performed is lacking, and addressing this gap is crucial for advancing research and practice in RE. In this regard, the framework of reflective practice used for investigating cognitive resilience [46] offers a promising start. Future papers will investigate how this can be used to inform research in RE.

References

1. Pellissier, R.: The implementation of resilience engineering to enhance organizational innovation in a complex environment. Int. J. Bus. Manag. **6**, 145 (2011)
2. Hollnagel, E., Woods, D.D.: Epilogue: resilience engineering precepts. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience Engineering Concepts and Precepts, pp. 347–358. Ashgate Publishing, Aldershot (2006)
3. Sheridan, T.B.: Risk, human error, and system resilience: fundamental ideas. Hum. Factors: J. Hum. Factors Ergon. Soc. **50**, 418–426 (2008)
4. Madni, A.M., Jackson, S.: Towards a conceptual framework for resilience engineering. IEEE Syst. J. **3**, 181–191 (2009)
5. Hale, A., Borys, D., Else, D.: Management of safety rules and procedures: a review of the literature. Institute of Occupational Safety and Health (2012)
6. Woods, D.D.: Creating foresight: lessons for enhancing resilience from Columbia. In: Starbuck, W.H., Farjoun, M. (eds.) Organization at the Limit: NASA and the Columbia Disaster, pp. 289–308. Blackwell, Malden, MA (2005)
7. Columbia Accident Investigation Board (CAIB): Report of the Space Shuttle Columbia Accident Investigation. National Aeronautics and Space Administration (2003)
8. Hollnagel, E., Woods, D.D., Leveson, N.G.: Resilience Engineering Concepts and Precepts. Ashgate, Aldershot (2006)
9. Sheridan, T.B.: Risk, human error, and system resilience: fundamental ideas. Hum. Factors **50**, 418–426 (2008)
10. Wildavsky, A.: Searching for Safety. Transaction Books, New Brunswick (1988)
11. Weick, K.E., Sutcliffe, K.H.: Managing the unexpected: resilient performance in an age of uncertainty. Jossey-Bass, San Francisco (2007)
12. Hopkins, A.: Learning From High Reliability Organisations. CCH Australia Limited, Sydney (2009)
13. Borys, D.M., Else, D., Leggett, S.: The fifth age of safety: the adaptive age. J Health Saf. Res. Pract. **1**, 19–27 (2009)
14. Perrow, C.: Normal Accidents: Living with High Risk Technology. Princeton University Press, Princeton (1999)
15. Schafer, D., Abdelhamid, T.S., Mitropoulos, P., Mrozowski, T.: Resilience engineering: a new approach for safety management. In: Construction Research Congress 2009: Building a Sustainable Future, April 5–7, pp. 766–775. ASCE, NY (2009)

16. Pillay, M., Borys, D., Else, D., Tuck, M.: Safety culture and resilience engineering: theory and application in improving gold mining safety. In: Gravity Gold 2010, pp. 129–140. AusIMM (2010)
17. Dekker, S.W.A.: Resilience engineering: chronicling the emergence of confused consensus. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience Engineering Concepts and Precepts, pp. 77–92. Ashgate, Aldershot (2006)
18. Epstein, S.: Unexampled events, resilience, and PRA. In: Hollnagel, E., Nemeth, C., Dekker, S.W.A. (eds.) Resilience Engineering Perspective, Volume 1: Remaining Sensitive to the Possibility of Failure, pp. 49–62. Ashgate, Aldershot (2008)
19. Haimes, Y.Y.: On the definition of resilience in systems. Risk Anal. **29**, 498–501 (2009)
20. Kontogiannis, T., Malakis, S.: A proactive approach to human error detection and identification in aviation and air traffic control. Saf. Sci. **47**, 693–706 (2009)
21. Weick, K.E., Sutcliffe, K.M.: Managing the unexpected: Assuring high performance in an age of uncertainty. Jossey-Bass, San Francisco (2007)
22. Woods, D.D.: Essential characteristics of resilience. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience engineering: concepts and precepts, pp. 21–34. Ashgate Publishing Ltd., Aldershot (2006)
23. Wreathall, J.: Properties of resilient organizations. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience Engineering Concepts and Precepts, pp. 275–285. Ashgate Publishing Ltd., Aldershot (2006)
24. Leveson, N.G., Dulac, N., Marais, K., Carroll, J.: Moving beyond normal accidents and high reliability organizations: a systems approach to safety in complex systems. Org. Stud. **30**, 227–249 (2009)
25. Hopkins, A.: The Problem of Defining High Reliability Organisations. Learning from High Reliability Organisations, pp. 5–16. CCH Australia Limited, Sydney (2009)
26. Flin, R.: Erosion of managerial resilience: from VASA to NASA. In: Hollnagel, E., Woods, D.D., Leveson, N.G. (eds.) Resilience Engineering Concepts and Precepts, pp. 223–233. Ashgate, Aldershot (2006)
27. Hale, A., Heijer, T.: Defining resilience. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience Engineering: Concepts and Precepts, pp. 35–40. Ashgate Publishing Ltd., Aldershot (2006)
28. Hollnagel, E.: Resilience: the challenge of the unstable. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience engineering concepts and precepts, pp. 9–17. Ashgate Publishing Ltd., Aldershot (2006)
29. Boring, R.L.: Reconciling resilience with reliability: the complementary nature of resilience engineering and human reliability analysis. In: Human Factors and Ergonomics Society 53rd Annual Meeting, pp. 1589–1593 (2010)
30. Hollnagel, E.: Prologue: the scope of resilience engineering. In: Hollnagel, E., Paries, J., Woods, D.D., Wreathall, J. (eds.) Resilience Engineering in Practice, pp. xxix–xxxix. Ashgate Publishing Company, Burlington (2011)
31. Schneider, M., Somers, M.: Organizations as complex adaptive systems: implications for complexity theory for leadership research. Leadersh. Q. **17**, 351–365 (2006)
32. Epstein, S.: Unexampled events, resilience and PRA. In: Hollnagel, E., Nemeth, C.P., Dekker, S.W.A. (eds.) Resilience Engineering Perspectives Volume 1: Remaining Sensitive to the Possibility of Failure, pp. 49–62. Ashgate, Aldershot (2008)
33. Manyena, S.B.: The concept of resilience revisited. Disasters **30**, 434–450 (2006)
34. Woods, D.D., Hollnagel, E.: Prologue: resilience engineering concepts. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience engineering: concepts and precepts, pp. 1–6. Ashgate Publishing, Aldershot, England (2006)
35. Reason, J.: Human error: models and management. BMJ Qual Saf **320**, 768–770 (2000)
36. Chialastri, A., Pozzi, S.: Resilience in the Aviation System. Computer Safety, Reliability, and Security, pp. 86–98. Springer, Berlin (2008)
37. Hollnagel, E.: Resilience engineering in a nutshell. In: Resilience Engineering Perspectives, vol. 1, pp. ix–Xii (2008)

38. Weick, K.E., Sutcliffe, K.M., Obstfeld, D.: Organizing and the process of sensemaking. Organ. Sci. **16**, 409–421 (2005)
39. Heikkila, J., Ulusitalo, T., Lappalainen, J., Rantanen, E.: Proactive and flexible safety management—resilience in Finland. Working on Safetynet, 7–10 Sept., Roros, Norway (2010)
40. Reason, J.: The dimensions of organisational resilience to operational hazards. In: British Airways Human Factors Conference: Enhancing Operational Integrity (1997)
41. Wood, M., Dannatt, R., Marshall, V.: Assessing institutional resilience: a useful guide for airline safety managers? Australian Transport Safety Bureau (2006)
42. Carthey, J., de Leval, M., Reason, J.: Institutional resilience in healthcare systems. Qual. Health Care **10**, 29–32 (2001)
43. Wreathall, J.: Properties of resilient organizations: an initial view. In: Hollnagel, E., Woods, D. D., Leveson, N.G. (eds.) Resilience Engineering Concepts and Precepts, pp. 275–285. Ashgate, Aldershot (2006)
44. Skogdalen, J.E.: Safety engineering: two different approaches. Saf. Sci Monit. **14**, Article 2 (2010)
45. Bracco, F., Bruno, A., Sossai, D.: improving resilience through practitioners' well-being: an experience in italian health-care. In: Fourth Resilience Engineering Symposium, pp. 43–49 (2011)
46. Back, J., Furniss, D., Blandford, A.: Cognitive resilience: reflection-in-action and on-action. In: Resilience engineering workshop, 25–27 June. Mines ParisTech (2007)
47. Back, J., Furniss, D., Hildebrandt, M., Blandford, A.: Resilience markers for safer systems and organisations. In: Harrison, M.D., Sujan, M.A. (eds.) Computer Safety, Reliability, and Security: Lecture Notes in Computer Science, 5219(2008) edn, pp. 99–112. Springer, Berlin (2008)
48. Bracco, F., Gianatti, R., Pisano, L.A.S., Savona, I.: Cognitive resilience in emergency room operations, a theoretical framework. In: Third symposium on resilience engineering. Mines ParisTech (2008)
49. Vogus, T.J., Sutcliffe, K.M.: Organizational resilience: towards a theory and research agenda. In: IEEE International Conference on Systems, Man and Cybernertics, pp. 3418–3422. IEEE, (2007)
50. McDonald, N.: Organisational resilience and industrial risk. In: Hollnagel, E., Woods, D.D., Leveson, N. (eds.) Resilience engineering concepts and precepts, pp. 155–180. Ashgate Publishing Ltd., Aldershot (2006)
51. Costella, M.F., Saurin, T.A., de Macedo Guimarães, L.B.: A method for assessing health and safety management systems from the resilience engineering perspective. Saf. Sci. **47**, 1056–1067 (2009)
52. Rasmussen, J., Svedung, I.: Proactive Risk Management in a Dynamic Society. Swedish Rescue Services Agency, Karlstad (2000)

The Integration of Worker Safety and Health into Sustainable Construction Practices: A Review

Ibrahim Mosly

Abstract The construction stage of a building lifecycle is a very dynamic stage with several activities on the job site that involve materials, workers, and moving and handling equipment. These construction activities should be sustainable and at the same time be safe for workers. Although many countries have construction safety and health regulations as well as green building rating systems (including for construction), they are not integrated: each has its own separate procedures and regulating institutions. This research aims to review the available literature related to construction sustainability and construction worker safety and health. It will assist in exploring the integration of worker safety and health into sustainable construction practices. The research findings demonstrate the need and significance of integrating worker safety and health into sustainable construction practices, as it can realize cost efficiencies.

Keywords Sustainability · Construction · Safety and health · Workers

1 Introduction

The concept of sustainability in buildings has become a subject of interest for many researchers. This is because significant potential for sustainability exists throughout the building lifecycle. The term "sustainability" represents a wide concept that includes economical, social, environmental, and resource aspects [1]. For a building to be called a sustainable building, it must implement sustainability practices throughout its lifecycle [1], including the construction stage. The term "green" primarily refers to building design and construction practices that affect the environment [1]. Thus, green practices are considered part of sustainable practices.

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Green building certifications aid in decreasing the carbon footprint of certain buildings as well as increasing public awareness of the use of energy, water, materials, and indoor air quality [2]. The design of green buildings draws much attention to the sustainability of the use of the final product and its user, but the process of building construction is ignored in terms of being a sustainable process [1]. Consequently, working on green construction or green buildings does not necessarily indicate a safer working environment for construction workers compared to traditional construction or buildings [2]. Construction worker safety and health are given minimum consideration in green building certification systems such as in Leadership in Energy and Environmental Design (LEED) rating system [1–4]. LEED can be classified as sustainable environmentally but not in relation to worker safety and health [4]. On the one hand, most countries mandate worker safety and health regulations on construction sites. On the other hand, countries that pursue sustainability practices, including green building certifications, generally render these practices optional for owners and developers. For example, US federal provides incentives to encourage green jobs training but does not do the same for occupational, safety, and health training [2]. Simultaneously, owners and developers perceive the achievement of green building certification to be a higher priority compared to the safety of the workers constructing these buildings.

Due to the lack of research on worker safety and health in sustainable construction [4] and the need to explore this research area further, this paper aims to review the available literature on construction sustainability and construction worker safety and health. It will assist in exploring the integration of worker safety and health into sustainable construction practices and discusses the benefits of such integration. This paper is divided into five sections. The first section is an introduction to the research. The second section presents the literature review, including subsections on (a) worker safety and health in construction, (b) sustainable construction practices, and (c) worker safety and health and sustainable construction practices. The third section discusses the research methodology followed in the present research. The fourth section presents the results and discussion of the literature review outcomes. The final section is the conclusion, where a summary of the research is presented.

2 Literature Review

2.1 Worker Safety and Health in Construction

The construction workplace is recognized as a dangerous environment for workers in many countries. This is due to the high rate of accidents that lead to worker injury, disability, or death. The construction industry is known to be a dynamic working environment with exposure to high risk [5]. The work environment for construction workers is dirty, noisy, and lacks natural lighting and ventilation [6]. Construction sites contain many hazards that could affect worker safety on a daily basis. For example, fire hazards are related to asphalt membranes, built-up felt roofing, and soldered plumbing installation jobs [7]. Moreover, exposure to noise and vibration is associated with work in mobile plants and/or the use of hand-held mechanical equipment [7]. This indicates that managing a safe construction work environment is not an easy task with all these conditions that represent a significant part of the industry.

Construction workers are exposed to heavy lifting, carry out repetitive activities, and perform their work in uncomfortable and restricted situations for prolonged periods [6]. Furthermore, these workers are subjected to high risk of injury, illness, and musculoskeletal symptoms [6]. The working conditions of construction sites are expected to reduce the natural age of workers [6]. Various symptoms are linked to different construction trades, for example, electricians usually suffer from knee and lower back pain, carpenters usually suffer from lower back pain, and plumbers usually suffer from knee pain [6]. Adding to that, the construction workforce is high-transit, as workers often move between construction firms, projects, and sites [5], thus continuously experiencing unfamiliar work environments and increasing their exposure to hazards.

One of the hurdles in the construction industry with respect to safety is that small subcontractors do not view safety as seriously as large construction companies do [8]. Thus, construction workers working with small subcontractor firms face a higher level of risk of injuries, disability, and death compared to those working with large construction companies.

2.2 Sustainable Construction Practices

Sustainable construction can be defined as the forming and accountable management of the built environment in a healthy manner based on resource efficiency and ecological values [9]. Sustainable construction pursues efficiency in natural resource consumption, reduction of environmental impact, fulfillment of human needs, and enhancement of quality of life [10]. The earlier consideration is given to sustainable construction during the project lifecycle, the better the outcomes achieved [10]. The main principles of sustainable construction are as follows [11]: (1) conservation of resource consumption, (2) reuse of resources, (3) recycling of resources, (4) protection of the environment, (5) maintenance of a non-toxic environment, (6) consideration of holistic lifecycle costs, and (7) pursuit of quality. Innovative strategies are involved in sustainable construction practices, and when adopted by construction firms they align with the goals of sustainable construction principles [12]. The innovation component in sustainable construction practices will introduce new concepts, procedures, and technology use in construction firms [12].

A study performed on the UK construction industry studied the determinant factors of the adoption of sustainable construction practices in the industry [13]. The study findings showed that three factors have a positive influence in driving sustainable construction practices in the industry: (1) government regulations, (2) top management commitment, and (3) construction stakeholder demands [13]. Another study identified sustainable construction drivers as follows [14]: (1) client awareness, (2) regulations, (3) demand, (4) incentives, (5) investment, (6) labeling/ measurement, (7) planning policy, and (8) taxes. The two most important drivers of sustainable construction are incentives and regulations [14]. The study also identified the barriers to sustainable construction as follows [14]: (1) affordability, (2) regulations, (3) lack of client awareness, (4) lack of business case understanding, (5) lack of demand, (6) lack of proven alternative technology, (7) lack of measurement standards, and (8) planning policy. The major barrier to sustainable construction is affordability [14].

2.3 Worker Safety and Health and Sustainable Construction Practices

Sustainability considers the environmental, economical, social, and resources impacts of construction as well as the implementation of its principles throughout the building lifecycle [2]. The social and economic aspects of sustainability are where worker safety and health are taken into account in the sustainable industry [9]. In order for a green construction process to be truly classified as sustainable, worker safety and health throughout the constructed building's lifecycle should be addressed [1]. Studies that looked into the impact of green design and construction on worker safety and health recommended considering worker safety and health in addition to end user safety and health [1, 4]. In reality, this is not the case; designs for construction worker health and safety are given less priority compared to designs for the environment [4]. Apart from including worker safety and health with that of the end user, other recommendations related to construction safety in the context of green construction include [2]: (1) incorporating worker health and safety as a part of the definition of green jobs, (2) avoiding the occurrence of hazards through design, (3) including worker health and safety in green building certifications, and (4) endorsing construction safety training programs.

Similar to green building rating and certification systems, efforts were made in a study, which was based on a Delphi survey, to develop a rating system for sustainable construction safety and health [15]. The developed system provides an opportunity to evaluate the safety performance of construction projects as well as improve and plan construction safety and health programs [15]. It represents a positive step in the integration of sustainable construction practices and worker safety and health but requires motivators to be widely implemented. A study determined that potential motivators that affect worker safety and health in sustainable construction fell under three groups [9]: (1) project organization, (2) leadership, and (3) company support.

Green construction hazards are almost identical to the traditional construction hazards. Green construction hazards include: falls, strains, sprains, punctures, slips, collisions, electrical, heat stress, etc. [2]. This overlap in hazards between green and none-green projects simplifies matters, as similar safety practices can be adopted in green projects with some enhancements. Unfortunately, the exposure time to known, high-risk hazards for workers was found to be higher in projects pursuing LEED certification compared to non-LEED certification projects [16]. Moreover, workers are exposed to a higher frequency of hazards, increased overexertion, and more unfamiliar and unsafe environments when working on LEED projects compared to non-LEED projects. New and innovative green technologies and products increase the occupational hazards of construction workers [17]. All of these issues indicate that green construction projects have lower safety and health measures for workers compared to traditional building construction projects.

3 Methodology

The research follows a qualitative approach that is based on a literature review survey. Mainly, the literature review survey was performed using the following academic databases: ScienceDirect, ProQuest, and SAGE. The keywords that were used in the search included: sustainable construction, worker, and health and safety. The main objective of the research is to explore the available literature on the integration of worker safety and health into sustainable construction practices. Furthermore, the research touches on the need and benefits of this integration.

4 Results and Discussion

Limited numbers of research studies related to worker safety and health in sustainable construction were found in the literature review process. On the contrary, a large number of research studies were found that related to worker safety and health in traditional construction. Researchers and interested stakeholders can use the wide range of available research studies on worker safety and health in traditional construction and expand it to fit sustainable construction characteristics. The literature review results related to sustainable construction and worker safety and health are illustrated in Table 1.

The literature review findings show that the topic explored in this paper is relatively new, as the oldest reference found directly related to the topic was published in 2006 and was an academic thesis. Furthermore, five references are academic theses, indicating the interest of a number of postgraduate students in the topic. According to Table 1, a variety of research methods were used in the studies related to worker safety and health in sustainable construction.

Table 1 Relevant study references from the literature review outcome

References	Type	Publication year	Methods used
[1]	Journal article	2007	Focus group
[2]	Report	2010	Views and opinions
[3]	Thesis	2006	Focus group
[4]	Journal article	2009	Questionnaire and interview
[9]	Journal article	2015	Questionnaire
[13]	Journal article	2013	Questionnaire
[15]	Journal article	2009	Delphi survey
[16]	Thesis	2009	Interview
[17]	Thesis	2013	Literature review
[18]	Journal article	2010	Analysis and modeling
[19]	Journal article	2013	Literature review
[20]	Thesis	2011	Interview

The integration of worker health and safety into sustainable construction practices appears to be an essential step in order to fully comply with the concept of sustainability. For example, workers constructing a green building must be treated similarly to the end users in terms of health and safety measures, as they are all considered green building stakeholders. This integration provides a holistic approach that considers the interests of all buildings construction stakeholders from top to bottom. Furthermore, it offers balance in building construction priorities with respect to sustainability measures and worker health and safety. Moreover, it increases cost efficiencies during the building construction stage by reducing the costs associated with construction accidents. A construction firm specializing in sustainable construction projects with a good worker safety and health record will also benefit from reduced insurance premiums. An update to the available green building rating and certification systems to include worker safety and health would be sufficient to eliminate this dilemma.

It appears necessary to conduct future research to identify the specific hazards workers are exposed to in sustainable construction. At the same time, these hazards must be ranked and grouped according to their level of risk to workers. Such studies must be holistic in order to include a wide range of sustainable construction stakeholders, including the workers. Furthermore, measures to manage the risks of hazard occurrence in sustainable construction must also be explored. A framework incorporating the risks of sustainable construction to workers and the measures for manage these risks would be very helpful for sustainable construction stakeholders. The costs of worker treatment and project impact from the additional accidents that occur due to hazards in sustainable construction should also be studied. This will strengthen support and provide more focus on workers in sustainable construction projects.

5 Conclusions

This study reviewed the available literature related to construction sustainability and construction worker safety and health and concluded the need to provide more consideration to worker safety and health in sustainable construction. This can be done by integrating worker safety and health into sustainable construction practices. Available green building rating and certification systems can be updated to include the safety and health of construction workers along with that of the end users. The increase of sustainable construction worker health and safety records will provide a number of cost efficiencies to the project. More detailed research in this area is required to support sustainable construction worker safety and health in the work environment.

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References

1. Gambatese, J., Rajendran, S., Behm, M.: Green design and construction: understanding the effects on construction worker safety and health. Prof. Saf. **52**(5), 28–35 (2007)
2. Chen, H.: Green and Healthy Jobs. CPWR—The Center for Construction Research and Training, Maryland, United States (2010)
3. Rajendran, S.: Sustainable Construction Safety and Health Rating System, in Civil Engineering. Oregon State University, Corvallis, USA (2006)
4. Rajendran, S., Gambatese, J., Behm, M.: Impact of green building design and construction on worker safety and health. J. Constr. Eng. Manag. **135**(10), 1058–1066 (2009)
5. Biggs, S., et al.: Safety leaders' perceptions of safety culture in a large Australasian construction organisation. Saf. Sci. **52**, 3–12 (2013)
6. Eaves, S., Gyi, D., Gibb, A.: Building healthy construction workers: their views on health, wellbeing and better workplace design. Appl. Ergon. **54**, 10–18 (2016)
7. Edwards, D., Holt, G.: Construction workers' health and safety knowledge: initial observations on some test-result data. J. Eng. Des. Technol. **6**(1), 65–80 (2008)
8. Nash, J.: Construction safety: best practices in training hispanic workers. Occup. Hazards **66** (2), 35–38 (2004)
9. Chandra, H.: Initial investigation for potential motivators to achieve sustainable construction safety and health. Procedia Eng. **125**, 103–108 (2015)
10. Al-Yami, A., Price, A.: A Framework for Implementing Sustainable Construction n Building Briefing Project, in 22nd Annual ARCOM Conference. Birmingham, UK (2006)
11. Kibert, C.: Sustainable Construction: Green Building Design and Delivery. John Wiley & Sons, New Jersey (2012)
12. Kheni, N., Akoogo, M.: Determinants of sustainable construction practices in ghana using structural equation modelling. J. Sustain. Dev. **8**(3), 67–78 (2015)
13. Akadiri, P., Fadiya, O.: Empirical analysis of the determinants of environmentally sustainable practices in the UK construction industry. Constr. Innov. **13**(4), 352–373 (2013)
14. Pitt, M., et al.: Towards sustainable construction: promotion and best practices. Constr. Innov. **9**(2), 201–224 (2009)

15. Rajendran, S., Gambatese, J.: Development and initial validation of sustainable construction safety and health rating system. J. Constr. Eng. Manag. **135**(10), 1067–1075 (2009)
16. Fortunato, B.: Impact of Leed on Construction Worker Safety and Health, in Civil Engineering. University of Colorado, Colorado, USA (2009)
17. Kwon, H.: Worker Safety and Health in Labor Practices in Sustainable Residential Buildings, in Sustainable Interior Environments. S.U.N.Y Fashion Institute of Technology, New York, USA (2013)
18. Panas, A., Pantouvakis, J.: An empirical framework for the performance-based evaluation of health and safety's contribution to sustainable construction. Organ. Technol. Manag. Constr. Int. J. **2**(2), 173–181 (2010)
19. Tawiah, K.: Occupational health and safety and sustainable development in Ghana. Int. J. Bus. Adm. **4**(2), 74–78 (2013)
20. Dewlaney, K.: Safety Risk Quantification and Mitigation for High Performance Sustainable Building Construction, in Civil, Environmental, and Architectural Engineering. University of Colorado, Colorado, USA (2011)

Practical Guide for Safety on Construction Site

Marek Rolinec, Karol Balog and Robert Bulla

Abstract The paper focuses at provision of a practical guide for the use during the safety coordination, work leaders/managers at implementation of construction projects and maintenance activities to create safe working conditions and to minimize the risk and number of work accidents. The thesis includes applicable practical solutions and procedures. In our contribution we tried to define the basic procedures that would contribute to safety coordination improvement on the sites not only in Slovakia while emphasizing the trends focused on monitoring human behavior, since human failures cause up to the two thirds of incidents. Data are taken from a nuclear power plant construction with over 40 million hours worked at various civil and installation activities. The tools we can use as efficiency indicators of individual actions taken. Their application in correct time can significantly contribute to minimize the work accidents and to protect health of employees.

Keywords Health and safety · Safety coordination · Behavior

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1 Introduction

The construction industry is one of the most important industries in the Slovak economy with more than 10 % employment. The construction industry takes the third place regarding the number of employed persons, and the second and third place regarding the number of work accidents. Table 1 shows the number of fatalities in four most risky industries:

In graph no. 1 we can clearly see a significant increase of the Employment rate within SR in 2013 with the lowest Employment rate identified in 2009 (Fig. 1).

Comparing the results stated above, we could see that the Employment rate in the Construction field in year 2010 reached critical level since in this year the Employment rate reached the lowest level. This relates to the international economic crisis affecting also SR. As well, we can see that the Employment rate in the Construction field after 2010 has not reached level as of year 2009.

The completion process of Nuclear Power Plant Mochovce (NPP Mochovce), Unit 3 and 4 (MO34) is for several years significantly impacting the Employment rate not only in Nitra region but also in SR in overall and represents approx. 5 % of the total worked hours in the Construction field [2] (Fig. 2).

Employment rate development in the completion process of NPP Mochovce, Unit 3 and 4, we present in Fig. 3, elaborated based on the output from the

Table 1 Work accident rate development by industries (statistical office of SR + Mochovce) [1]

	2011	2012	2013	2014
In Slovakia employees + self employees	2,341,720	2,296,589	2,496,319	2,295,195
Construction field employees + self employees	114,743	109,151	114,036	113,692
Completion process of Nuclear Power Plant Mochovce, Unit 3 and 4	2708	2910	3710	4805

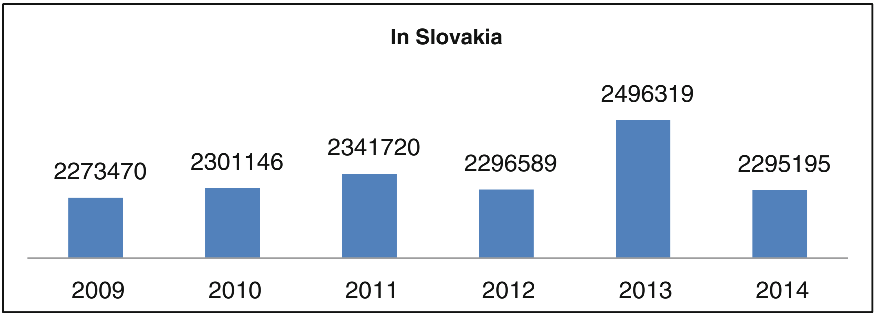

Fig. 1 Employees' rate development in the Slovak Republic [2]

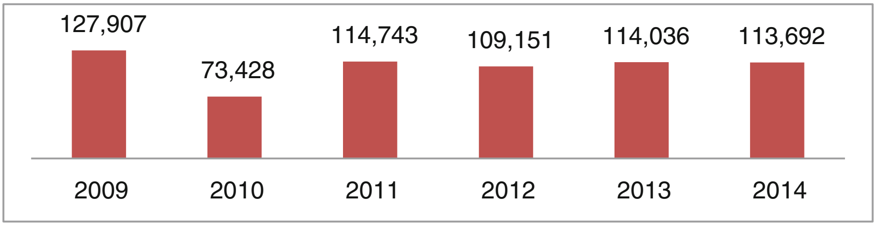

Fig. 2 Employment rate development in the construction field in the Slovak Republic [2]

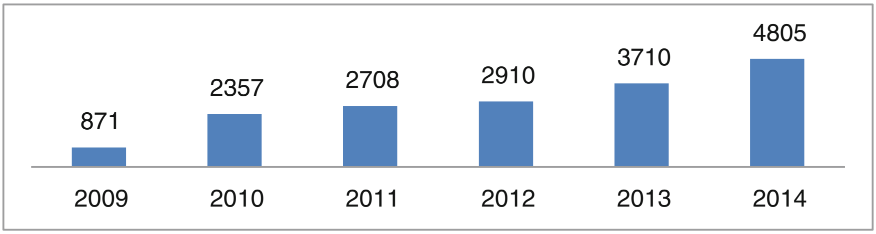

Fig. 3 Employment rate development in Nuclear Power Plant Mochovce Unit 3 and 4 [2]

Electronical System of Entries in NPP Mochovce, Unit 3 and 4. As we can see, the no. of employees is still increasing as of 2009, assuming the no. of occupational injuries to have an increasing trend. This, however, thanks to the set up Safety Management System is not actual, since in the Safety field it is necessary to propose on a daily basis new trends and not to be satisfied with results, since also the best results identified for several years, may be in a minute replaced or questioned [2].

It is obvious that the statistics in the HSE area are still high and the trends cannot be described as favorable since on a day to day basis there is identified a high no. of occupational injuries, fatalities as well as heavy body injuries. These do not approach 0 level—with the Self Employed persons being excluded from the statistical surveys, however, counted previously for 10 % of persons within the Construction field. From the practical experience, these Self Employed persons we can be describe as the most hazardous group of persons since they have to bear all costs related to HSE, i.e. courses, trainings, Personal Protective Equipment, revisions of the electrical equipment, etc. In addition, exactly in this area the Self Employed persons have a tendency to minimize their costs.

In order to be possible to reach a success when managing Safety, it is necessary to count also with this group of persons and pay increased attention to them.

When performing an analysis the causes of fatal and heavy body injuries in the Construction field are almost stable, concerned are especially injuries caused due to fall from height, crush with a burden, electrocution, injuries during excavation Works or injury caused by other person.

Next cause and a quite significant one related to the registered injuries has been identified to slipping/tripping hazard. Even despite the fact that the consequences of these injuries are not always severe, from the statistical point of view these injuries count to almost 2/3 of all registered injuries and it is necessary to solve also this issue in the prevention programs.

MO34 records show that six out of ten injuries were caused due to slipping/tripping hazard while this injury was primary caused by inattention of employee, i.e. cause no. 12 in compliance with Decree no. 500/2006 and not by faulty or dangerous conditions of the road [2–4].

Of course, we cannot underestimate the hazard of factors that during a long exposition period may cause various occupational diseases. In Construction conditions, concerned are mostly noise, vibrations, and fumes from welding or damages to the muscular system caused by unilateral load. Also for this purpose there have been adopted many preventive measures, i.e. installation of effective exhaust system, regular monitoring of the environment of our contractors or measuring different physical data of the environment, etc.

In comparison with other segments where hazards as well as exposition to these hazards are mostly on the same level, in the Construction field the situation is subject of alteration by progress of the Works. Therefore it is necessary to permanently adapt to the ongoing phase, to permanently monitor also the hazards coming thereof and to flexibly react on any found risks.

For this purpose, we use a tool dedicated to manage analysis of the Safety conditions named “Construction Safety Indicators” (CSI). This program is divided into two parts—to monitor all findings having character of any deviation from the legislation or from the project rules which in many cases are much more stricter and into second part focusing on monitoring and evaluation of the human behavior [1, 4, 5].

2 Construction Safety Management—Practical Experience

Monitoring of all findings we focus on in the Occupational Health and Safety, Fire Prevention including Environment and Emergency Planning and Preparedness field. Further part of this program is aimed on monitoring of the human behavior (BBS—behavior based safety) and identification of causes why workers violate the rules. CSI program generates large volume of data necessary to be analyzed using preventive and corrective measures we do adopt right after.

CSI system focuses on detection of findings not having character of incident, recorded or registered accident. It includes recording of observations (violation of legislation, project rules, work procedures, etc.) having potential to cause a damage. These observations are recorded daily during inspections [1].

2.1 Performance of Inspections

Safety Supervisors do perform the inspections. Each of them has assigned one of the areas at site. Division of the site into areas or zones we incorporated in the project rule called Integrated Safety Plan for Mochovce NPP units 3 and 4 completion and results from the number of workplaces and workers at site.

In October 2015, we reached the max. no. of workers during the day shift at site, i.e. around 5500, there have been established more than 800 workplaces in the Reactor Hall.

At this time there were for monitoring of the workplaces assigned approx. 28 Safety Supervisors from SE and BOZPO co.

The focus of their inspection activity is observance of legal and other requirements for the HSE field during activities performed by the contractors. Especially important is the fact that prevalent period of their working time they spend directly in workplaces of contractors.

In case of any defect, the safety Supervisor must correct the situation. In case of minor defects/nonconformities, correction is made immediately at the workplace or during the work shift. If the problem cannot be resolved the same day, a person responsible for given workplace/activity is contacted and advised to take necessary action. The next day, the Safety Supervisor checks removal of problem from the previous day.

This program was established to operate and created to match the requirements and specifications of the NPP Mochovce, completion process of Unit 3 and 4. BOZPO co. created this program and is operating it. BOZPO co. is playing very important role of the Site Safety Coordinator and represents a daily support during inspection activity [1].

2.2 Evaluation of Findings

Data collected from the inspection activity based on the selection criteria are evaluated from quantitative and qualitative point of view. In order to be possible to objectively evaluate and record the inspection activity there is used a Checklist that in the future can be replaced with an electronical one making the process easier.

Evaluation of all findings we do once a month with the results being presented to contractors during safety coordination meetings. The contractors shall propose corrective and preventive measures based on the results including reassessment of the occupational hazards.

Proposed corrective and preventive measures shall be then submitted via the coordination meetings to the Safety Coordinator [6].

2.3 Corrective and Preventive Actions' Efficiency

Implemented Corrective and Preventive Actions (CAPA) are subsequently checked by the Safety Supervisors. CAPA efficiency is evaluated based on the repeatability as follows [1]:

$$\mathrm{PN1} = \frac{\text{Number of findings in defined area before CA, PA}}{\text{Total number of findings}} \tag{1}$$

$$\mathrm{PN2} = \frac{\text{Number of findings in defined area after CA, PA}}{\text{Total number of findings}} \tag{2}$$

$$\eta_{CA,PA} = 100 - \frac{PN2}{PN1} \times 100[\%] \tag{3}$$

If the data analysis shows inefficiency of adopted corrective and preventive actions, the Owner notifies the contractor/supplier thereof.

This system can be also used as register of all defects found during the construction period, including monitoring of trends.

It is also important to add that the effectivity of measures is timely limited since the conditions of the construction site include also fluctuation of contractors as well as workers. It is also very important to repeat most of these measures on a regular base. Part of the system is also a program focusing on the human behavior known in the past as "One Safety" program [1].

2.4 Construction Safety Indicators—One Safety

The "One Safety" project focuses on behavior of workers because, as studies on the trend of injuries show, around 80 % of all injuries can be attributed to risky behavior on the part of workers during their work. Reducing risky behavior means reducing the number of injuries occurred.

The project features the following main characteristics:

- strong management commitment at all organizational levels
- application of common, homogeneous methodology within the Group to implement corrective actions following the observations made
- application to both Enel personnel and the personnel employed by contractors
- involvement of the lines, and also the HR, Procurement and Contract Department.

Application of this program requires to follow the below steps and focuses on the most important part of this process—feedback to/from workers [1, 6].

2.5 Feedback Principals

Observations allow different levels of intervention:

- interruption of the work in case of serious, immediate and unavoidable danger
- sharing the results at the end of the observation
- final analysis.

In order to share the results in a correct and effective way, it is advisable to follow the following indications:

- begin the discussion by highlighting the positive aspects of the observation, and pass on to the hazardous aspects at a later stage
- share the observations and try to understand the reasons for hazardous behavior.

Attempt is to reconstruct the activities carried out and the types of behavior adopted so that each worker can recognize its own errors and could be able to understand the consequences resulting from the hazardous behavior.

The “One Safety” principle is not set up on punishment, but on motivation for identified positive behavior. Workers who observe the Safety rules and who are able to answer the Safety questions or questions related to hazards at site, can be awarded with 5€–20€ voucher which can be used in canteens or buffets in MO34 premises. The next form of awarding are interesting books given to workers for reporting dangerous event or who proposed any practical ideas for the improvement of the Safety conditions. For the period of past two years, there has been assign for this purpose approx. 4000€.

Positive motivation is, however, in Slovakia still not as effective as in other countries and therefore it is necessary to use also less attractive methods of negative motivation. For this purpose we use so called “football method”. For violation of rules there is to the worker applied a Yellow Card. In case this worker receives within the upcoming 3 months a second Yellow Card, he has to pass additional training. This training means that each worker will lose 4 h from his/her working time and shall pay administrative cost of 20€. The aim of this training is to notify the workers on the consequences of dangerous behavior based on reconstruction of real events and as well, it includes verification of their knowledge in HSE, FP and Environment areas. The worker can continue in his work only after successful passing of given training. This method is quite effective since the prediction is almost 95 % and out of approx. 200 retrained persons, only 13 of them violate rules in the next period.

The next stricter punishment is issuing a Red Card, which can be applied not only for gross violation of HSE rules, however, also for already applied 3 Yellow Cards in a period from 3–6 months. Red Card means for a worker prohibition of access to all workplaces for a defined period (from 2 weeks up to 2 years).

To compare, there was in 2015 at site for positive behavior awarded approx. 300 workers with financial vouchers, but on the other side, for not observing of the Safety rules there was applied 2425 Yellow and 80 Red Cards [1, 4, 6].

2.6 Communication Tools

Very important tool to improve behavior and Safety culture is correct communication with all workers of contractors. For this purpose there are used several tools at site as for example communication campaigns focusing mostly on critical and hazardous activities (Figs. 4, 5). Topic of the campaigns is regularly updated and adapted to situations and risks at site. The next and very effective and flexible communication tool is Safety Message of the Week that is at the beginning of each week distributed via different channels to workers of contractors. These messages reflect current issues at site as for example, dangerous events, injuries, most frequently found violations or also various risks related to the weather conditions or to some specific activities performed.

Last but not least is Pre Job Brief as a very important tool which shall be passed by ach worker entering the site, i.e. workplace prior to performance of the activities. From the Safety point of view the quality and way of the Pre Job Brief is regularly supervised during inspection activities.

Of course, the communication cannot be one sided and therefore for this purpose we issue monthly newsletter “Together and Safely” where the workers can find a questionnaire ticket, fill it in case of their interest and put it into special boxes

Fig. 4 “Mind the risk”—safety campaign examples [1]

Fig. 5 “Work safely”—safety campaign examples [1]

placed at site. This is a way how we can distinguish and solve issues and initiatives of workers at site [1].

2.7 Coordination of Safety

Besides the above-mentioned supporting programs, correctly implemented safety coordination system defining responsibilities and duties is also a must.

The complete safety coordination process is included in the document called Integrated Safety Plan. All information are in regular daily and weekly intervals forwarded to all contractors and their workers [1].

3 Results

Construction of the nuclear power plant is monitored very closely, as the approach to safety in the construction phase is an important indicator of the Owner's approach to operational safety as well—the key one for operation of a nuclear installation. One of the ways to evaluate the success or non-success of the Safety Management System is to compare already achieved results with the results obtained in Construction field of SR [1, 6].

In order to be possible to compare results in SR in the HSE field with results of other countries of EU, in Table 2 you can see specific data available.

Comparison of the basic accident rate index shows that the frequency index on the completion project is 3-times better than in Slovakia, and the severity index for the completion project is even 6-times better than indicators of the Bureau of Statistics of the Slovak Republic for the construction industry. Especially it is important to look for and implement new tools mostly in aimed to minimize the human errors, to prevent the routine behavior as well as to cross so called safety Culture Bridge [1, 2] (Table 3).

Table 2 Safety results [1, 2]

	MO34 construction	SK construction	MO34 effectivity index
Total manhours	1 million man-hours/6 years	1 million man-hours/6 years	
Fatality/severity rate (FaR)	0.022	0.056	2.5
Frequency rate (FR)	0.640	1.979	3
Severity index (SI)	0.018	0.113	6

Table 3 Comparison with the European Union [2]

Member state		Average (2009–2011)
European union (15 countries)		1.55
1	United Kingdom	0.67
2	Netherlands	0.76
3	Sweden	1.26
4	Germany	0.80
5	Estonia	2.43
6	Denmark	1.10
7	Greece	0.85
8	Italy	1.58
9	Poland	3.30
10	Ireland	1.19
11	Belgium	2.04
12	Hungary	2.18
13	Finland	1.04
14	Switzerland	1.57
15	Malta	0.50
16	**Slovakia**	0.59 **(2/29)**
17	Spain	1.98
18	Czech Republic	2.01
19	Cyprus	3.48
20	Austria	2.13
21	France	3.22
22	Slovenia	1.93
23	Portugal	2.90
24	Luxembourg	2.53
25	Romania	4.53
26	Bulgaria	2.26
27	Croatia	1.68
28	Lithuania	3.75
29	Latvia	3.52

Unfortunately, we were not able to reach 0 in the most important category—fatal accidents—and recorded one fatal accident in MO34 in May 2015. This accident occurred to self-employed person. Consequently, all our records for the 6-year period with approximately 43 million man-hours worked without any severe or fatal accident were erased. This injury has showed us that in the occupational health and safety field while managing one of the biggest civil projects in the EU no satisfaction with 0 is possible, there has to be done everything to prevent giving over following of the safety rules.

From the practical point of view, I know that to reach 0 accident level is possible to be achieved. In order to reach this level, all workers have to be involved in the safety area, have to be fully notified with all hazards, must at the same timework smart, and think safe [1, 2].

4 Discussion

If we follow only numbers, it's obvious that implemented system interconnecting many practical tools together with correct application significantly reduces the risk of work accidents and, if set efficiently, can even save human lives.

50,000,000 worked hours are similar to the working fund of a factory employing 1000 workers for 25 years. Thus, such volume of worked hours provides an excellent tool for assessment of success or failure of the system as whole. However, there still exists a hazard of injury caused by the human factor. Important is to do everything to have such cases in register the least as possible [1].

5 Summary

Protection of health and life of our friends and co-workers is the top priority for everyone working in the safety area. The construction industry, but also other similar industries (maintenance, installation and dismantling activities) are ruled by strict legislation based on European standards and regulations prepared and formed in Slovakia over the time. Their current shape has been often redeemed by health and lives of workers in all industries.

However, only observance of legislation in modern world is not enough. Therefore, it is necessary to start sharing practical and proven tools for the safety management. If good and proven experiences continue to be considered a secret or knowledge of individuals working in the safety area, our workers will continue to pay the highest price for their mistakes. But if we share our practical experiences, we can help to protect the most precious thing we have—our health and life.

References

1. Slovenské elektrárne, a.s., completion process of Unit 3 and 4, internal sources and procedures. Slovakia
2. National labour inspectorate Košice: Annual report 2009–2014
3. Hill DC. Construction safety management and engineering. Illinois, 60018-2187. ISBN 1-885581-46-7
4. Petersen D. Techniques of safety management: a systems approach. 4th ed. Illinois, 60018-2187. ISBN 1-885581-39-4

5. Petersen D. Safety management: a human approach. 3rd ed. Illinois 60018-2187. ISBN 1-885581-36-X
6. BOZPO, spol. s.r.o.: Construction safety indicators, electronical version. Slovakia

Health and Safety Regulation and Its Compliance Among Small and Medium-Sized Enterprises Contractors in Ghana

Zakari Mustapha, Clinton Aigbavboa and Wellington Thwala

Abstract The Ghanaian construction industry has been domination by Small and Medium Sized-Enterprises (SMEs) contractors and this domination has been attributed to the rate of urbanization in the country. Whilst, poor Occupational Health and Safety (OHS) practices by these contracts have resulted in a high rate of occupational accidents. Non-compliance with Health and Safety (H&S) regulations among SMEs contractors' has led to their inability to manage Occupational Health and Safety (OHS). The purpose of the study was to identify the causes of SMEs contractors' non-compliance with H&S regulations. An extant review of literature was conducted, that provided the road map to source out information relevant to SMEs contractors' Health and Safety (H&S) practices in Ghana. The study adopted the Delphi survey method of data collection to investigate the study objective. List of experts (construction professionals and academics) were generated from peered reviewed conference proceedings and journal articles. A structured Delphi technique questionnaires were administered amongst the selected construction experts who consented to participate in the study. The rating of the SMEs non-compliance with H&S regulations were based on either the impact was considered to be high or very high. Data collected were analysed using Microsoft EXCEL, spread-sheet software. The findings reveal that limited knowledge of OHS, unavailabilty of H&S policy and knowledge on H&S policy implementation have high impact on SMEs contractors' non-compliance with H&S regulations. Other findings were that the SME contractors provided limited training to their employees on H&S regulations and management bottleneck. The study contribute to the body of knowledge on the causes of SMEs contractors' non-compliance with H&S regulations in the Ghanaian construction industry.

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Keywords Health and safety · Compliance · Regulation · SMEs contractors'

1 Introduction

The construction industry in Ghana is dominated by Small and Medium-Sized-Enterprises (SMEs) contractors [1–4]. Their domination has not improved on the OHS practices, but rather increased the accident rate in the construction industry in Ghana. Accidents and injuries are likely to be minimised if workers know the correct procedure in carrying out their activities and abide by them [5]. SMEs contractors play a role as sub-contractors for large firms and offer operational flexibility [1]. The compliance of SMEs contractors was found to have an effect on their ompliance levels within individual employees in the construction industry [6]. SMEs contractors non-compliance with safety regulations is affected by their financial, expertise and staffing capabilities [6, 7]. Since SMEs contractors conceive compliance in a different way to the view of enforcers [7]. This paper attempts to demonstrate H&S regulations and its compliance among SMEs contractors in Ghana. The paper discusses OHS Act and SMEs contractors.

2 Design/Methodology

The Delphi survey was selected for the study based on the criteria that was developed from the research questions under investigation. Experts were made up of aacademics and construction professionals (building technologists and quantity surveyors). A Delphi Study is a group decision mechanism requiring qualified experts who have deep understanding of the issues at hand [8]. Expects were expected to meet a minimum of at least five (5) minimum criteria: residency—have lived in any of the Metropolitan/Municipal/District in Ghana at least more than one (1) year, knowledge—has knowledge of Health and Safety (H&S) in the construction industry, academic qualification—has been presented an earned degree (Bachelors-degree/Masters-degree/PhD) related to any field, certification of employment/experience focusing on construction development or sustainable issues, experience—has a history of or currently performing consultation services for the government of Ghana, individuals, businesses, agencies, companies, and or organizations, relating to construction or other sustainable development.

The experts must exhibit a high degree of knowledge of experience in the subject matter in addition to extensive theoretical knowledge, employment—currently serves (or has previously served) in a professional or voluntary capacity (e.g., at place of employment—institution, business, agency, department, company) as supervisor or manager of establish that is involved with construction or sustainable development in Ghana, influence and recognition—has served or currently serving as a peer reviewer for one or more manuscripts received from a journal editor prior to its publication in the primary literature, with focus of the manuscript(s) on construction or sustainable development, authorship—is an author or co-author of peer-reviewed publications in the field of construction with emphasis in Ghana, has prepared and presented papers at conferences, workshop or professional meetings focusing on construction, sustainable development and H&S, research—has submitted one or more proposals to or has received research funds (grant or contract) from national, local government, regional, and or private sources that support construction, sustainable development and studies related to H&S, teaching—has organized, prepared, and successfully presented one or more H&S or sustainable development training workshops focusing on the group for which expertise is sought. The workshop or course must have been on H&S practices or has served as an individual or as a collaborative instructor in the teaching of one or more Polytechnics or University courses focusing on construction, sustainable development or related field, membership-member of a professional body (as listed on the expert questionnaire).

The expert should also be the representative of a professional body so that their opinions may be adaptable or transferable to the population and finally, willingness—Experts must be willing to fully participate in the entire Delphi survey. The selected expects for the paper represented a wide variety of backgrounds and guarantee a wide base of knowledge [9]. Rowe et al. [9] recommendations were adopted for the current study. The number of respondents should be large enough to ensure that all perspectives are represented, but not so large as to make the analysis of the results unmanageable by the researcher [10]. The adoption of five of these criteria was considered more stringent than the recommended number of at least two criteria by [9, 11]. The five minimum criteria were framed after the four recommendations made by [12], with the inclusion of experts' residency status, which was considered to be compulsory for all selected experts. This was considered significant because experts were required to have a wide-ranging understanding of H&S practices within their locality.

Nine (9) experts were used for the study and this number was considered adequate based on literature recommendations from scholars which have employed the technique previously. Hallowell and Gambatese [13] suggested that since most studies incorporate between eight (8) and sixteen (16) panellists, a minimum of eight (8) is reasonable. This was beyond the given limit in the current study. Hallowell and Gambatese [13] argued that the size of a panel should be dictated by the study characteristics, number of available experts, the desired geographical representation and capacity of the facilitator. Experts were asked to rate the impact of other factors in predicting H&S regulation and its compliance among Small and Medium-Sized Enterprises (SMEs) contractors in Ghana. Data obtained from the survey was analysed with Microsoft EXCEL, spread-sheet software. The output from the analysis was a set of descriptive statistics such as means, median, standard deviations and derivatives of these statistics.

3 Occupational Health and Safety Act and SMEs Contractors

Factories, Offices and Shops Act 1970, Act 328 and the Mining Regulations 1970 are the two major edicts in Ghana that provide guidance in the provision of OHS practice and management [14]. Considering the multifaceted distribution of industrial operations in Ghana, these edicts are fragmented and limited in scope. Even though, the concept of OHS was introduced in the Ghanaian industries before the introduction of the Factories, Offices, and Shops Act 1970 [14], but the Ghanaian construction industry which is dominated by SMEs contractors is faced with OHS problems.

The OHS regulation normally requires that SMEs contractors take some action likely to involve expertise, finance and management. Taking into account the characteristics of SMEs contractors, they are likely to find regulations difficult to implement because they have limited resources that result in strict control of staffing. There is also limited personnel to monitor changing legal requirements, interpret and implement the necessary control measures [7]. The Confederation of British Industry (CBI) notes that SMEs contractors have special needs of their own and are faced with the challenge of one or more of a group of special characteristics. Some of the special characteristics of SMEs contractors as reported in [7] are lack of specialist skills, low cash flow, small asset base etc. [7].

Arewa and Farrell [15] posited that SMEs contractors have limited time in dealing with regulatory requirements. While adequate OSH training and education as indicated by [16] will enhance the compliance of SMEs contractors with OSH regulations. Hence, this is not feasible due to lack the staff with the requisite knowledge in OHS regualtions. Within the SMEs contractors, responsibility for dealing with regulations often fall on the proprietor who may not have any specialist skills. SMEs contractors do not have representatives when it comes to policy review, this denies them the opportunity to implement and monitor legal requirements [7].

4 Findings

Findings from the Delphi survey show that the factors that causes SMEs non-compliance with H&S regulations were varied in nature. From the ten (10) listed measurement variables that were identified by the experts to have effect on SMEs contractors' non-compliance with H&S regulations in Ghana. Only four (4) factors or measurement variables (limited company resources, unavailable Health and Safety (H&S) policy, limited knowledge of OHS and limited access to body responsible for the implementation of H&S policy) were considered by the experts to have reached consensus with IQD cut-off ($IQD \leq 1$) score on H&S

Table 1 Factors that causes SMEs non-compliance with H&S regulations

Factors that affect SMEs in not (to) complying with H&S regulations	Median	Mean	SD	IQD ≤ 1
Limited company resources	7.00	7.43	1.05	0.82
Unavailable health and safety (H&S) policy	8.00	7.71	1.28	0.71
Limited knowledge of occupational health and safety (OHS)	8.00	7.71	1.28	0.71
Inability to employ H&S personnel	7.00	7.00	1.07	1.25
Inability to train employees on H&S regulations	8.00	7.43	1.59	3.00
Lack of knowledge on H&S policy implementation	7.00	6.86	1.64	1.61
Lack of coordination of the implementation of H&S policy within the organisation	7.00	6.57	1.92	2.25
Limited access to body responsible for the implementation of H&S policy	7.00	7.00	0.93	0.25
Lack of cooperation from client	6.00	6.00	1.93	1.50
Management bottleneck	7.00	6.43	1.84	1.50

SD = standard deviation; IQD = Interquartile deviation

compliance as shown in Table 1. From the ten (10) factors or measurement variables, nine (9) had high impact (HI: 7–8.99) on factors that causes SMEs non-compliance with H&S regulations. Only one (1) factor or measurement variable had medium impact (MI: 5–6.99) on factors that affect SMEs non-compliance with H&S regulations (Table 1).

Results from the study revealed that the following ten factors or measurement variables were considered by the experts to have varying impact on SMEs contractors' non-compliance with H&S regulations.

- Limited company resources (HI)
- Unavailable Health and Safety (H&S) policy (HI)
- Limited knowledge of Occupational Health and Safety (OHS) (HI)
- Inability to employ H&S personnel (HI)
- Inability to train employees on H&S regulations (HI)
- Lack of knowledge on H&S policy implementation (HI)
- Lack of coordination of the implementation of H&S policy within the organization (HI)
- Limited access to body responsible for the implementation of H&S policy (HI)
- Lack of cooperation from client (MI)
- Management bottleneck (HI).

From the impact ratings of the factors, findings revealed that 9 of the factors or measurement variables have a high impact (HI: 7.00–8.99), while only one factor or measurement variable has a medium impact (MI: 5.00–6.99) and four other factors or measurement variables have medium impact.

5 Discussion of the Findings

This section presents the discussions of the findings from the Delphi survey on the factors that cause SMEs contractors non-compliance with Health and Safety (H&S) regulations. SMEs contractors are found not to be able to comply with H&S regulations due to several factors, some of which may be beyond their control and others out of their reach [6]. Findings are that SMEs constractors have limited company resources, knowledge of OHS and access to experts to implement H&S policy. These findings correspond with the findings of [6, 7]. Further findings revealed that SMEs contractors do not have ample time to discuss H&S policy [15]. Hence, the resultants of their non-compliance with H&S regulations.

6 Conclusion and Recommendation

The purpose of the study was to identify the causes of SMEs contractors non-compliance with H&S regulations. Findings have revealed that SMEs contractors lack resources and knowledge of OHS. Others are lack of access to H&S expetts and time to discuss about H&S. It is recommended that governemnt should make it mandatory for all SMEs contractors to employ H&S personnels. SMEs contractors should make funds available for H&S training of their. A workshop or seminar should be organized by the H&S personnel to educate other employees on H&S issues.

References

1. Ofori, G., Toor, S.R.: Leadership and construction industry development in developing countries. J. Constr. Dev. Ctries. (2012). http://web.usm.my/jcdc
2. Laryea, S.: Challenges and opportunities facing contractors in Ghana. In: Laryea, S., Leiringer, R., Hughes, W. (eds.) Proceedings of the West Africa Built Environment Research (WABER) Conference, pp. 215–226. Accra, Ghana, 27–28 July 2010
3. Kheni, N.A., Dainty, A.R.J., Gibb, A.G.F.: Health and safety management in developing countries: a study of construction SMEs in Ghana. Constr. Manag. Econ. **26**(11), 1159–1169 (2008)
4. Frempong, G., Essegbey, G.: Towards an African e-Index, SME e-ACCESS AND USAGE across 14 African countries, pp. 25–27 (2006). http://www.researchictafrica.net
5. Zin, S.M., Ismail, F.: Employers' behavioural safety compliance factors toward occupational, safety and health improvement in the construction industry. In: ASEAN Conference on Environment-Behaviour Studies, Savoy Homann Bidakara Bandung Hotel, pp. 15–17. Bandung, Indonesia (2011)
6. Department of Occupational Safety and Health Annual Report (DOSH): Department of occupational safety and health: labour and human resources statistics (2008). http://www.mohr.gov.my/

7. Health and Safety Executive (HSE): Making an impact on SME compliance behaviour: an evaluation of the effect of interventions upon compliance with health and safety legislation in small and medium-sized enterprises (2005)
8. Okoli, C., Pawlowski, S.: The Delphi method as a research tool: an example, design considerations and applications. Inf. Manag. **42**, 15–29 (2004)
9. Rowe, G., Wright, G., Bolger, F.: Delphi—a re-evaluation of research and theory. Technol. Forecast. Soc. Chang. **39**, 238 (1991)
10. Linstone, H.A., Turoff, M.: The Delphi method: techniques and applications (2002). http://www.is.njit.edu/pubs.php
11. Dalkey, N.C., Helmer, O.: An experimental application of the Delphi method to the use of experts. J. Inst. Manag. Sci. **9**, 458–467 (1963)
12. Adler, M., Ziglio, E.: Grazing into the oracle: THE Delphi Method and its Application to Social Policy and Public Health. Kingsley Publishers, London (1996)
13. Hallowell, M.R., Gambatese, J.A.: Qualitative research: application of the Delphi method to CEM research. J. Const. Eng. Manag. ASCE **136**(1), 99–107 (2010)
14. Annan, J.S., Addai, E.K., Tulashie, S.K.: A call for action to improve occupational health and safety in ghana and a critical look at the existing legal requirement and legislation. Saf. Health Work (2015). http://www.e-shaw.net/
15. Arewa, A.O., Farrell, P.: A review of compliance with health and safety regulations and economic performance in small and medium construction enterprises. In: Smith, S.D. (ed) Proceedings 28th Annual ARCOM Conference, 3–5 September 2012, Edinburgh, UK, pp. 423–432. Association of Researchers in Construction Management (2012)
16. Idubor, E.E., Oisamoj, M.D.: An exploration of health and safety management issues in Nigeria's effort to industrialise. European Sci. J. **9**(12). ISSN: 1857-7881 (Print) e-ISSN 1857-7431 159 (2013, April)

Utilization of Viewing Aids for Safe Operations with Excavators

Markus Koppenborg, Michael Huelke, Peter Nickel, Andy Lungfiel and Birgit Naber

Abstract Camera monitor systems (CMS) and mirrors are intended to support excavator operators' understanding of the surrounding and help prevent accidents. However, little is known about visual information acquisition of operators of large construction machinery, especially during machine movements. In this field study, utilization of viewing aids and other information sources during rotating movements of excavators was investigated by means of eye-tracking and task observation. Results show that, while CMS monitors and left mirrors were used for many rotating movements, other information sources around the machine were also attended, such as the right frontolateral area and the area around the attachment. The article discusses implications for safety and machinery design, such as positioning of viewing aids.

Keywords Accident prevention · Construction machinery · Viewing aids · Camera-monitor-systems · Closed-circuit television CCTV · Eye-tracking · Task observation

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1 Introduction

Recent technological developments regarding construction machinery have aimed at increasing operator visibility from the cabin to the area around the machine. In the case of hydraulic excavators, direct sight has been improved, among others, by enlarged cabin windows and shorter counter weights, thus decreasing obstructions to the machine's side and rear areas. Measures addressing indirect sight include additional viewing aids, such as mirrors or camera monitor systems (CMS). Similar to direct sight improvements, these are intended to support operators' understanding of the surrounding and thus help to prevent collision accidents between the machine and humans or obstacles.

Measures of prevention addressing collision accidents have a long history on construction sites. Personal protective equipment, such as reflective clothing, or wearable sensors, as well as proper operator training are important safety aspects. Similarly, preventing access of humans to the area around mobile machinery by means of traffic patterns or restrictions contribute to safer work conditions. However, priority should be given to technical measures. Here, installation of additional viewing aids can be regarded a compelling solution. As mirrors and CMS can compensate a lack of direct sight they should be useful for operators to monitor the areas around the machine and, finally, prevent collision accidents. However, in order to assess, select and develop viewing aids and other technologies, empirical evidence on operator visual information acquisition during critical maneuvers is necessary.

Therefore, this study was initiated by the German Social Accident Insurance Institution for the Building Trade (BG BAU) to investigate excavator operator information acquisition. More precisely, utilization of viewing aids and other information sources during critical maneuvers (i.e. rotation movements) was measured in a field study by means of eye-tracking and task observation. Results are expected to further enhance our understanding of operator information acquisition behavior and support future measures of prevention.

2 Related Work

2.1 Information Needs and Viewing Aids in Excavators

Working with excavators usually includes rotating movements of the upper structure to the right and left, e.g. when loading, moving and discharging material. During such operation, collisions can occur on both sides of the machine, as the boom and the counterweight swing out into both lateral areas. Therefore, to prevent collisions, monitoring of these critical areas is necessary when rotating the upper structure. Importantly, this has to be achieved in addition to the primary excavating task at hand which can place high demands on the operator in terms of information acquisition and processing.

While the cabin allows direct sight to the frontal area including the boom and the attachment, the left lateral area can be monitored by using the left rearview mirror or by direct sight when turning the head and upper body (i.e. "look over the shoulder"). With regard to the right lateral area, direct sight can be obstructed by the boom and other parts of the machine. Hence, multiple rearview mirrors can be installed on the right side of the machine in a way that at least one mirror can be seen regardless of the boom's position. In modern excavators, the area directly behind the machine is covered by a CMS on the counterweight that displays this area on a monitor in the cabin.

This configuration of mirrors and CMS is in accordance with EN ISO 474 on safety principles for construction machinery [1]. It also conforms to ISO 5006 on operators' field of view in earth-moving machinery [2]. However, this standard, according to a decision of the European Commission [3], fails to meet essential health and safety requirements regarding visibility [4, 5] and is therefore currently under revision.

Notwithstanding this development, some manufacturers and construction companies have opted for an additional CMS to cover the right lateral area supplementing or substituting mirrors on the right side of the machine. Where machines are already equipped with a CMS for rear view, both the rear and the right lateral area can be displayed on the monitor (e.g. with split-screen). Thus, a number of partially redundant means for direct and indirect sight are available to operators. For the assessment, selection and further development of appropriate viewing aids and other technical measures, empirical evidence on information acquisition behavior of machine operators is required. However, so far, only few studies have focused on how operators of construction machinery acquire visual information.

2.2 Operator Information Acquisition Behavior

Hella et al. [6] used eye-tracking during grader operation and could show that during reversing movements, total dwell time on viewing aids was rather small, while glances directly to the rear area accounted for almost half of the total dwell time. This may point towards a preference of direct as compared to indirect sight. However, a study by Koppenborg et al. [7] showed that for reversing maneuvers with excavators, operators used all information sources, and especially the CMS monitors and rearview mirrors. With regard to rotating movements, a simulation study by Nakamura et al. [8] demonstrated more horizontal eye-movements during swinging as compared to other excavator movements. In the same study, this finding could be replicated with experienced operators and a real excavator in an outdoor environment. More horizontal eye-movements could imply visual information acquisition to prevent collisions of the boom with objects in the surrounding. However, glances on viewing aids (i.e. mirrors and CMS) were not reported.

As empirical evidence on operator information acquisition behavior for critical movements is scarce, this study investigated excavator operators' utilization of viewing aids and other information sources for rotating movements during regular work on real construction sites. To this end eye-tracking and task observation were employed and glances on information sources were analyzed.

3 Methods

3.1 Sample

Data collection took place on four different construction sites, each with a different operator and excavator and with different surrounding conditions (i.e. amount of co-workers, machines, and obstacles in the workspace). Measurement duration was between 3 and 5 h (M = 4.0, SD = 0.7), excluding regular breaks and all pauses related to setting up and calibrating of devices. Operators were male, mean age was 46 years (SD = 12.2) and professional experience with excavator operation was 16.8 years (SD = 8.4).

The sample comprised crawler and wheeled excavators of different manufacturers with a length of 10 m and a mass of 21–30 tons. Only backhoes, trench cleaning buckets and grabs were used as equipment for typical work activities, such as trenching, grading, object transport, and loading and spreading of material (including loading of trucks).

In all machines direct sight from the cabin to the right side was partly obstructed depending on the position of the boom and direct sight to the rear was obstructed by the counterweight. All machines were equipped with a CMS displaying the right lateral area and the area directly behind the machine on a monitor in the cabin (with split screen). All machines had one left rearview mirror and one, two or three right rearview mirrors. Configuration and adjustment of all mirrors and CMS were in accordance with regulations and corresponded to what operators were used to working with for at least one year.

3.2 Apparatus

A head-mounted eye-tracker "Dikablis" (Ergoneers GmbH, Manching, Germany) was employed for eye-movement recording, with a sampling rate of 25 Hz, scene camera field of view of 120°, four point calibration, contrast pupil detection and D-Lab 3 (Ergoneers GmbH, Manching, Germany) as recording software. Operator head and body movements were not limited by the eye-tracker and exiting and reentering the cabin was possible for operators at all times.

Simultaneous to eye-movement recording, excavator tasks and movements (i.e. rotating movements) were category coded by observation using a recording device developed for this purpose [9]. Additionally, operations were video recorded using a GoPro Hero 3® for subsequent correction of observational data, if necessary. Information on site and machine characteristics, as well as demographic data was gathered by guided interviews.

3.3 Procedure

All sites were visited on two consecutive days. The first visit served to conduct a trial measurement to let operators get accustomed to the measurement devices. To further minimize behavioral adaption, the purpose of the study was described in broader terms to operators. Written informed consent was obtained from all involved personnel. Main measurements on the second visit started in the morning and lasted until the early afternoon or until the end of the shift. Eye-tracking and task observation were done continuously, and interruptions of the work processes were kept to a minimum. After measurements operators were interviewed, debriefed and thanked with a small present.

3.4 Selection of Rotating Movements

Of all observed rotating movements, only rotations to the right were selected for further analysis. Further, only those rotations were selected where operators had limited direct visibility of the area into which they would move the upper structure. To this end, four criteria for selection were applied, namely the rotation angle, and three types of movements preceding the rotating (see Table 1). First, rotations were selected that exceeded a rotation angle of 45°. Rotations that are preceded by forward travelling movements allow direct operator visibility of both critical areas shortly before the rotation. Therefore, second, rotations were included where no forward travelling occurred within 60 s before the rotation. Oftentimes rotations to the right are immediately preceded by rotations to the left. Operators may not deem it necessary to monitor a critical area that the upper structure has occupied only

Table 1 Criteria for selection of rotating movements to the right for subsequent eye-movement analysis

No.	Inclusion criterion	Description
1	Rotation exceeds 45°	Only rotating movements that exceeded a rotation angle of 45°
2	No prior travelling movements	Only rotating movements that were not preceded by forward travelling within 60 s before the rotation
3	No prior rotation to the left	Only rotating movements to the right that were not preceded by a rotation to the left within 60 s before the rotation
4	Beginning of clusters	Only the first three rotating movements of each cluster

seconds before. Therefore, third, rotations to the right were included that were not preceded by rotations to the left within 60 s before the rotation. Finally, oftentimes rotation movements occur in clusters consisting of repetitions of alternating left and right rotations (i.e. repetitive back and forth swinging). Operators may not deem it necessary to monitor an area at the end of a cluster after having repeatedly rotated into the critical areas. As a fourth criterion, therefore, only the first three rotating movements of each cluster were selected.

3.5 Data Preprocessing and Analysis

Observational data on selected rotating movements were corrected manually and frame by frame by using video recordings of work activities and the coding software Noldus Observer® XT 12 (Wageningen, Netherlands). For subsequent eye-movement preprocessing and analysis, rotation intervals were defined, each including one selected rotating movement plus a period of 4 s preceding the start of the rotation.

For processing of eye-movement data D-Lab 3 was used. During rotation intervals, incorrect pupil position was corrected frame by frame and manually. Further, glances on seven different AOI were coded frame by frame and manually, and according to [10]. As shown in Fig. 1, the first three AOI represented viewing aids for indirect sight, namely the CMS monitor, the left rearview mirror and the right rearview mirrors. The latter four AOI represented information sources around the machine that were attended by direct sight through the cabin windows. These comprised the left lateral area which could be seen when operators rotated their

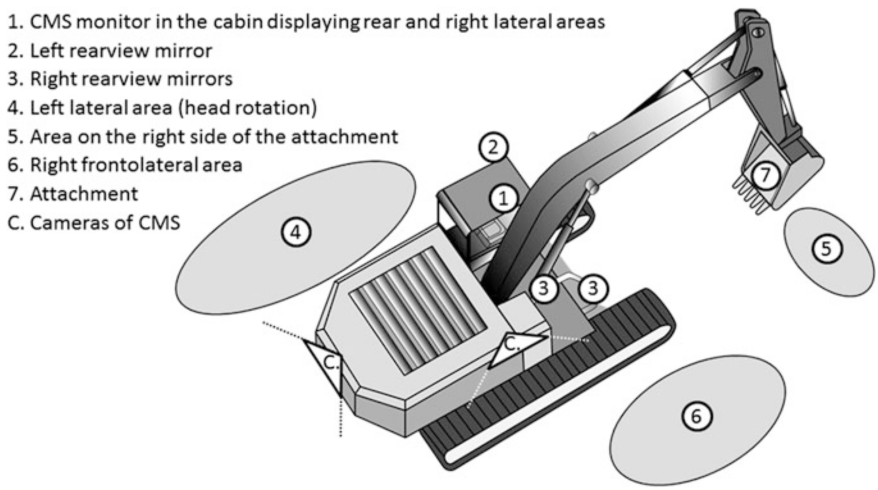

Fig. 1 Schematic representation of areas of interest (AOI) for eye-movement analysis during rotation intervals, and position of CMS cameras; glances on (*4*) and (*6*) could extend beyond the areas depicted in this illustration

head ("look over the shoulder"); the area on the right side of the tool; the right frontolateral area of the machine, which could be seen when operators looked beneath or through the hydraulic cylinders of the boom; and, lastly, the attachment.

As a measure of utilization of each AOI, percentages of intervals with at least one glance on each AOI were calculated over the aggregated sample and for each individual construction site.

4 Results

A total of 997 rotating movements to the right were observed during all four measurements. Of these, 132 rotating movements were selected by applying the criteria mentioned above. Selected movements had a total duration of 858 s and a mean movement duration of 6.6 s (*SD* = 3.6). As a measure of utilization of viewing aids and other information sources, percentages of rotation intervals with at least one glance on each AOI were calculated. With regard to viewing aids, results show that the CMS monitor was used in 34.1 % of all intervals, while the left and right mirrors were used in 22.0 and 0.8 %, respectively (Fig. 2). With regard to

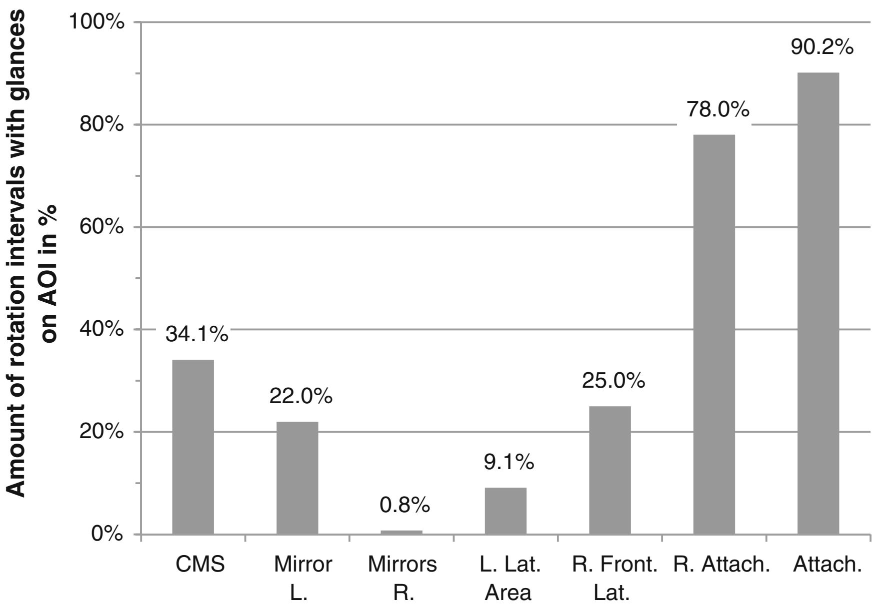

Fig. 2 Amount of rotation intervals with glances on AOI in percent of total number of rotation intervals (for variations, see Table 2). Abbreviations: *CMS* = CMS monitor, *Mirror L.* = left mirror, *Mirrors R.* = right mirrors, *L. Lat. Area* = left lateral area by rotating the head ("look over the shoulder"), *R. Front. Lat.* = right frontolateral area by glancing under or through hydraulic cylinders, *R. Attach.* = area on right side of attachment, *Attach.* = attachment

Table 2 Percentages of rotation intervals with glances on an AOI during rotation intervals for each site; rotations were selected to include only rotations where direct sight of lateral areas was limited

Site no.		1	2	3	4
Number of rotation intervals		40	30	47	15
Intervals with glance on AOI (in % of all intervals)	CMS monitor	25.0	90.0	17.0	0
	Mirror left	15.0	60.0	8.5	6.7
	Mirrors right	0	0	0	6.7
	Left lateral area by head rotation	10.0	13.3	6.4	6.7
	Right frontolateral area	47.5	6.7	12.8	40.0
	Area on right side of attachment	57.5	100	95.7	33.3
	Attachment	92.5	90.5	93.6	73.3

information sources accessible by direct sight through the cabin windows, glances on the left lateral area by head rotation ("look over the shoulder") occurred in 9.1 % of all intervals. Glances below and through the hydraulic cylinders onto the right frontolateral area of the machine could be found in 25.0 % of all intervals. The area right next to the attachment was attended in 78.0 % of all cases. The attachment itself was attended in 90.2 % of all intervals.

Similarly, percentages of intervals were calculated for individual construction sites. As shown in Table 2, utilization of the CMS monitor varied between 0 and 90 %. Percentages of intervals with glances on the left and right mirrors varied between 6.7 and 60.0 %, and between 0 and 6.7 %, respectively. Utilization of the left lateral area by head rotation varied between 6.4 and 13.3 %, while glances on the right frontolateral area varied between 6.7 and 47.5 %. Utilization of the right area next to the attachment varied between 33.3 and 100 %. Glances on the attachment varied between 73.3 and 93.6 %.

5 Summary and Discussion

In addition to rearview mirrors, modern excavators are oftentimes equipped with CMS to enhance operator visibility of the right lateral area of the machine and thus prevent collision accidents. To assess, improve and further develop viewing aids and other technical measures of prevention, evidence on operator information acquisition is necessary. Therefore, this study investigated utilization of viewing aids and other information sources during rotating movements of excavators by means of eye-tracking and task observation. During rotation intervals, operators attended the CMS monitor and, to a lesser extent, the left mirror. Further, the right frontolateral area, the area around the attachment, and the attachment were much attended information sources. Analysis of individual construction sites revealed variations of these aggregate values that could be explained by individual operator characteristics or by different situational, organizational or task demands across construction sites. Results can be useful to further develop methods for accident prevention on construction sites.

Rotating movements require operators to monitor both sides of the machine, as the boom and the counterweight swing out into these areas. Correspondingly, the left mirror and direct sight to the left was used by operators. For the area on the right side, the CMS monitor was attended, while right mirrors were regarded only in rare cases. Further, operators also looked beneath or through the hydraulic cylinders to monitor the frontolateral area of the machine by direct sight. This raises the question how information about this latter area is gained in situations where the position of the boom obstructs direct sight. Taken together, these findings converge with results of a previous study [7], showing that excavator operators used all information sources, and especially the CMS monitor and the left mirror for reversing movements. Results further indicate that the area immediately around the attachment and the attachment itself carry information relevant to operators. Glances that move back and forth between these areas may not primarily represent monitoring against collisions, but could rather constitute a comparison of current to target position of the boom and the attachment.

Our data on eye-movements contain information on foveal information acquisition, yet it is possible that peripheral perception plays a role for the operation of excavators. It would be interesting to investigate factors that influence peripheral information acquisition, such as the machine's dimensions or obstructions of direct sight. Further, the sample of four construction sites may not represent all personal, situational, organizational or task factors that contribute to utilization of viewing aids.

It is also important to point out that this study examined a selection of recorded rotating movements. On a typical work day, however, construction tasks can require operators to rotate hundreds of times. This should be kept in mind when considering the design of viewing aids and other technical measures to prevent collision accidents. More precisely, viewing aids should facilitate perception, understanding and behavioral adaption from the first to the last rotation movement. One prominent design factor relates to positioning of viewing aids, as this influences the effort of utilization and mental integration of information from different sources. Other factors include, but are not limited to, display quality, and size and field of vision of viewing aids, as they determine the size of displayed elements (e.g., a human). Improvements of these and other aspects could facilitate utilization, enhance understanding and thus lead to safer behavior that would eventually help reduce accidents with excavators.

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References

1. EN ISO 474-1: Earth-moving Machinery—Safety—Part 1: General Requirements. CEN, Brussels (2009)
2. ISO 5006: Earth-moving Machinery—Operator's Field of View—Test Method and Performance Criteria. ISO, Geneva (2006)
3. European Commission. Implementing Decision No. 2015/27 (Earth-moving Machinery). O. J. EU L, 4/24 (2015)
4. European Commission: Directive 2006/42/EC (Machinery Directive). O. J. EU L, 157/24 (2006)
5. Commission, European: Guide to application of the machinery directive 2006/42/EC. European Commission, Brussels (2010)
6. Hella, F., Laya, O., Schouller, J., Fontaine, P.: Visual attentional demand requirement in tasks related to mobile machinery driving: preliminary results of an eye movement analysis. In: Gale, A., Brown, I., Haslegrave, C., Taylor, S. (eds.) Vision in Vehicles, vol. 8, pp. 188–194. Loughborough University, Leicestershire UK (2012)
7. Koppenborg, M., Huelke, M., Nickel, P., Lungfiel, A., Naber, B.: Operator information acquisition in excavators—insights from a field study using eye-tracking. Manuscript accepted for publication in: LNCS, In: 18th International Conference on Human-Computer Interaction. Springer, Heidelberg (2016)
8. Nakamura, T., Fukuya, K., Mannen, S.: Eye movement and useful field of view in the operations of an excavator. In: Gale, A. (ed.) Vision in Vehicles, vol. 10, pp. 159–167. Loughborough University, Leicestershire UK (2012)
9. Koppenborg, M., Lungfiel, A., Naber, B., Nickel, P., Huelke, M.: Ein flexibles Gerät zur Tätigkeitskodierung per Beobachtung—Anforderungen und Ergebnisse einer Erprobung. In: 61. Kongress der Gesellschaft für Arbeitswissenschaft, B.1.12, pp. 1–6. GfA-Press, Dortmund (2015) [A Flexible Device for Coding Work Activities by Observation – Requirements and Preliminary Results]
10. ISO 15007: Road Vehicles—Measurement of Driver Visual Behaviour with Respect to Transport Information and Control Systems—Part 1: Definitions and Parameters. ISO, Geneva (2002)

Resilience Engineering, Gaps and Prescription of Safe Work Method Statements Part 1: The View of Organisational Outsiders

Manikam Pillay

Abstract The construction industry is frequently cited for its poor safety performance. In spite of this, many countries continue to rely on contemporary, prescriptive approaches to improve performance in the sector. In Australia, one such approach, Safe Work Method Statements (SWIMS), have been mandated in construction work. However, there is limited empirical research on SWIMS, so their ability to improve health and safety is largely unknown. This is a significant gap in our knowledge. Recent research suggests that Resilience Engineering (RE), which is an innovation in organisational health and safety management, offers a promising approach, by understanding the gap between work as imagined and work as performed. SWIMS provide a practical tool by which such a gap can be investigated in construction settings. Recent research also suggests that organisations are part of a broader socio-technical system. As such, gaining a view of the different elements of the system is an important first step towards developing an understanding of the role SWIMS play in health and safety risk management. This paper first describes the socio-technical system that constitute construction work; followed by an exploration of the meaning SWIMS as ascribed by the external agencies as the first 'outsider' of this system. It is based on an analysis of data collected as part of a larger PhD study of the prescription and practice of SWMS in the Australian construction industry.

Keywords Construction health and safety · Resilience engineering · Safe work method statements · Work-as-imagined

1 Introduction

The industry has always been considered to have one of the highest injury and fatality rates [1], with the same type of accidents continuing to occur over time [2]. There are a number of things that occur in construction work that set it apart from

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other traditional industries such as manufacturing. Construction work can be dispersed physically over several, sometimes distant, locations, with each construction site deemed to be a new workplace, effectively creating a series of 'mobile factories' which are disassembled and relocated once the project is completed [3]. However, the conditions at the new site might be completely different from earlier sites. Construction working environments can also be very dynamic, with frequent rotations of work teams, changing weather conditions, and a high proportion of unskilled, temporary and transient workers [4]. In addition, construction work is risky because of outdoor operations, work-at heights and use of sophisticated plant and machinery [5]; on some of the more larger construction projects tendering processes associated with sub-contracting may give little attention to safety, leading to cost and corner cutting [6]. On-site subcontracting also increases the risks of injuries [7]; with the nature of the work, poor attitudes and behaviours, ignorance, pressure from budget cuts and time restraints compounding the risks [5]. Moreover, some of the "unique work practices within the construction industry make it vulnerable to poor OHS outcomes" [8]. The industry is also highly fragmented, and the temporary nature of works that are involved means that lessons from previous works are not adequate to predict new sources of hazards [9]. In essence, this means that the construction industry is a complex one [10, 11]. A possible consequence of this is that improving health and safety in construction work can be more difficult than in a manufacturing facility [4], necessitating more innovative approaches. However, many organisations continue to rely on contemporary approaches, including standards, regulations, procedures and behaviour modification programs in the industry; in some cases due to regulations. In Australia one of such requirements includes safe work method statements (SWIMS), which have been regulated for high risk construction activities. However, apart from some guidance provided by state safety regulators, there is limited empirical research on SWIMS [12]. It is therefore questionable whether SWIMS are of any benefit in addressing construction health and safety risks, or merely an attempt by regulators to create an illusion of safety through paperwork.

1.1 SWIMS, Gap Between Work-as-Imagined Versus Work-as-Performed and Resilience Engineering

In essence, SWIMS are similar to safety rules [12, 13], and a key assumption behind their use is that workers will follow them. However, people do not always do so, and violations of safety rules are common in industry [14]. Moreover, sometimes some violations are necessary for achieving safety [15, 16]. In the field of organizational learning it has been identified that workers were quick to realize that no matter how clearly the rules were specified, the world was (to some degree) unpredictable, and they had to be prepared to use their innovative skills [17]. Such learning, according to the author, led them to adapt; subsequently, these adaptations become part of norm. Moreover, because procedures and rules 'always require an interpretation to bridge the gap between assumed and actual conditions, work as actually done is always different from work as imagined' [18]. Hence there will be always be gaps between work-as-imagined (as assumed by rule makers) and work-as-performed (by those for who these designed for). What is important about this gap (between work as imagined by management and work as actually performed by workers) is that it is also an important factor in resilience engineering (RE) [19–21], which is the most recent innovation in health and safety management. Hence SWIMS offers us a way of exploring the gap between work-as-imagined and-work-as performed. A central research question which can be asked is do SWIMS enhance or impede RE as a health and safety management strategy in the Australian construction industry? Answering this question through empirical research is an important first step in understanding the role SWIMS play in construction safety.

1.2 Conceptual and Theoretical Framework

Advancing research on RE and SWIMS requires the use an appropriate conceptual and theoretical framework to set a boundary and provide a focus for research. This research is broadly aimed at developing an understanding of whether SWMS enhance or impede RE as a health and safety strategy in construction. According to the new thinking about safety and accident prevention, safety is a dynamic property [21–23] that emerges out of the interactions between different elements and sub-units of a socio-technical system [24, 25]. An understanding of the socio-technical framework that constitutes construction and SWIMS is thus important in answering the research question. One such framework is presented in the next section.

2 The Socio-technical System of Construction Work

The socio-technical system (STS) was first proposed as a way of understanding how different stakeholders could influence the way risks are managed in dynamic work environments [26]. The STS presented by the author included several levels including government, regulators and associations, company, management, staff and work. In the state of Victoria, Australia, where this research was conducted, the socio-technical structure can be decomposed into at least six levels, illustrated in Fig. 1.

The first level involves the government, and three key agencies that are involved include the Australian Building and Construction Commission (ABCC), Federal Safety Commissioner (FSC) and Safe Work Australia (SWA). The ABCC was an independent statutory body established following a Royal Commission of Inquiry into the Building and Construction Industry [27]. Until its abolishment in 2011 the

Fig. 1 The socio-technical system of construction safety in Victoria, Australia

ABCC had the primary responsibility of ensuring that ‘building work is carried out fairly, efficiently and productively for the benefit of all building industry participants and for the benefit of the Australian economy as a whole’ [28]. Whilst its main focus was the enforcement of industrial relations, the Act also enabled the establishment of the Office of the Federal Safety Commissioner (OFSC) for (i) promoting sustainable occupational health and safety cultural change in the building and construction industry, (ii) developing and administering the Australian Government Building and Construction OHS Accreditation Scheme, and (iii) identifying and progressing initiatives to improve OHS performance [29]. The activities of these agencies were directed at organisations involved in building and construction works for the Federal Government. This is different to the third agency, Safe Work Australia (SWA), which is a tripartite body composed of state governments, unions and industry representatives, and which is charged with the responsibility of ‘improving health and safety and workers’ compensation arrangements across Australia [30]. SWA is jointly funded by the Federal, State and Territory governments through an intergovernmental agreement (IGA) signed in July 2008. Its main mission is to reduce death, injury and disease in the workplace. Unlike the ABCC and the OFSC, which are predominantly involved with building and construction Safe Work Australia is involved in all industry sectors. Most recently, SWA developed and released the Model Work Health and Safety Act 2010, Model Work Health and Safety Regulations 2011, and a series of Codes of Practice, to fulfil the agenda of ‘harmonisation’ of health and safety laws.

The second level is the regulator who translates the government’s aspirations into safety law and enforces this in industry. The agency responsible for this is WorkSafe Victoria, through the Occupational Health and Safety Act 2004 and Occupational Health and Safety Regulations 2007. They also adopt the Model

COPs issued by the SWA. It is at this level that the legal prescription of SWIMS is established.

The third level includes a myriad of Associations of employers and unions, such as the Housing Industry Association (HIA), Master Builders Association (MBA), Civil Contractors Federations (CCF), Master Plumbers Association (MPA). In addition, a number of different segments and interest groups specific to building and construction may also be represented here; such as Australia's Largest Residential Builders (ALRB), Volume Home Builders (VHB). The main union involved is the CFMEU (Construction Division). Both types of associations provide advocacy, consultancy, and advisory services to assist their members make sense of state safety policy. It is at this level that the legal prescriptions are translated into advisory documents that are then made available for use, including 'generic SWIMS' which can be accessed and used by members.

The fourth level includes the company which undertakes the construction work, oversee development and construction, set broad policies and frameworks for works, operations, and safety. It is at this level that senior managers translate the legal requirements into organisational policies, standards and/or rules. In doing so they may seek advice and assistance of the Association to which they belong. At this level the legal prescriptions of SWIMS are translated into organisation controls.

The fifth level is represented by line managers, and these can be a varied group, from project and/site managers, depending on how the company is structured. In domestic construction their job involves managing a portfolio of construction jobs; in doing so they may work with a range of trade supervisors. These line managers are responsible for establishing and meeting targets for production and safety, selecting and inducting sub-contractors. They may work with OHS personnel to implement broad-level organisational controls handed down by senior management.

The sixth level is represented by the workers, comprised of a myriad of building and construction supervisors, subcontractors, tradesmen, apprentices and employees. At this level the supervisors play two distinct roles. One of these is as a manager for either one specific contract or a number of construction projects and it is here that they implement organisational policies, procedures and controls, including SWIMS. The other is as an employee, where they themselves are expected to follow policies, procedures that have been laid down by their organisation. So supervisors may play a role both in the prescription and in the practice of SWIMS.

The above discussion reveals that there are at least five different levels of involved in prescribing SWIMS in residential construction industry. Three of these are based outside of the construction organisation; these have been labelled as organisational outsiders. Two are based inside; these have been labelled as organisational insiders. The sixth level, which is also part of organisational insiders, is where the practice of SWIMS can be most evident. Gaining an understanding of SWIMS therefore requires an exploration of what this means to different stakeholders in this STS.

One method that has been suggested to be useful entails multi-level analysis which is a useful way of understanding organisational systems and enables researchers to develop a deep insight into the realities of the complex nature of work in organisations [31]. Such an approach has been previously used earlier to investigate learning from errors in healthcare and patient safety [32, 33]. This framework can therefore be applied to investigate the prescription and practice of SWIMS.

3 The Prescription of SWIMS According to Organisational Outsiders

In order to test the STS framework, data was collected at a number of levels. The reminder of this paper discusses the prescription of SWIMS as according to organisational outsiders. For ease of discussion, results will be presented under two subtopics; government/regulator and association.

3.1 Government/Regulators' Prescription of SWIMS

The views of government/regulator are based on an analysis of two main sets of data. The first included a series of documents (comprised of standards, regulations, codes of practice, discussion papers, reports, submissions, codes of practice and 'generic SWIMS' for a range of activities). The second included interviews with six-key informants from the regulator. The informants worked as Health and Safety Inspectors, were all male, aged between 32 and 60 and had been in their current role from one to twenty-one years. Five key themes emerged at this level.

Safe System of Work. The first theme that emerged from the various understandings of SWIMS is that it is a safe system of work, one that 'sets out the method that will be used to undertake a particular task and the way that any hazards and risks associated with that task will be controlled' [34]. An example of this was illustrated in "… *it looks at the tasks that need to be undertaken, what are the hazards and risks associated with those tasks that need to be undertaken and what are the risk control measures that you're going to put into mitigate those risks*"… *PAR048*. The 'system of work' includes the method, or way the proposed work is expected to be done; and the 'way hazards and risk of the work are to be controlled' suggests it is about safety. They were very similar to 'job safety analysis' or JSAs, which is a method of identifying hazards with a focus on the relationships between the worker, tasks, tools and the working environment [4].

Live Strategy for Risk Control. The second theme was that SWMS are a live strategy for controlling risks. They are live because (i) they are required to be developed before the work actually commences, and (ii) maintained up-to-date during the course of the work. The expectations that SWMS are developed before the work actually commences is expressed in the following example: "… *SWMS* *should be treated as a live document in that they might go through detail in the SWMS of how they're going to do the works* etc. *but in any given time things may come up where they're going to alter how they're going to conduct a particular task. So it's no use going back to a SWIMS where it's no longer relevant so it's a live document so if anything changes then a SWIMS should then be changed to reflect any of the changes …*" *PAR049.* For this informant keeping SWIMS alive was about ensuring the written document was relevant to the work at hand, with any changes in task reflected in the written document.

Relevant for Some Work. The third theme suggested SWIMS were required for some, not all construction work. Both the government and regulator stipulate SWIMS come into play when doing 'high-risk construction work', including a prescribed list of nineteen specific activities. Thus activities such as bricklaying, framing, and concreting did not necessarily require SWIMS. In addition, the laying of concrete foundation for single storey buildings, plumbing and drainage works only necessitated one when this is being done by an excavator. In a similar manner the construction of pre-fabricated homes and pre-fabrication of precast concrete panels or roof trusses at a workshop were not deemed to warrant not a SWIMS [35]. The distinction that is used by regulators is to use the term designated high risk work (DHRW): "*We just look to see if they have got a* (*SWMS*) *when they are doing designated high risk work …*" *PAR044.*

Regulators took more interest in those SWMS that are for designated high risk construction work: "I only look at the ones for high risk work, I don't look at the other ones …, I am not interested in them …" PAR044.

A Cognitive Artefact. The fourth theme that emerged at this level was that SWIMS represented a form of cognitive artefact [36, 37]. Such artefacts significantly amplify the basic purpose of physical things one uses in daily life. The following excerpt illustrates this: "*Preparing a SWMS is part of the planning of the work*" [38, 39].

> "Well, a SWMS is just to demonstrate that you have thought through the process of how you are going to do the job"… PAR044.

According to the above, SWIMS can be used for planning and organising the work at hand, by thinking about the process of work, including the sequence in which it is going to be executed. This planning is expected to start well before the work starts, and usually revolves around hazards, risks and means of controlling them: *To make people involved in carrying out the activity stop and think about how they're going to do it …, rather than getting half-way through a job and thinking,* '*oh, gee, how am I going to get up there now? How am I going to finish this bit?*'*… PAR047.*

Johns and Nemeth [36] have suggested that cognitive artefacts are useful in instances where it is impossible to perform the tasks. It is proposed they are also useful identifying both unanticipated and unexampled threats, particularly when the work environment and contexts can change from day to day, and new hazards can be introduced if multiple works are going on (for example, digging up a trench next to an area where roof tiling is going on, as opposed to digging a trench only or doing roof tiling only). Having SWIMS meant forcing people to think about hazards and risks of the additional tasks they may not have been previously exposed to on the site.

A Tool for Social Interactions. The fifth theme that emerged here is that they are a tool for interacting with people. One form of this interaction involves consulting with people involved in the work: "*Employees, HSRs, as well as contractors and their employees, must be consulted in the preparation of the SWMS so far as is reasonably practicable*" [38, 39]. The regulator saw this consultation to include a range of actors, including workers, health and safety representatives, contractors and their workers. A second form of interaction involved informing people about the work at hand, an example of which was expressed in the following: " *It is to inform the employees how to do the job, that's what it should be for … This is how we we're going to do the job and this is the system of work that we're going to use*" … *PAR046*. Informing involves communication, one of the fundamental requirements for achieving high levels of safety performance [40]. A third form of interaction involved ensuring those who are responsible for carrying out the work are actually involved in developing the SWMS. The importance of such interaction was expressed in the following example: "… *it's no point in having someone sitting in an office who may have done the work previously, writing out one and then saying,* "*here, this is for you to do*". *It has to be done by the people, they're organised by the people who are doing the job because they're the people who do the job, they're the best ones qualified to write it and they're the best ones of course to later on carry it out. And, if it needs reviewing, they're the best people to review it as well*" … *PAR045*. For this informant reviewing a SWMS meant engaging with people who were expected to be involved in doing the work. Completing a SWMS in the office and handing it out for someone to follow was not good enough because it was devoid of context.

3.2 The Association's Prescription of SWIMS

This section includes findings from one employer association who chose to participate in the study, based on an analysis of discussions held with 1 informant, an OHS expert, and a review of documents. Two themes emerged from this level.

A Form of Control. The association who was involved in this study had not defined what a SWIMS was. If there was one, it had not been publicly expressed in the documents they supply and maintain on their websites. However, they '*see SWMS as a very critical component of safety management, especially in construction*' (Association informant). According to this view SWIMS is an element of safety management. This term has a number of definitions, but a most recent one by Hollnagel is "a kind of control … of organisational functions and practices that together produce safety" [41]. In this regard SWIMS represents a form of control for bringing about safety. However, whether this control is exerted as a 'process' or as an 'action' according to the Hale and Swuste [42] criteria was not really clear.

Required for All Construction Work. The association had view that SWIMS should be limited to construction work activities. However, they believe that there is no need to suggest the term 'high risk work';

> (The Association) considers that the regulations should not use the term 'high risk construction work'… [43].

They used an example to demonstrate the following point:

> *"…if a painter is painting a wall and there is energised electrical installation behind the wall, the painter would be required to complete a safe work method statement…even though there is no risk arising from the energised electrical installation. As the safe work method statement must include the hazards and risks "associated with" the high risk work (rather than the hazards and risks of that work) the safe work method statement would not need to cover the hazards and risks of the energised electrical installation (there are none) but associated hazards and risks (such as manual handling)…"* [43]. The submission went on to argue that SWIMS should not be an automatic requirement but come in only *if there is a risk to health and safety* [emphasis added].

In terms of the types of construction work to which SWIMS were relevant to, the association believed all construction work had to be the subject of SWIMS. This was evidenced by an observation of at least 41 different SWMS available on its website at the time the data was collected. The list was in fact twice that suggested by the government and regulator, and included different trades, work activities and equipment. What was different, however, was that it is possible that a work activity could be expected to have more than one SWIMS. For example, roof tiling on a domestic housing construction could be the subject at least thirteen different ones.

4 Conclusion

A STS framework was used to investigate SWIMS and RE in the Victorian residential construction sector. The findings of the two levels of organisational outsiders revealed a wide diversity in the prescription of SWIMS. While the government/regulator saw these as a safe system of work, a live strategy for controlling risks, relevant to (designated) high risk work activities, a cognitive artefact for planning work, and as tool for social interactions; the association saw these as form of control, and relevant for all works and trades. The latter also believed SWIMS should not be automatic requirement, but kick in if there is a risk to health and safety. In this light this view appears to be closer to the regulator than the government.

Findings at these two levels also suggested that there are at least three ways in which SWIMS contribute to safety. The first is by acting as a cognitive artefact, the second as a tool for socially interacting with workers, and third as a form of control. What appears to be clear from these two main groups is that the association investigated here appear not to have been influenced by the government/regulator.

An interesting question that arises here is the extent to which of these outsiders influence the prescription of SWMS in their member organisations. This may become clearer from an understanding of the views from the organisational insiders.

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References

1. Cheng, E.W.L., Ryan, N., Kelly, S.: Exploring the perceived influence of safety management practices on project performance in the construction industry. Saf. Sci. **50**, 363–369 (2012)
2. Swuste, P., Frijters, A., Guldenmund, F.: Is it possible to influence safety in the building sector? Saf. Sci. **50**, 1333–1343 (2012)
3. Bakri, A., Zin, M., Misnan, M.S., Mohammed, A.H.: Occupational safety and health (OSH) management systems: towards development of safety and health culture. In: 6th Asia–Pacific Structural Engineering and Construction Conference (ASPEC 2005), pp. C19–C28 (2005)
4. Rozenfeld, O., Sacks, R., Rosenfeld, Y., Baum, H.: Construction job safety analysis. Saf. Sci. **48**, 491–498 (2010)
5. Choudhry, R.M., Fang, D.: Why operatives engage in unsafe work behavior: investigating factors on construction sites. Saf. Sci. **46**, 566–584 (2008)
6. Dingsdag, D.P., Biggs, H.C., Sheahan, V.L., Cipolla, D.J.: A Construction Safety Competency Framework: Improving OH&S Performance by Creating and Maintaining a Safety Culture. Cooperative Research Centre for Construction Innovation (2006)
7. Azari-Rad, H., Philips, P., Thompson-Dawson, W.: Subcontracting injury rates in construction. In: 55th Annual Meeting of the Industrial Relations Research Association, pp. 240–247. IRRA (2003)
8. Vimonsatit, V., Nikraz, O.: Occupational health and safety: an expected learning outcome of civil engineering graduates. In: 2011 AAEE Conference, pp. 536–542 (2011)
9. Al-Humaidi, H.M., Tan, F.H.: Construction safety accidents, laws and practices in Kuwait. In: Gurasciao, M., Brebbia, C.A., Garzia, F. (eds.) WIT Transactions on the Built Environment, vol. 108, pp. 399–408. WIT Press (2009)
10. Bertelsen, S., Koskela, L.: Approches to managing complexity in construction project management. In: Becon 2005: The 1st International Conference on Complexity and the Built Bnvironment, pp. 1–13 (2005)
11. Doloi, H., Lim, M.Y.: Measuring performance in construction projects—a critical analysis with an australian perspective. In: Construction and Building Research Conference of the Royal Institute of Chartered Surveyors, 6–7 Sept. RICS, Georgia Tech, Atlanta USA (2007)
12. Borys, D.: The role of safe work method statements in the Australian construction industry. Saf. Sci. **50**, 210–220 (2012)
13. Pillay, M., Borys, D., Else, D.: Exploring safe work method statements in the Australian construction industry. In: Proceedings of the Fourth Resilience Engineering Symposium, pp. 203. MINES ParisTech, Paris (2010)
14. Dekker, S.: Failure to adapt or adaptations that fail: contrasting models on procedures and safety. Appl. Ergon. **34**, 233–238 (2003)
15. Besnard, D., Greathead, D.: A cognitive approach to safe violations. Cogn. Technol. Work **5**, 272–282 (2003)

16. Alper, S.J., Karsh, B.: A systematic review of safety violations in industry. Accid. Anal. Prev. **41**, 739–754 (2009)
17. Schein, E.H.: Three cultures of management: the key to organizational learning. Sloan Manage. Rev. **38**, 27–38 (1996)
18. Huber, S.A., van Wijgerden, I., de Witt, A., Dekker, S.W.A., Hollnagel, E.: Resilience Engineering: New Directions for Measuring and Maintaining Safety in Complex Systems—4th Progress Report. School of Aviation, Lund University (2007)
19. Nemeth, C.P.: Resilience engineering: the birth of a notion. In: Hollnagel, E., Nemeth, C.P., Dekker, S.W.A. (eds.) Resilience Engineering Volume I: Remaining Sensitive to the Possibility of Failure, pp. 3–8. Ashgate, Aldershot (2006)
20. Wreathall, J.: Properties of resilient organizations: an initial view. In: Hollnagel, E., Woods, D. D., Leveson, N.G. (eds.) Resilience Engineering Concepts and Precepts, pp. 275–285. Ashgate, Aldershot (2006)
21. Hollnagel, E., Woods, D.D.: Epilogue: resilience engineering precepts. In: Hollnagel, E., Woods, D.D., Leveson, N.G. (eds.) Resilience Engineering: Concepts and Precepts, pp. 347–358. Ashgate, Aldershot (2006)
22. Cook, R.I., O'Connor, M., Render, M.L., Woods, D.D.: Operating at the sharp end: the human factors of complex technical work and its implication for patient safety. In: Manuel, B.M., Nora, P.F. (eds.) Surgical Patient Safety: Essential Information for Surgeons in Today's Environment, pp. 19–30. American College of Surgeons, Chicago (2004)
23. Cook, R.I., Rasmussen, J.: Going solid: a model of system dynamics and consequences for patient safety. Qual. Saf. Healthc. **14**, 130–134 (2005)
24. Rasmussen, J., Svedung, I.: Proactive Risk Management in a Dynamic Society. Swedish Rescue Services Agency, Karlstad (2000)
25. Ale, B.J.M., Brighton, P.W.M., Baram, M.: Risk management. Saf. Sci. Monit. **10** (2006) (Article 2)
26. Rasmussen, J.: Risk management in a dynamic society: a modelling problem. Saf. Sci. **27**, 183–213 (1997)
27. Cole, T.R.H., The Honourable: Reform—Occupational Health and Safety, vol. 6. Royal Commission into the Building and Construction Industry (2003)
28. Department of Employment and Workplace Relations: Building and Construction Industry Improvement Act 2005. Canberra (2010)
29. Office of Federal Safety Commissioner: Fact Sheet: Guidance for Producing Safe Work Method Statements (SWMS). In: Department of Education, E.a.W.R. (ed.). Office of Federal Safety Commissioner, Canberra (2010)
30. Safe Work Australia: How to Manage Health and Safety Risks: Draft Code of Practice. SafeWork Australia, Canberra (2010)
31. Hitt, M.A., Beamish, P.W., Jackson, S.E., Mathieu, J.E.: Building theoretical and emprical bridges across levels: multilevel research in management. Acad. Manage. J. **50**, 1385–1399 (2007)
32. Wiig, S., Aase, K.: Fallible humans in infallible systems? Learning from errors in healthcare. Saf. Sci. Monit. **11** (2007) (Article 6)
33. Wiig, S., Lindoe, P.H.: Patient safety on the interface between hospital and risk regulator. J. Saf. Res. **12**, 411–426 (2009)
34. National Occupational Health and Safety Commission (NOHSC): regulation impact statement for the draft national code of practice for the prevention of falls in general construction. In: National Occupational Health and Safety Commission (ed.). Commonwealth of Australia, Canberra (2005)
35. Safe Work Australia: Code of Practice: Construction Work. Safe Work Australia, Canberra (2012)
36. Jones, P.H., Nemeth, C.: Cognitive artifacts in complex work. In: Ambient Intelligence for Scientific Discovery, pp. 152–183 (2005)
37. Norman, D.A.: Cognitive artifacts. In: Carroll, J.M. (ed.) Designing Intercation: Psychology at the Human-Computer Interface, pp. 17–38. Cambridge University Press, Cambridge (1991)

38. WorkSafe Victoria: Working safely in the housing construction industry: a handbook for the construction regulations. In: Victorian WorkCover Authority (ed.), vol. VWA 1125/01/01.08. WorkSafe Victoria, Melbourne (2008)
39. WorkSafe Victoria: Working safely in the general construction industry: a handbook for the construction regulations. In: Victorian WorkCover Authority (ed.). WorkSafe Victoria, Melbourne (2008)
40. Ayers, G., Culvenor, J.F., Sillitoe, J., Else, D.: Meaningful and effective consultation and the construction industry of Victoria, Australia. Constr. Manage. Econ. pp. 1–25 (2012) (iFirst)
41. Hollnagel, E.: From protection to resilience: changing views on how to achieve safety. In: Eighth International Symposium of the Australian Aviation Psychology Association. (2008)
42. Hale, A.R., Swuste, P.: Safety rules: procedural freedom or action constraint? Saf. Sci. **29**, 163–177 (1998)
43. Master Builders Australia: Submission to Safe Work Australia Model Work Health and Safety Regulations and Model Codes of Practice. (2011)

Part III
Risk Management

Risk Assessment of Aluminium Foundry SME Using Ergonomics Approach

Amarria Dila Sari, Muhammad Ragil Suryoputro, Ratih Dianingtyas Kurnia and Hari Purnomo

Abstract Small and Medium Enterprises (SMEs) is one of Indonesian economics unit. In facing the competition of the global era, business owners challenged to work more efficient also more effective. Foundry industry is a SME industry body to process ore into finished metal. One of the critical work stations is on the lathing section. In this industry most workers are not using personal protective equipment in the working environment. This study aim to identify the hazard based on risk control and assessment methods. Sixty three participants was conduct in this study. The result shows that hazard identification consist of corrosive materials, flammable liquids, manual material handling risks, non-ergonomic tool design risk, WMSDs risk, the risk of getting work injury, indoor air quality, and machine hazard.

Keywords Hazard · Ergonomics approach · Foundry · SME

1 Introduction

Small and medium industries have an important role in the national economy of Indonesia, because it provides a double impact on the local and national economy and create employment. Small and medium enterprises (SMEs) are the key to the country's economy and it is crucial to achieve the national economic goals [1]. A Small Business Deregulation Task Force in Australia stating that OHS is one of the key employment issues of concern to SMEs, in 1997 [2]. OHS issues in SMEs are not too different from those in large companies with similar industry sectors. In general, the problem is with some unique factors related to the structure and function of the SMEs which hinders the improvement of OHS in the workplace.

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Small and medium industries cannot be separated from a variety of internal and external problems. One of them is the potential for accidents and work errors caused by human factors, so that the necessary action and prevention methods were thoroughly needed [3]. The metal casting industry has long been considered to be a hazardous industry characterized by exposure to both chemical and physical hazards [4]. Sites contaminated with hazardous materials are topical and urgent problems throughout the world, remediation based on risk used to develop maximum security cost effective sanitation methods for land users in the future [5]. Foundry industries vary in terms of materials and processes, resulting in occupational exposure to various substances hazards or work activities which may lead to illness, injury, illness or death [6].

Umbul Jaya Cooperative is one of Yogyakarta's cooperatives that oversee several foundry industries in the southern Yogyakarta area. As a medium scale industry with huge market demand, it would be a strong potential to create a number of production lots. Effective work is the work done productively. Safety in the workplace and prevention measures is one of the greatest supporting it. The guarantee of health and safety at work can prevent a company or organization of technical barriers in the era of globalization.

Safety is all means and efforts to prevent the occurrence of accidents. In this case, safety is closely related to the engine, a working tool in the process of grounding the workplace and the environment, and ways to do the job [7]. The purpose is to protect the safety of labor safety in performing their duties, protect the safety of everyone who is in the location of the workplace and protect the safety of equipment and production resources in order to always be used efficiently. However, out of many factories that stand, only partially meets the standard layout, security, and safety both for workers and the company itself, causing work accidents to occur [8].

2 Methods

2.1 Subject

This research was conducted in four foundry SMEs of aluminium castings in Wirosaban, southern area of Yogyakarta. Each SME has a number of different workers and the design of work area is different as well. There are 63 workers participated in this study. Workers were continuously observed for their activities where some of working processes were recorded. The detail of respondents and industry involved in this study can be seen on Table 1.

Foundry 1 has six divisions including molding (15 workers), foundry (2 workers), polishing (3 workers), filing (4 workers), and turning lathe (8 workers). Accidents that have occurred are at the turning where aluminium molds apart and thrown hitting the head. In addition, the other risk is the hot liquid from the

Table 1 Data details of foundry SMEs

Foundry SMEs	Total of workers	Work time	Type of product	Total of production per day
Foundry 1	32 people	7.30 AM–3.30 PM	Frying pan	600
Foundry 2	7 people	7.00 AM–2.00 PM	Cake mold	400
Foundry 3	7 people	7.30 AM–3.00 PM	Cake mold	300
Foundry 4	17 people	8.00 AM–4.00 PM	Motorcycle spare part	700

smelting. Foundry 2 has 5 divisions including molding (4 workers), cutting (1 worker), filing (1 worker), finishing (1 worker), and the free section (1 worker). Until this year, work accident has never been occurred in foundry 2. Foundry 3 has four divisions including molding (2 workers), polishing (2 workers), turning (2 workers), and the casting (1 worker). In the third foundry, accidents that have occurred are cast spill on workers shoes to shoes melted. Foundry 4 has divisions including foundry (2 workers), molding using sand (5 workers), molding using molder (2 workers), welding (5 workers), and finishing (1 worker). Accident that has occurred at a foundry 4 was an incident where worker exposed a splashing of molten aluminium. Overall, the entire foundry has been providing personal protective equipment for each worker, but OHS constraints experienced by each foundry workers is the lack of discipline in the use of personal protective equipment.

2.2 *Tasks*

The tools used in this study include:

1. Hazard assessment checklist, to inspect hazard findings of research sites [9].
2. Recorder, for recording the interview result.
3. Digital camera, for documentation.

Hazard checklist used in this study refers to the guide checklist of Hughes and Ferrett [9]. Hazard checklist for risk assessment should display the frequency of each risk, its severity, as well as individual factors and occupational factors that may be causing the risk. The risk assessment results will indicate the areas requiring risk control measures [10].

The study began with a preliminary observation. The next step is by conducting a brief interview to the main board or owner of each SME to find out how the work systems goes on in it, as well as OHS risks that may be found and have occurred in foundry work area. The next is direct observation to the production area and documenting all details of the work area to identify the hazard with the help of hazard assessment checklist.

			Severity				
			1 – Insignificant Dealt with by in-house first aid, etc	**2 – Minor** Medical help needed. Treatment by medical professional/hospital outpatient, etc	**3 – Moderate** Significant non-permanent injury. Overnight hospitalisation (inpatient)	**4 – Major** Extensive permanent injury (eg loss of finger/s) Extended hospitalisation	**5 – Catastrophic** Death. Permanent disabling injury (eg blindness, loss of hand/s, quadriplegia)
Likelihood	**5**	Almost certain to occur in most circumstances	5 - Medium (M)	10 - High (H)	15 - Extreme (X)	20 - Extreme (X)	25 - Extreme (X)
	4	Likely to occur frequently	4 - Low (L)	8 - High (H)	12 - High (H)	16 - Extreme (X)	20 - Extreme (X)
	3	Possible and likely to occur at some time	3 - Low (L)	6 - Medium (M)	9 - High (H)	12 - High (H)	15 - Extreme (X)
	2	Unlikely to occur but could happen	2 - Low (L)	4 - Low (L)	6 - Medium (M)	8 - High (H)	10 - High (H)
	1	May occur but only in rare and exceptional circumstances	1 - Low (L)	2 - Low (L)	3 - Low (L)	4 - Low (L)	5 - Medium (M)

Action Priority		
1	(red)	*Immediate*
2	(orange)	*Urgent*
3	(yellow)	*Planned*
4	(green)	*For consideration*

Fig. 1 Risk assessment table and the action priority [9]

On the checklist of hazard identification, each hazard that was found has to be categorized according to its frequency and severity that may result from the hazard as seen as Fig. 1. Once the hazard category is found, the action priority guide can help us to recommend an appropriate solution to prevent the risk of the work in order to improve the work quality of the foundry SME.

3 Results and Discussions

3.1 Hazard Identification

Hazard identification is the crucial step of risk assessment. The entire hazards listed and identified are only significant hazards which could result in serious harm to the workers [9]. Some hazards that can be identified in accordance to Ribeiro [6], some of the most common causes of injury and illness in these foundry industries are: contact with hot metal [11], fire and explosion [12], extreme temperatures [11, 13], and noise and vibration [11].

Fig. 2 Workers at drilling division

Safety of casting and forging SMEs, about 78 % of the workers are not using personal protective equipment, even though the workers are exposed to high noise, temperature and dust [14]. Occupational safety and ergonomics practices are almost missing in most of the processes. The workers in the drilling and filing division do not use personal protective equipment other than earmuffs as seen as Fig. 2. The work is done with awkward posture that does not comply with the provisions of ergonomics so it would result in a risk of injury or WMSDs.

Figure 3 shows that the workers at the refining division are working on cramped work area where the finished products are stacked in the empty space in the work area. The working process produce noises and waste in form of aluminium flakes and aluminium dust which are stacked in a long time, and the workers did not use any personal protective equipment besides masker, which not all of the workers did. This can result in air pollution, injury of the workers' hearing and respiratory system.

In Fig. 4, it is shown that workers in the molding and casting division do not use personal protective equipment that is adequate, given that they are working in an area with a high temperature at which a liquid aluminium itself can reach temperatures of 800 °C. This is very worrying because a little mistake can cause serious injury.

Based on the review of work incidents that have occurred and observation of the work area with consideration of the risk of each zone, identification of potential hazard is formed as shown in Table 2.

Fig. 3 Workers at refining division

Fig. 4 Workers at molding and casting division

3.2 Risk Assessment

The risk assessment carried out by filling the hazard identification checklist and applied to the entire foundry SME studied. Some types of hazard that was found in the work area are listed to be assessed based on the frequency of occurrence and the severity of each of these hazards. Table 2 shows a list of hazard found in the work

Table 2 Potential hazards found in the foundry SMEs

Type of hazard	Potential hazard
Chemical	Corrosive material
	Dangerously reactive liquid
	Flammable liquid
	Toxic material
Ergonomics	Manual material handling
	Lighting
	Work posture
	Non-ergonomic tool design
	Risk of slip/fall incidents
	WMSDs
Health	Disorders, injuries
	Pandemic (flu)
Workplace	Indoor air quality
	Confined space
	Sick building syndrome
Safety	Electrical
	Machinery
Physical	Work stress
	Violence

area. The results of each checklist will be visible from the inferred categories based on the frequency and severity of each hazard risk as seen as Tables 3 and 4.

From Tables 2 and 3 we can see that the frequency and severity of each hazard may vary in each foundry. However, based on the inferred category, some of the potential hazard requires full attention. Some of them are corrosive materials, flammable liquids, manual material handling risks, non-ergonomic tool design risk, WMSDs risk, the risk of getting work injury, indoor air quality, and machine hazard, that has the category of “high” even “extreme” in each foundry.

Corrosive materials and flammable liquids are more prevalent in the smelting division. In addition, the temperature of liquid aluminium can reach 800 °C, while the work is carried out almost without personal protective equipment at all. One of the causes is the lack of discipline and lack of awareness of workers against the dangers and risks of the job. Manual material handling is at high risk because most of the works in the foundry SMEs are done without using the correct work posture, while the manual work, primarily in molding division, requiring considerable power because the molder mass is quite heavy. It is of course also has an effect on the risk of WMSDs. Other hazard is the risk of injury, which of course can be caused by human error and equipment failure or machine hazard, so the layout and placement of working tools is important and awareness of personal protective equipment usage is very noteworthy. Indoor air quality also has a high risk for this work because it is associated with aluminium, which at the filing division, a pile of dust can be found and it will pollute the air. Besides, the dust waste also has an odor

Table 3 Potential hazards found in the foundry SMEs

Potential hazard	Foundry 1		Foundry 2		Foundry 3		Foundry 4	
	Likelihood	Severity	Likelihood	Severity	Likelihood	Severity	Likelihood	Severity
Corrosive material	3	3	3	3	3	3	3	3
Dangerously reactive liquid	2	5	2	1	2	1	2	4
Flammable liquid	2	4	2	5	2	5	3	4
Toxic material	3	2	3	2	3	2	3	2
Manual material handling	4	5	4	5	4	5	4	5
Lighting	3	2	2	2	2	2	1	1
Work posture	2	2	5	4	5	4	5	4
Non-ergonomic tool design	2	4	3	4	3	4	5	4
Risk of slip/fall incidents	3	3	2	1	2	1	1	1
WMSDs	4	4	4	4	4	4	4	4
Disorders, injuries	2	4	2	4	2	4	2	4
Pandemic (flu)	1	3	1	4	1	4	3	4
Indoor air quality	2	4	4	4	4	4	3	4
Confined space	2	1	3	1	3	1	3	1
Sick building syndrome	2	4	2	1	2	1	3	3
Electrical	1	4	1	4	1	4	1	2
Machinery	2	4	4	3	4	3	1	3
Work stress	1	1	1	1	1	1	1	1
Violence	2	4	1	1	1	1	1	4

Table 4 Category of hazards found in the foundry SMEs

Potential hazard	Category of hazard			
	Foundry 1	Foundry 2	Foundry 3	Foundry 4
Corrosive material	High	High	High	High
Dangerously reactive liquid	High	Low	Low	High
Flammable liquid	High	High	High	High
Toxic material	Medium	Medium	Medium	Medium
Manual material handling	Extreme	Extreme	Extreme	Extreme
Lighting	Medium	Low	Low	Low
Work posture	Low	Extreme	Extreme	Extreme
Non-ergonomic tool design	High	High	High	Extreme
Risk of slip/fall incidents	High	Low	Low	Low
WMSDs	Extreme	Extreme	Extreme	Extreme
Disorders, injuries	High	High	High	High
Pandemic (flu)	Low	Low	Low	High
Indoor air quality	High	Extreme	Extreme	High
Confined space	Low	Low	Low	Low
Sick building syndrome	Low	Low	Low	High
Electrical	Low	Low	Low	Low
Machinery	High	High	High	High
Work stress	Low	Low	Low	Low
Violence	Low	Low	Low	Low

that stung enough and it is feared that it may have an effect on the diseases of internal organs such as the lungs and throat.

On work postures hazard, foundry 1 is the only foundry that has low risk on it. This is because this foundry has a work station that are almost in accordance with the ergonomics rules where the workers doing their work by sitting on a chair and putting their stuff or work on the table with corresponding height. While on the other foundry, all the work tends to be done in squatting position, bending position, and sometimes with the head bend down. This is certainly very risky to the health of bones and muscles, and can lead to the WMSDs risk.

4 Conclusions

OHS issues in the foundry SMEs at Wirosaban-Yogyakarta area are still very high and thus require special attention from foundry's administrators, workers, and government. Repairs can begin by instilling a sense of awareness of the importance of OHS and the use of personal protective equipment. In addition, a lot of redesign work of tools can be applied to the foundry, for example, designing a special shoe which is easy to use and resistant to the heat of aluminium liquids. Another improvement that can be done is by designing a cover for the entire machine used in foundry, in order to reduce the risk of injury caused by direct contact with the tool either intentionally or unintentionally.

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References

1. Seneviratne, M., Phoon, W.O.: Exposure assessment in SMEs: a low-cost approach to bring OHS services to small-scale enterprises. Ind. Health **44**, 27–30 (2006)
2. Small Business Deregulation Task Force: Time for Business. AGPS, Canberra (1996)
3. Arifin, M.: Perancangan Tata Letak Pada Unit Pengecoran Logam dengan Sinkronisasi Lintasan Kerja Untuk Meminimalisasi Hazard di ED Alloycasting Production C-Maxi. Islamic State of Sunan Kalijaga University, Yogyakarta (2013)
4. Lei, L., Dempsey, P.G., Xu, J., Ge, L., Liang, Y.: Risk factors for the prevalence of musculoskeletal disorders among Chinese foundry workers. Int. J. Ind. Ergon. **35**(3), 197–204 (2005)
5. Stezar, I.-C., Modoi, O.-C., Török, Z., Ajtai, N., Crişan, A.-D., Coşara, G.-V., Senzaconi, F., Ozunu, A.: Preliminary investigation and risk assessment of contamination on an industrial site in Maramures county. Environ. Eng. Manag. J. EEMJ **10**(1) (2011)
6. Ribeiro, M.G., Walter Filho, R.P.: Risk assessment of chemicals in foundries: the international chemical toolkit pilot-project. J. Hazard. Mater. **136**(3), 432–437 (2006)
7. Silalahi, B., Rumondang, S.: Manajemen Keselamatan dan Kesehatan Kerja. Pustaka Binaman Pressinda, Jakarta (1995)
8. Fatoni, R., Mayasari, H.D., Sholaika, A.M., Susanto, Y.: Perancangan Ulang Tata Letak Pabrik dan Analisa Keselamatan dan Kesehatan Kerja. Simposium Nasional TAPI XII, ISSN 1412-9612.2013
9. Hughes, P., Ferrett, E.: Introduction to Health and Safety at Work: For the NEBOSH National General Certificate in Occupational Health and Safety. Routledge, Abingdon (2015)
10. Internationl Ergonomics Association, International Commission on Occupational Health: Ergonomics Guidelines For occupational Health Practice in Industrially Developing Countries (2010)
11. Gomes, J., Lloyd, O.L., Norman, N.J.: The health of the workers in a rapidly developing country: effects of occupational exposure to noise and heat. Occup. Med. **52**, 121–128 (2002)
12. Topping, M.: Occupational exposures limits for chemicals. Occup. Environ. Med. **58**, 138–144 (2001)
13. Rodahl, K.: Occupational health conditions in extreme environments. Ann. Occup. Hyg. **47**, 241–252 (2003)
14. Singh, L.P., Bhardwaj, A., Deepak, K.K., Sahu, S.: Small and medium scale casting and forging industry in India: an ergonomic study. Ergon. SA, **22**(1) (2010)

Domestic Safety and Accidents Risk Perception by Active Elderly

Laura Martins, Béda Barkokébas Jr., João Baptista and Pedro Arezes

Abstract The improvement in the quality of life of older people goes far beyond the responsibility of the healthcare sector. Thus, it seems necessary to create accident prevention strategies and manage all the conditions involving the physical and social environment of the elderly. Although it is widely recognized that aging is a process that affects all human beings, it is noted that very often the elderly refuse to notice or consider this process, since the residential dwellings remain without any adjustments or with slightly adaptations, for almost their entire life. The purpose of this study is to discuss the perception of the elderly regarding the relationship between accident risk at home and their physical condition when performing daily activities, by establishing a comparison between the activities carried out by the elderly and the needed home adjustments throughout their life cycle.

Keywords Home safety · Perception of accident risk · Active elderly

1 Introduction

The world is growing old. World Health Organization (WHO) stated that world's population over 60 years is increasing from current 841 million to 2 billion in 2050, and alert that in 2020 there will be, for the first time in history, a higher number of people over 60 years than the number of children up to five years [1].

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This finding leads to considerations related to elderly people, about their role in society, life quality and the interventions oriented to support the aging process. In that matter, this paper presents considerations about the development of strategies of accident prevention and management of the physical and social environment of seniors.

The current study consists in the discussion of the elderly perception in the matter of the relationship between accident risks in their domestic environment and their physical condition in performing everyday activities. This observation emerged from documental and literature review, tracing a parallel between activities carried out by seniors and the adaptions needed in home environment throughout their life cycle.

As described by Arking [2], aging is a chronological, degenerative and progressive process that occurs to all living beings in higher and lower proportions, although environmental factors may contribute to accelerate or slow down this process. Despite this diagnosis, the prognosis of increased life expectancy begins to change paradigms that old age is the twilight of life and the elderly do not have more vitality and intellectual and professional performance. On contrary, it is notable in the twenty-first century a return of this population to the labor market, social living and productivity.

Corroborating this idea, Fontaine [3] explain that the convergence of pharmaceutical discoveries, the improvement of living conditions and a raise of cultural level caused an "explosion" of competitive, healthy and happy elderly.

In contrast, what is noticed is that the elderly do not realize or consider relevant to perform changes in their homes foreseeing the aging process, due to the observation that houses seemed to remain without any adjustments (or with only slight adjustments), rather than functional and deeper alterations, related to habitational space configuration, furniture and appliances.

The senior's domestic environment is the fundamental space in the process of independence and autonomy. Several factors contribute for them to stay in the same environment for several years. In this sense, while the space should inspire confidence and safety, it must recognize that the knowledge of the environment in their small details is a strong appeal in order to bring internal tranquility for the elderly, ensured by a sense of identity.

According to Ferrara [4], the territories of a space are characterized by their cultural consequences. By overcoming its physical or conceptual dimension, the space faces its constructability and, through it, turns into sign that builds a story and a dynamic. The inexorable fact is that, with aging, material references become stronger, translating in to the attachment to artifacts, spaces and memories that recollect the past. According to the author, the environment experience, through sensation and perception, leaves a residue of knowledge or cognitions on the central nervous system. Many of our experiences within the physic environment have a significant load of affection, resulting in emotions, beliefs, feelings, attitudes, judgments and values.

In the current article, it is defended that residence for the elderly becomes their unconditional refuge, where they feel safe and are capable of managing their everyday activities.

Environments offer the elderly a sense of belonging and identity where they recognize themselves and dominate the space. Humans established strong bonds with spaces throughout life and this attachment translates as an important element in this construction, with all references concentrated in a specific environment. This is one of the aspects that contribute most to the resistance of change, unconsciously forcing seniors to stay where they feel safe. Influences of the environment on individuals have become object of research in several fields of scientific knowledge, and environmental psychology played an important contribution in this specific area.

The relationship with home environment can be attenuated by knowing its physical and cognitive characteristics, making it less hostile and allowing greater efficiency performing daily activities.

According to Moser [5], environmental psychology can analyze, explain and provide information that can identify conditions involved in person-environment congruence and wellbeing, improving decision-making process.

In aging process, physiologic aspects of the organism experience a process of natural wear, that occurs in a slow, gradual way, non-perceptible by the elderly, who are used to perform specific tasks during several years.

Darè [6] observes that for most people, the living environment is accessible and can be used in a natural way, but at different times of our lives, difficulties can be experienced in the same living spaces and also using products. Facing those difficulties, people will force, on daily basis, an adaption that most of the times brings injuries that are only perceived later. The elderly are, therefore, risking their physical integrity and increasing the risk of falls and injuries while performing everyday tasks.

In that matter, maintaining independence and autonomy is a fundamental and priority factor for the elderly and must be considered in any adaption proposition aimed at this population.

In this context, the issue of quality of life of the elderly in home environments generates a growing concern of services and public policies focused in health, safety and social inclusion. The matter needs to be dealt in several spheres of society and some concepts can contribute to this understanding.

2 Active Aging

The World Health Organization (WHO) adopted the term “active aging” in the late 90s. It seeks to convey a broader message than “healthy aging” and recognize, in addition to health care, other factors that affects how individuals and populations age [7].

The politics structure for active aging, according to the WHO [8], is based in the United States Principles for Older Adults such as independence, participation, assistance, self-fulfillment and dignity. Therefore, it requires actions on three basic pillars: health, participation and safety. In the health aspect, assuming that with risk factors kept low and protection factors kept high, people enjoy a better quality of life, remaining healthy and able to care for their own lives, as they get older. Concerning participation, with the support of the labor market, education, social and health policies and programs for full participation in socioeconomic, cultural and spiritual activities, according to their fundamental human rights, capacities, needs and preferences allowing individuals to continue to contribute socially with paid and unpaid activities as they age. Finally, regarding safety, assuming policies and programs addressed to the needs and rights of the elderly to social, physical and financial security, ensuring protection, dignity and assistance through support to families and community in the care of older people.

The elderly from the twenty-first century are more socially and economically active than their predecessor. The decline in fertility after 1970 and the retreat of the entry age in active life—due to longer schooling because of specialization levels demanded in the labor market—combined with retirement funding problems and the need to increase family income, contributed to the elderly beginning to play a more significant role in society.

The World Assembly on Ageing, organized by the UN in Vienna, in October 1982 [8], pointed out that many concerns attributed only to the family should be shared by the public and private services supporting the elderly. Therefore, in order to fulfill its social responsibility, governments should provide community actions to minimize possible damage from elderly discrimination.

According to Keinert and Rosa [9], responsibility for aging well, supported by law, is addressed to the person, society and the state. The state need to create conditions so that the individual and society are able to play their roles, especially in terms of prevention and improving life quality of the elderly; which does not relieve the state to provide adequate public services to guarantee their rights.

It is argued that public policies must consolidate the active aging concept, tracing guidelines that consider elderly people a community resource, citizens with rights and duties.

3 Aging and Accident Risk

Considering relevant to the research, it is also important to approach a few physiological aspects of aging and its consequences on the everyday living of the elderly.

In that subject, a question arises about the matter: can the elderly perceive if the environment, furniture and equipment with which they interact on a daily basis meet their needs, from the ergonomic point of view, without prejudice to their physical constitution? Do they simply get used to live and relate to that environment without realizing their inadequacies, thereby increasing the accident risk?

In order to understand the process of environmental perception that occurs during aging in home context, it is necessary to acknowledge the main physiological changes in the human body and, from that, seek viable solutions for a safe and comfortable relationship with the environment.

Arking [2] affirms that, "I believe that is important to people familiar with the sociological and psychological aspects of gerontology also know the biological aspects of aging and the implications of current researches in their own field".

Laville and Volkoff [10] set some effects of the decline process of physiological and mental functions, mobilized by labor activity: Decreased ability to intense physical effort and joint mobility; Weakening of the body's balance system, responsible for many of the falls experienced by elderly people; Fragility of sleep; Decrease in speed of information processing; Fragility of immediate memory and sustained attention.

Thus, with aging, acquisition and treatment of new information become slower. This process occurs in every aspect, in relationships between people and between individuals and equipment. In this aspect, it has to be considered that the individual initial education is one of the determining factors in this process because, from the first years of school, individuals framed for themselves cognitive tools that facilitate learning through life.

The theory of "Disposable Soma", presented in the 70s by the biologist Thomas Kirkwood, now director of the Aging and Health Institute of the University of Newcastle, in England, is one of the most consensual view among aging researches. According to this theory, people begin the aging process at 30 years old because they fail to be interesting from an evolutionary point of view, this happens because the soma—our body with its tissues and organs—starts to lose the functions of protection and carrying the genes of reproductive cells. It is, therefore, a process of natural selection. Starting at age 25, the body begins to lose 1 % of its functional capacity every year. Sensorial organs, being the means by which our body relates to the outside world, are the first ones to realize the sensations arising from this relationship. In old age, these senses undergo profound modifications, except the taste, contributing to changes in the perception of the environment [11].

Exemplifying those modifications, Arking [2] discuss the vision, "[…] It is assumed that changes in the structure of the crystalline protein are correlated with decreased visual acuity on aging […]". Further, Arking states that aging is a degenerative process presented in two different ways. First, aging increases the likelihood of death with time. Second, it reduces the ability of the individual to resist extrinsic stress, commonly considered as the loss of vigor or vitality.

Thus, the relation of the elderly physical condition with their accident risk perception at home, during the course of daily activities throughout their life cycle, is a topic that deserves a depth research and analysis.

The nature of perception is considered a process of information extraction from people to obtain knowledge about their environment.

According to Perracini [12], home accidents resulting from falls are a major public health problem, representing two thirds of accidental deaths.

In this regard, much has been researched on the issue of falls, in particular related to physical and material aspects, with a wide field yet to be studied regarding individual perception within home safety in order to develop accident prevention strategies and management of the conditions that involve physical and social environment.

4 Risks and Domestic Safety

Despite all technological advances, domestic accidents are still a reality, which brings consequences for the victim, their family and society. Unfortunately, this situation is still accepted as inevitable fact, with few actions towards prevention.

It is observed that, most times, preventive measures are taken after the accident occurs. Accident prevention requires knowledge of risks and awareness of all those involved in order to avoid such conditions, not only in the home environment, but also at workplaces, in traffic and in public places.

Designing an effective accident control system demands treating the causes. Therefore, some questions need answers: Why the insecure action occurred? What are the existing unsafe conditions? Which system and environment failures exist?

In addition, some concepts should be understood, such as human errors, unsafe environment condition and classification of environmental risks and risks factors.

Human error is a fault committed in the execution of a task that may cause accidents. Human errors can occur for the following items:

- Negligence, which is the lack of attention and the use of inadequate equipment while performing a task;
- Incompetence, described by the lack of knowledge in performing a task;
- Malpractice/Unskillfulness, when performing a task or working in the wrong way due to the lack of knowledge of the activity [13].

Unsafe conditions in the environment are related to unsafe conditions at home. It is the lack of necessary care required to properly perform a task without accidents. Therefore, there must be constant vigilance regarding what actions may cause accidents in domestic environment, informing the person in charged so the measures are taken, avoiding possible accidents [14].

Regarding the classification of environmental risks and risks factors it is relevant to refer that environmental risks are classified according to causative nature. Thus the risk types can be grouped in: chemical, which are cause by chemicals (vapors, gases, liquids, dusts, mists, fumes); physical, caused by energy exchange between the person and the environment (heat, electricity, infrared and ultraviolet radiation, ionizing radiation, pressure, impacts and others); and biological, caused by agents that produces infections and allergies (virus, bacteria and fungi) [15].

When risk factors are found in the environment, an unsafe condition is established. Often it is believed that danger only exists outside of the perimeters of the house, but statistics show that most of the houses or domestic spaces (kitchens, bedrooms, bathrooms, gardens, etc.) are responsible for several types of accidents, where the main affected are the elderly and children.

Several factors can cause accidents. Firstly it is highlighted those related to the physical and psychological conditions of people, then those related to physical, social and cultural conditions of the living environment.

Elderly people present certain characteristics that frequently lead them to become domestic accident victims. Some symptoms of aging, such as the decrease in physical strength, lack of attention and concentration, weaker vision and hearing, slower movements and slower reactions, state the beginning of a life more frequently dependent of others and more willing accidents, such as falls. Besides, advanced age is usually followed by the loss of their spouses, partners or friends and by other restrictions that can lead to feelings of loneliness and isolation.

For family members of the elderly, the emotional and physical load of taking care of someone in those circumstances can be large, causing stress situations, depression and nervous exhaustion. In the case of an accident of the elderly, that load increase significantly.

5 Domestic Environments Suited to Active Elderly

Culturally, accidents are noticed as inevitable situations, not wished by people, especially because people usually think it is never going to happen to them. However, facing and thinking about the accident, it is perceived that, in many cases, the situation could be avoided.

In the matter of the elderly, prevention consists in anticipate the situations, avoiding that any damage happens, through physical, material, emotional and social care exercises. In that way, prevention should be understood and performed by families and government sectors, through public politics.

A safe house consists in a residence designed with the intent of minimize accident risks, introducing a new concept that aims to provide safety, comfort, independence and quality of life for the elderly.

Thorough analysis of each environment, difficulties in performing tasks in specific spaces can be diagnosed:

- Bedroom—The activities performed in the bedroom, in general, are: sleeping, resting, watching television, reading, writing, clothing choosing, etc. That means that bedrooms should be wide, ventilated, well-lit and comfortable. Windows with interesting views act as positive stimulation, as the contact with the outside can positively influence the emotional state of the elderly. Furniture should include the use of wheelchair, which is a very common need for the elderly.

- Bathroom—The bathroom is one of the places with highest rates of accidents, especially because it is a wet area. A proper planning of these environments should consider a non-slip floor, especially in the bathroom box; bathtubs should be avoided; support bars near the shower and the sink; mirror at the proper height for the elderly; toilet with higher elevation; good lightning and, if possible, with presence sensors; faucets with lever handle; and an adequate space for wheelchair maneuvers.
- Kitchen—Just as the bathroom, the kitchen is a dangerous space for elderly, because, besides being a wet area, presents several accident risks, including falls, burns and injuries while handling sharp objects. It is important to reiterate that the article discuss active seniors living in their homes and often prepare their meals.
- Hall/Passageway and stairs—Circulation areas should be well lit, with light switches at each end of the stairs. The first and the last steps must be signalized and non-slip floor should appear in all steps. A firm handrail should be placed on both sides of the stairs. Stairs must always be clear, avoiding putting shoes, books, tools and other objects.
- Deposit or garage—In order to avoid confusion, all chemical products must be kept in their original packaging and properly identified. Hazardous chemicals should be stored in special places. Sharp or potential dangerous tools must be kept in proper functioning and stored in special places. For example, gasoline and other inflammable products must be kept in closed containers away from heat sources (preferable outside the residence limits).
- Other outhouses from the residence—Keep the terraces, balconies and hallways without puddles. All areas should be well lit. Protective screens securely fixed to the windows. Avoid poisonous plants and thorns in the garden or inside the house. Keep attention to the pool areas. Plan escape routes in case of fire or emergency and train all residents of the house to practice these routes.

It is possible to engage actions that, without a doubt, will contribute to make residential environments safer. Primarily, to achieve safety, obedience of the norms is crucial, performing maintenance and relevant inspections. In addition, it is required care and special attention both with the elderly and children. Lastly, safe habits are requisition for all equipment, installations and environments.

The analysis performed in this paper included manual analysis [16], report analysis [17] and the authors' experience resulting in the most common accidents in domestic environment and its main causes:

1. Accident by fall—In residential environments there may be two types of falls: the ground level caused by slipping, tripping, being pushed, etc.; and by level difference caused by stair falling, high doorjamb or step, or when climbing chairs or other furniture that does not have this purpose.
2. Accident by poisoning, allergies, irritation and burning—Poisoning usually result from ingestion or inhalation of toxic products; allergies are consequence

of inhalation, ingestion or skin contact with several products; and irritation and burning are produced by skin contact.

3. Accident by burn—Burns can be caused by contact, projection of objects, particles or liquids at elevated temperatures or by contact with caustic products like soda, acids, etc.
4. Accident by fire and explosion—Starting a fire requires three elements present in every household: air, fuel and heat focus. When the fuel is gas, its leakage or similar situation can cause an explosion.
5. Accident by electric shock—The risk of electric shock is always present in homes, but the risk becomes more evident when the environment is damp and/or the person is barefoot. It is necessary to keep a permanent alert state in electricity use, with special attention to bathroom, laundry and kitchen areas, and also appliances such as refrigerator, washing machine, dish washer, etc.
6. Accident by respiratory asphyxia—Asphyxia occurs from lack of oxygen by its impossibility of reaching lungs or blood. Oxygen cannot reach the lungs when the airways are obstructed.
7. Accident per hit and stumbling—Produced in disorderly environments or caused by the presence of objects and equipment in the circulation areas.
8. Accident by animal or insect bites—dogs, cats, rats, etc. may become dangerous for the elderly. These animals usually can be carriers of contagious and deadly diseases such as rabies and anger, or simply can cause injury by negligence or without intention.

6 Final Considerations

From the discussion on the perception of the elderly as the relationship between risk of accidents at home and their physical condition in performing daily tasks, it is understood that the activities carried out by the elderly and the necessary adjustments in the home environment, throughout the life cycle, is a complex theme. The issue involves not only the architecture field, but requires a dialogue between the several involved areas of knowledge, such as ergonomics, safety engineering, medicine, physiotherapy and others related to the specific situation.

In this sense, the goal is life quality and autonomy. Improving accessibility, comfort and safety is, therefore, essential in planning an elderly person's house.

The study of the process of human perception and its relation with the built space facilitate the understanding of how the levels of perception suffer with aging, caused by the wear of the sensory organs.

Changings in the environment can cause conflicts with elderly people used to determined procedures and the safety in their living space for decades, which means a familiar space. The affectivity feeling that elderly people have about their living place is fundamental when there is a redefinition or planning of a new way of living. It is important to consider and preserve their references.

Thus, the environment influences on people have been object of research, but the perceiving and dealing with those references is a subject that deserve further study.

Analyzing the accidents raised in the research, its causes and prevention measures proposed, it is concluded that domestic accidents can be avoided if they are previously studied and if proper prevention measures are adopted. Such preventive measures must be developed from the understanding of the elderly life cycle, aiming their comfort, safety and autonomy.

All the aspects about domestic accidents with elderly people raised and discussed in this paper seem to highlight that only from the clear understanding of how they happen and what are the direct consequences for people involved, it is possible to determine the basis for the project adjustments of the environments designed for the elderly.

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References

1. Organização das Nações Unidas: O Mundo terá 2 Bilhões de Idosos em 2050 (2014). https://nacoesunidas.org/mundo-tera-2-bilhoes-de-idosos-em-2050-oms
2. Arking, R.: Biologia do Envelhecimento. FUNPEC Editora, São Paulo (2008)
3. Fontaine, R.: Psicologia do Envelhecimento. Edições Loyola, São Paulo (2010)
4. Ferrara, L.D.: Espaços Comunicantes. Annablume Editora, São Paulo (2007)
5. Moser, G.: Examinando a Congruência Pessoa-Ambiente: o principal desafio para a Psicologia Ambiental. Estudos de Psicologia **8**(2), 331–333 (2003)
6. Darè, A.C.: A Percepção do Idoso do Meio Ambiente Doméstico. In: Congresso Brasileiro de Pesquisa e Desenvolvimento em Design, 7, 4p., Curitiba (2006)
7. Kalache, A., Kickbusch, I.: A global strategy for healthy ageing. In: World Health **50(**4), 4–5 (1997)
8. Organização Mundial de Saúde: Envelhecimento Ativo: Um Projeto de Política de Saúde. Departamento de Prevenção de Doenças Não-transmissíveis e Promoção de Saúde Envelhecimento e Curso de Vida. In: Encontro Mundial sobre Envelhecimento. 2., Madri (2002)
9. Keinert, T.M.M., Rosa, T.E.C.: Direitos Humanos, Envelhecimento Ativo e Saúde da Pessoa Idosa: Marco Legal e Institucional. BIS. Boletim do Instituto de Saúde **47**, 4–8 (2009)
10. Laville, A., Volkoff, S.: Envelhecimento e Trabalho. In: Falzon, P. (eds.) Ergonomia, pp. 111–121. Editora Blucher, São Paulo (2007)
11. Hazin, M.M.V.: Os Espaços Residenciais na Percepção dos Idosos Ativos. 2012. 150 f. Dissertação (Mestrado em Design), Universidade Federal de Pernambuco. Recife (2012)
12. Perracini, M.: Prevenção e Manejo de Quedas no Idosos. In: Ramos L.R.,Toniolo Net, Geriatria e Gerontologia. Guias de Medicina Ambulatorial e Hospitalar/UNIFESP Escola Paulista de Medicina. Editora Manole, São Paulo (2010)
13. Mendes, D.: Fatores Humanos: Gerenciando Falhas Humanas, http://temseguranca.com/fatores-humanos-gerenciando-falhas-humanas/
14. Chelenper, D.: Condições Inseguras de Risco x Comportamentos de Riscos, http://seguranca2013.blogspot.com.br/2013/03/condicoes-inseguras-ou-de-riscos-x.html
15. Ministério do Trabalho.: Portaria no 25, de 29 de Dezembro de 1994, Anexo IV—Classificação dos Principais Riscos Ocupacionais em Grupos, de Acordo com a sua Natureza e

a Padronização das Cores Correspondentes, http://portal.mte.gov.br/data/files/FF8080812BE-914E6012BEA44A24704C6/p_19941229_25.pdf
16. Fundación Mapfre: Guia de Prevenção: Riscos Domésticos para os Idosos, www.fundacionmapfre.com.br/Portal/Fundacao/Arquivos/…/381.pdf
17. Barkokébas, Jr., B., Véras, J.C., Souza, S.S.B., Moraes, W.L., Coelho, F.G.L.: Estudo das Externalidades na Atividade de Distribuição de Energia Elétrica Relacionadas aos Acidentes com Terceiros na Região Metropolitana do Recife. Relatório Técnico-científico, Recife (2006)

Risk for First Responders Due to Cognitive Workload and Communication Loss

Edwin Irwin, Robert Guest and Moin Rahman

Abstract We investigated the effects of multiple wireless devices on human performance in emergency situations. The objective of the research was to observe in a naturalistic setting the kinds of interpersonal and wireless communication losses experienced by first responders during emergency responses, and to determine both their causes and their effects on human performance and safety. Assessment of the cognitive and physical workload of first responders indicated moderate levels of workload and perceived temporal stress. Although tactical team leaders naturally experience increased workload due to the nature of their roles, radio communications loss did not significantly impact that load. However, it was noted that despite the safety detriments, first responders continued with mission tasks without ensuring an acceptable level of radio communication with cohorts. Recommendations were made to mitigate communications loss, minimize risk, enhance safety, and ensure first responders maintain situation awareness.

Keywords Human factors · Cognitive workload · Communication loss · First responders

1 Introduction

The purpose of this research was to analyze first responder mission critical communications to determine the potential for increased levels of radio frequency (RF) interference to first responder personal area networks (PANs). PANs include the rapidly expanding range of wireless devices first responders carry into emergency scenarios [1]. Mercer Engineering Research Center (MERC) was tasked to

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evaluate the RF environment during several medium to large size exercises. The scope of this task was to collect RF data, conduct research and analysis on the threat of RF interference during multi-agency exercises, and determine what effect such interference has on first responders.

There are many types of interference that can be present in a first responder environment and degrade communications. They include: co-channel interference (devices transmitting on the same frequency), adjacent signal interference (channel power from one signal falling within the channel of another), transmitter spurious emissions (transmitting energy outside of its base band), intermodulation (mixing of signals producing sums and differences at undesirable frequencies), multipath (receiving more than one instance of a radio transmission with phase-shift), power equipment noise, structural/materials interference (RF attenuation due to material absorption), equipment setup interference (particular to interoperability gateways), and equipment failure interference [2].

Human factors, such as stress and workload, may not only be affected by, but may also contribute to, a breakdown in communication and performance, which can impair performance or safety. For instance, poor training, time stress, danger-induced emotional arousal and modulation of cognition, high workload, etc. may negatively affect different stages of communication and performance [3]. The results are numerous: the inability to perceive an auditory signal due to excessive cognitive load (auditory exclusion), the inability to perceive a visual stimulus due to excessive cognitive load (inattentional blindness), breakdown of thought and speech processes, poor radio discipline, and inability to adhere to standard operating procedures, such as closed-loop communications [4, 5].

2 Methodology

A naturalistic experimental methodology was chosen for this study. This methodology enabled the researchers to concurrently collect RF and human factors data in the field with more ecological validity than would be possible in a laboratory setting.

Naturalistic experiments involve identifying or creating realistic scenarios in which the independent and dependent variables of interest are likely to change. The researchers then develop data collection protocols for those scenarios. This type of experiment promotes greater fidelity in measurement of the complex human responses involved in emergency situations. It also reduces the demand-effect on human performance, since the subjects have no insight into what is being measured. A significant limitation in this type of experiment is the lack of control over the independent variables, making future replication by other researchers more difficult.

2.1 Radio Frequency Instrumentation Design

Even though the most prevalent frequency bands used by the modern first responder community are VHF (approximately 150–160 MHz) and UHF (approximately 450–900 MHz), the potential exists for operating environments using a wider range. With many segmented bands allocated to public safety, the full first responder RF spectrum is broad. It currently ranges from HF (3 MHz and up), when an emergency scene is supported by Amateur Radio Emergency Service, to approximately 5 GHz with the presence of WiFi, Bluetooth, and other wireless devices [6].

The researchers selected a suite of sensor equipment that was capable of performing spectral analysis up to 6 GHz. As important as the technical specifications of the equipment were, the size, transportability, and interconnectivity of the equipment were deciding factors. The instrumentation included remote RF sensors, power supplies, receive antennas (GPS and broadband RF), and networking components. The sensors (and supporting hardware) were designed to be placed on portable towers and set up around an emergency exercise, providing full coverage of the spectra within the scene as well as geolocation of spectral sources.

2.2 Human Factors Instrumentation Design

Audio feeds from first responders and incident commanders were developed using wireless Lavalier microphones and transmitters. Countryman E6 ear-worn, omnidirectional microphones were used to pick up all audio in the immediate environment around the tactical team leaders, including radio traffic, ambient noise, and verbal traffic. The microphone booms were formed into a semicircle in order to place the microphone in the ear canal on the radio receiver side, so recording levels would be equivalent to the sound levels perceived by the first responder. Field testing showed the audio sensitivity was sufficient to record clear speech outdoors from individuals speaking at conversational levels (approximately 40 dBA) 10 feet away from the microphone. Each microphone was connected to a Sennheiser EW300 transmitter, which was mounted on the clothing of the first responder in a manner that would least interfere with movement or function.

Global positioning system (GPS) time synchronization of the human factors data with the RF data was provided using an Ambient Clockit ACC501 time controller with a GPS receiver. The time was output by the Clockit as longitudinal time code (LTC), which is an audio-encoded time signal that was synchronously mixed as a separate channel in the audio recording.

Measurement of the factors affecting workload for first responders during each scenario was accomplished using a mix of psychophysical instruments and self-rating questionnaires. These included the Borg CR10 rating of perceived exertion [7], The NASA Task Load Index (TLX) [8], and a high velocity human factors (HVHF) questionnaire developed based on research by Rahman [9].

The Borg CR10 was used to gather data on first responders' physical workload. First responders were asked to rate their state of exertion before they began their role in the scenario, then again after they had completed their tactical activity. The NASA Task Load Index (TLX) is commonly used to provide a rating of physical and cognitive workload based on user ratings along 6 subscales: mental demands, physical demands, temporal demands, personal performance, effort, and frustration. The HVHF questionnaire adds dimensions of complexity, confusion, and predictability that have been found to impact error rate and situational awareness in emergency situation. In addition, self-rating questions about each individual's level of comfort in the current role within the scenario and post hoc ratings of communication quality were included.

2.3 Site Selection, Exercise Details, and Site-Specific Instrumentation Setup

The researchers selected Guardian Centers as a venue for conducting controlled testing and evaluation for two of the three exercises that included both RF and Human Factors (HF) data collection. These were large-scale multi-agency and multi-jurisdictional exercises.

The other HF and RF exercise was a federally directed and supported exercise with a national scope. The US Army Northern Command sponsored Vigilant Guard 2015, a multi-jurisdictional, natural disaster response exercise in Georgetown, SC. It was a simulation of the Hurricane Hugo response from 1989.

2.4 Human Factors Analytical Framework

Random selection and assignment of first responders into specific groups for HF data collection and analysis was not feasible due to the design of the exercises. The participants were thus purposefully selected for participation in the study, though the impact of selection bias was addressed in the statistical analysis.

The researchers worked with the incident commanders at each scenario to identify which teams were performing complex, time-sensitive, and both mentally and physically demanding tasks. The commander assigned a specific squad leader to wear the audio instrumentation. This helped mitigate the potential for researcher selection bias.

The incident commander (IC) was instrumented in order to collect audio from both endpoints of the communications link between the tactical teams and the IC. This was crucial for allowing the researchers to identify when communications was

Table 1 Participant demographic data distribution from the subway exercise

Years of experience	EMA	EMS	Fire	National guard	Police
<2	0	0	6	6	3
2–5	0	2	6	8	2
6–10	2	0	0	4	3
>10	0	8	16	1	11
Total	2	10	28	19	19

EMA = emergency management agency; EMS = emergency medical service (ambulance, medical transport)

lost and why. It also provided a broader measure of radio traffic through the IC and a qualitative assessment of situational awareness and control by the commander.

Demographic data was collected on all of the instrumented participants and the majority of the other first responders in the scenario. Data was collected on a total of 81 participants. Table 1 shows the demographic distribution of participants.

Audio data was manually extracted from each recorded audio channel. All verbal exchanges (direct voice) with the team leader and all radio traffic between the team leader and other units were logged in the data collection spreadsheet. Each exchange was categorized with regard to the modality of communication (direct or radio) and the type of communication involved. The radio voice (for simplicity referred to as radio) communications were classified into types, such as Call Request, Call Acknowledgement, Command, Correction, etc.

Each radio exchange was marked in the audio recording software with the marker number and time logged in the data collection spreadsheet. Notes on problematic transmissions, such as repetitions due to ignored or lost transmissions were logged in the transmission logs as they occurred.

The wide variability among individuals in verbal expression as well as differences in information content between communication modalities was a significant concern when planning the means to measure the amount of information transmitted verbally, by radio, and by gestures or signals. The data was normalized by weighting each data point by a categorical value representing the minimum amount of information that can be transmitted. For example, the minimum verbal data exchange (radio or interpersonal) requires 3 words, even if one or more are tacitly understood; subject, verb, and object. Gestures and signals like alarms or flashing lights involve only a verb; e.g. ‘stop’, ‘listen’, ‘look’. The researchers therefore assigned a value of 6 bytes to each verbal data exchange and 2 bytes to every gestural or signal exchange. These values were based on the 2 bytes required to represent a word in a computational data stream.

This technique dramatically underestimates the total amount of data transmitted verbally in most normal exchanges. However, the normalization allows for a comparison between subjects who are terse versus those who are wordy. It also allows for a comparison between those who use good radio operating procedures versus those who speak with their team members more expansively during tactical exchanges. In addition, it enabled the calculation of the error rates for both interpersonal (voice) and radio transmissions. Information loss could thus be expressed as a ratio of the error information to the total amount of information (minus the correction and the requests for repetition, which would otherwise be duplicative).

3 Results

Table 2 provides a compilation of RF and voice communications traffic derived from the audio streams for the incident command post and five of the tactical teams deployed during the VG15 scenario. Since the incident commander was not considered a tactical team, his voice communications were not included in the analysis.

As can be seen in the table, there were significant losses of radio communications throughout the scenario. The causes of radio information loss between the instrumented tactical teams and the incident command post (IC) arose from 4 types of causes: ignored by the receiver, radio failure, RF path absorption, or busy talk channel. Table 3 shows the categorical distribution of losses.

The ignored transmissions and busy channel losses were minor and inconsequential to the exercise, since the transmitting parties persisted in making contact despite the delays, and the receiving party (the incident commander) rapidly came up to speed with the rate of communications with the tactical units.

RF path absorption was prevalent in the VG15 scenario. This was consistent with findings from the subway rescue exercise in the GC 15 scenario, which also showed signal path absorption as the primary cause of radio information loss between the instrumented tactical teams and the IC. 58 % of total radio traffic in VG15 was absorbed by the surrounding structures while teams were in the primary tactical zone. The amount of radio information lost by instrumented tactical teams from this source alone was 32 %. The instrumented teams in the subway explosion scenario (GC15) lost even more information from RF signal absorption, even though the IC was located in a mobile command post equipped with high-powered repeaters and antennas. Table 4 summarizes the radio traffic loss from instrumented teams at each scenario. All of the RF losses experienced by the instrumented tactical teams were due to signal loss resulting from structural transmissivity of the buildings surrounding them.

Radio traffic volume was similar between the GC14 and GC15 scenarios at approximately 20 % of the total flow of information in the tactical scene. The scenario in VG15 had a much lower proportion of radio traffic, which was reflective of the amount of difficulty with radio communications faced by 3 of the 5 instrumented teams, as well as the limited need for radio in the two remaining teams who worked short-range, outdoor tactical environments.

The RF losses, as a proportion of the total tactical information flow for each team, reflect the difference between outdoor (line-of-sight) and indoor tactical environments. The GC14 team worked on the outside of the structure with clear line-of-sight to the tactical command trailer. They experienced no difficulty with RF

Table 2 Measures of information lost, transmitted by interpersonal voice and by radio

Team	Radio traffic						Voice traffic					
	Incorrect	Ignored/lost	Request repeat	Total XMIT	% Total comms	Radio info loss (%)	Incorrect	Ignored/lost	Request repeat	Total XMIT	% Total comms	Verbal loss
IC	0	4	3	261	–	7	–	–	–	–	–	–
SAR1	0	5	1	9	11 %	75	0	0	0	72	89 %	0 %
SAR2	0	6	1	13	5 %	58	0	0	7	258	95 %	3 %
SAR3	0	13	0	21	13 %	62	0	0	2	145	87 %	1 %
Triage	0	1	0	14	8 %	15	0	0	1	161	92 %	1 %
Recon	0	7	0	7	4 %	100	0	0	3	159	96 %	2 %

Losses are broken out by tactical team. IC = incident command, SAR = search and rescue, RECON = reconnaissance

Table 3 Causes of radio traffic loss

TEAM	Ignored	Incorrect	Unintelligible	Channel selection	Radio failure	Busy channel	Path absorption	Environmental noise	Frequency crosstalk	Noise floor
IC	2					1	11			
SAR1	2						4			
SAR2							7			
SAR3					13					
Triage	1									
Recon					7					

Table 4 Summary of radio traffic losses from instrumented tactical teams at three exercise scenarios

Scenario	Total traffic	Total RF traffic	Info by radio (%)	Radio traffic lost	Radio loss (%)	RF loss	Radio loss from RF (%)
GC14	416	82	20	11	13	0	0
VG15	859	64	7	34	53	11	32
GC15	717	164	23	48	29	47	98

signal attenuation, but ambient noise and the use of self-contained breathing apparatus (SCBA) combined to reduce the radio traffic information by 13 %. On the other hand, the GC15 teams lost 29 % of their radio traffic, almost all of which was due to RF signal attenuation.

The proportion of total information lost due to RF signal loss/degradation was a small proportion of the total information flow within any of the tactical scenes, with a maximum of 6.5 % lost at GC15. However, this was a significant portion of the radio traffic, which has the greatest impact on situational awareness and safety.

In order to discuss the effect of radio traffic losses on mental and physical workload, it is important to assess the workload experienced by the complete cohort of first responders from whom data was collected. Table 5 provides a breakdown of median scores (n = 81) from all of the questionnaires used at the scenarios. The ratio of median score to maximum score is given in the table for the entire cohort to allow comparison between questionnaire instruments.

As can be seen in the table, the physical and mental stress scores between the instruments are very comparable. As a group, the median scores indicate moderate levels of workload and time pressure. The median absolute deviation of the TLX scores for Mental Stress, Physical Stress, Temporal Stress, and Effort (centering around 4) are comparable to deviations of ±1 in the HVHF domains.

The median TLX scores for Performance and Frustration show very low input from those domains, reflecting the well-structured nature of the exercises where roles and responsibilities are well-defined in advance. The high scores in the HVHF domains of Complexity and Predictability are indicative of the complex nature of the exercises and the challenges of coordination with outside agencies.

Data was collected from nine tactical teams, involving 23 first responders, among the three exercise scenarios. The results are shown in Table 6. As expected, the tactical teams show a different level of stress than the whole-group scores indicated, and with much less variance. Where the rating domains were similar between HVHF and TLX, such as physical stress and mental stress scores, both showed similar responses.

For example, physical stress ratings showed a significant increase, consistent with the difference between tactical actors and responders having more sedentary roles. The mental stress ratings were likewise consistent, though they showed no appreciable difference from the cognitive stresses of the wider group of responders. The tactical teams found the scenarios much less predictable, expended much greater effort, and experienced greater frustration than the wider group as well.

Table 5 Median ratings of human factors characteristics that impact workload

	Complexity	Predictability	Clarity	Time	Mental stress	Physical stress	TLX mental	TLX physical	TLX temporal	TLX performance	TLX effort	TLX frustration	Max BORG
GC14	5.5	4.5	3	3.8	4.3	5	11	15	8.5	10.5	13	7.5	1.5
VG15	6	6	4	6	5	4	13	11	15	6	15	12	3
GC15	5	4	4	3	4	3.5	10	5.5	8	5.5	11	4	1
ALL	6	5	3.5	4	4.5	4	11	10.5	9.5	6	11.3	7	1
MAD	1	1	1.5	2	1.5	1	4	5.5	4.5	2	3.8	4	
Ratio	0.86	0.86	0.43	0.71	0.71	0.71	0.60	0.70	0.55	0.35	0.70	0.55	0.5

MAD is the median absolute deviation. RATIO is the ratio of the median rating to the maximum score in each column

Table 6 Data from 9 team leaders

	Complexity	Predictability	Clarity	Time	Mental stress	Physical stress	TLX mental	TLX physical	TLX temporal	TLX performance	TLX effort	TLX frustration	Max BORG CR10
GC14	6	4.5	3.5	4.5	4.5	5	12	14	8.5	8	12.5	11	5.5
VG15	6	6	2	6	5	5	14	13	16	6	14	14	5
GC15	5.5	5	3	3.5	4	5.5	11	12.5	10.5	7	13	11	4
ALL	6	6	3	5	5	5	12	14	11	7	14	11	5
MAD	0.0	1.0	1.0	1.0	1.0	1.0	2.0	3.0	4.0	2.0	2.0	3.0	2.0
Ratio	0.86	0.86	0.29	0.79	0.71	0.79	0.63	0.68	0.80	0.33	0.65	0.55	0.60

A comparison of the data from the 9 team leaders shows expected differences and similarities with their team members. Team leaders had much greater clarity in the mission than their team members, and felt greater time pressure. There was a more moderate increase in the physical stress and effort they had to exert compared to their team members. However, examination of the results in Tables 5 and 6 shows there was no correlation between the physical or cognitive workload and the information loss among team leaders from the 3 exercise scenarios.

The data were compiled from the results of questionnaires given to first responders at each of the exercise scenarios. The total includes 23 first responders who made up 9 tactical teams within the three scenarios.

4 Discusssion

Emergency exercises were purposefully selected for the experiments to reflect real-world environments, rather than laboratory situations. This naturalistic experimental approach provided excellent correspondence to situations and phenomena commonly experienced by first responders.

The data collection scenarios included outdoor and indoor environments, rural and urban areas, environments with and without high levels of RF noise, and areas of low RF transmissibility. The collected data provided clear measurements of the types of technology issues that can be expected in these situations and the human impact that such impediments to radio communications can have on first responders.

Communication issues have a significant and predictable impact on first responders. Teams of responders moving into a tactical environment tend to maintain a sharp focus on accomplishing their assigned tasks. Training and experience reinforce their frequent use of radio communications with tactical leaders to support status monitoring and situational awareness outside the tactical envelope.

However, radio communications most often assumes a secondary priority for the tactical responders such that the team leaders continue to push toward their objectives even when radio communication becomes more difficult. Increases in the cognitive workload of tactical responders can reduce their awareness of risk and their ability to mitigate losses in radio communications. A cascade of events leading to negative outcomes can occur when this increased risk is amplified by loss of situational awareness outside the tactical envelope.

This type of risk cascade was exemplified in real outcomes. It was seen in both the VG15 Eagle Complex scenario and in the subway explosion scenario at GC15. In both cases, responders continued to move through the tactical environment notwithstanding complete, or almost complete, loss of communication with tactical command and without implementing effective mitigation strategies. The only difference in the outcomes of the two teams was that VG15 moved toward an area of increased risk (into a structurally unstable building), while GC15 moved into a benign area and avoid (notional) injury.

5 Conclusions

Some environments will not support RF transmissions of any frequency. In such cases, augmenting the signals with portable wireless repeaters might be a useful mitigation strategy. A key support for making this technology feasible is the ability for first responders to recognize the loss of RF connectivity as it happens. Current portable communication devices only signal connectivity loss when keyed up by the first responder. Modifying hand-held radios to continually monitor connectivity would improve the situational awareness of the first responders and offer an early opportunity to mitigate potential risks.

Although it is attractive to consider adding more interactive wireless technology to the suite of equipment carried by first responders, the effect on the workload of people within the tactical envelope should be of paramount consideration. As was clear from the workload analysis results, cognitive and physical workload was moderate to high when the participants were burdened only with portable radios. The addition of devices that draw from visual or processing attention channels could be counterproductive, and possibly dangerous. Modifications to existing devices that reduce cognitive load, such as verbal status prompts from radios rather than signal tones that must be interpreted, could help mitigate some of the problems seen during the exercise scenarios.

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References

1. Baldini, G., et al.: Survey of wireless communication technologies for public safety. In: IEEE Communications Surveys and Tutorials, vol. 16, No. 2. Second Quarter (2014)
2. Doumi, T.L.: spectrum considerations for public safety in the United States. IEEE Commun. Mag. (2006)
3. Klein, G., Ross, K.G., Moon, B.M., Klein, D.E., Hoffman, R.R., Hollnagel, E.: Macrocognition. IEEE Intell. Syst. **18**(3), 81–85 (2003). doi:10.1109/MIS.2003.1200735
4. Rahman, M.: (2007). High Velocity human factors: human factors in mission critical domains in nonequilibrium. In: Proceedings of the Human Factors and Ergonomics 51st Annual Meeting. Human Factors and Ergonomics Society, Santa Monica, pp. 273–277
5. Pritchett, A.: Preface to the JCEDM special issue on situation awareness. J. Cogn. Eng. Decis. Making **9**(1), 3 (2015). doi:10.1177/1555343415572807
6. Kumbhar, A., et al.: A Comparative study of land mobile radio and LTE-based public safety communications. In: Proceedings of IEEE South East Conference, Apr 2015
7. Borg, G., Borg, E.: Principles and experiments in category-ratio scaling. Reports from Department of Psychology, No. 789. Stockholm University, Stockholm (1994)

8. Hart, S.G., Staveland, L.E.: Development of NASA-TLX (task load index): results of empirical and theoretical research. In: Hancock, P.A., Meshkati, N. (eds.) Human Mental Workload. North Holland Press, Amsterdam (1988)
9. Rahman, M.: Understanding naturalistic decision making under life threatening conditions. In: Proceedings of the 9th International Conference on Naturalistic Decision Making. The British Computer Society, Swindon, pp. 121–128 (2009)

Mental Workload Analysis Using NASA-TLX Method Between Various Level of Work in Plastic Injection Division of Manufacturing Company

Egah Hasta Puspawardhani, Muhammad Ragil Suryoputro, Amarria Dila Sari, Ratih Dianingtyas Kurnia and Hari Purnomo

Abstract This work presents the mental workload analysis within the manufacturing industry that produced automotive product. The productivity of company dropped to 77, 13 % from January to March 2015 while product defects and absenteeism increased from 1.63 to 3.49 %. This paper aimed to measure the mental workload based on job position and the shift work. The method that used is NASA-TLX, which involved 48 employees. The result shown that the highest mental workload (MWL) was in night shift with MWL score 71.9, and iindicator of temporal demand on the morning shift by 18.2. Whereas the post of leader has the highest score which is 70.2. Because the mental workload is high, the researchers proposed to conduct relaxation training, where most of employees stated that their body and mind become fresh and willingly to continuously apply the relaxation training.

Keywords Mental workload · Stress · Training · Job position · Relaxation

1 Introduction

In manufacturing company, individual and group productivity greatly affect the performance of the company, this is caused by the processing of raw materials info finished products [1]. Because basically the company wants to reach the target and able to compete with other companies, and therefore employees must have a good performance in the work so that the target company which has been set can be achieved [2]. Work has become complex enough to require the use of team at all hierarchical levels, with the success of an organization depends to a large extent on the ability of teams to collaborate and work effectively in solving complex problems [3]. The employee's performance can be affected by several factors, one of which is a high mental workload. Job stress can be understood as a situation where a person

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faces the task or job that can not be reached by their ability [4]. Stress is seen as a general and non-specific response against any physiological or psychological demands that come from outside and within him [5]. The higher mental workload is the lower the performance of the employee, and vice versa [6]. According to data from a survey of 1400 workers, more than one-third of the respondents express that had more workload, where they work with a longer time and lunch breaks are shorter so that the work can be completed, finally workers began experience fatigue and exhaustion, they finally not able to handle so that many stress symptoms start to arise physically and mentally [7]. High work stress will cause to decreased work motivation which can lead to decreased morale, discipline, work performance, and reduced levels of quality of work because the job is not done wholeheartedly by the employees, so that the resulting product turn to be imperfect and increase the number of defective products, thus further would cause material damage to the company [8]. Haga et al. [9] stated that for physical workload, it is conceptually reasonable to assume that the amount of accumulated workload effect on the worker (i.e. fatigue) can be estimated by integrating work intensity by time-on-ask. As for mental workload, on the other hand, accumulated size of the effect of workload may not correspond to measured size of momentary workload [9].

This study uses a NASA-TLX because based on a study conducted by Luximon and Goonetilleke [10], it was stated that SWAT is not so sensitive to be used on a job that has a low mental workload. And one of the advantages is that the component ratings can help investigators to find the source of job performance problems or mental workload [11]. Preliminary study result shows that the level of mental workload and work stress experienced by employees is classified, and it is necessary to measure the mental workload so employees can do improvement efforts. Mental workload measurements done using the NASA-TLX method. This method is in the form of a questionnaire developed by the emergence of subjective measurement needs an easier but more sensitive at measuring the workload [12]. By because it will be conducted to measure mental workload using the NASA-TLX in the production employees of manufacturing companies. The purpose of this study was to determine the level of mental workload of employees, identify the positions and work shifts which have the highest level of mental workload, knowing mental workload indicators which are the most influential and perform optimization mental workload levels experienced by employees.

2 Methods

2.1 Subject

Forty-eight employees of a manufacturing company's production of the four groups working shifts participated in different positions for this research. This number of employees is the population for the plastic injection division. The demographic data of all participants was divided into three sections. The first section was the age of respondents. There were three groups involved in this study; late teens of 17–25 years old (represented 46 % of the population), early adulthood of 26–35 years (46 %) and adult 36–45 years old (8 %). Move on to the second section, the working experience, there are only two groups defined. The majority of the population was below six years of experience, for about 92 % of the population. It was then classified as employees with new working period. Hence, the next 8 % group was having experience for about six to ten years which classified as working lives. The third section was the percentage of the intensity of the use of machinery in a week. The larger part of the respondent, 85 % of employees use machines ≤10 times, and other is more than 20 times.

Overall employee is still relatively young and his future is still new. While Fig. 1 shows the positions and the number of members of the four working groups (groups A, B, C and D) of the company's manufacturing these:

Each group consisted work shifts of 12 people with a leader who has the responsibility of the production process. While the setter has the responsibility to set the machine and quality control to check the finished product. Preparation of the raw material are governed by crusser and manufacture of products made by the operator. There are three shifts at manufacturing companies, namely the morning shift (7 am to 3 pm), the day shift (3 pm to 11 pm) and the night shift (11 pm to 7 am).

2.2 *Measuring Equipment*

The tools used in this study include:

(a) Questionnaire, to determine the demographic characteristics of the respondents such as age, Body Mass Index, healthiness, years of service, gender, occupation, intensity of use of the machine, and future use of the machine.
(b) NASA-TLX Questionnaire, to measure the perceived mental workload respondents [11].
(c) Questionnaire of satisfaction, to know the response of relaxation training on the implementation, facilities, and training materials.
(d) Laptop, sound system, and projector, for the implementation of relaxation training.
(e) Digital camera, for documentation.

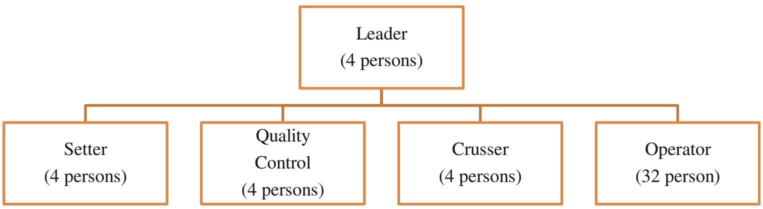

Fig. 1 Job position

2.3 Tasks

In this research, there are two types of data collection, which uses NASA-TLX questionnaire and relaxation training satisfaction questionnaires, the following assignments are as follows:

(a) For NASA-TLX questionnaire [11], the questionnaires were distributed to employees after doing a job like making plastic products for the automotive or education in accordance with the company's production targets. NASA-TLX questionnaires were filled by each person on each shift (morning, afternoon, and night shift). The NASA-TLX questionnaire contains a table of weighting and rating scale against six indicators.
(b) Satisfaction questionnaires of relaxation training were distributed and filled by employees after finishing the relaxation training with duration of 60 min. The questionnaire contains about respondents' satisfaction based on the material, the speakers, the facilities, and the perceived benefits.

3 Result and Discussions

3.1 Comparison of Indicator Value Average Based on Job Position

As seen in Fig. 2, there were various comparison of indicator value average based on both job position and shift work identified.

An indicator that has the highest influence on the mental workload is FR (frustration) and EF (effort), where the highest point is in the position of the operator. Based on their work position, the position of the leader has the highest mental workload on EF (Effort) and TD (Temporal Demand) on the afternoon shift. Leaders have the responsibility to achieve the target of production where the production processes are carried out by the members, so that the efforts are undertaken to complete this responsibility in order to motivate and supervise all members. Working time of the afternoon shift has its own production demand, when the previous shift could not reach the target, the leader should govern its members to reach and finish the target that has not been reached. With a larger load than the previous shift, the more the burden will be felt, as proposed by Tunjungsari [13], that the ever-increasing burden will lead to employees becoming stressed.

For Crusser position, the highest mental workload is seen at EF indicator (Effort), followed by TD (Temporal Demand) which is on the afternoon and morning shift. Crusser position is in charge of preparing all raw materials to be used for the production process, so that the speed of preparation time is very influential, especially in the morning shift. On the morning shift, the entire demand of raw

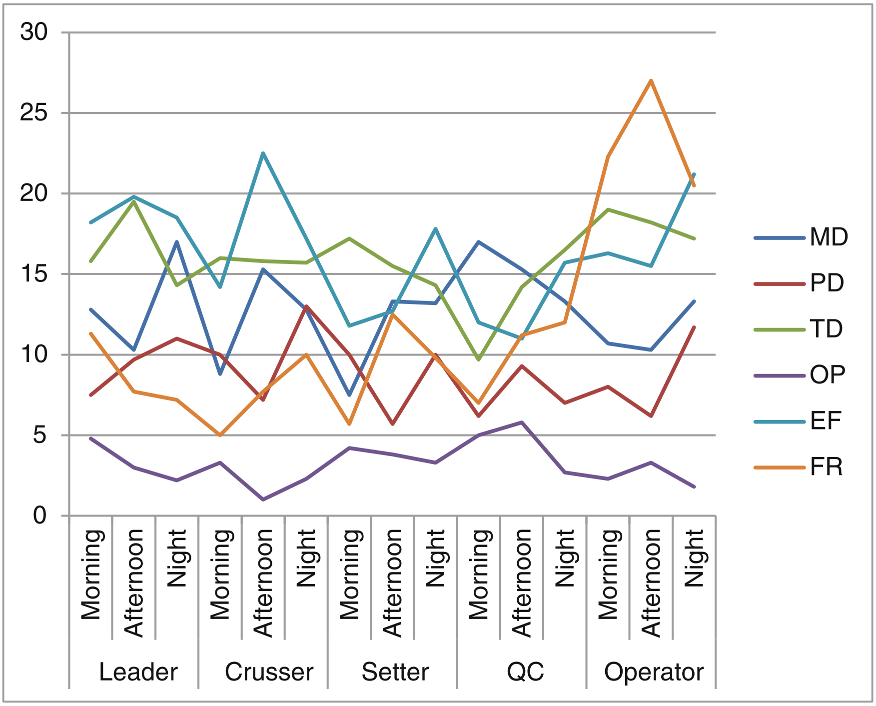

Fig. 2 Comparison of indicator value average based on job position per shift work

materials for one day has to be prepared based on the estimated amount, so that the demand could greatly affect temporal indicators. For day and night shift indicators that affect crusser is effort, both physically and mentally. It is a race against time to fulfill the production target which leads the worker to get exhausted.

In Setter position, mental workload is seen on the night shift of indicator EF (Effort), followed by TD (Temporal Demand) in the morning shift. Setters are responsible for the preparation of mold production processes for a day where they are asked to work fast. While on day and night shifts, physical and mental effort are felt in certain job such as mold removal, mold checking and setting bigger machine because if not careful then the output could be rejected.

In contrast to other positions, the position of Quality Control (QC) has the highest mental workload on the MD indicator which is on the morning shift followed by TD (Temporal Demand) on the night shift. Lastly, the operator position has the highest mental workload on the indicator FR (Frustration) on the day shift, followed by its morning shift and indicator EF (Effort) on the night shift. The operators have the responsibility for the entry of raw materials, production process, and finishing that has to be done in certain time. Besides, the outputs are expected to be perfect so the frustration level is high.

Based on the results and the overall comparison, it can be seen that the biggest complaint of mental workload is on the indicator FR (frustration), and EF (effort). Employees' satisfaction of work is greatly affected by work stress [14]. One way to reduce such complaints is to introduce what it was relaxation to the workers. Relaxation training can help people become calmer and ease the mental load, so that these efforts can be an attempt at a really helpful.

3.2 Comparison of MWL Average Per Shift Work

Based on Fig. 3, the night shift had a larger average of MWL which is at 71.9. As for the morning and afternoon shifts, the MWL averages are at 66.5 and 67.3. Overall the workload experienced by each shift can be considered as high, with different score. This is because work on the night shift had the greatest impact, followed by morning and afternoon shift towards an increase in blood pressure and pulse rate in causing stress [6]. The responsibility to product at night until the early morning hours is a challenge. Due to the amount of concentration needed and the workers have to focus so that the product is not defective, and this is leading to high perceived mental workload.

3.3 Comparison of Indicator Value Average Per Indicator

As a manufacturing company with make-to-order system and mass products with limited production lead time, it makes employees must work quickly and accurately. In general, temporal demand, frustration, and effort affect the pressure of employees in completing the work according to the MWL average. Hertzum and Holmegaard [15] said that a higher mental workload can indeed be affected by time because the narrower the time the higher the perceived mental workload as identified in Fig. 4.

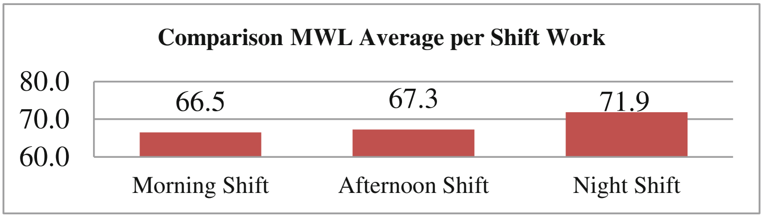

Fig. 3 Comparison of MWL average per shift work

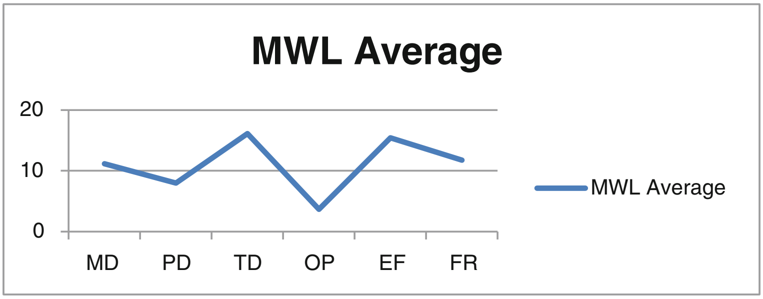

Fig. 4 Comparison of indicator value average per indicator

3.4 Comparison of MWL Average Based on Job Position

From the five existing positions, in the Fig. 5, on the production of plastic injection, the operator has the highest MWL average, followed by Leader position. Leader has the responsibility for the performance of its members and superiors. If the group members do not work on target, then the leader must be responsible to superiors due to a mismatch done on their job. Meanwhile, the operator has a lot of work with the demands of product perfection and timeliness.

After discussing with the management, there was a solution to decrease the mental workload suffered by the employee, relaxation training. Relaxation is a form of exercises to reduce stress [16]. Some positive responses of the relaxation training are workers feel that their stress is reduced, diminished mental load, soul and body be refreshed, good for health, and feel calmer. In addition, workers also feel that relaxation training is very helpful. Besides, the ability of human resource management to motivate employees can enhance the capabilities and productivity of employees [17].

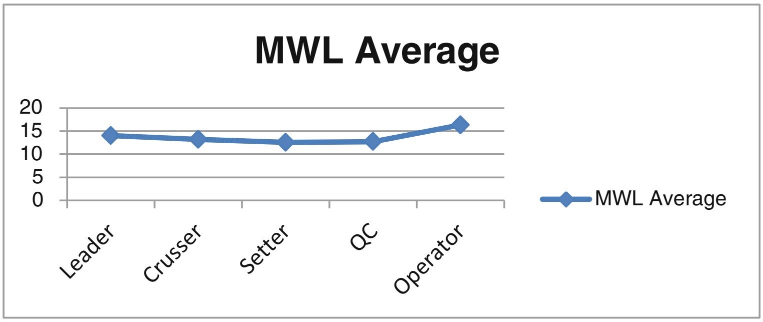

Fig. 5 Comparison of MWL average based on job position

4 Conclusion

Based on the result of the study, it can be concluded that the highest mental workload is operator and in the night shift. However, the indicator of temporal demand is more dominant compared with other indicators. From overall research, the right method to ease the mental workload is by holding relaxation training, and the employee takes positive energy from it. Further research will be expected to measure the level of mental workload after running the relaxation training.

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References

1. Koesmono, H.T.: Pengaruh Budaya Organisasi Terhadap Motivasi dan Kepuasan Kerja Serta Kinerja pada Sub Sektor Industri Pengolahan Kayu Skala Menengah di Jawa Timur **7**(2), 171–188 (2005)
2. Annisa, D.R.: Perbedaan tingkat stres antara karyawan produksi dan karyawan non produksi Pt. Bara Jaya Energy Site Bantuas. Psychology Studies Program, 17 August 1945, University (UMJ), Samarinda (2013)
3. DeChurch, L.A.: Mesmer-Magnus J.R.: The cognitive underpinnings of effective teamwork: a meta-analysis. J. Appl. Psychol. **95**, 32–53 (2010)
4. Widyasari, J.K.: "Hubungan antara kelelahan kerja dengan stres kerja pada perawat di Rumah Sakit Islam Yarsis Surakarta," Universitas Sebelas Maret (2010)
5. Badri, R.A.: Manajemen Stres Kerja Pada beberapa Karyawan Dan Buruh PT Monier Tangerang, Universitas Indonesia (2012)
6. Asdyanti, R.: Analisis Hubungan Beban Kerja Mental dengan Kinerja Karyawan Departemen Contract Category Management di Chevron Indoasia Business Unit. Science Program Business Administration, University of Indonesia, Depok (2012)
7. Halil, I.S., Russeng, S.S., Saleh, L.M.: Stres Kerja Pada Operator Mesin Pembangkit Listrik Di PT. PLN (Persero) Sektor Tello Makassar. Media Kesehat. Masy. Indones. **5**(3), 25–31 (2009)
8. Widyadara, H.: Pengaruh Stres Kerja terhadap Motivasi Kerja Karyawan di CV. Indobordir Bandung Universitas Pendidikan Indonesia. Education Studies Program Management Office, Indonesian education university, Bandung (2014)
9. Haga, S., Shinoda, H., Kokubun, M.: Effects of task difficulty and time-on-task on mental workload. Jpn. Psychol. Res. **44**(3), 134–143 (2002)
10. Luximon, A., Goonetilleke, R.S.: Simplified subjective workload assessment technique. Ergonomics **44**(3), 229–243 (2001)
11. Hart, S.G.: NASA-Task load Index (NASA-TLX); 20 years later. In: Proceedings of the human factors and ergonomics society annual meeting, vol. 50, no. 9. Sage Publications (2006)
12. Hendrawan, B., Ansori, M., Hidayat, R.: Pengukuran dan Analisis Beban Kerja Pegawai Bandara Hang Nadim 1–14 (2008)
13. Tunjungsari, P.: Pengaruh stress kerja terhadap kepuasan kerja karyawan pada Kantor Pusat PT.Pos Indonesia (PERSERO) Bandung **1**(1), 2–4 (2011)

14. Rehman, M.U., Irum, R., Tahir, N., Ijaz, Z., Noor, U., Salma, U.: The impact of job stress on employee job satisfaction: a study on private colleges of Pakistan. J. Bus. Stud. Q. **3**(3), 50–56 (2012)
15. Hertzum, M., Holmegaard, K.D.: Perceived time as measure of mental workload: effects of time constraints and task success. Int. J. Hum. Comput. Interact. **29**(1), 26–39 (2013)
16. Sagala, M.: “Efek Pelatihan Relaksasi Untuk Menurunkan Stres Kerja Pada Karyawan Di. Pt Madubaru Yogyakarta,” EMPATHY J. Fak. Psikol. **2**(1) (2013)
17. Chen, T.H., Wu, K.H., Lin, W.J., Horna, W.I., Shieh, C.J.: Incorporating workload and performance levels into work situation analysis of employees with application to a Taiwanese Hotel Chain. Am. J. Appl. Sci. **7**(5), 692–697 (2010)

Safe Distance for Machinery Actuators: Is After-Reach Speed a Constant?

Roger Jensen and Terrence Stobbe

Abstract A common setup for industrial machines is to install a pair of actuator buttons a safe distance from the point of operation. Safety codes specify that minimum distance by assuming a constant hand speed of 1.6 m/s. To examine the adequacy of that value, a simulated power press with a moving ram was set up for measuring actual hand speed for three placements of the buttons. For each placement, a randomized complete block experiment with nine students provided after-reach hand speed data. Results indicated that after-reach hand speed is not a constant because it varies both with placement of the buttons and distance within placement.

Keywords After-reach speed · Safe distance · Machine safeguarding · Power press

1 Introduction

Thousands of workers sustain amputations each year. Using government data, McCaffery estimated that in the year 1977 on-the-job amputations in the United States totaled 21,000 [1]. Of the 21,000 amputations, 96.8 % occurred to the upper

The first author conducted the experiment as part of his Ph.D. Dissertation entitled *Safe Hand-button Distance for Mechanical Power Presses*, West Virginia University, 1989. The second author chaired the dissertation committee. Neither the experiment nor results have been reported in the open literature prior to this paper.

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extremities (finger, hand, wrist or arm). This finding was followed up by the U.S. Bureau of Labor Statistics with a special survey of workers who incurred a work-related amputation to the upper extremities. Results of the survey indicated that presses were the source of 10 % of the upper extremity amputations [2].

The frequency of press-related amputations prompted a series of investigations by the U.S. National Institute for Occupational Safety and Health (NIOSH) to examine a common hazard in press operations known as "after-reach" [3–5]. The after-reach hazard occurs when the operator reaches toward the point of operation of a power press, shear, or other machine after initiating the down-stroke mechanism by pressing two palm buttons. Such a mistimed reach is thought to be an instinctive reaction by the operator in response to observing that the part was not set squarely in the desired position.

Mechanical power presses and several other types of industrial machines require a method of actuation and a means of safeguarding. A common way to integrate the actuation method with safeguarding is to use a pair of palm buttons for actuation and locate the buttons a "safe distance" from the point of operation. Such buttons are generally referred to as "palm buttons" because they were originally intended to be pushed with the palms of the hands. However, as a precaution against inadvertent pressing of a button, it is considered good engineering practice to surround each palm button with a guard that will make it difficult to unintentionally press a button [6]. This precaution has been incorporated into safety regulations such as those of U.S. Occupational Safety and Health Administration [7]. This protection generally takes the form of a metal ring surrounding the buttons. When a palm button is surrounded by a "ring guard", operators find it difficult to use their palms. Instead they may use their three middle fingers, thumb, or knuckle. Even so, the buttons are still referred to as palm buttons. A survey of mechanical power presses in Finland found that over 60 % are operated with two palm buttons [8].

Safety codes and regulations of industrialized countries specify that when dual palm-buttons serve as actuators for the machine operation, the button must be located no closer than some minimum distance from the point of operation. In a typical mechanical press, this is any location that will be smashed when the ram descends to smash or cut a workpiece sitting on the lower die (or "nest"). This "safe distance" is determined for each press based on two factors: the time to move the hand into the die area (T_{hand}), and the time it takes to remove the hazardous kinetic energy of the descending ram (T_{ram}). One way to remove the hazardous energy is for a brake to stop the descending ram before it impacts the workpiece; the other is for the ram to complete the downstroke.

The current press safety standard used by most countries was derived by making the assumption that after-reach speed can be modelled as a constant. Using this assumption, the standard inequality for calculating safe distance is derived as follows. The operator should be safe when the following condition applies.

$$T_{hand} > T_{ram} \tag{1}$$

The approach used to create a safety regulation out of this inequality has been based on the assumption that the hand movement can be adequately described by the basic equation of uniform motion:

$$\text{distance} = \text{velocity} \times \text{time}, \tag{2}$$

where velocity is a vector. In practice, however, velocity is replaced by speed (a scalar). By replacing velocity in Eq. 2 with speed (S), the equation becomes distance = S × time. Rearranging the equation to have time on the left side gives

$$\text{time} = \text{distance}/S. \tag{3}$$

By replacing distance with safe distance (SafeD) in Eq. 3, the equation for uniform motion may be expressed as T_{hand} = SafeD/S. Substituting this ratio for T_{hand} in Eq. 1 yields Eq. 4.

$$\text{SafeD}/S > T_{ram} \tag{4}$$

Solving Eq. 4 for SafeD gives the standard formula for calculating SafeD,

$$\text{SafeD} > S \times T_{ram} \tag{5}$$

Methods are available to determine T_{ram}, but the value for reach speed required experimentation using realistic simulations. A critical review of the experiments used to choose 1.6 m/s as a hand speed constant revealed serious weakness in sample sizes, number of trials, and attempts to simulate press operations and after reaches [9].

Only one experiment, conducted many years after the 1.6 m/s value was entrenched in the standards, provided a realistic simulation, used actual machine operators, and had a large enough sample size for examining variability. That was a NIOSH study reported by Pizatella and Moll, initially presented at a conference [10] and later as a full journal article [4]. Their study participants were 60 machine operators, and nearly all operated a press as part of their job. The participants operated a simulated power press built for the experiment. Each started operating in a standard, rhythmic way until a randomly-timed action caused the part to be displaced. The operators responded, per instructions, by reaching quickly to correct the part location. Their times to reach from the actuator button to the point-of-hazard was measured. The researchers noted that 40 % of machine operators are not always protected by the standard formula using 1.6 m/s because they can reach faster than the 1.6 m/s. Pizatella and Moll concluded that a change in "safe distance" regulations is needed, but a specific recommendation could not be developed from their experiment because only two placements of the buttons were included. The absence of multiple palm-button placements made it impossible to examine the effect of distance on after-reach speed.

A more recent experimental study of press operator hand speed examined "approach speed" of the hand during regular press operation [11]. Four young and four older subjects participated. The experiment compared approach speed for a press equipped with traditional hand actuators versus being equipped to provide presence-sensing device initiation (psdi). For one part of the experiments, the operators were asked to operate at a fast pace. The operators were significantly faster using the psdi. For the two-hand button trials, the average hand speeds were about: 1.2 m/s for the over 50 participants and 1.6 for the younger participants. The experiment was not designed to simulate after-reach speed when using palm buttons, and therefore, does not directly provide data applicable to the issues addressed in this paper. However, the reported mean hand speeds were in the range predicted by prior studies.

The experiment reported here was undertaken to extend the NIOSH study. The specific purpose of this paper is to address an important initial question: Is after-reach speed a constant or a variable? If after-reach speed is a constant, then it should be the same: (a) for a waist-level and a face-level placement, and (b) for varying distances within each placement.

2 Methods

2.1 Apparatus

In order to conduct an experiment with practical value, a simulated power press was used. It had a moving ram that was designed and constructed to prevent injury if any part of the subject's hand is caught in the point of operation [12]. The same apparatus was also used for the NIOSH study [4] and for other experiments summarized in a paper by Collins et.al. [12].

Like real presses, the simulated press was capable of being set up for actuation by various mechanisms including presence sensing devices, foot switches, and hand buttons. For this experiment, it was equipped for actuation by the operator using both hands concurrently to depress a pair of buttons. The buttons used in this experiment were commercial palm buttons with ring guards.

Three palm-button placements areas were used. Figure 1 shows example placements within each of the three placement areas. Small arrows show the direction an operator presses the buttons. Also depicted in Fig. 1 is a lower die. The ram is not shown.

For this experiment wooden templates were constructed and fastened to the sides of the original simulator housing. Holes were drilled in the templates for bolting the palm-button assembly into the desired positions. The apparatus allowed the operators to set a workpiece on the lower die for stamping, and then remove it after a

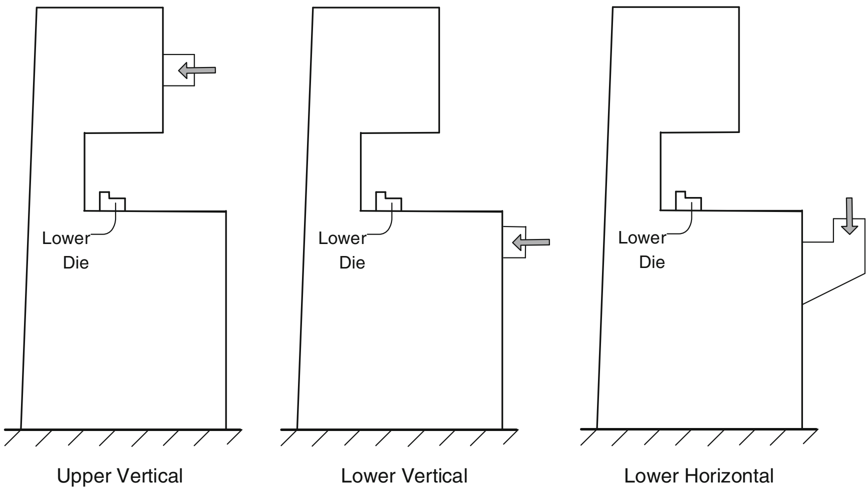

Fig. 1 Side views of simulated press indicating three palm-button placements and direction for pushing buttons

stroke. Video tape recording of the motions were made from one camera placed so as to detect direction of hand motion in the fore-and-aft direction.

The palm buttons were spaced 56 cm (22 in.) apart, the same as in the NIOSH experiment. This is a separation distance commonly found in off-the-shelf palm-button actuators. One study that varied width found that it had no effect on after-reach time other than to affect the reach distance, i.e., reach distance is the important variable, not width [13]. Consequently, the use of a 56 cm separation distance in the experiment was expected to provide a valid simulation of typical hand-button actuated mechanical power press operations in U.S. industry.

After-reach time was measured with timing equipment that started when the left palm button was released and ended when any part of the subject's hand interrupted a light curtain at the near-side of the lower die.

2.2 Experimental Design

The experimental methods were the same as those in the NIOSH experiment, except that in this experiment the distance between the hand buttons and the die was varied. There were actually three distinct experiments, one for each of the placements. The form of each experiment was a randomized complete block design. Each subject was a block; treatments were the eight randomly selected positions of the dual palm-buttons within each placement.

The positions of the palm buttons were varied. This was accomplished by defining, for each placement, an area in which the pair of palm buttons could be located according to anthropometric data [14]. Within each area, eight positions were randomly determined. In the upper vertical placement and the lower vertical placement, one extra position was also included. These two positions were the same as those used in the NIOSH experiment. The inclusion of these positions provided an opportunity to directly compare mean after-reach speeds of subjects in this study with corresponding speed reported by Pizatella and Moll [4].

2.3 Procedures

Each subject came into the laboratory for testing on three separate days, one for each of the three placements. The order was balanced so that each placement was scheduled as the first day for three subjects, the second day for three, and the third day for three. Before testing after-reach times, each subject practiced the routing feeding operation for 5 min. During the fourth and fifth minutes of the practice session, the subject was presented with at least three after-reach signals. This training was the same as that used in the NIOSH experiment [4].

On the days for upper vertical and lower vertical placements, the initial position of the palm buttons matched those used in the NIOSH study [4]. That position was used to collect the initial after-reach times. This trial was followed on that same day by the randomly ordered 8 test positions in that placement. On the day a subject was scheduled for the lower horizontal placement, the testing started with the eight randomly-ordered positions. For all tests, subject performed the routine operation when, at random times, the part was displaced from the die, providing a visual signal for a trial. A trial consisted of one reach with one hand from the left palm button to a target located on the lower die. In order to make the results comparable to those obtained in the NIOSH study [4], each subject performed four trials in each position, and only the fastest of the four was used as the observation for that position.

2.4 Participants

Nine male subjects participated in all three placements. Men were used for two reasons. First, because data from the 1980 U.S. Census indicated that 69 % of press operators are male; and second, the findings of the NIOSH study [4] indicated that males had faster after-reach speeds than females. Thus, by using male subjects the experiment was expected to be more applicable to those apparently at greatest risk. Subjects were recruited from the West Virginia University, College of Engineering. All were seniors or graduate students in engineering. Their mean age was 28, with a range from 21 to 38 years. Each subject signed a consent form after receiving a verbal explanation of the study. The NIOSH Human Subjects Review Board approved the experiment and consent form. No injuries occurred during the experiments.

3 Results

The first analysis sought to learn how well the college subjects in this study may be representative of working machine operators in terms of after-reach speeds. Clearly, the most representative data on the after-reach speed of machine operators are those obtained in the NIOSH study [4]. The NIOSH paper reported the mean and standard deviation of after-reach speeds based on a stratification of gender and 10-year age ranges. From these stratified groups, the group selected for comparison was the males in the age range 20–30 years of age. One reason for this selection was that among the NIOSH groups, the young males were faster than any other group; and that means that young males are most at risk of exceeding the protection afforded by palm-button placements established using the 1.6 m/s hand-speed constant. A second reason was the ages of the college students in this study, 21–38 (mean 28), was close to the 20–30 age span used by NIOSH. An additional similarity was in the number of subjects in the NIOSH study (12) and this study (9). The comparisons are presented in Table 1 and Fig. 2.

Figure 2 provides a visual comparison of the after-reach speed distributions for the two identical palm-button placements—upper vertical and lower vertical. The bins for frequency ranges spanned 0.4 m/s. For example, the bin labeled 1.6 actually includes speeds from 1.6 to 1.999 m/s.

For upper placement, the NIOSH subjects had speeds that were more broadly dispersed than the college students in this study. The mean speed of the NIOSH subjects (2.18 m/s) was larger than subjects in this study (1.59 m/s). Of the twelve NIOSH subjects, 10 exceeded the hand-speed constant of 1.6 m/s. For the lower vertical placement, the speeds were similar in the two studies for both mean and distribution.

The second analysis compared the mean after-reach speeds of the two studies and two identical placements. Table 2 shows the mean speeds. The right column indicates that the ratio of mean speeds in the upper placement to the lower placement. In this study, the faster mean speed was in the lower placement—opposite of the NIOSH study. The bottom row of Table 2 indicates the ratio of mean speeds in

Table 1 Descriptive statistical data comparing the two studies of after-reach speed using two identical palm-button placements

Study	Mean (m/s)		S. D. (m/s)		Percent > 1.6 m/s	
	Upper	Lower	Upper	Lower	Upper	Lower
This study	1.59	2.24	0.32	0.49	56	89
NIOSH [4]	2.18	2.09	0.68	0.70	83	75

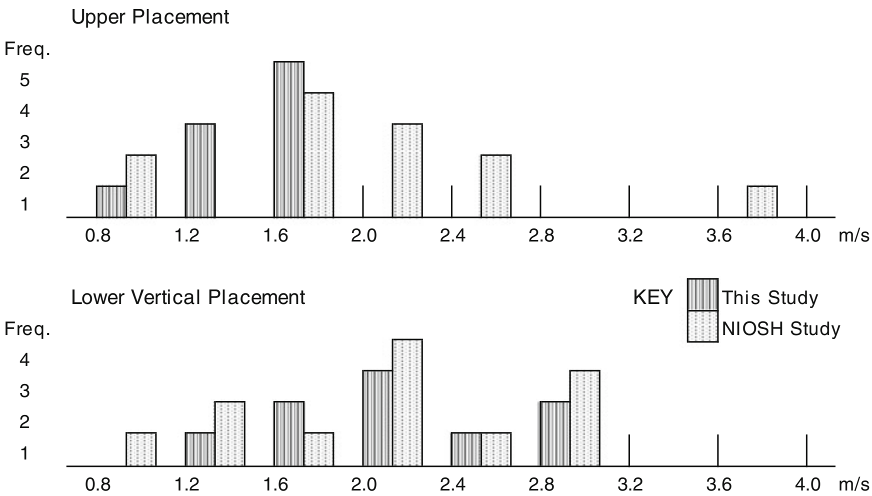

Fig. 2 Frequency histograms for comparing distributions of after-reach speeds (m/s) found in the NIOSH study [4] and this study for the upper and lower palm-button placements. These results are for young male subjects

Table 2 Comparison of mean speeds for two matching placements in two studies

Study	N	Placement mean speed (m/s)		Row ratio[b]
		Upper	Lower	
This study	9	1.59	2.24	0.71
NIOSH study	60	1.45	1.23	1.18
Column ratio[a]		1.09	1.82	

[a]Ratio of means speed in this study to mean speed in the NIOSH study
[b]Ratio of upper placement mean speed to lower placement mean speed

this study to the corresponding speed in the NIOSH study. The subjects in this study had faster mean speeds than those in the NIOSH study. This finding was expected because this study involved only young male subjects.

The third analysis tested the null hypothesis that after-reach speed (S) is not affected by distance (D). Data used for this analysis consisted of the after-reach times in the eight positions by the nine subjects. One placement was missed due to a scheduling error. It was replaced using standard missing data procedures, and the degrees of freedom were reduced by one. Results presented in the Table 3 show that this hypothesis is very unlikely for all three placements. The alternative hypothesis, that S is affected by D, is far more probable. This finding contradicts the common assumption that after-reach speed is a constant.

Table 3 Results of linear regression analyses for S = a + b(D)

Placement	N	(a) Intercept	(b) Coefficient	Probability that Coefficient = 0
Upper vert.	72	0.255	2.785	0.002
Lower vert.	72	1.022	1.275	0.010
Lower horiz.	71	1.035	1.337	0.015

4 Discussion and Conclusions

The purpose of this paper was to address an important initial question: Is after-reach speed a constant or a variable? First, the mean S for the 60 machine operators in the NIOSH study was faster for upper vertical placements than for lower vertical placements. Although this study with nine subjects found the opposite, the larger sample in the NIOSH study warrants greater confidence. Second, after-reach speed increases with increasing distance of the movement (see Table 3). Taken together, results established that after-reach speed is a variable.

Going beyond the stated purpose of this paper, results also indicate that setting up a press using mean after-reach speed is a flawed concept. If a normal distribution applies to after-reach speeds of press operators, then half will exceed the mean. It would be more appropriate to use, instead of mean speed, a speed suitable to protect a larger proportion of press operators. The subjects in both studies and both placements had substantial portions (see Table 1) of their after-reach speeds exceed the 1.6 m/s value.

A limitation of the present study is the use of sample population of male students. To examine this concern, mean after-reach speeds of the nine subjects were compared with that of the 60 machine operators studied by Pizatella and Moll [4]. Both groups of subjects had the same amount of practice with the press simulator prior to the actual testing of their after-reach speed, and in both experiments the subjects had four after-reach signals to respond to, with the fastest of the four being used for all subsequent analyses. Comparing their respective mean speeds in the same positions of the palm buttons (Table 1), neither group was consistently faster.

Because the subjects in this study were not drawn from a large population of industrial machine operators, applying the findings beyond this study should be done cautiously. These subjects were not greatly different from the NIOSH young males in terms of mean after-reach speed. However, the NIOSH study established that young male operators are faster than the others in their study. Thus, if a revision of the safe distance formula is attempted, it would make sense to base it on young males—if young males are protected, then others will be protected.

The regression equations in Table 3 should not be used to predict after-reach speed for a broad range of machine operators. Firstly, they are based on young males, and secondly, they predict mean after-reach speed without accounting for the variability of individuals.

The subjects showed increasing speed as the movement distance was increased. In reviewing the videotape records of the after reaches, it appeared that the greater distance simply provided a longer time for the hand to move at a near maximal velocity. That is, the movements began with the hand at zero velocity. This was followed by a period of acceleration to a relatively fast movement speed. For the shorter distance movements, the hand only had a brief time to continue in this fast phase before the fingers entered the hazard area. In the longer distance movements, the hand was able to extend the fast speed phase for a longer time before the fingers entered the hazard area. This resulted in an overall faster average speed through the whole distance.

It is recommended that instead of looking for a constant value of S, a new model be developed for predicting after-reach time of press operators, T_{hand}. An apparently logical approach would be to replace S in Eq. 5 with an equation that more closely matches experimental data. Such an equation should account for placement (upper or lower), distance within placement, and variability.

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References

1. McCaffery, D.P.: Work-related amputations by type and prevalence. Mon. Labor Rev. **104**(3), 35–41 (1981)
2. Bureau of the Census: Public-Use microdata samples, a sample. Described in User's Guide, Part A.Text. Government Printing Office, Washington, DC (1983)
3. Pizatella, T.J., Etherton, J.R., Jensen, R.C., Oppold, J.A.: Investigation of the after-reach hazard in two-hand controlled power press operations. Scand. J. Work Environ. Health **9**, 194–200 (1983)
4. Pizatella, T.J., Moll, M.B.: Simulation of the after-reach hazard on power presses using dual palm button actuation. Hum. Factors **29**(1), 9–18 (1987)
5. Horton, J.T., Pizatella, T.J., Plummer, R.W.: The effect of palm button location on hand reach speed for power press operations. In: Karwowski, W. (ed.) Trends in Ergonomics/Human Factors III, pp. 963–969. Elsevier, Amsterdam (1986)
6. National Safety Council: Power Press Safety Manual, 3rd edn. Author, Chicago (1979)
7. U.S. Department of Labor: General Industry, OSHA Safety and Health Standards (29 CFR 1910), subpart O, section 217, Mechanical Power Presses. www.osha.gov/standards
8. Suokas, J.: The effect of power-press regulations in Finland. J. Occup. Accid. **5**, 1–8 (1983)
9. Jensen, R.C., Pizatella, T.J.: Critical review of studies to support safe-distance formulas for power press actuation mechanisms. In: Karwowski, W. (ed.) Trends in Ergonomics/human Factors III, pp. 953–962. Elsevier, Amsterdam (1986)
10. Pizatella, T.J., Moll, M.B.: Simulation of the after-reach hazard on dual palm button workstations. Proc. Hum. Factors Soc. **29**, 824–828 (1985)
11. Katoh, Z., Fukuta, Y., Nakashima, Y., Takeuchi, Y., Takamatsu, M., Yoshihara, S.: A study on approach speeds of the hands under metal press machine operation. Proc. Hum. Factors Ergon. Soc. **45**, 1119–1122 (2001)

12. Collins, J.W., Pizatella, T.J., Etherton, J.R., Trump, T.R.: The Use of Simulation for Developing Safe Workstation Designs for Mechanical Power Presses. J. Saf. Res. **17**(2), 73–79 (1986)
13. Masters, R.W.: The location of two-hand trip devices on full revolution mechanical power presses with regard to operator safety. Unpublished Master's Thesis, Texas A & M University (1973)
14. Jensen, R.C.: Safe hand-button distance for mechanical power presses. Unpublished Dissertation, West Virginia University (1989)

Beyond the Pleasures of Music: Are Music Teachers at Risk?

Rui B. Melo, Filipa Carvalho and Ana Delgado

Abstract This study intended to find whether music teachers' exposure to noise has got potential to produce hearing impairments and to investigate their actual hearing status. Twenty music teachers from a Portuguese college-level school of music were surveyed for their daily noise exposure and were submitted to several hearing tests. Occupational history, self-reported hearing disorders and use of personal hearing protectors were among the information collected with a questionnaire. Most teacher's daily exposure to noise is below 80 dB(A), and less than 15 % of them were diagnosed with mild sensorineural hearing loss. Occupational exposure to noise does not seem to be the only factor responsible for this impairment. Recommendations on how to reduce the risk of hearing loss and control noise exposures are suggested and awareness rising strategies are under consideration.

Keywords Noise exposure · Hearing damage · Music school · Teaching activities

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1 Introduction

Music is present in all cultures around the world. In most cases, it is pleasant, and invokes emotion. Yet, most musical instruments are capable of producing damaging sound levels. In acoustics, noise is an unwanted, unpleasant and disturbing sound, varying from quiet but annoying to loud and harmful. Thus, a thin line separates music from noise.

Musicians and music teachers rely on their hearing ability to earn a living. Therefore, a hearing impairment would have a more significant impact on their livelihood and quality of life when compared to other professionals and the public in general.

Aside with hearing loss, exposure to high intensity music for long periods may induce symptoms such as temporary threshold shift (TTS), tinnitus, hyperacusis, distortion and diplacusis [1]. These should be regarded as warning signs of hearing loss.

Although European Union member states must comply with the minimum health and safety requirements regarding the exposure of workers to the risks arising from noise established in 2003 [2] it does not provide specific guidance regarding musicians and entertainment professionals.

Several authors have studied noise exposure and noise-induced hearing loss (NIHL) among symphony orchestra [3–6] and rock/jazz musicians [7] as well as among opera personnel [8]. Although teaching environments have not been that much explored, the prevalence of NIHL among university student musicians has been studied [9] and three studies on the exposure of music teachers to noise were found [10–12]. The daily noise exposure exceeded 85 dB(A) for most of the high-school music teachers sampled [10, 11]. For this reason, Kozłowski and Młyński [12] have studied the acoustic treatment of classrooms relying on resonant panels and absorbing materials as a mean to reduce music teachers' sound exposure.

A few inconsistencies found in the literature raised a few questions concerning the role played by music on the development of NIHL among teachers. Moreover, these last studies took place in elementary and high schools where students themselves are likely to produce high noise levels. Therefore, the purpose of this study was to investigate the detrimental potential of noise on college-level music teachers, to raise awareness of the harmful potential of musical instruments and to provide guidelines on how to minimize noise exposure.

2 Materials and Method

In order to achieve the set of objectives previously established we selected a college-level music school to undertake the study in three main steps: noise monitoring in different types of music classes, teachers' hearing loss assessment and self-reporting symptoms associated with hearing problems and occupational exposure history.

2.1 Participants

Twenty-six of the thirty-seven full-time music teachers volunteered to participate in the study. From these, six did not fill in the questionnaire and three of them did not show at the hearing tests session. Altogether, only twenty teachers (effective participation rate of 54 %), of which 80 % were males, fully engaged in the process by completing the three assessment stages. All participants, aged between 30 and 65 years old (47.7 ± 9.8), signed an informed consent form prior to data collection.

Daily activities included individual classes for teaching how to play different types of instruments and singing. Most common musical instruments were the harpsichord, the piano, the trombone, the saxophone, the clarinet and cellos. Group classes were devoted to composition, listening and analysis, to chamber music and jazz ensembles, and to choir rehearsals. Occasionally, teachers also participated in performances directing their students in choirs, bands or orchestras.

2.2 Noise Measurements

Sound level measurements and analysis relied on equipment from Bruel & Kjær: an integrating sound level meter type 2260, a sound calibrator type 4231, and Protector Type 7825 software.

Each measurement session began with checking the sound meter batteries and its calibration. In most classes, three measurements were accomplished, each lasting at least five minutes. All measurements followed ISO 9612 (2009) guidelines [13].

The A-weighted equivalent continuous noise level (L_{Aeq}) and the peak sound level (L_{peak}) were obtained and the daily noise exposure ($L_{EX,8h}$) was computed afterwards.

2.3 Hearing Tests

Skilled health professionals completed three different types of hearing tests on all teachers using an otoscope, a tympanometer from Grason Stadler, model Gsi38, and an audiometer from Madsen, model Midimate 622.

Otoscopies ensured that the ear canals were free of any obvious problems that might affect the test results or require referral to a doctor.

Tympanometry tested the condition of the middle ear and mobility of the eardrum and the conduction bones, allowing the detection of fluid in the middle ear, perforation of the eardrum, or wax blocking the ear canal.

Pure Tone Audiometry (PTA) allowed determining the faintest tones a teacher can hear at selected frequencies. Our attention was on air-conduction hearing threshold levels at 0.25, 0.5, 1, 2, 3, 4, and 8 kHz.

As previously asked, all teachers avoided noise exposures during the 12 h preceding the hearing tests, which took place in an insulated room.

2.4 Questionnaire

All twenty participants completed a questionnaire via Google Forms so that they could fill it wherever and whenever they would feel it would be appropriate.

The questionnaire consisted of items on: (a) demographic data; (b) professional experience; (c) past and actual occupational data; (d) reporting of self-perceived hearing problems and interference with work activities and (e) use of hearing protective devices.

2.5 Data Processing

Daily noise exposure ($L_{EX,8h}$), normalized over an 8-h period, was computed using Eq. (1).

$$L_{EX,8hx00A0;h} = L_{Aeq} + 10\log\left(\frac{t}{8}\right). \tag{1}$$

Where L_{Aeq} is the measured A-weighted equivalent continuous noise level and t is the daily time exposure to L_{Aeq}, expressed in hours.

As a reference, legally established limits [2] such as Exposure Limit Values (ELV), Upper Action Values (UAV) and Lower Action Values (LAV) for both $L_{EX,8h}$ and L_{Cpeak} were used (Table 1).

Table 1 Noise exposure limit and exposure action values [2]

	$L_{EX,8h}$ dB(A)	L_{Cpeak} dB(C)
Exposure limit values	87	140
Upper exposure action values	85	137
Lower exposure action values	80	135

The produced audiograms enabled the determination of the type (conductive, sensorineural or mixed), degree, and configuration (pattern of hearing loss across frequencies) of hearing loss. The degree categories established by the Bureau International d'Audiophonologie (BIAP) were applied [14]: normal/subnormal hearing, mild, moderate, severe, very severe and total hearing loss.

For the statistical analyzes, we resorted to the Statistical Package for the Social Sciences (SPSS 21). Measures of location and dispersion were used for the descriptive analyzes. Additionally Mann-Whitney and Chi-square tests were applied.

3 Results

Music teaching requires teachers to perform different activities throughout the day, the week and even the month. Therefore, computing their daily exposure to noise is not an easy task since there are not two identical workdays. For that reason, daily noise exposure values presented in Tables 2 and 3 combine the daily time length of classes, which ranged between 2.0 and 8.0 h (6.0 ± 1.9 h), with the measured equivalent continuous noise level. The weekly duration of teaching activities ranged from 4.0 to 31.3 h (14.7 ± 6.8 h).

As far as the musical instruments are of concern, the clarinet stands out as the most risky one to teach how to play. In fact, clarinet classes imposed daily exposures to noise above the LAV of 80 dB(A).

Group classes involving music composition, listening and analysis appear to be the quietest, subjecting teachers to lower daily noise exposure values. On the other

Table 2 Music teachers' daily noise exposure and peak sound levels in individual classes

Class type	$L_{EX,8h}$ dB(A)	L_{Cpeak} dB(C)
Cello	77.0 ± 2.0	106.5
Clarinet	84.1 ± 2.1	111.5
Harpsichord	67.8 ± 2.0	102.0
Piano	72.5 ± 2.1	105.4
Singing	78.2 ± 1.9	106.7
Trombone	77.3 ± 2.5	106.7

Table 3 Music teachers' daily noise exposure and peak sound levels in ensemble classes

Class type	$L_{EX,8h}$ dB(A)	L_{Cpeak} dB(C)
Chamber music	80.5 ± 2.0	102.1
Composition	68.1 ± 2.2	101.2
Jazz	86.6 ± 1.6	114.2
Listening/analysis	73.3 ± 1.8	107.2

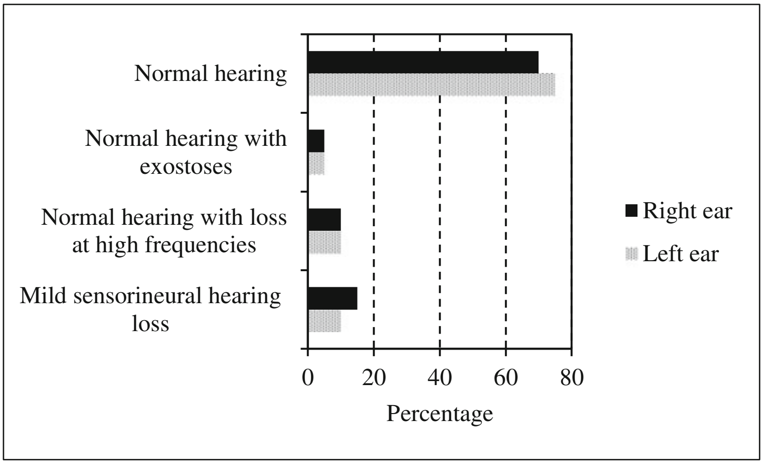

Fig. 1 Teachers' diagnosed hearing losses

hand, classes in which students play ensemble were responsible for the highest daily noise exposures. Collaborative jazz classes presented values above the UAV of 85 dB(A).

Overall, $L_{EX,8h}$ < 80 dB(A) for 75 % of the teachers, 80 dB (A) ≤ $L_{EX,8h}$ < 85 dB(A) for 15 %, and 85 dB(A) ≤ $L_{EX,8h}$ < 87 dB(A) for 10 %. There were no daily noise exposure values above the ELV of 87 dB(A).

It is possible to realize that all sound peak levels were below the LAV of 135 dB (C) in both individual and group classes.

The preliminary tests revealed no serious problems in the ear canals, although one participant presented exostoses and seven had wax blocking it.

The analysis of the simple tonal audiograms obtained for both ears of all participants identified mild sensorineural hearing loss in 10 % (left ear) and 15 % (right ear) of the teachers (Fig. 1).

Two teachers presented a decrease at high frequencies, which is similar to age related hearing loss.

Most participants presented normal hearing for the left ear (50 %) and the right ear (75 %). The first stage, corresponding to a hearing loss between 30 and 40 dB at 4 kHz, included 40 % (left ear) and 15 % (right ear) of the participants, whereas only two participants were in the second stage, in which high frequencies of conversation are affected. In this case, only one of them had bilateral hearing loss. There were no teachers in stage 3 (deep and irreversible deafness).

Prior jobs of 75 % of the participants involved noise exposure and included activities such as playing in orchestras (46.7 %) and teaching music (40 %).

Most teachers (75 %) had more than 16 years of experience in the field of music and 45 % of them have been working at this same school for more than 15 years.

In order to increase their income or even to fulfill their personal goals, 85 % of the participated in extracurricular activities involving music. Among these activities were private music lessons, self-practicing or even participation in live performances, which took place mainly on a daily basis (35 %) or every week (35 %).

As far as the hearing symptoms are of concern, at least 70 % of the workers did not feel tinnitus and 90 % had no difficulties in following a conversation. Nevertheless, those presenting this difficulty felt it in the left ear (50 %) or in both ears (50 %). Sleeping disturbances were also reported and 40 % of the participants struggled to begin to sleep. As for sleep quality, only 25 % ranked their sleep duration as bad and 20 % classified its depth as bad.

Although only one teacher wears earing protection, he does not do it on a regular basis. Still 80 % of them considered it would have a beneficial effect preventing hearing disorders but would also interfere with their daily activities according to 70 %.

4 Discussion

The obtained daily noise exposure values for college-level teachers were below those found for high-school teachers [10, 11]. The use of noise dosimetry allows monitoring every noise teachers are exposed to through the day, while the use of sound meters restricts noise measurements to music class's periods. On the other hand, high-school students are likely to be technically less developed and rather enthusiastic when playing their musical instruments than those at university level.

Nevertheless, music teachers' exposure to sound levels is likely to be high enough to result in hearing damages, and certain categories of instruments are more prone to produce louder sounds. However, these differences were not reported in other studies covering music teachers.

We have found a reduced number of teachers with NIHL. Yet, this does not seem to be associated with the daily noise exposure values as most of the teachers placed in stage 1 (Fig. 2) presented $L_{EX,8h}$ < 80 dB(A) and none of the participants subjected to 85 dB(A) ≤ $L_{EX,8h}$ < 87 dB(A) were placed in stage 2. Additionally, the fact that teachers participate in teaching and performing activities beyond normal working hours at school suggests that music teachers' susceptibility to NIHL cannot be ascribed solely to teaching activities. This will certainly increase noise exposure time and may subject teachers to higher sound levels. It is also known that noise exposure is cumulative and according to several teachers exposure happened in their past jobs, which may have contributed to the NIHL.

Noise control usually observes a hierarchy of principles, which begins with the elimination of the noise hazard itself, followed by reduction of noise levels, physical separation of people from noise, reduction of the number of people exposed to noise, reduction of exposure duration, people's self-protection.

Music schools are about music teaching and music playing. Hence, eliminating the noise source is out of the question and other type of solutions to minimize noise exposures is vital. However, this particular environment leaves room for a limited

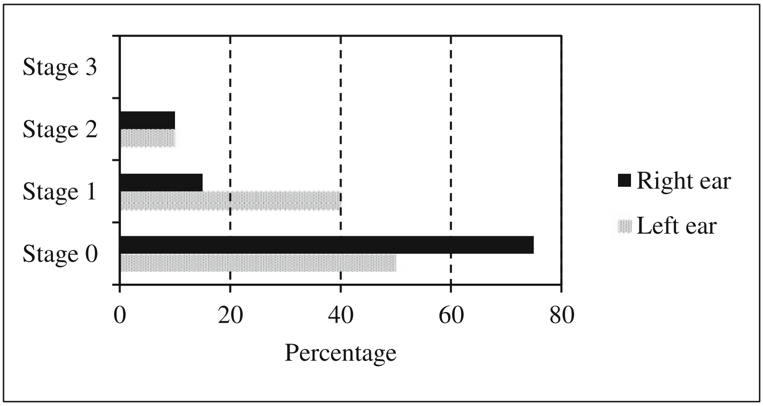

Fig. 2 Hearing loss stages of the teachers

number of control measures and the implementation of a hearing conservation program must be emphasized.

Raising awareness of the harmful potential of musical instruments regarding sound levels they can achieve is imperative in music schools. This would be benefit for both students and teachers, although with different approaches. Provision of suitable information should cover both of them and teachers should additionally be provided with training sessions. In fact, music students' participation in noise control should be part of their educational process as they will be future professional musicians or even music teachers [15]. Those exposed to high sound levels should be enrolled in a health surveillance program.

Teaching location definitely plays a relevant role and attention is required to both its dimensions and acoustic qualities. Smaller classrooms force teachers to stand closer to the instruments' output but the use of resonant panels, on both ceilings and walls, and the fitting with absorbing material such as carpeting, drapes on blank walls and windows have a positive impact [12]. Teachers should position themselves behind loud directional instruments such as clarinets.

Noise exposure over a week is cumulative. Therefore, careful planning of the classes and timetabling are of major relevance. Spreading out noisiest classes as much as possible across the week and sharing them equally among the teaching staff are good principles. Where possible, splitting classes in order to reduce the number of musical instruments in classroom is also a possibility. Softer and quieter compositions are the right choice either to be played or listened and analyzed in classes. Likewise, students should be required to play their musical instruments less enthusiastically, saving their energies to performances, and teachers ought to avoid playing along with them.

Finally, proper personal hearing protectors are available, and should be selected after considering all previous suggestions. The use of hearing protection may seem odd among musicians and they are typically unwilling about wearing them [16].

Pre-molded earplugs are rather inexpensive and deliver moderate attenuation to preserve sound quality. Their attenuation characteristics are not as flat as that of the custom-molded protectors [17].

Custom-molded earplugs offer different levels of protection (usually between 9 and 25 dB). While providing high frequency attenuation, they allow lower frequency sounds to pass through, mostly with no attenuation. This type of protector is more expensive than the first ones and present very little occlusion effect [17].

5 Conclusion

Not many music teachers are exposed to excessive sound levels during their daily teaching activities, $L_{EX,8h} < 80$ dB(A). Still, it was possible to identify classes where sound levels were higher and the most powerful musical instruments.

A small fraction of the participants presented mild sensorineural hearing loss, which cannot be exclusively attributed to noise arising from music classes. Nevertheless, there is a potential risk of hearing loss for college-level music teachers, which demands the implementation of measures for the reduction of noise exposure and prevention of hearing disabilities.

The results of this study would be improved if measurements were repeated with a dosimeter. It is likely that during rehearsals musical instruments produce different sound levels from those generated in a performance and this fact could be explored in the future.

References

1. Zhao, F., Manchaiah, V.K.C., French, D., Proce, S.M.: Music exposure and hearing disorders: an overview. Int. J. Audiol. **49**, 54–64 (2010)
2. Directive 2003/10/EC of the European Parliament and of the Council of 6 February, on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). Official J. Eur. Union **46**, 38–44 (2003)
3. Schmidt, J.H., Pedersen, E.R., Juhl, P.M., Christensen-Dalsgaard, J., Andersen, T.D., Poulsen, T., Bælu, J.: Sound exposure of symphony orchestra musicians. Ann. Occup. Hyg. **55**, 893–905 (2011)
4. Pawlaczyk-Łuszczyńska, M., Zamojska, M., Dudarewicz, A., Zaboriwski, K.: Noise-induced hearing loss in professional orchestral musicians. Arch. Acoust. **38**, 223–234 (2013)
5. Russo, F.A., Behar, A., Chasin, M., Mosher, S.: Noise exposure and hearing loss in classical orchestra musicians. Int. J. Ind. Ergon. **43**, 474–478 (2013)
6. Jansen, E.J.M., Helleman, H.W., Dreschler, W.A., de Laat, J.A.P.M.: Noise induced hearing loss and other hearing complaints among musicians of symphony orchestras. Int. Arch. Occup. Environ. Health 153–164 (2009)
7. Kähäri, K., Zachau, G., Eklof, M., Sandsjö, L., Möller, C.: Assessment of hearing and hearing disorders in rock/jazz musicians. Int. J. Audiol. **42**, 279–288 (2003)
8. Laitinen, H.M., Toppila, E.M., Olkinuora, P.S., Kuisma, K.: Sound exposure among the finnish national opera personnel. Appl. Occup. Environ. Hyg. **18**, 177–182 (2003)

9. Phillips, S.L., Henrich, V.C., Mace, S.T.: Prevalence of noise-induced hearing loss in student musicians. Int. J. Audiol. **49**, 309–316 (2010)
10. Behar, A., MacDonald, E., Lee, J., Cui, J.K., Wong, W.: Noise exposure of music teachers. J. Occup. Environ. Hyg. **1**, 243–247 (2004)
11. Zivkovic, D., Pityn, P.: Music teachers' noise exposure. Can. Acoust. **32**, 84–85 (2004)
12. Kozłowski, E., Młyński, R.: Effects of acoustic treatment on music teacher's exposure to sound. Arch. Acoust. **39**, 159–163 (2014)
13. ISO: ISO 9612: Acoustics—Determination of occupational noise exposure—Engineering method. International Organization for Standardization, Genève (2009)
14. BIAP: Recommendation n. 02/1 bis audiometric classification of hearing impairment, International Bureau International d'Audiophonologie, Liege. http://www.biap.org/en/component/content/article/65-recommendations/ct-2-classification/5-biap-recommendation-021-bis
15. Chesky, K.: Schools of music and conservatories and hearing loss prevention. Int. J. Audiol. **50**, S32–S37 (2011)
16. Laitinen, H., Poulsen, T.: Questionnaire investigation of musicians' use of hearing protectors, self-reported hearing disorders, and their experience of their working environment. Int. J. Audiol. **47**, 160–168 (2008)
17. Patel, J.: Musicians' hearing protection: a review. HSE RR664—Research Report. Health & Safety Executive, Buxton (2008)

Assessment of Health Risks for Rescue Workers in Evacuations During Person Transportation with Rescue Devices in Corridors and Stairways

Sonja Kwee-Meier, Karsten Müller, Alexander Mertens and Christopher M. Schlick

Abstract Elderly and other mobility reduced persons (PRM) are often dependent on the assistance of rescue workers in evacuations. However, only few rescue devices are suitable for evacuations in multi-storey environments, such as high-rise buildings. Moreover, efficiency is a critical factor for potentially dangerous rescue work as well as a psychological factor for waiting PRM. Hence, the presented research aims at increasing efficiency of person transportation in evacuation situations while protecting the health of rescue workers against injuries by the selection of rescue devices. A criteria catalogue in consideration of the needs of rescue workers and PRM and device dissemination was developed. Subsequently, rescue devices were selected for a realistic investigation on a multi-storey passenger ship for level and stairway transports. A rescue chair with a gliding track-system in the downstairs condition resulted in the lowest physical strain and a fabric rescue seat with over shoulder strap was revealed most flexible.

Keywords Workplace health · Safety · Physical strain · Rescue workers · Work physiology

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1 Introduction

Demographic change in Europe led to an increased percentage of elderly people and persons with reduced mobility, PRM [1, 2]. Their walking speed is likely to be much slower, especially on inclined surfaces and stairs [3–6]. Moreover, PRM might not be able to escape by themselves at all because of the specific emergency circumstances or stairs as the only vertical egress option in high-rise buildings, defined by the NFPA by a height of more than 72 ft (~23 m) [7]. While the number of high-rise buildings is continuously growing, most elevators are too dangerous to use in emergencies, especially under fire conditions, and new approaches for fire protected elevators are not yet widely distributed [8]. Moreover, interviews with physically disabled people revealed that surrounding healthy and fit people are not as cooperative and helpful as under normal conditions. Time delays for (self-) evacuation of PRM would allow less disturbed walking and transportation of PRM. Koo et al. have demonstrated effectively shorter evacuation times when delaying the evacuation for wheelchair users [9]. Furthermore, Cepolina showed reduced evacuation times in general by phased evacuation preventing capacity drops at bottlenecks [10]. Nevertheless, evacuee acceptance of group-wise delayed evacuation alarms and the ethicality, particularly when leaving the assumed weakest behind, are doubtful. In conclusion, assistance should be provided for PRM in the event of an emergency [11].

Rescue work in evacuations is very stressful, especially in high-rise buildings and without demand-reducing options in rescue devices. Injury risks for rescue workers, such as emergency medical technicians and paramedics, are higher than for most other professions [12]. The related field of patient transportation has comprehensively been investigated. Standard devices for patient transports such as stretchers have been analyzed and compared for various criteria including physical demands and affordability [13, 14]. However, there is only few research on mass evacuations in multi-storey environments considering the needs of persons with mobility impairments [15, 16].

Therefore, we developed a criteria catalogue in consideration of the physical demands for rescue workers, the needs of PRM, with whom we had conducted interviews beforehand, and the present and potential dissemination of the rescue devices (see Sect. 2). Four devices were selected accordingly for a cross-category rescue device investigation: a standard wheelchair as often used by PRM, a rescue chair with a gliding track-system, a widely disseminated rescue sheet with vest harnesses, and a fabric rescue seat with over shoulder strap. The investigation took place on a multi-storey passenger ship through cabin corridors, upstairs and downstairs.

2 Rationale for Mass Evacuation Rescue Devices

First, criteria for the selection of rescue devices, particularly helpful for mass evacuations, were defined in consideration of the perspectives of rescue workers and the transported persons with reduced mobility (PRM). Table 1 provides an overview (see Sect. 2.1). The hereby selected rescue devices for the practical investigation are presented in Sect. 2.2.

2.1 Criteria Catalogue

Physical Demands for Rescue Workers. For rescue workers, physical demands are clearly the key criterion as they determine over short- and long-term health effects as well as evacuation speed. Subcriteria are the device type, the number of required rescue workers and required lifting. There are three types of rescue devices relevant for mass evacuations in multi-storey environments. Wheeled devices reduce physical demands in level transport but stairs are likely to cause problems. The level of physical demands is extraordinarily sensitive to the PRM's weight for devices that can only be carried, requiring several rescue workers and highly ergonomic design. Gliding devices particularly reduce physical demands in stairways. For instance, matrasses are often used in hospitals [17]. Unlike most carrying devices, wheeled and especially gliding devices reduce numbers of required lifts of

Table 1 Criteria catalogue for selection of rescue devices for potential mass evacuations in multi-strorey environments

Criteria	Subcriteria	Defined by
Physical demands for rescue workers	Device type	Wheeled (demand-reducing in level transport)/ (exclusively) to carry/gliding (demand-reducing in stairways)
	Number of rescue workers	Optimal number of required rescue workers with regard to understaffing but as well to physical demands
	Required lifting	E.g. at start or on landings between stairs
Position of person with reduced mobility (PRM)	With regard to bottlenecks	Less required space in sitting than in lying position
	PRM perspective	Prior interviews with PRMs: lying = loss of overview, perceived degradation, etc.
Dissemination	Presently	Devices used in everyday life by PRMs, e.g., wheelchairs, or commonly used by rescue workers
	Potentially	Affordability, required space for storage, e.g., in the upper floors of high-rise building

the transported person in/on the device. However, mixed designs of these types can also be found (see Sect. 2.2).

Position of Person with Reduced Mobility. The position of the transported PRM is important for two reasons. Escape routes from most constructed environments lead through plenty of bottlenecks, such as small landings in stairways, needed to turn in the worst case by 180°. The lying position obviously requires more space than the sitting position. The downside of the sitting position is the infeasible immobilization of the PRM. However, the sitting position seems advantageous over the lying position with regard to the research purpose to identify mass rescue devices for evacuations. Moreover, interviews with PRM have been conducted beforehand and revealed a psychological aversion against the lying position as it was associated with loss of overview and perceived as degrading in prior experiences. Rescue workers often experience resistance behavior of PRM in anxiety states in evacuations. Hence, aversions against the position are likely to exacerbate anxiety induced tendencies of resistance.

Dissemination. There are two dimensions of dissemination, one in the present and one in future view. Regarding the present, firstly, some rescue devices are more often used by rescue workers than others, for instance, rescue sheets are highly common rescue devices, because they are highly affordable and require only little space for storage, for example, in vehicles. Secondly, PRM often use devices in everyday life, such as wheelchairs, that can be helpful for evacuations. The key advantage of such rescue devices is that they are automatically on-site and certainly known how to be used. The other dimension is the potential dissemination, as there is the tendency of increasing heights of constructed environments, such as high-rise residential and office buildings, claiming for continuous storage of affordable rescue means in upper floors to enable instant evacuation by the help of neighbors and colleagues.

2.2 *Rescue Device Selection for Practical Investigation*

Standard Wheelchair. Wheelchair users are often strongly dependent on this device and about 3 % of the population belong to this group because of disabilities [18], indicating a wide dissemination of wheelchairs. The prior interviews with PRM and experience reports of rescue workers further revealed the unwillingness of PRM to egress from their wheelchair for perceived helplessness or supplemented medical devices. Regarding wheelchairs' specifications, the mostly large and robust wheels were reported to result in low physical demands for PRM transports. Nevertheless, wheelchairs significantly slow down evacuations even in escape routes on one level [9] and most escape routes include stairways. Hence, a standard wheelchair (see Fig. 1) was included in the investigation to examine this conflict of PRM's needs against potential stairway risks.

Fig. 1 Selected rescue devices in level condition; *from left to right*: standard wheelchair, rescue chair, rescue sheet with vest harnesses, and rescue seat

Rescue Chair with Gliding Track-System. There are different types of rescue chairs. The most common is the hand-carried stair chair with handles to carry persons through stairways, causing high physical demands [19, 20]. Fredericks et al. found that a stairwell track system significantly reduces the physical demands over the hand-carried chair [21]. Adams and Galea showed an increased evacuation speed over the hand-carried version by 31 % and over other sliding devices, for instance, being 42 % faster than a dragged mattress [22]. Rescue chairs, sometimes called stair chairs or evacuation chairs, are specifically laid out for stair transports by their gliding track-systems and the previous studies particularly focused on this aspect. Therefore, we included the rescue chair with the gliding track-system in our more holistic approach with specific corridor trials using the integrated wheels.

Rescue Sheet with Vest Harnesses. Rescue sheets are very common rescue devices because of their affordability and their little storage space requirements, for instance, in vehicles. Moreover, they are more flexible regarding space requirements in use than boards or stretchers. Although the lying transport position is not preferred by most PRM, it might be advantageous for highly mobility impaired persons. However, a rescue sheet is a carrying device implying high physical demands. Thus, the equipment for these trials was complemented by vest harnesses. With regard to the low evacuation speeds of the related drag mattresses in Adams and Galea [22], sliding sheets were excluded for the investigation.

Rescue Seat with Over Shoulder Strap. Rescue seats are relatively new devices that have only been investigated by Lavender et al. to the best of the authors' knowledge [20], who identified the examined fabric seat as handy but highly stressful for the hands. Therefore, a rescue seat with an over shoulder strap was chosen for the investigation (see Fig. 1).

3 Protocol of the Cross-Category Rescue Device Investigation

As realistic and challenging environment a multi-storey passenger ship was chosen as venue for the investigation of rescue devices, because modern cruise ships in fact reach the height of high-rise buildings, for instance, the Oasis of the Seas with 72 m height and 16 passenger stories.

Tests for each rescue device, wheelchair, rescue chair, rescue sheet, and rescue seat, were scheduled for level, upstairs, and downstairs transports. The standard wheelchair had to be excluded from stairway transports for unsafe gripping possibilities. For level transport testing, a person was transported three times through cabin corridors in a round walk (see Fig. 2). Three fire doors with a sill each were located on the route for realistic testing. The overall distance was 195 m with a time measuring distance of 45.6 m (solid red line in Fig. 2a) and a way back to the starting of about 19.3 m (dashed red line in Fig. 2a) for three times. This distance was reduced for carrying rescue devices to 127.7 m with a time measuring distance of 32.9 m (solid red line in Fig. 2b) because of the higher physical demands. Transportation in stairways was tested separately upstairs and downstairs over two levels. Each stair consisted of 15 steps.

At the beginning, participants answered demographic questions regarding age, body height and weight. Before and after each test, we measured blood pressure and heart frequency. The perceived exertion during person transportation was rated on the 15-grade Borg scale [23], based on Borg [24], from 6 for "no exertion at all" to 20 for "maximal exertion". In order to evaluate physical demands for critical body

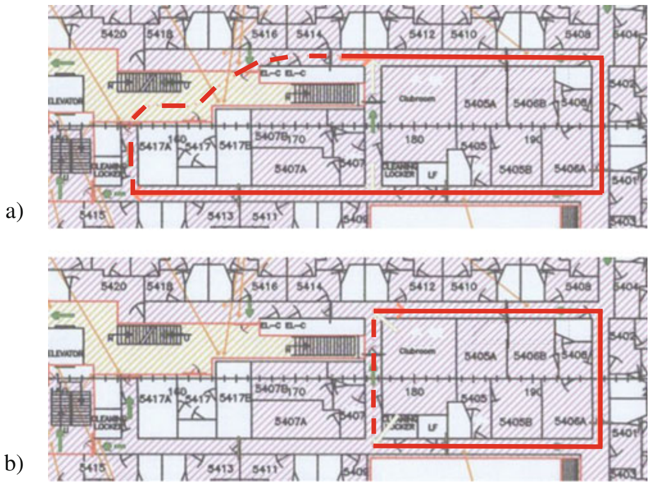

Fig. 2 Ship plans presenting the corridor section for the investigation; **a** long round walk for wheeled rescue devices with 45.6 m time measuring distance (*solid red line*), **b** short round walk for carrying rescue devices with 32.9 m time measuring distance (*solid red line*)

regions such as back and neck and potential asymmetric strain, participants were further asked to indicate their perceived strain differentiated by body regions on a 7-level scale from 1 for "no strain at all" to 7 for "very high strain" [25, 26]. For a deeper understanding, semi-structured interviews regarding individually perceived physical strain, comfort, and further relevant aspects concluded each test.

4 Findings of the Cross-Category Rescue Device Investigation

4.1 Standard Wheelchair

Transportation times with the wheelchair were the shortest in the corridor condition over all rescue devices (see Fig. 5), indicating high efficiency of level transportations. High comfort and usability and conversely low perceived strain were reported, emphasized by the low ratings of perceived exertion on the Borg's RPE scale ("light exertion", see Fig. 6) and the merest increase in systolic blood pressure as physiological measure (see Fig. 7). Worrying is the perceived strain in the hands (see Fig. 8). Interviews revealed problems in curves. Hence, rescue workers who often operate wheelchairs over longer distances should be supported by wrist bandages to prevent long-term health injuries. Strain in the upper back is likely to occur in tall rescue workers as handles of standard wheelchairs are relatively low with a height of ~90 m (see Figs. 3 and 4).

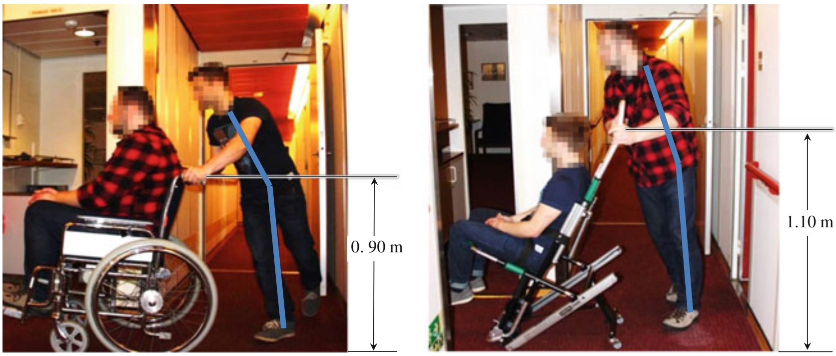

Fig. 3 Transports with wheelchair (*left*) and rescue chair (*right*) in the corridor condition. The wheelchair operator corresponds to the 5th percentile in body height, still bent (*left*), and the rescue chair operator to the 95th, already stretched (*right*), stressing the handle height issue

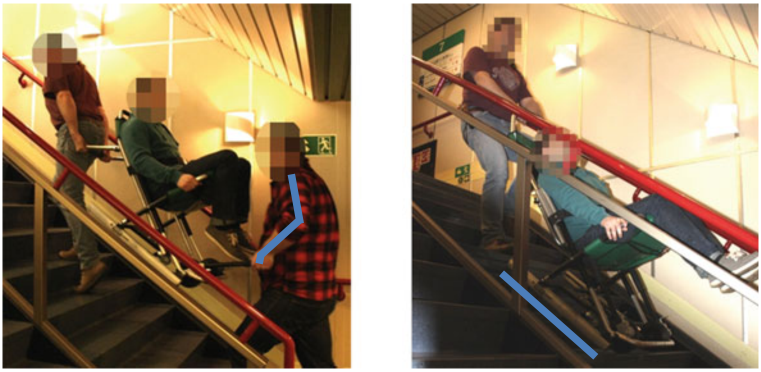

Fig. 4 Transports with rescue chair upstairs (*left*) and downstairs by use of the gliding but self-braking track-system (*right*)

4.2 Rescue Chair with Gliding Track-System

Transports with the rescue chair in the corridor condition were the second fastest with 12 % longer required time than with the wheelchair (see Fig. 5). Transports were rated with "(somewhat) hard" effort (see Fig. 6). Accordingly, there were medium increases in systolic blood pressure (see Fig. 7). In contrast to the wheelchair, handles were relatively high ($\sim$1.10 m), causing problems for smaller rescue workers (see Fig. 3), especially at sills, only surmountable by rescue worker ≤5th percentile when dragging the rescue chair backwards, leading to orientation problems.

Upstairs transportation required two workers, especially stressful for the succeeding worker with unnaturally angled arms and wrists (see Fig. 4). The leading worker can in fact also walk forward because of long handles and carry with straight arms, decreasing perceived strain. The downstairs transportation is

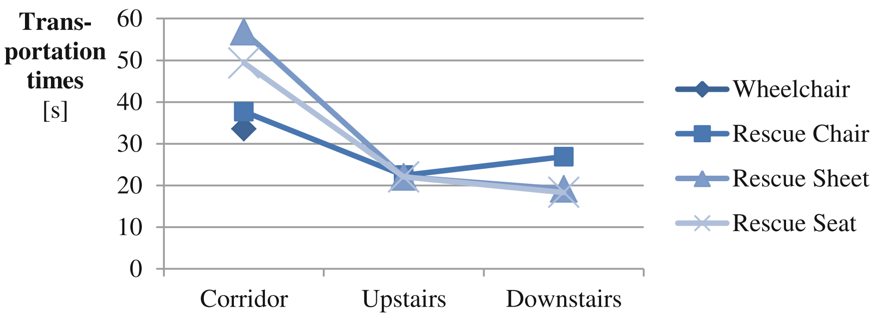

Fig. 5 Mean transportation times for rescue chair, rescue sheet, and rescue seat over all conditions and the wheelchair in the corridor condition (corrected for differences in round walk distances)

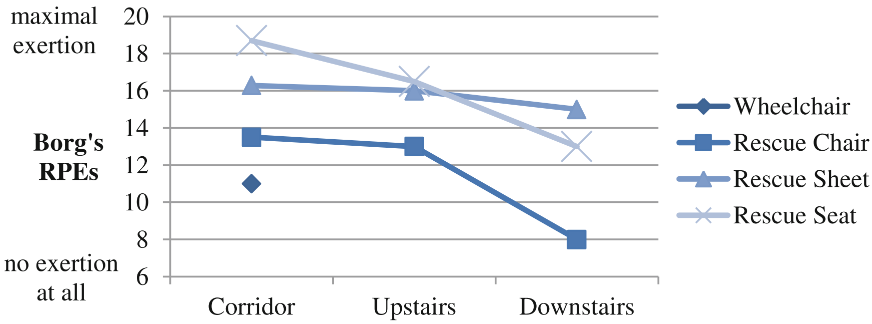

Fig. 6 Mean ratings of perceived exertion, according to Borg's RPE scale from 6 for "no exertion at all" to 20 for "maximal exertion", for person transportation with the rescue chair, rescue sheet, and rescue seat over all conditions and the wheelchair in the corridor condition (corrected for differences in round walk distances)

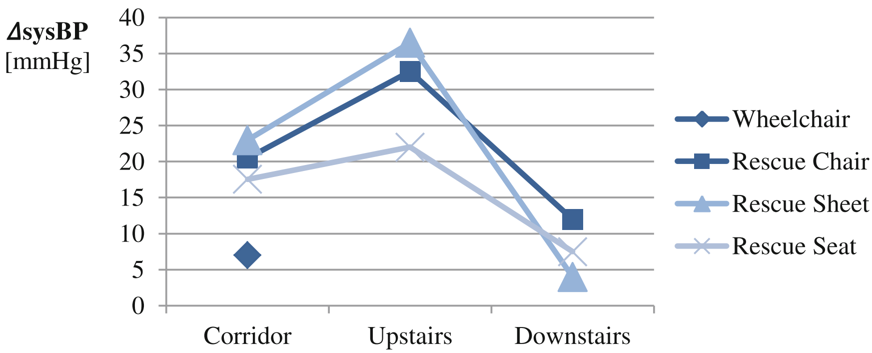

Fig. 7 Mean increases of systolic blood pressures (sysBP) for transportations with the rescue chair, rescue sheet, and rescue seat over all conditions and the wheelchair in the corridor condition (corrected for differences in round walk distances)

strikingly low in effort (see Fig. 6). The gliding track-system allows transportation with only one worker and reduces load by the self-braking track-system, making a second operator optional conversely to research results for prior rescue chairs [27].

4.3 Rescue Sheet with Vest Harnesses

Narrowness necessitated the rescue workers to walk behind each other in the corridor condition (see Fig. 9). The unfavorable force direction of load from behind caused an inevitably bent body posture of the leading rescue worker despite the vest harness, causing very high strain in the legs (see Fig. 8) and the slowest

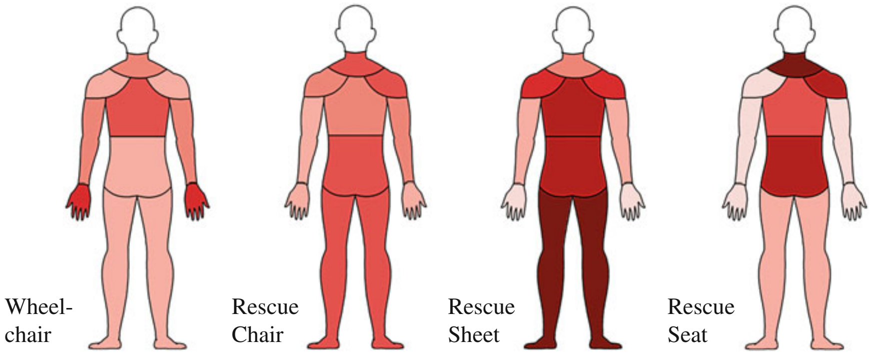

Fig. 8 Mean perceived strain of body regions in the corridor condition, from light to dark red for ratings on the 7-level scale from 1 = "no strain at all" to 7 = "very high strain"; each right side depicts the side with higher strain

Fig. 9 Transports with the rescue sheet using vest harness, in the corridor condition (*left*) and downstairs (*right*)

transportation times in the corridor condition (see Fig. 5), which do not include the time for the elaborate ingress and egress due to the vest harnesses.

Rescue workers had to walk next to each other in stairways to be able to ensure a safe PRM position. Even when walking next to each other, the low PRM position was very problematic, potentially causing back injuries. The transports over all conditions were reported to be "(very) hard" according to Borg's RPE with especially high increases in systolic blood pressure in the upstairs condition (see Fig. 7).

Fig. 10 Transports with rescue seat in the corridor condition (*left*) and upstairs (*right*)

4.4 Rescue Seat with Over Shoulder Strap

The fabric strap design and the sitting transport position led to perceived high handiness of the rescue seat and great advantages in bottlenecks and landings. However, perceived strain was similarly high as for transports with the rescue sheet through corridors and upstairs (Fig. 6). However, it was lower downstairs, also indicated by merely increasing systolic blood pressure (see Fig. 7). The analysis differentiated for body regions reveals the highly one-sided physical demands because there is only one strap over the opposite shoulder, which is very problematic for the critical neck region (see Figs. 8 and 10).

5 Conclusion and Future Work

A criteria catalogue for rescue devices for evacuation contexts was developed in consideration of physical demands for rescue workers but also integrating the perspective of persons with reduced mobility (PRM) from previously conducted interviews with PRM. Furthermore, present and potential dissemination aspects of rescue devices, such as on-site storage in high-rise buildings, were considered. On the basis of this criteria catalogue, four devices were selected from different categories for practical investigation: a standard wheelchair as often used by PRM in everyday life, a rescue chair with a gliding track-system, a widely disseminated rescue sheet, and a fabric rescue seat with over shoulder strap. The cross-category investigation took place on a multi-storey passenger ship in cabin corridors and stairways.

The findings indicate advantages and disadvantages for rescue devices in different conditions. The standard wheelchair was very efficient and low in strain in corridors. However, it was not regarded as suitable for actual stairways. In contrast, the rescue chair with a gliding and self-braking track-system outperformed the other three devices in downstairs transportation with very low strain for rescue workers. Nevertheless, it is disadvantageous for level transportation compared to the wheelchair because of the smaller wheels causing problems at obstacles, such as sills. The carrying devices, i.e. rescue sheet and rescue seat, showed prevailingly higher physical demands than the wheeled devices. In spite of the use of vest harnesses with the rescue sheet, efficiency and usability were very low, whereas the fabric rescue seat with the over shoulder strap was revealed very handy with low space requirements for storage and advantages for bottlenecks and highly challenging environments. However, perceived strain was strongly one-sided. Therefore, future work will focus on a new approach of a rescue seat with ergonomic and strain-reducing design to prevent rescue workers from short- and also long-term health injuries when evacuating in challenging environments impossible for wheeled or electrical devices.

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References

1. bpb (Federal Agency for Civic Education): Demographic change and migration in Europe. Policy Brief **24** (2013)
2. Federal Statiscal Office: Demografischer Wandel in Deutschland. Wiesbaden (2010)
3. Boyce, K.E., Shields, T.J., Silcock, G.W.H.: Towards the characterisation of building occupancies for fire safety engineering: capabilities of persons with disabilities to move on horizontal and inclined surfaces. Fire Technol. **35**(1), 51–67 (1999)
4. Spearpoint, M., MacLennan, H.A.: The effect of an ageing and less fit population on the ability of people to egress buildings. Saf. Sci. **50**(8), 1675–1684 (2012)
5. Kuligowski, E., Peacock, R., Wiess, E., Hoskins, B.: Stair evacuation of older adults and people with mobility impairments. Fire Saf. J. **62**(Part C), 230–237 (2013)
6. IMO, International Maritime Organization: Guidelines for evacuation analysis for new and existing passenger ships. MSC Circular n. MSC/Circ. 1238, 30 Oct (2007)
7. NFPA: NFPA 101 Life Safety Code. National Fire Protection Association, Quincy (2012)
8. Bukowski, R.W.: Addressing the needs of people using elevators for emergency evacuation. Fire Technol. **48**(1), 127–136 (2012)
9. Koo, J., Kim, Y., Kim, B.: Estimating the impact of residents with disabilities on the evacuation modeling in a high-rise building: a simulation study. Simul. Model. Pract. Theory **24**, 7–83 (2012)
10. Cepolina, E.M.: Phased evacuation: an optimization model which takes into account the capacity drop phenomenon in pedestrian flows. Fire Saf. J. **44**(4), 532–544 (2009)
11. Shields, T.J., Boyce, K.E., McConnell, N.: The behaviour and evacuation experiences of WTC 9/11 evacuees with self-designated mobility impairments. Fire Saf. J. **44**(6), 881–893 (2009)
12. Reichard, A.A., Marsh, S.M., Moore, P.H.: Fatal and nonfatal injuries among emergency medical technicians and paramedics. Prehosp. Emerg. Care **15**(4), 511–517 (2011)

13. Jones, A., Hignett, S.: Safe access/egress systems for emergency ambulances. Emerg. Med. J. **24**(3), 200–205 (2007)
14. WorkSafeBC: High-Risk Manual Handling of Patients in Healthcare. British Columbia (2005)
15. Koo, J., Kim, S.K., Kim, B.I., Christensen, K.M.: A comparative study of evacuation strategies for people with disabilities in high-rise building evacuation. Expert Syst. Appl. **40**, 408–417 (2013)
16. Ronchi, E., Nilsson, D.: Fire evacuation in high-rise buildings: a review of human behaviour and modelling research. Fire Sci. Rev. **2**(7), 1–21 (2013)
17. Schultz, C.H., Koenig, K.L., Lewis, R.J.: Implications of hospital evacuation after the Northridge, California, earthquake. N. Engl. J. Med. **348**(14), 1349–1355 (2003)
18. Federal Statistical Office Germany: Statistik der schwerbehinderten Menschen 2013. Wiesbaden (2014)
19. Lavender, S.A., Conrad, K.M., Reichelt, P.A., Meyer, F.T., Johnson, P.W.: Postural analysis of paramedics simulating frequently performed strenuous work tasks. Appl. Ergon. **31**(1), 45–57 (2000)
20. Lavender, S.A., Hedman, G.E., Mehta, J.P., Reichelt, P.A., Conrad, K.M., Park, S.: Evaluating the physical demands on firefighters using hand-carried stair descent devices to evacuate mobility-limited occupants from high-rise buildings. Appl. Ergon. **45**(3), 389–397 (2014)
21. Fredericks, T.K., Choi, S.D., Butt, S.E., Kumar, A.R.: Biomechanical analyses of paramedics using stairchairs. In: Proceeding of the XVI Annual International Occupational Ergonomics and Safety Conference (2002)
22. Adams, A.P.M., Galea, E.R.: An experimental evaluation of movement devices used to assist people with reduced mobility in high-rise building evacuations. In: Pedestrian and Evacuation Dynamics, pp. 129–138. Springer, New York (2011)
23. Borg, G.: An introduction to Borg's RPE-scale. Mouvement Publications, Ithaca, New York (1985)
24. Borg, G.: Perceived exertion as an indicator of somatic stress. Scand. J. Rehabil. Med. **2**(2–3), 92–98 (1970)
25. Corlett, E.N., Bishop, R.P.: A technique for assessing postural discomfort. Ergonomics **19**(2), 175–182 (1976)
26. Wahlström, J., Hagberg, M., Toomingas, A., Tornqvist, E.W.: Perceived muscular tension, job strain, physical exposure, and associations with neck pain among VDU users; a prospective cohort study. Occup. Environ. Med. **61**(6), 523–528 (2004)
27. Fredericks, T.K., Butt, S.E., Kumar, A.R., Amin, S.G.: Biomechanical analysis of EMS personnel using stair chairs with track systems. Proc. 11th Ann. Int. J. Ind. Eng. Theor. Appl. Pract. (2006)

Analytical Hierarchy Process-Based Methodology for Selection of Safety Parameters in Manufacturing Industry

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Abstract This study uses the analytical hierarchy process (AHP) to quantify important safety parameters and to analyse the weight scores of main and sub parameters. Questionnaires have been developed for collecting the expert feedback. Based on the analysis of expert's choice and consistency test, this study identified the weight scores of nine main and forty sub-factors. The purpose of this study is to prioritise the safety parameters of manufacturing industries regarding worker's safety according to the expert's choice. Six experts are taken from manufacturing industry background. The results of this study shows that personal protective equipment (PPE) has the first priority with highest weightage i.e. 30.6 % and workplace layout and housekeeping at last with 2.5 % weightage. The entire main and sub-factors have consistency ratio less than 10 % which is acceptable. It is recommended that PPE should be provided to the workers in manufacturing industries for safe work environment.

Keywords Manufacturing industry · Analytical hierarchy process (AHP) · Occupational safety of workers

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1 Introduction

Multi-criteria decision making approach has many folds which not only help the researcher to prioritize the factors responsible for the implementation in industries. The approach AHP was the effort of Saaty around 1977. This approach has a wonderful collaboration of mathematics and interaction of the work performed. On the application of such approach, one becomes handy in analyzing and revealing the statistics of his research work. AHP has been very effective in making complicated, often irreversible decisions. In this we are using multi-level hierarchical type structure of objectives, sub criteria, criteria, and alternatives. Pair wise comparison has been studied in this paper. Pair wise comparison methodology has impact in finding the weight scores of decision criteria and the relation performance actions of the alternatives in relations of each entity. To ensure the methodology, consistency was also taken into account [1].

Many researchers have been benefited with the AHP and implementation of the decision criteria in various industries has increased the growth level of their manufacturing. Some of these were in integrated manufacturing [2], in assessment of technology asset decisions by Boucher [3] in flexible type industrialized systems [4], in layout design [2], and in many other engineering related fields [5].

AHP is an Eigen value approach which could be implemented by pair-wise comparisons. With the help of AHP methodology we can calibrate the numeric scale for the measurement of qualitative as well as quantitative performances. The range of scale from 1/9 (least value) to 9 for (absolutely more important), which covers the complete range of the comparison.

1.1 Applications of AHP

1. To prioritize the factors which have impact on production and software development etc.
2. It is used to choose the strategies for improvement in safety features for motor vehicles.
3. It is used to estimate the cost and schedule for material requirements and planning.
4. To select the components of desired software from several software vendors.
5. It is used to evaluate the qualitative approach to R n D proposals.

2 Methodology

The analytical hierarchy process (AHP), was introduced for decision criteria. This study is carried out on a model, which has application of AHP on safety parameters of manufacturing industries regarding worker's safety. On AHP model, we designed a questionnaire for expert's opinion. Finally, we find out the weights for the safety parameter of manufacturing industries. The composition of descriptive model and AHP is as follows [3].

2.1 Step 1: Identification of the Problem and Pin Point the Responsible Factor

The study created a occupational safety awareness and, based on literature analysis identified important key factors (Organizational Attributes, Occupational Safety and Health services/documentation, Workplace Layout and Housekeeping etc.) as the criteria for analyzing safety factors for manufacturing industry. On the basis of analysis which is based on the AHP query, we recognized the importance of all types of safety factor to understand the importance responsible safety factor in manufacturing industry.

2.2 Step 2: Selection of Factors

Based on the significant behaviors for occupational safety, many researchers have studied and evidenced. The factors in the first hierarchy included main nine factors from literature review, norms and laws of safety and expert's feedback.

2.3 Step 3: Design of Questionnaire for Data Collection

The data can be collected in the form of questionnaire which encompasses the various possible factors that have been added as pair wise comparison. The same is presented in Table 1 where in 9 point scale has been provided.

Table 1 The definition and explanation of the AHP 9-point scale

Intensity of relative importance	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two neighbouring scales

2.4 Step 4: By the Use of Questionnaire to Collect Data from Experts

After design of questionnaire, we take the expert's opinion by pair-wise comparison as mentioned in Table 1.

2.5 Step 5: Consistency Test

After pair wise comparison we checked the CI to ensure the working of model. The CI as follows [6].

$$CI = \frac{\lambda \max - n}{n - 1} \tag{1}$$

Notation—λmax is the maximum eigen value of the matrix and n is denoted as the number of factors. The Consistency Ratio (CR) [7]

$$CR = \frac{CI}{RI} \tag{2}$$

where RI is random index tabulated in Table 2 [4].

For the working of model, framing of questionnaire and optimization of the factors responsible, this all is ensured by the calculated value of CR. When the value of CR is below or nearly equal to 10 %, then the questionnaire is considered best fit and when the CR is above 10 %, the questionnaire should be revised as it might not be catering the possible factors.

2.6 Hierarchy of AHP Model

See Fig. 1.

2.7 Pair-Wise Comparison of Sub Factors Under First Main Factor (F1)

- F1A. Safety and health policy (SHP),
- F1B. Safety and health department/division/committee (SHD)

Table 2 Random Index. n is the number of factors

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

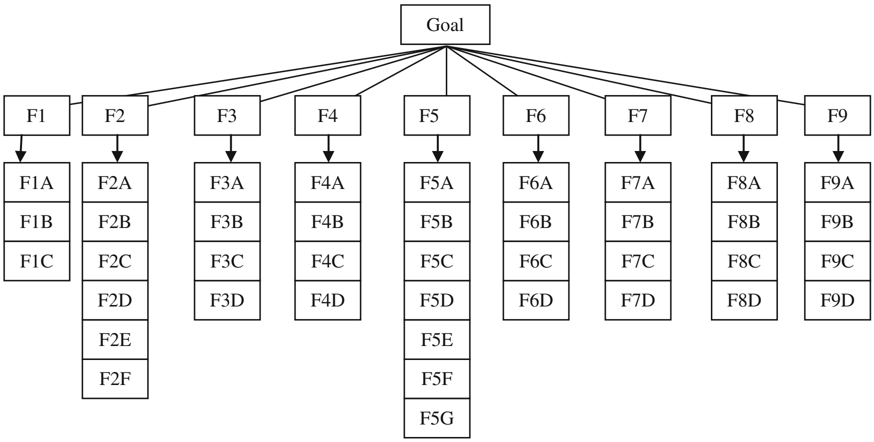

Fig. 1 Hierarchy of AHP model

Table 3 Pair-wise comparison

SHP	9	7	5	**3**	1	3	5	7	9	SHD
SHP	9	7	**5**	3	1	3	5	7	9	QSHS
SHD	9	7	5	**3**	1	3	5	7	9	QSHS

- F1C. Qualified safety and health specialists/officers/engineers (QSHS) (Table 3)

In this pair-wise comparison, experts have three sub-factors for comparison and made subjective judgement on respective factor they like best. In this pair-wise comparison we have matrix of the order 3. In this 3 order matrix, the diagonal position element is unity and the upper triangular portion of the matrix is entered as follows:

1. If the judgemental value from expert is towards the LHS of 1, then the same value has to be entered as shown below.
2. If the judgemental value from expert is towards the RHS of 1, then the reciprocal of the same value has to be entered as shown below [8].

$$A = \begin{array}{c} \\ \text{SHP} \\ \text{SHD} \\ \text{QSHS} \end{array} \begin{array}{c} \begin{array}{ccc} \text{SHP} & \text{SHD} & \text{QSHS} \end{array} \\ \begin{pmatrix} 1 & 3 & 5 \\ & 1 & 3 \\ & & 3 \end{pmatrix} \end{array}$$

After this matrix, we have to fill the matrix which is below the diagonal line, now for this matrix reciprocal values of the upper diagonal are used.

After doing this we get entire comparison matrix.

$$A = \begin{array}{c} \\ SHP \\ SHD \\ QSHS \end{array} \begin{array}{c} \begin{array}{ccc} SHP & SHD & QSHS \end{array} \\ \begin{pmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{pmatrix} \end{array}$$

It is to be remembered that the positive value must be entered in the matrix to avoid any type of miscalculation. After this, the eigen value and eigen vector is computed.

Finally, summation of every column of the whole reciprocal matrix is performed.

$$A = \begin{array}{c} \\ SHP \\ SHD \\ QSHS \\ \\ \end{array} \begin{array}{c} \begin{array}{ccc} SHP & SHD & QSHS \end{array} \\ \begin{pmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{pmatrix} \\ \begin{array}{ccc} 23/15 & 13/3 & 9 \end{array} \end{array}$$

After this each element of the matrix should be divided by the total value of the column and normalized relative weight is computed. Sum of every column should be 1 to ensure the performance of the result.

$$A = \begin{array}{c} SHP \\ SHD \\ QSHS \\ Sum \end{array} \begin{array}{c} \begin{pmatrix} 15/23 & 9/13 & 5/9 \\ 5/23 & 3/13 & 3/9 \\ 3/23 & 1/13 & 1/9 \end{pmatrix} \\ \begin{array}{ccc} 1 & 1 & 1 \end{array} \end{array}$$

Normalized principal Eigen vector is calculated by arithmetic mean of respective rows.

$$W = 1/3 \begin{pmatrix} 15/23 & 9/13 & 5/9 \\ 5/23 & 3/13 & 3/9 \\ 2/23 & 1/13 & 1/9 \end{pmatrix} = \begin{pmatrix} 0.637 \\ 0.258 \\ 0.105 \end{pmatrix}$$

Priority vector is also known as the normalized principal Eigen vector. Since priority vector is normalized, so that the sum of all elements in the priority vector is 1. Relative weight has shown by the priority vector. In our case SHP is 63.7 %, SHD is 25.8 % and QSHS is 10.5 %. Expert's appreciable factor SHP is ranked 1st, SHD as 2nd and QSHS as 3rd. This study computes the ranking of factors. Relative weight is also a ratio scale. From this analysis, It is shown that SHP is 2.46 times more than SHD and SHP is 6.06 times more than QSHS.

We have to check consistency of expert's preferred factor apart from the relative weight. For that, we need principle Eigen value. We can obtain Principle Eigen valve from the sum total of multiplication of each element of eigen vector and the sum total of columns of all reciprocal matrix.

$$\lambda_{\max} = 23/15(0.637) + 13/3(0.258) + 9(0.105) = 3.039$$

Now, after Eigen value we have to find out fist Consistency Index(CI) and secondly Consistency Ratio (CR).

Consistency Index (CI)

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}$$

We have $\lambda_{\max}$ = 3.039 and three comparisons (n = 3),

Therefore consistency index is CI = 0.0195.

After consistency index we have to find (CR) i.e.

$$CR = \mathrm{CI}/\mathrm{RI}$$

Value for RI taken from Table 2 [2]. Then we have

$$\mathrm{CR} = 0.0195/0.58 = 3.3\,\%$$

Now 3.3 % < 10 %, thus expert's personal assessment about factors preference shows consistent. So in this way we can find out Eigen values and consistency ration for every factor and sub-factor. Consistent ratio in all the comparison is less than 10 %. The final result is shown in Table 4.

Table 4 The final results

Main factors	Sub-factors	Eigen vector (%)	Priority
Organizational attributes	Requirement of written Safety and health policy	63.7	1
Eigen vector = 14.0 %	Requirement of safety and health department/division/committee	25.8	2
	Qualified safety and health specialists/officers/engineers	10.5	3
Occupational Safety and Health	Facility for periodical medical examination	12.8	3
Services/documentation	Provision of Health/medical insurance	20.9	2
Eigen vector = 7.6 %	Provision of first aid services (box/doctor/physician)	48.2	1
	Documentation of safety and health program	6.8	5
	Records of accident and injury	7.2	4
	Need of absenteeism records	4.1	6

(continued)

Table 4 (continued)

Main factors	Sub-factors	Eigen vector (%)	Priority
Workplace Layout and Housekeeping	Adequate and smooth material flow	6.6	4
Eigen vector = 2.5 %	Safe and smooth production line layout	25.7	2
	Neat and clean floors, walls and ceilings	53.0	1
	Provision of proper disposal of waste	14.6	3
Equipment and hand tools safety and machine guarding	Need of periodic inspection	15.9	3
	Availability of proper machine guards	39.9	1
Eigen vector = 10.1 %	Proper space for hand tools storage	8.1	4
	Provision of training programs for hand tools and equipment use	36.0	2
Fire Prevention, fire fighting and electrical safety	Provision of fire detection system	5.4	6
	Provision of alarm system	9.6	5
	Need of fire fighting training and emergency plan	11.3	4
Eigen vector = 22.8 %	Need of extinguishing system	35.2	1
	Provision of emergency Exit and exit signs	3.3	7
	Covered electrical cables	22.2	2
	Proper electrical wiring	13.0	3
Material handling and storage	Provision of safe and proper type of truck	7.5	4
	Safe cranes and conveyors	50.8	1
Eigen vector = 4.6 %	Need of inspection schedule	26.5	2
	Provision of safe storage and stacking	15.1	3
Occupational exposures	Skin contact with liquid chemicals	50.8	1
Eigen vector = 4.7 %	Exposure to noise and vibration	26.5	2
	Exposure to high thermal conditions	15.1	3
	Monitoring of occupational exposures	7.5	4
Personal protective equipment (PPE)	Adequate provision of PPE	57.0	1
	Proper types and use of PPE	16.8	3
Eigen vector = 30.6 %	Proper maintenance of PPE	7.5	4
	Adequate training on PPE usage	18.7	2
Hygiene factors	Availability of safe drinking water	26.8	2

(continued)

Table 4 (continued)

Main factors	Sub-factors	Eigen vector (%)	Priority
Eigen vector = 3.0 %	Availability of clean bathrooms, toilets, urinals	8.0	4
	Availability of rest area, canteen and closets	8.1	3
	Provision of proper lighting and ventilation	57.1	1

3 Result

See Table 4.

4 Conclusion

In this paper the factor related to safety of worker's for iron and steel manufacturing industries have been examined in detail with AHP expert decision making system. According to expert feedback the very first priority regarding the safety is personal protective equipments after that fire prevention system, organizational attributes and so on. Weight age of each sub-factor is shown in the given the above table. It is recommended that PPE should be provided to the workers in manufacturing industries for safe work environment. This confirmed how AHP methodology can assist in the selection of safety parameters for manufacturing industries.

References

1. Saaty, Thomas L.: How to make a decision: the analytic hierarchy process. J. Oper. Res. **48**, 9–26 (1990)
2. Traintaphyllou, E.: Using the analytic hierarchy process for decision making in engineering applications: some challenges. J. Ind. Eng. **2**, 35–44 (1995)
3. Viswanadhan, K.G.: How to get reponses for multi-criteria decisions in engineering education—an AHP based approach for selection of measuring instrument. Saf. Sci. **56**, 87–91 (2009)
4. Yorio, P.L., Wachter, J.K.: The impact of human performance focused safety and health management practices on injury and illness rates: do size and industry matter. Saf. Sci. **62**, 157–167 (2014)
5. Mudavanhu, N., Zhou, T., Dzomba, P.: An assessment of small and medium enterprise owners' occupational safety and health efforts: the case of Southerton, Harare, Zimbabwe. J. Sci. Res. Rep. **4**(3), 407–418 (2013)
6. Shikdar, A.A., Al-Araimi, S.A.: Ergonomic conditions in small manufacturing industries. Sci. Technol. **6**, 61–70 (2001)

7. Shikdar, A.A., Sawaqed, N.M.: Worker productivity, and occupational health and safety issues in selected industries. Comput. Ind. Eng. **45**, 563–572 (2003)
8. Tiwary, G., Gangopadhyay P.K. A review on the occupational health and social security of unorganized workers in the construction industry. Indian J. Occup. Environ. Med. **15** (2011)

Relationship Between Exposure to Xylenes and Ethylbenzene Expressed Either in Concentration in Air and Amount of Their Metabolites Excreted in the Urine

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Abstract The urinary excretion of methylhippurics, mandelic and phenylglyoxylic acids was studied in histopathological technicians (102 subjects; 14 men and 88 women) exposed to Xylol (xylenes and ethylbenzene). From each worker, the urine sample was analyzed by HPLC-UV and xylene isomers and ethylbenzene in air samples were determined by GC-FID. The mean values of time-weighted average (TWA) exposure to xylol in the Pathological Anatomy Lab were 119 ± 49 p.p.m. (mean ± S.D.) with a range 50–190 p.p.m. for xylene and 131 ± 50 p.p.m. with a range 68–200 p.p.m. for ethylbenzene. There was a linear correlation between the

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8-h time weighted average exposure either to xylene isomers or ethylbenzene and the concentrations of methylhippuric acids (MHA) isomers or mandelic (MA) and phenylglyoxylic acids (PGA) in urine. The r^2 value for the regression equation between total xylenes exposure and total MHA was 0.471 (positive correlation) and for the regression equation between ethylbenzene and MA + PGA was 0.950 (high positive correlation). No difference was found in the correlation between quantitative exposure and excretion in the three xylene isomers. Both MHA and MA + PGA can be used as indicators of commercial xylol exposures. So, the determination of the concentration of these metabolites in post-shift urine provides an effective means of estimating and monitoring human exposure to Xylol. Extrapolation of data from this study predicted a MHA concentration in post-shift urine of 1.27 g/g creatinine after exposure to a TWA of 100 p.p.m. of total xylenes and 0.7 g/g creatinine of MA + PGA after exposure to a TWA of 100 p.p.m. of ethylbenzene.

Keywords Xylene · Ethylbenzene · Risk occupational exposure · BEI

1 Introduction

Xylol (commercial or mixed xylenes) is an aromatic hydrocarbon widely used in industry and medical technology as a solvent. Ethylbenzene is commonly present in mixed xylenes; in fact, the technical product contains approximately 40 % m-xylene and approximately 20 % each of o-xylene, p-xylene, and ethylbenzene (up to 25 % of in technical grades of mixed xylenes) [1, 2]. In Pathological Anatomy Labs, xylol is the most widely used solvent in various tasks, like tissue cleaning process, staining, cover slipping or deparaffinization of tissue. These substances may present a hazard as the result of contact with the body or absorption into the body, through the skin, by ingestion or inhalation. Histopathological technicians who routinely come in contact with xylol-contaminated solvents in the workplace are the population most likely to be exposed to high levels of this solvent [3, 4].

Air concentrations of volatile organic compounds, as xylene and ethylbenzene, are typically at parts per million (p.p.m.) levels in the workplace, they rarely exceed parts per billion (p.p.b.) levels in the general environment [5]. Several studies have been conducted on the airborne concentrations of xylenes and ethylbenzene in some workplaces [6–21]. The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended 100 p.p.m. as the threshold limit value for occupational exposures to xylene and ethylbenzene in workplace air. Similar values have been used as standards or guidelines in many countries [22]. Health and safety authorities in most countries, including Portugal, recommend for xylene a threshold limit value (TLV) of 50 p.p.m. and for Ethylbenzene of 100 p.p.m. the working environment [23].

Biological measurements (biomarkers) have been considered as alternatives to air sampling for assessing chemical exposures because they account for all possible exposure pathways (e.g., inhalation, ingestion, and dermal uptake) and individual susceptibility [24–27].

Xylene vapour is absorbed rapidly from the lungs, and xylene liquid and vapour are absorbed slowly through the skin. Of the xylene absorbed, about 95 % is metabolized in the liver primarily by the microsomal system of mixed-function oxidases (Cyt-P450) notably that of CYP2B1 and CYP2E1, as well as the activities of UDP-glucuronosyltransferase, DT-diaphorase and glutathione S-transferase [28–33]. This substance is metabolized primarily by oxidation to the methylbenzyl alcohols, followed by further oxidation to the corresponding methylbenzoic acids (toluic acids). These can be conjugated with glycine to form methylhippurates, or with UDPglucuronate to form acyl glucuronides [34–36]. 70–80 % of metabolites are excreted in the urine within 24 h [34]. However, the many variables which affect the absorption, metabolism and clearance of xylene include exercise, alcohol intake, cigarette smoking, co-exposure to other solvents, gender, and gastrointestinal, hepatic and renal pathology [33]. Methylhippuric acid (MHA), the main urinary metabolite, is used as dose indicator in biological monitoring of exposed workers to xylene [37–39]. When workers are exposed to xylenes at low exposure levels (up to 20 ppm), the end-of-shift urinary excretion of methylhippurates is a good indication of exposure because these methylhippurates are normally not present in urine [40, 41].

Ethylbenzene is rapidly and efficiently absorbed in humans via the inhalation [42]. Most of the metabolism of ethylbenzene is governed by the oxidation of the side chain [43]. Engstrom assumed 60 % absorption of inhaled ethylbenzene and calculated that 83 % of the 300 ppm dose was excreted in the urine within four hours of exposure. The principal metabolites were 1-phenylethanol, mandelic acid, and benzoic acid. Metabolism proceeded mainly through oxidation of the ethyl moiety with ring oxidation appearing to play a minor role. Other metabolites included acetophenone, ω-hydroxyacetophenone, phenylglyoxal, and 1-phenyl-1, 2-ethandiol. Ring oxidation products include p-hydroxy- and m-hydroxyacetophenone, 2-ethyl- and 4-ethylphenol. With the exception of 4-hydroxyacetophenone all these other metabolites were seen only in trace amounts [44]. The oxidation of ethylbenzene to 1-phenylethanol by human liver microsomes and recombinant human cytochrome P450s was investigated by Sams et al. and this, authors demonstrated, that CYP2E1 is the major enzyme responsible for high-affinity side chain hydroxylation of ethylbenzene in human liver microsomes [20, 29, 45]. Activity of this enzyme in the population is highly variable due to induction or inhibition by physiological factors, chemicals in the diet or some pharmaceuticals. This variability can be incorporated into the risk assessment process to improve the setting of occupational exposure limits and guidance values for biological monitoring [45]. Mandelic (MA) and phenylglyoxylic acids (PGA), the main urinary metabolites, are used as dose indicators in biological monitoring of exposed workers to ethylbenzene [46].

The American Conference of Governmental Industrial Hygienists has recommended an upper limit for these indicators, called a biological exposure index (BEI), of 1.5 g MHA/g creatinine measured from an end of shift urine sample after a TWA exposure to 100 p.p.m. and 0.7 g MA, and PGA/ g creatinine measured from an end of shift at the end of the workweek urine sample after a TWA exposure to 100 p.p.m. [46]. The results are expressed per gram of creatinine to allow for spot urine sampling and partially standardize for urinary dilution. There have been several relatively large field studies in which correlations between occupational xylene exposure and urinary MHA excretion have been observed [41, 47, 48]. The majority of biological tests rely on the analysis of chemical substances in blood, urine or expired air. Urine is easy to collect, even in large quantities, and the procedure is non-invasive. This biological medium is suitable for determining water-soluble metabolites of organic chemicals in individuals exposed to chemicals with short biological half times, or with fluctuating concentrations in the air, the level of metabolite in urine samples collected at the end of shift. It is commonly a better indicator of the average exposure during the shift compared to the level of the substance in exhaled air or blood [49]. For some substances, such as xylene and ethylbenzene, the use of urinary creatinine and specific density is recommended to correct chemical concentrations in urine [2]. The renal excretion is regulated by three mechanisms: glomerular filtration, tubular secretion and tubular reabsorption [50]. Changes of any of these mechanisms may have a significant influence on the elimination of a chemical.

The objective of this study was to investigate the correlation between level TWA atmospheric xylene and ethylbenzene exposure (p.p.m.) and urinary MHA and MA and PGA, respectively expressed per gram of creatinine.

2 Materials and Methods

2.1 Subjects and Exposure

Histopathological technicians were engaged in Pathological Anatomy Labs in various tasks, like tissue cleaning process, staining, cover slipping or deparaffinization of tissue, and were exposed to xylol (Xylene and Ethylbenzene). Air sample collection by personal diffusive sampling and collection of urine samples at the end of the shift and at the end of the workweek from 102 exposed workers (14 men and 88 women) were conducted on the same day (the fourth or fifth day of a working week). There were no significant differences in ages between the two sexes.

2.2 Personal Monitoring of Exposure

Measurements of time-weighted average (8-h TWA) exposure to Xylol (Xylene and Ethylbenzene) were made using SKC standard model—224-44EX passive personal air samplers. The workers were monitored on a Friday for 4 h in the morning and 4 h in the afternoon. All air samples were refrigerated at 4 °C prior to solvent extraction. Analysis, after deadsorption with carbon sulphide, was carried by gas chromatography according to the NIOSH method 1501 [51].

2.3 Urinary Metabolite Analysis

Urine samples were collected near the end of an eight hour shift. Samples were refrigerated immediately, transferred to the analytical laboratory, and kept frozen until analysed. The three isomers of methylhippuric acids (MHAs), Mandelic (MA) and phenylglyoxylic acids (PGA) and creatinine were determined by HPLC-UV [52]. The HA and MHA concentrations were expressed corrected for creatinine concentration. The concentrations in the urine of non-exposed workers were cited from a previous publication [47, 53, 54].

2.4 Statistical Analyses

Unweighted statistical analyses were performed with SPSS 21. We used simple linear regression models to investigate relationships between air and urinary metabolites. The derived R2 value was used to evaluate the strengths of associations in regression models. All percentages and results from regression models represent population-weighted values. Student's test and the X2 test were used when necessary.

3 Results

3.1 Exposure to Xylenes and Ethylbenzene

The mean values of time-weighted average (TWA) exposure to xylol in the Pathological Anatomy Lab were 119 ± 49 p.p.m. (mean ± S.D.) with a range 50–190 p.p.m. for xylene and 131 ± 50 p.p.m with a range 68–200 p.p.m) for ethylbenzene. Among the three xylene isomers, m-xylene was the most abundant and accounted for about half of the xylenes.

3.2 *Urinary Metabolite Concentrations Before and After Exposure to Xylenes and Ethylbenzene*

Methylhippuric, mandelic and phenylglyoxylic acids concentrations were determined in the urine of 102 exposed histopathological technicians, and the correlation of the concentrations with the time weighted average intensity of exposure was calculated for total at the three xylene isomers and ethylbenzene respectively.

We found significant work-shift-related differences in MHA, being 0.00 ± 0.00 for pre-shift and 1.47 ± 0.71 for end-of-shift (t = 20.755, $p < 0.05$); and significant work-shift-related differences in MA + PGA, being 0.33 ± 0.14 for pre-shift and 1.65 ± 1.16 for end-of-shift (t = 12.866, $p < 0.05$) (Table 1).

The correlations between total post-shift MHA and total TWA xylene exposure and between post-shift MA + PGA and TWA ethylbenzene are shown in Fig. 1.

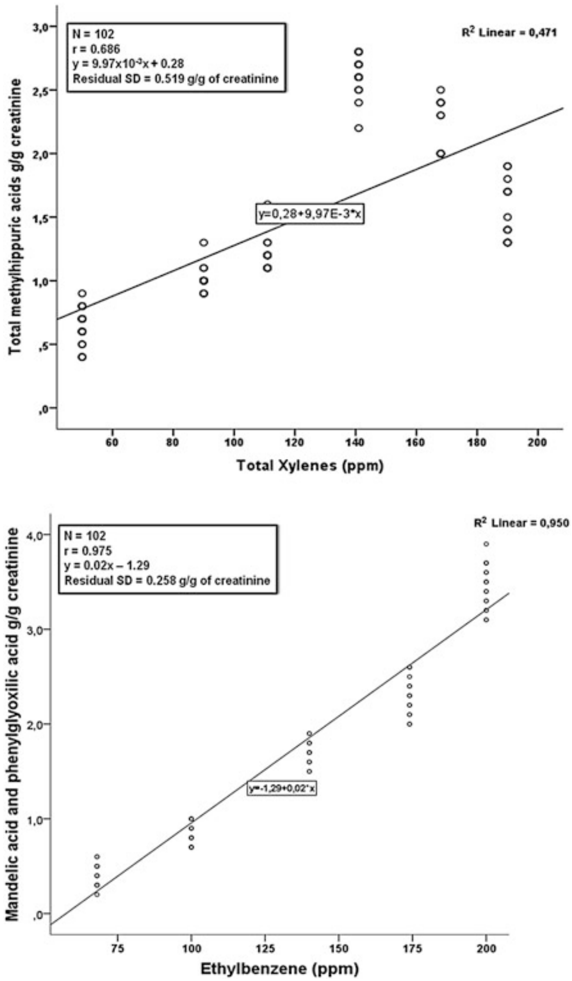
The r^2 values for the regression model between total MHA obtained from the post-shift urine and atmospheric TWA xylene exposure were 0.471. The r^2 values for the regression model between total MA + PGA obtained from the post-shift urine and atmospheric TWA ethylbenzene exposure were 0.950.

Extrapolation of data from this study predicted a MHA concentration in post-shift urine of 1.27 g/g creatinine after exposure to a TWA of 100 p.p.m. of total xylenes and 0.7 g/g creatinine of MA + PGA after exposure to a TWA of 100 p.p.m. of ethylbenzene.

Table 1 Concentrations of metabolites of xylene (MHAs) and ethylbenzene (MA + PGA) in the urinary samples collected at the pre-shift and post-shift

	Methylhippuric acids (g/g creatinine)		Mandelic acid + phenylglyoxylic acid (g/g creatinine)	
	Pre-shift	End-of-shift	Pre-shift	End-of-shift
Arithmetic mean	0.0	1.5	0.3	1.7
Standard deviation	0.0	0.7	0.1	1.1
Median	0.0	1.3	0.3	1.5
Minimum	0.0	0.4	0.0	0.3
Maximum	0.0	2.8	0.9	3.9
BEI	–	1.5	–	0.7

Fig. 1 Correlations between exposure indices (total xylenes levels in air and urinary MHA from a post-shift urine sample; and ethylbenzene levels in air and urinary MA + PGA from a post-shift urine sample)



4 Discussion

Our study has shown a linear relation between the concentrations of methylhippuric acids and mandelic and phenylglyoxylic acids in urine collected at the end of a workshift and the time weighted average intensity of exposure to xylenes and ethylbenzene during an 8 h workshift when the two solvents were inhaled in combination.

A total xylenes and ethylbenzene were detected at high levels in indoor air, above the thresholds established by Health and safety authorities of Portugal [23].

The linear correlation between TWA atmospheric levels and metabolites was comparable with that found in other studies [55].

In occupational exposure to total of xylene, the biological indicator values, equivalent to 100 p.p.m. TWA exposure and determined by extrapolation for post-shift MHA level models, were 1.27 g/g creatinine, which is slightly less than the 1.5 g MHA/g creatinine measured from an end of shift urine sample by the ACGIH [46] comparable with that found in other studies [47, 56] and low in other study [55].

From occupational exposure to ethylbenzene the biological indicator values, equivalent to 100 p.p.m. TWA exposure and determined by extrapolation for post-shift MA + PGA level models, were 0.71 g/g creatinine, which is the same as the 0.7 g MA + PGA/g creatinine measured from an end of shift urine sample by the ACGIH [46].

If deemed a threshold limit value (50 p.p.m.) recommended for the xylene by Health and Safety Authorities of Portugal [23], the biological indicator value derived from this study was 0.7 g MHA/g creatinine. We are corroborating Jacobson and McLean when we say caution should be exercised when interpreting large extrapolations such as these as extrapolation is reliant on both a good fit for the regression model and linearity of the biological response [56].

The combined exposure did not result in a mutual inhibition of the metabolism of xylenes and ethylbenzene, contrary to that observed in other studies [55, 57], so no sign of alteration in the urinary metabolite patterns of either xylenes or ethylbenzene could be detected.

5 Conclusion

Occupational exposures at 140 p.p.m., both methylhippuric acids and mandelic and phenylglyoxylic acids can be used as indicators of commercial xylol exposures. So, monitoring xylol exposure in workers for the urinary biomarkers using the analytical methods here proposed is simple, adequate and useful.

Nevertheless, regular monitoring of environmental levels of xylene and ethylbenzene in the workplace requires the implementation of appropriate engineering controls, as well as the disclosure of a culture of best practices and its adherence by the laboratory staff, to allow safe use of xylol and to minimize the risk of occurrence of adverse effects.

References

1. Fishbein L.: Xylenes: uses, occurrence and exposure: environmental carcinogens: methods of analysis and exposure measurement. In: Fishbein LO'Neill I.K. (ed.) Benzene and alkylated benzenes, pp. 109–120. World Health Organization, International Agency for Research on Cancer, Lyon, France (1988)
2. American Conference of Governmental Industrial Hygienists: Documentation of the Threshold Limits Values and Biological and Indices. 7th ed. American Conference of Governmental Industrial Hygienists, Cincinnati, OH (2013)
3. Kandyala, R., Raghavendra, S.C., Rajasekharan, S.T.: Xylene: an overview of its health hazards and preventive measures. J Oral Maxil Pathol. **14**(1), 1–5 (2010)
4. Dias-Teixeira M., Rangel R., Dias-Teixeira A., Domingues V., et al.: Risk of exposure to xylene in a pathologic anatomy laboratory: occupational safety and hygiene. In: Arezes P.M., et al. (eds.) Taylor and Francis Group, London (2013)
5. Rappaport, S.M., Kupper, L.L.: Variability of environmental exposures to volatile organic compounds. J. Exp. Anal. Environ. Epidemiol. **14**(1), 92–107 (2004)
6. Periago, J.F., Prado, C.: Evolution of occupational exposure to environmental levels of aromatic hydrocarbons in service stations. Ann. Occup. Hyg. **49**(3), 233–240 (2005)
7. De Palma, G., Poli, D., Manini, P., Andreoli, R., et al.: Environmental and biological monitoring of exposure to monoaromatic hydrocarbons and to methyl tert-butyl ether in a group of petrol station workers. G Ital di Med Lav Ergon. **33**(3 Suppl), 49–52 (2011)
8. Kongtip, P., Anthayanon, T., Yoosook, W., Onchoi, C.: Exposure to particulate matter, CO_2, CO, VOCs among bus drivers in Bangkok. J. Med. Assoc. Thai. **95**(6 Suppl), 169–178 (2012)
9. Bieniek, G., Łusiak, A.: Occupational exposure to aromatic hydrocarbons and polycyclic aromatic hydrocarbons at a coke plant. Ann. Occup Hyg. **56**(7), 796–807 (2012)
10. Bieniek, G.: Aromatic and polycyclic hydrocarbons in air and their urinary metabolites in coke plant workers. Am. J. Ind. Med. **34**(5), 445–454 (1998)
11. Bieniek, G., Kurkiewicz, S., Wilczok, T., Klimek, K., et al.: Occupational exposure to aromatic hydrocarbons at a coke plant: Part II. Exposure assessment of volatile organic compounds. J. Occup. Health. **46**(3), 181–186 (2004)
12. Ciarrocca, M., Tomei, G., Fiaschetti, M., Caciari, T., et al.: Assessment of occupational exposure to benzene, toluene and xylenes in urban and rural female workers. Chemosphere **87** (7), 812–819 (2012)
13. Vyskocil, A., Truchon, G., Leroux, T., Lemay, F., et al.: A weight of evidence approach for the assessment of the ototoxic potential of industrial chemicals. Toxicol. Ind. Health **28**(9), 796–819 (2012)
14. DeHate, R.B., Johnson, G.T., Harbison, R.D.: Risk characterization of vapor intrusion in former manufactured gas plant sites. Regul. Toxicol. Pharmacol. **59**(2), 353–359 (2011)
15. Smith, K.W., Proctor, S.P., Ozonoff, A., McClean, M.D.: Inhalation exposure to jet fuel (JP8) among U.S. Air Force personnel. J. Occup. Environ. Hyg. **7**(10), 563–572 (2010)
16. Chmielowiec-Korzeniowska, A.: The concentration of volatile organic compounds (VOCs) in pig farm air. Ann. Agric. Environ. Med. **16**(2), 249–256 (2009)
17. Desogus, G.F.: The environmental monitoring of the exposure to chemical contamination in operating rooms. G Ital Med Lav Ergon. **29**(3 Suppl), 417–418 (2007)
18. Hein, M.J., Waters, M.A., van Wijngaarden, E., Deddens, J.A., et al.: Issues when modeling benzene, toluene, and xylene exposures using a literature database. J. Occup. Environ. Hyg. **5** (1), 36–47 (2008)
19. De Palma, G., Poli, D., Manini, P., Andreoli, R., et al.: Biomarkers of exposure to aromatic hydrocarbons and methyl tert-butyl ether in petrol station workers. Biomarkers **14**(4), 343–351 (2012)
20. Jiménez-Garza, O., Márquez-Gamiño, S., Albores, A., Caudillo-Cisneros, C., et al.: CYP2E1 phenotype in Mexican workers occupationally exposed to low levels of toluene. Toxicol. Lett. **210**(2), 254–263 (2012)

21. Engström, K., Härkönen, H., Kalliokoski, P., Rantanen, J.: Urinary mandelic acid concentration after occupational exposure to styrene and its use as a biological exposure test. Scand. J. Work Environ. Health **2**(1), 21–26 (1976)
22. Paustenbach D.J.: Occupational exposure limits in ILO encyclopedia of occupational health and safety. In: Herrick, R.F. (ed) International Labor Organization, Geneva (2011)
23. Ministério da Economia e do Emprego: Threshold limit value for occupational exposures Diário da República 1ª Série. pp. 580–589. (2012)
24. Mutti, A.: Biological monitoring in occupational and environmental toxicology. Toxicol. Lett. **108**(2–3), 77–89 (1999)
25. Sabbioni, G., Jones, C.R.: Biomonitoring of arylamines and nitroarenes. Biomarkers **7**(5), 347–421 (2002)
26. Lin, Y.S., Kupper, L.L., Rappaport, S.M.: Air samples versus biomarkers for epidemiology. Occup. Environ. Med. **62**(11), 750–760 (2005)
27. Pirkle, J.L., Sampson, E.J., Needham, L.L., Patterson, D.G., et al.: Using biological monitoring to assess human exposure to priority toxicants. Environ. Health Perspect. **103**(3 Suppl), 45–48 (1995)
28. Elovaara, E., Engström, K., Häyri, L., Hase, T., et al.: Metabolism of antipyrine and m-xylene in rats after prolonged pretreatment with xylene alone or xylene with ethanol, phenobarbital or 3-methylcholanthrene. Xenobiotica **19**(9), 945–960 (1989)
29. Gut, I., Terelius, Y., Frantík, E., Linhart, I., et al.: Exposure to various benzene derivatives differently induces cytochromes P450 2B1 and P450 2E1 in rat liver. Arch. Toxicol. **67**(4), 237–243 (1993)
30. Raunio, H., Liira, J., Elovaara, E., Riihimäki, V., et al.: Cytochrome P450 isozyme induction by methyl ethyl ketone and m-xylene in rat liver. Toxicol. Appl. Pharmacol. **103**(1), 175–179 (1990)
31. Savolainen, H., Vainio, H., Helojoki, M., Elovaara, E.: Biochemical and toxicological effects of short-term intermittent xylene inhalation exposure and combined ethanol intake. Arch. Toxicol. **41**, 195–205 (1978)
32. Toftgård, R., Halpert, J., Gustafsson, J.A.: Xylene induces a cytochrome P-450 isoenzyme in rat liver similar to the major isozyme induced by phenobarbital. Mol. Pharmacol. **23**(1), 265–271 (1983)
33. Lieber, C.S.: Cytochrome P-4502E1: its physiological and pathological role. Physiol. Rev. **77**(2), 517–544 (1997)
34. Langman, R.J.: Xylene: its toxicity, measurement of exposure levels, absorption, metabolism and clearance. Pathology **26**, 301–309 (1994)
35. Low, L.K., Meeks, J.R., Mackerer, C.R.: Health effects of the alkylbenzenes. II. Xylenes. Toxicol. Ind. Health **5**(1), 85–105 (1989)
36. Miller, M.J., Edwards, J.W.: Possible preferential metabolism of xylene isomers following occupational exposure to mixed xylenes. Int. Arch. Occup. Environ. Health **72**(2), 89–97 (1999)
37. Sugihara, R., Ogata, M.: Quantitation of urinary m- and p-methylhippuric acids as indices of m- and p-xylene exposure. Int. Arch. Occup. Environ. Health **41**(4), 281–286 (1978)
38. Młynarczyk, W., Slusarek, D.: Use of methylhippuric test in industry for assessing exposure to xylene. Med. Pr. **32**(6), 445–449 (1981)
39. Lowry, L.K.: Biological exposure index as a complement to the TLV. J Occup Med **28**(8), 578–582 (1986)
40. Jonai, H., Sato, M.: Exposure indices for painters exposed to toluene and xylene at low concentrations. Ind. Health **26**(3), 197–202 (1988)
41. Kawai, T., Mizunuma, K., Yasugi, T., Horiguchi, S., et al.: Urinary methylhippuric acid isomer levels after occupational exposure to a xylene mixture. Int. Arch. Occup. Environ. Health **63**(1), 69–75 (1991)
42. Agency for Toxic Substances and Disease Registry (ATSDR). http://www.atsdr.cdc.gov/toxprofiles/tp110-p.pdf

43. Fishbein, L.: An overview of environmental and toxicological aspects of aromatic hydrocarbons IV. Ethylbenzene. Sci. Total Environ. **44**(3), 269–287 (1985)
44. Engstrom, K.M.: Metabolism of inhaled ethylbenzene in rats. Scand J Work Env Hea. **10**(2), 83–87 (1984)
45. Sams, C., Loizou, G.D., Cocker, J., Lennard, M.S.: Metabolism of ethylbenzene by human liver microsomes and recombinant human cytochrome P450s (CYP). Toxicol. Lett. **147**(3), 25–260 (2004)
46. American Conference of Governmental Industrial Hygienists: TLVs and BEIs, Threshold Limit Values for Chemical Substances and Physical Agents. 7th ed. American Conference of Governmental Industrial Hygienists, Cincinnati, OH (2013)
47. Inoue, O., Seiji, K., Kawai, T., Watanabe, T., et al.: Excretion of methylhippuric acids in urine of workers exposed to a xylene mixture: comparison among three xylene isomers and toluene. Int. Arch. Occup. Environ. Health **64**(7), 533–539 (1993)
48. Huang, M.Y., Jin, C., Liu, Y.T., Li, B.H., et al.: Exposure of workers to a mixture of toluene and xylenes I. Metabolism. Occup. Environ. Med. **51**(1), 42–46 (1994)
49. Heinrich-Ramm R., Jakubowski M., Heinzow B., Molin Christensen J., et al.: Biological monitoring for exposure to volatile organic compounds. Pure Appl. Chem. **72**(3), 385–436 (2000)
50. Subcommittee on Biologic Markers in Urinary Toxicology, Board on Environmental Studies and Toxicology, Commission on Life Sciences National Research Council: Biologic Markers in Urinary Toxicology. The National Academies Press, Washington (1995)
51. Pendergrass S.M.: Hydrocarbons, aromatic, national institute for occupational safety and health, editor manual of analytical methods (NMAM) (2003)
52. Dias-Teixeira A., Dias-Teixeira M., Rangel R., Tarelho S., et al.: Development and validation of HPLC-UV method to determine creatinine and metabolites of xylene in urine: Acta Medicinae Legalis et Socialis, In: Vieira D.N., et al. (ed). Coimbra University Press, Coimbra (2010)
53. Vanroosmalen, P.B., Drummond, I.: Simultaneous determination by gas-chromatography of major metabolites in urine of toluene, xylenes and styrene. Br. J. Ind. Med. **35**(1), 56–60 (1978)
54. Poláková, M., Krajcovicová, Z., Melus, V., Stefkovicová, M., et al.: Study of urinary concentrations of mandelic acid in employees exposed to styrene. Cent. Eur. J. Public Health **20**(3), 226–232 (2012)
55. Jang, J.Y., Droz, P.O., Kim, S.: Biological monitoring of workers exposed to ethylbenzene and co-exposed to xylene. Int. Arch. Occup. Environ. Health **74**(1), 31–37 (2001)
56. Jacobson, G.A., McClean, S.: Biological monitoring of low level occupational xylene exposure and the role of recent exposure. Ann. Occup. Hyg. **47**(4), 331–336 (2003)
57. Engström, K., Riihimäki, V., Laine, A.: Urinary disposition of ethylbenzene and m-xylene in man following separate and combined exposure. Int. Arch. Occup. Environ. Health **54**(4), 355–363 (1984)

Risk of Exposure to Formaldehyde in Pathological Anatomy Laboratories

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Abstract This work described an analysis study of the risk of occupational exposure to formaldehyde in pathology labs of university. One hundred thirty-two air samples of the breathing zone were collected in the activity labs (macroscopic examination of surgical pieces or biopsy, tissue processing and chemical waste disposal), during five weeks. To quantify the formaldehyde present in the ambient of histology laboratory, NIOSH 2016 method was used, for this matrix, based on the formaldehyde derivatization reaction in tubes acidified with 2,4-DNPH was optimized. The geometric mean ambient concentrations of formaldehyde, among the activities under investigation, were between 0.7 and 3.7 ppm indicating high levels of the substance during the week. It was verified that 100 % of the students had exposures above the exposure limit, i.e., greater than a maximum concentration (MC) of 0.3 ppm (NP 1796: 2007).

Keywords Formaldehyde · Pathology labs · Histology · Occupational exposure

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1 Introduction

Medical laboratory (ML) jobs in general and histology tasks in particular are not risk-free activities because of the wide range of chemical, mechanical, biologic, and environmental hazards the histotech (HT) is exposed to, all of which can pose immediate or long-term health consequences [1].

In many laboratories as in the Pathology during routine histology procedures Formaldehyde (HCHO) plays an important part as based reagents. The history of formaldehyde, as an industrial and laboratory reagent, is well presented in many publications [2].

HCHO, a colorless gas, is rarely found in its original state because it has a short half-life in the air due to its decomposition in light. Formaldehyde (methanal) is manufactured as a product of catalytic oxidation of methanol (CHOH). The concentrated water solution (37–40 %) of formaldehyde is called Formalin by its German trade name. The anatomical pathology practice uses Neutral Buffered Formalin (NBF) to prevent acidification due to formaldehyde's tendency to be oxidized into formic acid. The buffer solution also enhances the formation of monomeric formaldehyde (methylene hydrate), as a fixation reagent. The volume of fixative must be 15–20 times over the sample volume and the tissue must be completely immersed in the solution [3].

The possible routes of exposure to formaldehyde are inhalation (major route), ingestion and dermal absorption. Almost no data are available in the literature on dermal exposure [4].

There are two aspects of formaldehyde exposure: local at the place of the initial contact (respiratory and digestive tracts, skin, etc.) and general as a result of absorption.

Short term exposure to formaldehyde is known to cause irritation of the eyes, skin, and mucous membranes of the upper respiratory tract [5]. Animal studies indicate that high concentrations can injure the lungs and other organs of the body [5]. In polluted atmospheres, formaldehyde may contribute to eye irritation and unpleasant odors that are common annoyances.

Acute and chronic health effects of formaldehyde vary depending on the individual. The typical threshold for development of acute symptoms due to inhaled formaldehyde is 800 ppb; however, sensitive individuals have reported symptoms at formaldehyde levels around 100 ppb [6, 7].

The common symptoms from acute exposure to formaldehyde manifest as irritation of the throat, nose, eyes, and skin. This upper respiratory tract irritation can potentially exacerbate asthma symptoms and other respiratory illnesses [7–14].

In addition to acute health effects of formaldehyde, chronic exposures in occupational settings have also been extensively studied. Respiratory symptoms of chronic runny nose, chronic bronchitis, and obstructive lung disease have all been suggested [15–17].

Formaldehyde is classified as carcinogenic and acetaldehyde as probably carcinogenic by International Agency for Research on Cancer (IARC) [18, 19].

Exposure to this solution can be dangerous and should be controlled/monitored by occupational hygiene procedures. If correlations exist between urinary values and environmental data, and if the first are easily obtainable, it is worth the inconvenience to consider this method of biological monitoring as a possibility to obtain a highly sensitive and specific exposure index, and it can also be applied for biological monitoring of occupational exposure to low levels of solvents or to solvent mixtures [20]. Air concentrations have been widely used to evaluate exposure to HCHO in occupational environments [21].

Approximate numbers of persons who were exposed to levels of formaldehyde above 0.1 ppm [0.12 mg/m^3] are presented by major industry sector, including medical laboratories and embalming fluids [18].

Concentrations of formaldehyde in Histopathology labs are sometimes high, e.g. during tissue disposal, preparation of formalin and changing of tissue processor solutions [22].

The usual mean concentration during exposure is approximately 0.5 ppm [0.6 mg/m^3]. In the Pathology laboratory (Sweden) were found 0.5 ppm [0.7 mg/m^3] [23], the same type of laboratory in Germany and Finland 0.5 ppm [0.6 mg/m^3] [24], in Hospital laboratories (Finland) were found 0.5 ppm [0.6 mg/m^3] [25], in Teaching laboratory (USA) 0.3 ppm [0.4 mg/m^3] [26] in Histology laboratory (Israel) 0.4 ppm [0.5 mg/m^3] [27]. In three hospital-histopathology laboratories the usual mean concentration during exposure is greater than 0.9 ppm [15].

Standards referred to as legal standards or as recommendation standards are established by several organizations in the world.

Threshold Limit Values (TLVs) is the value used to determine if one or the other of these exposure limits is inherently more stringent, so that exposure monitoring strategies may be devised which efficiently use available resources and effectively control exposures to meet both exposure limits [28]. The Time Weighted Average (TWA) is the term used in the specification of Occupational Exposure Limits (OELs) to define the average concentration of a chemical to which it is permissible to expose a worker over a period of time, typically 8 h. And the Short Term Exposure Limit (STEL) is the maximum permissible concentration of a material, generally expressed in ppm in the air, for a defined short period of time (typically 5 or 15 min, depending upon the country). This "concentration" is generally a time-weighted average over the period of exposure. These values, which may differ from country to country, are often backed up by regulation and therefore may be legally enforceable [21].

In Portugal, the current, legally binding, OEL for HCHO is 260 mg/m^3 (0.3 ppm), as an 8 h time-weighted average (TLV-TWA). This value is consistent with the Indicative Occupational Exposure Limit Value (IOELV) of the European Union. Although STEL is unavailable.

2 Methodology

2.1 Indoor Air Measurement of HCHO Vapor

One hundred twenty-three air samples of the breathing zone were collected in the activity labs (macroscopic examination of surgical pieces or biopsy, tissue processing and chemical waste disposal), during five weeks, except on Tuesdays (absence of academic stage). Three samples were collected each day.

Air samples collection were done by means of passive air samplers equipped with high purity silica gel (ultra-low background), treated with (2,4-Dinitrophenylhydrazine), 6 × 110 mm size, 2-section, 150/300 mg sorbent of SKC, at flow-rate of 0.13 L/min for 15 min. Sampling is conducted by taking a breathing zone air sample. Breathing zone samples provide the best indication of the concentration of contaminants in the air the employee is actually breathing, because the concentration is deemed to be constant [29].

After sampling, the sample cartridges and field blanks are individually capped and placed in shipping tubes with polypropylene caps. Sample identifying tags and labels are then attached to the capped tubes. The capped tubes are then placed in a polypropylene shipping container cooled to sub ambient temperature (<4 ºC).

2.2 Samples Analysis

The samples (trip blank, field blank and field samples) are returned to the laboratory in a shipping container and stored in a refrigerator at (<4 ºC) until analysis. The time between sampling and extraction *will/must* not exceed 2 weeks. As background levels in the cartridges may change due to adsorption during storage, there are always compared field samples to their associated field and trip blank samples, stored under the same conditions.

Samples were desorbed in 10 mL carbonyl-free acetonitrile. Qualitative and quantitative analysis is carried out with high performance liquid chromatography coupled with a diode array detector (DAD). This procedure is described in detail by Iraneta et al. [30].

3 Results

This study showed all 8-h TWA breathing zone formaldehyde concentrations sampled within the university pathological anatomy laboratory during the histological steps (macroscopic examination of surgical pieces or biopsy, tissue processing and chemical waste disposal) during five weeks.

Triplicate samples of formaldehyde were collected daily, except on Tuesdays (no work), holidays and weekends.

Table 1 Formaldehyde concentration in indoor air throughout the week

Day of the week	Number of samples	Concentration (ppm)	
		Mean ± DVP	Range
Monday	31	0.7 ± 0.4	0.4–2.7
Wednesday	31	1.0 ± 0.7	0.3–3.9
Thursday	35	1.1 ± 0.7	0.4–2.8
Friday	32	3.7 ± 3.0	0.5–7.3

Of 132 air samples collected 3 samples were excluded from statistical analysis due to a laboratory accident, in which there was a spill of a 2.0 L container formaldehyde 10 % during the changing of the tissue processor. In this period there were found concentrations of 10.1; 10.3 and 10.6 ppm.

The airborne concentrations of formaldehyde increased over the week. Checking if on average the highest concentration values during the macroscopic registration activity (1.9 ± 0.3), followed by the discharge of effluents (1.6 ± 0.3) and tissue processing (1.4 ± 0.3).

Friday is the day of the week where there are higher levels of formaldehyde in the airborne (Table 1), whatever the task.

There are no statistically significant differences in daily activities of macroscopic examination of surgical pieces or biopsy and chemical waste disposal ($p = 0.1$; $\alpha = 0.05$) and between the tissue processing and chemical waste disposal ($p = 0.4$; $\alpha = 0.05$) as well as between Wednesday and Thursday ($p = 0.3$; $\alpha = 0.05$).

4 Discussion

After reviewing all data from all of the air sampling studies, the results indicated that university staff and students who occupied the pathological anatomy laboratory during the histological steps (macroscopic examination of surgical pieces or biopsy, tissue processing and chemical waste disposal) were exposed to formaldehyde levels greater than the NP 1796: 2007 of 0.3 ppm.

Therefore the engineering controls, administrative controls, and personal protective equipment utilized for this university pathological anatomy laboratory are not preventing formaldehyde overexposures from occurring to individuals in the laboratory.

A number of research studies have shown that the mean formaldehyde concentrations for both breathing zone and area samples in pathology or histology laboratories were higher than the recommended ceiling standard established by USA-ACGIH which is 0.3 ppm [15, 23–27, 31].

The formaldehyde exposure level of staff in pathology laboratories, surgery rooms, and endoscopy wards of eight hospitals of Tehran University of Medical Sciences collected and analyzed 141 samples. The research reported mean levels of formaldehyde ranging between 0.13 ppm in endoscopy wards and 0.96 ppm in pathology laboratories. The authors concluded that the levels of formaldehyde at pathology laboratories exceeded the recommended ceiling standard established by USA-ACGIH which is 0.3 ppm [31].

Some reasons that may account for the differences of formaldehyde concentrations could include work practices or different ventilations rates.

5 Conclusion

The highest level of concentration of formaldehyde in the university pathological anatomy laboratory exceeded the recommended ceiling standard established by NP 1796:2007 which is 0.3 ppm. Thus, it is recommended that formaldehyde levels should be measured periodically, specially during the macroscopic examination of surgical pieces or biopsy, tissue processing and chemical waste disposal, and local exhaust ventilation system should be installed, and personal protective equipment, such as safety glass and gloves, should be available and be used to prevent direct skin or eye contact.

References

1. Buesa, R.J.: Histology safety: now and them. Ann. Diagn. Pathol. **11**(5), 334–339 (2007)
2. Buesa, R.J.: Histology without formalin? Ann. Diagn. Pathol. **12**(6), 387–396 (2008)
3. Rhodes A.: Fixation and Fixatives: Theory and Practice of Histological Techniques: Theory and Practice of Histological Techniques. In: Suvarna, S.K., Layton, C., Bancroft J.D. (eds.) Churchill Livingstone, Edinburgh, pp. 69–93 (2013)
4. European Commission.: Human exposure characterisation of chemical substances, quantification of exposure routes, Joint Research Centre, Editor Physical and Chemical Exposure Unit: Ispra (2005)
5. National Research Council (U.S.). Committee on AldehydesAssembly of Life Sciences (U.S.). Committee on Aldehydes: Formaldehyde and Other Aldehydes ed. Board on Toxicology and Environmental Health Hazards. National Academy Press, Washington, DC (1981)
6. Bender, J.R., Mullin, L.S., Graepel, G.J., Wilson, W.E.: Eye irritation response of humans to formaldehyde. Am. Ind. Hyg. Assoc. J. **44**(6), 463–465 (1983)
7. Main, D.M., Hogan, T.J.: Health effects of low-level exposure to formaldehyde. J. Occup. Med. **25**(12), 896–900 (1983)
8. Nunn, A.J., Craigen, A.A., Darbyshire, J.H., Venables, K.M., et al.: Six year follow up of lung function in men occupationally exposed to formaldehyde. Br. J. Ind. Med. **47**(11), 747–752 (1990)
9. Schachter, E.N., Witek Jr., T.J., Brody, D.J., Tosun, T., et al.: A study of respiratory effects from exposure to 2.0 ppm formaldehyde in occupationally exposed workers. Environ. Res. **44** (2), 188–205 (1987)
10. Witek Jr., T.J., Schachter, E.N., Tosun, T., Beck, G.J., et al.: An evaluation of respiratory effects following exposure to 2.0 ppm formaldehyde in asthmatics: lung function, symptoms, and airway reactivity. Arch. Environ. Health **42**(4), 230–237 (1987)

11. Anderson, R.C., Stock, M.F., Sawin, R., Alarie, Y.: Toxicity of thermal decomposition products of urea formaldehyde and phenol formaldehyde foams. Toxicol. Appl. Pharmacol. **51** (1), 9–17 (1979)
12. Bracken, M.J., Leasa, D.J., Morgan, W.K.: Exposure to formaldehyde: relationship to respiratory symptoms and function. Can. J. Public Health **76**(5), 312–316 (1985)
13. Imbus, H.R.: Clinical evaluation of patients with complaints related to formaldehyde exposure. J. Allergy Clin. Immunol. **76**(6), 831–840 (1985)
14. Kilburn, K.H., Warshaw, R., Boylen, C.T., Johnson, S.J., et al.: Pulmonary and neurobehavioral effects of formaldehyde exposure. Arch. Environ. Health **40**(5), 254–260 (1985)
15. Alexandersson, R., Hedenstierna, G., Kolmodin-Hedman, B.: Exposure to formaldehyde: effects on pulmonary function. Arch. Environ. Health **37**(5), 279–284 (1982)
16. Holness, D.L., Nethercott, J.R.: Health status of funeral service workers exposed to formaldehyde. Arch. Environ. Health **44**(4), 222–228 (1989)
17. Malaka, T., Kodama, A.M.: Respiratory health of plywood workers occupationally exposed to formaldehyde. Arch. Environ. Health **45**(5), 288–294 (1990)
18. International Agency for Research on Cancer World Health Organization.: Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 88. International Agency for Research on Cancer, Lyon Cedex 08, 497 (2006)
19. International Agency for Research on Cancer World Health Organization: Working Group on the Evaluation of Carcinogenic Risks to Humans: Wood dust and Formaldehyde. Vol. 62. International Agency for Research on Cancer, Lyon Cedex 08, 423 (1995)
20. Imbriani, M., Ghittori, S.: Gases and organic solvents in urine as biomarkers of occupational exposure: a review. Int. Arch. Occup. Environ. Health **78**(1), 1–19 (2005)
21. American Conference of Governmental Industrial Hygienists Staff: Documentation of the threshold limit values and biological exposure indices, 7 ed. Vol. 2. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio: 194 (2008)
22. Suvarna, K.S., Layton, C., Bancroft, J.D.: Bancroft's Theory and Practice of Histological Techniques, 7th edn. Churchill Livingstone, Edinburgh (2012)
23. Rosén, G., Bergström, B., Ekholm, U.: Occupational exposure to formaldehyde in Sweden. Arbete Hälsa. **50**, 16–21 (1984)
24. Triebig, G., Schaller, K.-H., Beyer, B., Müller, J., et al.: Formaldehyde exposure at various workplaces. Sci. Total Environ. **79**(2), 191–195 (1989)
25. Heikkilä, P., Priha, E., Savela, A.: Formaldehyde (Exposures at Work), Vol. 14. Finnish Institute of Occupational Health and Finnish Work Environment Fund (in Finnish), Helsinki (1991)
26. Tan, Y.-M., DiBerardinis, L., Smith, T.: Exposure assessment of laboratory students. Appl. Occup. Environ. Hyg. **14**(8), 530–538 (1999)
27. Shaham, J., Gurvich, R., Kaufman, Z.: Sister chromatid exchange in pathology staff occupationally exposed to formaldehyde. Mutat. Res. **514**(1–2), 115–123 (2002)
28. Tuggle, R.M.: The relationship between TLV-TWA compliance and TLV-STEL compliance. Appl. Occup. Environ. Hyg. **15**(4), 380–386 (2000)
29. Ohima, J.: Gaseous contaminant distribution in the breathing zone. Ind. Health **50**(3), 236–238 (2012)
30. Iraneta, P., Seymour, M.J., Kennedy, E.R.: Formaldehyde: Method 2016: manual of analytical methods (NMAM). In: Eller, P.M., Cassinelli, M.E. (eds.) National Institute for Occupational Safety and Health, DHHS. Cincinnati, NIOSH) (1998)
31. Ghasemkhani, M., Jahanpeyma, F., Azam, K.: Formaldehyde exposure in some educational hospitals of Tehran. Ind. Health **43**(4), 703–707 (2005)

From Virtual Reality to Neutral Buoyancy—Methodologies for Analyzing Walking Pattern on Moon and Mars

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Abstract In the past, anthropometrical data have been collected only on microgravity, or measured from Apollo mission images, leading to low accuracy of the data [1]. Starting with Virtual Reality—based experiments, this research provides an investigation into methodologies that focuses on the collection of basic anthropometrical and postural data needed to develop interfaces for the Moon and Mars gravity environments. The learning objectives of this work are: (1) Analysis of methodologies for studying human movement and posture in Moon-Mars gravity; (2) Development of new instruments of investigation and methodologies; (3) Support of user-centered design in Moon Mars habitat projects.

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1 Introduction: Safety and Simulation

Space radiation, differences in gravity, rarified or very tenuous atmosphere, extreme temperatures and isolation characterize the Moon and Mars as extreme work environments. In those environments, the human biorhythm, its sensory perception, and its entire psycho-physiological system are severely challenged. This affects human subjects' perception, deambulation, motion, and general interaction with the environment. To create future Moon and Mars habitats based on "human-centered design", we will have to investigate all the factors that impact human interaction to try to increase the safety [2], productivity, and comfort of the astronauts. In this perspective, we are focusing on the investigation of anthropometrical data and interaction movements to address the walking patterns and the interactions of the astronauts inside and outside the habitat.

The walking pattern is a factor that is determined by all the human factors in relation to the system:

- Physiological factors (the configuration and the state of the body impact the walk, e.g., weight, muscular mass, stiffness of the legs, age, eyesight, perception of gravity and verticality…).
- Psychological factors (the personal approach and the psychological feeling impact the walk, e.g., being tired, afraid, happy, late, …).

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- Operational and technical factors (the task that we are approaching impacts the walk, e.g., carrying material, over short distances, over long distances, outside, inside, with extra vehicular suits, without EVA, …).
- Environmental factors (the environmental characteristics influence the walk, e.g., mechanical properties of the soil, partial gravity, temperature, light, bare visual surroundings with no reference, interior habitat crowdedness, gravity, radiation, …).
- Socio-cultural factors (your culture in relation to social aspects influence the walk, e.g., you are alone, in a group, on vacation, in a work context, with background music, …).

This means that in order to truly understand walking patterns, we should analyze them during the mission. However, considering that in order to conduct a Moon mission, we should have been collecting mission data, we need to apply different solutions to get as close as possible to the real factors [3]. Isolating a determining analysis factor could also help to achieve better results. For example, focusing the research on the interaction between walking and the effects of reduced gravity may help to understand a specific aspect. Moreover, this will then later need to be validated in relation to the influence of all the other factors (psychological, operational, etc.). Gravity is indeed one of the most interesting aspects. Influence of gravity acceleration (g = 981 cm/s^2 on Earth, 162 on Moon surface), considering that the g coefficient acting on the *maculae* of *utriculus* and *sacculus* inner ear gravity and motion sensors [4] is an unavoidable element of their mathematical functions.

For example, research led by our work group [5] and using images and videos from NASA's Apollo missions [6] shows that when we walk on the Moon with one of the three modalities—modified walk, hop, side step [7]—the different walking patterns have an impact on the visual field. In particular, the head is more tilted downwards; as a consequence, our eyesight is lowered and we see a narrower visual field. This could, for example, reduce the perception of obstacles and decrease balance. In other words, while we walk, we cannot see so far, which makes it more difficult to avoid obstacles and increases the possibility of tripping up [5]. This research shows for example the strong correlation between walking movement and eyesight.

2 Methodologies

There are different methodologies to simulate the Moon and Mars environment in order to analyze kinematic and anthropometrical data:

2.1 Real Images and Video

Analysis of existing Apollo mission videos and images. Posture and movement are real and not reconstructed; we also have direct influence on all factors involved, such as terrain, bare visual field, psychological impact of being on the Moon far

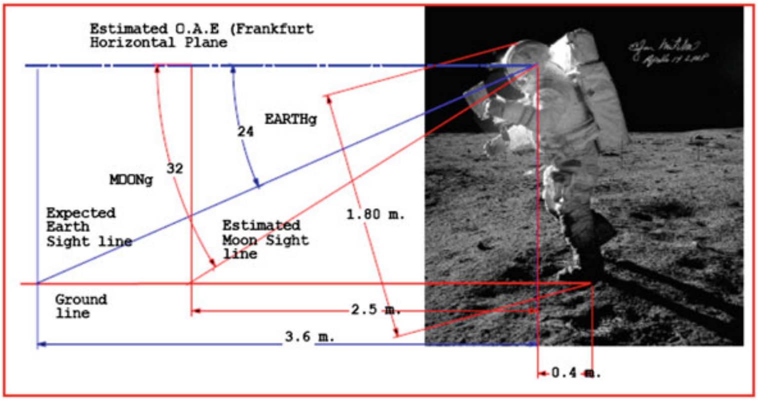

Fig. 1 Tentative interpretation of Moon walking posture and sight-line image. Apollo 14, 1971 © NASA & M. Masali

away from Earth; reduced weight, etc. The problem is that the angle of view is not optimal for the data analysis; also, we do not have any exact reference for the measurements. In the image, the research on the sight line using an image from the Apollo 14 mission is depicted [5] (Fig. 1).

2.2 *Virtual Reality with Unloaded Weight*

The user interacts with the virtual Moon-Mars habitat and landscape, while the Moon gravity is simulated with the help of special cables that are balanced in proportion to the user's weight. Inside a 3D virtual environment, the user's movements are tracked and reproduced by an avatar. This solution is very effective in giving the user a visual perception of the surroundings. The image depicts an image by the Italian Mars Society of the V-ERAS system during a Mars mission simulation (Fig. 2).

2.3 *Neutral Buoyancy (Adapted for Moon/Mars Gravity Simulation)*

The Neutral Buoyancy Facility is a swimming pool where a person's body is in buoyancy to simulate microgravity. By using a combination of distributed mechanical loads on different parts of his body (and, possibly, of floaters to optimize the application point of the resultant force) a realistic reduced gravity effect can also be achieved. Inside, the subject can interact with a Moon or Mars habitat or terrain created within the Neutral Buoyancy Facility. The Fig. 3 different neutral buoyancy facilities: the ALTEC Neutral Buoyancy Test Facility (NBTF)

Fig. 2 V-ERAS system of the Italian Mars Society © Italian Mars Society [13]

Fig. 3 Neutral Buoyancy Facility Altec © Altec [14]

(5 × 9 × 4 m) with windows, the Neutral Buoyancy Lab at NASA's Sonny Carter Training Facility, and the Neutral Buoyancy Facility at the Astronaut Training Center of the European Space Agency (ESA). Both are equipped with a control room, a crane to hoist and submerge equipment; the dimensions allow hoisting of a full size ISS mock-up. Combined use of neutral buoyancy and virtual reality could also be used to increase science results [8]. This kind of solution is very convenient to reduce the weight and control the movement, but needs to consider the viscosity of the water and the equipment or tubes for breathing under water (Figs. 4 and 5).

2.4 Vertical Treadmill (Adapted as Inclined Treadmill)

The user is attached to strings distributed along his body and walks on a treadmill that is vertical if he is simulating exercise in microgravity. Currently the DLR is developing a treadmill that has an inclination that results in weight reduction corresponding to Moon or Mars gravity. As explained by the co-author

Fig. 4 Control Center, Neutral Buoyancy Facility at the European Astronaut Centre © ESA–H. Rueb [15]

Fig. 5 Neutral Buoyancy Lab at NASA's Sonny Carter Training Facility © NASA [16]

Prof. Rittweger, the angle is calculated using the gravity level of the Moon (0.16 g) and Mars (0.38 g) and computing them with the arc sin (=asin) function. Thus, asin (0.16) = 9.207°, and asin (0.38) = 22.33°. The treadmill will then be inclined by 9° for simulating walks on the Moon and by 22° to simulate walks on Mars (Fig. 6).

Fig. 6 Vertical Treadmill of DLR © DLR edited by Schlacht and Rittweger [17]

2.5 *Treadmill with Reduction of Weight*

As reported by Kram et al. [9] p. 823: "This device applied a nearly constant upward force to the subject's center of mass. The harness consisted of a bicycle saddle attached to a U-shaped section of polyvinyl chloride pipe (total mass 1.74 kg). A wide padded belt held the subject at a comfortable location on the saddle. Upward forces applied to the subject were measured using a force transducer. Two spring elements were arranged in series, connected by cables and separated by a pulley. To increase the amount of tension, additional rubber springs were added in parallel. Additional springs were only added when the force of the original springs became inadequate, in order to maximize spring length and keep the force fluctuations as small as possible. A hand winch reeled in a cable connected to the springs, allowing us to control the length of the springs."

2.6 *Unloaded Deambulation on Moon or Mars Terrain*

The user is followed on his path on Moon or Mars terrain by suited suspension cable systems that decrease the user's weight to reproduce Moon or Mars gravity. This system is easily applicable for simulation of extra vehicular activity, while it is a bit more complex to build for simulation inside a Moon-Mars habitat analogue. The problem is that being connected to cables restricts the freedom of movement, reducing the possibility of spontaneous movement. On the other hand, this system is very good for testing the interaction with the environment, which is not possible, for example, inside the treadmill. Moreover, the system could also be used in mission simulations where other human factors that influence the walk are also considered and supported (e.g., isolation, terrain, bare visual surroundings, …) (Figs. 7 and 8).

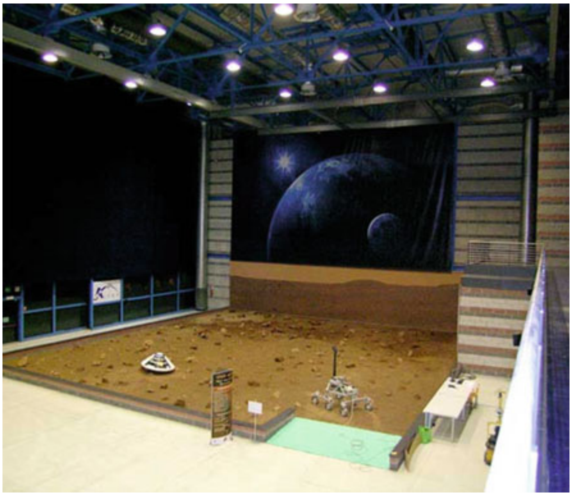

Fig. 7 ALTEC Moon-Mars Terrain for IVA test © LUNA Consortium, visualization: space applications services, 2015 [18]

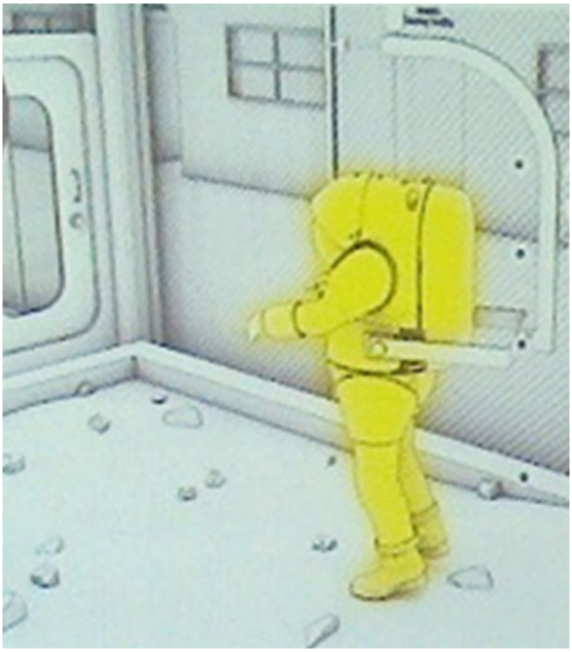

Fig. 8 ESOL European Simulation and Operations Laboratory © LUNA consortium, visualization: LIQUIFER Systems Group, 2015

2.7 Parabolic Flight

The user experiences the interaction in a different type of gravity for 20 s in a parabolic flight maneuver that recreates Moon or Mars gravity. Parabolic flight is the only way to test the effect on the vestibular system. However, the problem is

Fig. 9 Parabolic flight with Moon gravity and treadmill © NASA [19]

that there is only a very limited amount of time and limited space (the airplane's interior) available (e.g. Noverspace flight [10]). To face the second problem, one solution that has been applied before is to have a treadmill on the flight.

2.8 Combination

The methodologies presented here can be combined into new methodologies. For example, research has been done on the analysis of walking by simulating different types of gravity with: treadmill in parabolic flight, treadmill in a neutral buoyancy facility, and virtual reality in a neutral buoyancy facility [11, 12] (Fig. 9).

3 Conclusion

In summary, during the Apollo missions more than 50 years ago, no anthropometrical studies were carried out as far as we know. The necessity to collect data is very consistent with state-of-the-art research. We still have little knowledge of how people will interact with the Moon environment. Specifically, it is not known which posture, which kind of walking and running motions they will use both inside and outside a Moon station. Considering recent plans for Moon and Mars missions where humans will spend extensive time in reduced gravity conditions, the need for field data is a priority in order to be able to design the right architecture, infrastructure, and interfaces.

This research is aimed at reconsidering the methodologies from the viewpoint of anthropometry and human system interaction in different types of gravity and carrying out new investigations that may help to prepare for the next Moon mission, but which can also be used for advanced applications on Earth. The various experimental setups and methodologies described here are also extremely promising in terms of basic research aimed at better understanding human physiological mechanisms ruling equilibrium, deambulation, and related topics. Nevertheless we must take in account that out of the case of Moon-Mars gravitation simulation in parabolic flight (or centrifuge for Jupiter) any Earth surface experiment would be unavoidably biased by the terrestrial value of g on the vestibular system.

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References

1. NASA: Anthropometric Source Book. Anthropometry for Designers, vol. 1. (1978)
2. Schlacht, I.L., Nazir, S., Manca, D.: Space vs. chemical domains: virtual and real simulation to increase safety in extreme contexts. Proc. Manuf. **3**, 1817–1824 (2015)
3. Nazir, S., Totaro, R., Brambilla, S., Colombo, S., Manca, D.: Virtual reality and augmented-virtual reality as tools to train industrial operators, Ian David Lockhart Bogle and Michael Fairweather. In: Proceedings of the 22nd European Symposium on Computer Aided Process Engineering, pp. 17–20 (2012)
4. Twizell, E.H.: A variable gravity model of the otolith membrane. App. Math. Modell. **4**, 82–86 (1980)
5. Masali, M., Schlacht, I.L., Argenta, M., Gamba, M., Ligabue Stricker, F., Micheletti Cremasco, M.: Human adaptation in extreme conditions: anthropology and ergonomics applied to outer space. Int. J. Anthropol. **28**(2/3), 171–185. 15p. (2013)
6. Reinert, A.l.: For All Mankind. Video http://www.imdb.com/title/tt0097372/ (1989)
7. Kubis, J.F., Elrod, J.T., Rusnak, R., Barnes, J.E.: Apollo 15—Time and Motion Study. NASA Manned Spacecraft Center, Jan 1972, NASA M72-4. NASA Technical Reports Server http://ntrs.nasa.gov/ (1972)
8. Benassai, M.: The ALTEC—Neutral Buoyancy Test Facility: a powerful tool for physiology and neuroscience research. Life in space for life on earth. In: Proceedings of the Conference Held 18–22 June 2012, at Aberdeen, UK. ESA-SP vol. 706, id.26 (2013)
9. Kram, R., et al.: Effect of reduced gravity on the preferred walk-run transition speed. J. Exp. Biol. (1997). http://jeb.biologists.org/content/200/4/821.long
10. Noverspace: Video showing the Moon gravity flight. https://www.youtube.com/watch?v=1ieR8hIXUIg (2012)
11. De Witt, J.K., et al.: The preferred walk to run transition speed in actual lunar gravity. J. Exp. Biol. **217**, 3200–3203. (2014). http://jeb.biologists.org/content/217/18/3200
12. Akin, D.L., et al.: Habitat design and assessment at varying gravity levels. In: 44th International Conference on Environmental Systems 13–17 July 2014, Tucson, Arizona ICES-2014-264 www.spacearchitect.org/pubs/ICES-2014-264.pdf (2014)
13. V-ERAS Training for OEWF Analog Astronauts: http://erasproject.org/v-eras-training-for-oewf-analog-astronauts/#!
14. Neutral Buoyancy Facility Altec: http://www.altecspace.it/wp-content/uploads/2013/06/IMMAGINE-NR-6.jpg

15. Astronaut Training Division: http://www.esa.int/About_Us/EAC/Astronaut_training_division/
16. Alexander Gerst in Spacewalk Training: http://m.esa.int/var/esa/storage/images/esa_multimedia/images/2011/09/alexander_gerst_in_spacewalk_training8/9804756-3-eng-GB/Alexander_Gerst_in_spacewalk_training_article_mob.jpg
17. Studie zum Laufbandtraining in simulierter Schwerelosigkeit (AVATAR-Studie): http://www.dlr.de/me/desktopdefault.aspx/tabid-7713/16004_read-39349/
18. The ALTEC Mars Terrain Demonstrator: http://www.altecspace.it/en/facilities/mmtd
19. Moonwalking Astronauts Can Move Surprisingly Fast. http://www.space.com/27285-astronauts-moon-walking-speed-spacesuits.html

Applying HFACS Approach to Accident Analysis in Petro-Chemical Industry in China: Case Study of Explosion at Bi-Benzene Plant in Jilin

Yunhua Gong and Yunxiao Fan

Abstract The Human Factors Analysis and Classification System (HFACS) is a framework for classifying and analyzing human factors associated with accidents and incidents. It is a commonly utilized tool for investigating human contributions to aviation accidents in China. Human factors also contribute to many accidents in petro-chemical industry. The goal of this paper is to apply HFACS approach to analysis of explosion at Bi-benzene Plant in Jilin and classify the human factors causing the occurrence of this accident. Results showed that HFACS is useful and feasible in accident analysis in this case. And, the human factors were clearly classified for the cause analysis. Recommendations were proposed to include HFACS in accident investigation.

Keywords HFACS · Accident analysis · Human factors

1 Introduction

According to Hollnagel, the choice of a model to analyze an accident is crucial because it will determine the analyst's perspective and therefore guide the conclusions of the investigations and preventive measures resulting from these conclusions [1]. Accident analysis is guided by the well-known "What-You-Look-For-is-What-You-Find" principle.

In China, in accident analysis reports issued by the State Administration of Work Safety accident causes are shown as direct causes and indirect causes. Direct causes

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are defined as unsafe acts, unsafe conditions of equipment, inappropriate working environments, and the other causes are attributed to indirect causes. There is no specific analysis models adopted. And, the relations among different causes are not analyzed.

Originally, HFACS was designed for the military aviation domain. Hence, use of the HFACS to understand accident causation and improve system safety is commonplace within the aviation industry. It has also been applied to the classification and analysis of accidents in the railway industry, mining industry and maritime industry [2, 3]. Accidents in shipping industry has been analyzed using HFACS too [4]. Recently, it is also applied into analysis on adverse clinical incidents [5, 6]. However, there was no research which was found to use HFACS in Petro-chemical industry.

Utilizing concepts of human error, it views accidents as the result of human errors of various types. Traditional theories of accident causation suggest that accidents are caused by sequences of causal events which are initiated by a single 'root cause' event, such as catastrophic equipment failure or an unsafe human action. However, the classification of human error is not defined, which is not easy to get corresponding interventions. And, it is considered that human errors contribute to most of the accidents.

Since little information is currently available about the application of HFACS in petro-chemical industry and whether their analysis needs are met, this study provides an insight into this issue by obtaining a practitioner evaluation of HFACS and understanding how the method's usage characteristics affect its use in a petro-chemical accident analysis. The principle aim of this study is to provide an initial insight into the use of HFACS within the context of accident investigation in Petro-chemical industry. By conducting this study, it is hoped that a greater understanding of the extent of the HFACS research practice gap in petro-chemical industry could be achieved.

Because of the lack of official accident analysis report, this research collected information from the literatures published related to this accidents.

2 Method

HFACS is a methodology that has proven particularly useful across domains when investigating and identifying human factors with respect to accidents [7]. HFACS is a human error taxonomy based on Reason's well-known "Swiss Cheese" model of accident causation. The structure of HFACS is hierarchical, defining nineteen causal factor categories within four levels or tiers (Fig. 1). The four tiers include unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. Each level is dependent on the previous one and factors are assumed to progress from active to latent conditions as they progress up the hierarchy from unsafe acts to organizational influences.

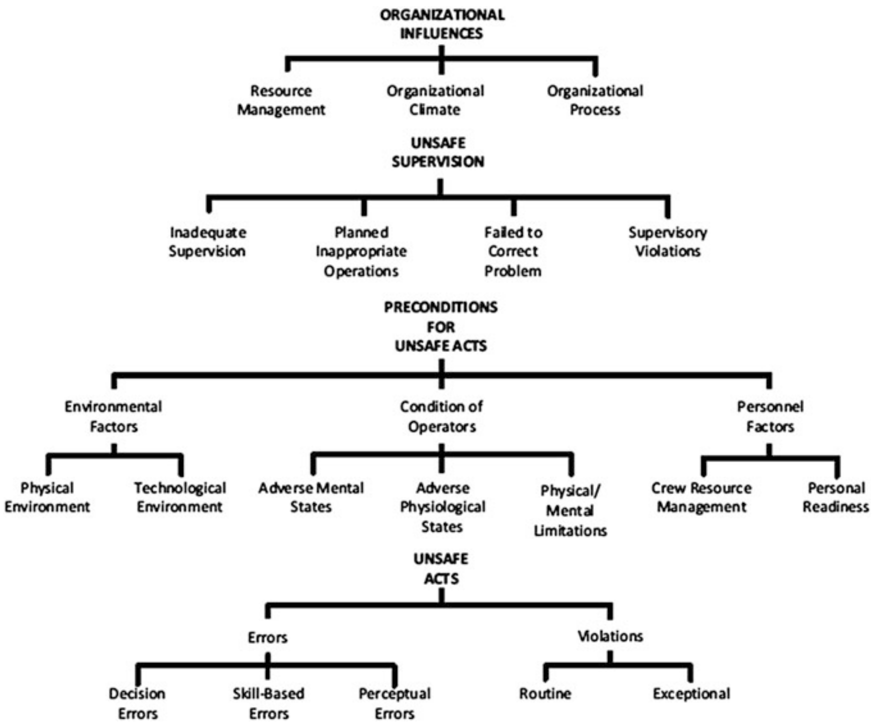

Fig. 1 The HFACS framework [8]

3 Case Presentation

On 13th October 2005, a team leader worked as a substitution for an operator who was off work in Bi-benzene Plant in Jilin. According to analysis results of the liquid at the distillation tower bottom, liquid discharging operation should be carried out. On 10:10 am, the team leader started to discharge the residual liquid. However, before this operation he stopped the feeding without turning off the heating steam valve of the preheater. In that case, the temperature of the distillation tower raise quickly and exceeded the permitted temperature of the process. On 11:35 am, the team leader noticed the high temperature and turned off the heating steam valve. The temperature descended rapidly. On 1:21 pm, when the team leader started to feed the liquid again, he turned on the heating steam valve first, which caused the temperature to go up to the operation limit temperature again. On 1:34 pm, when he turned on the crude nitrobenzene feeding pump, the preheater exploded. And, the Nitrobenzene prefractionator and nitrobenzene distillation tower exploded one after another. A fire also occurred following the explosion. This accident caused

8 deaths, 60 persons injured and 6.9 million RMB financial loss. The leakage caused by this accident polluted the water in Songhua River in Northeast of China. And the water supply had to stop for 4 days [9].

4 Results

Since there is no official accident analysis report on this event, the human errors causing this accident was classified mainly according to the information from a thesis of Jilin University [9] (Table 1).

Table 1 Human errors analysis using HFACS

Error type			Human errors in this accident
Unsafe acts	Errors	Decision errors	None identified
		Skill-based errors	As a team leader, the operator failed to follow the procedure in a normal operation
		Perceptual errors	None identified
	Violations	Routine	None identified
		Exceptional	The discharge of residential liquid was a normal intermittent operation, which should be conducted without turning off liquid feeding Before discharging the residual liquid, the operator stopped the feeding without turning off the heating steam valve of the preheater When the team leader started to feed the liquid again, he turned on the heating steam valve first, which caused the temperature to go up to the operation limit again
Preconditions for unsafe acts	Environmental factors	Physical environment	None identified
		Technological environment	None identified
	Conditions of operators	Adverse mental states	None identified
		Adverse psychological states	None identified
		Physical/mental limitations	None identified
	Personnel factors	Crew/resource management	There was only one operator in the whole process, which led to the process lack of control There was no real time information collection on the abnormal situation on site, which caused no correction decision in emergencies
		Personal readiness	None identified

(continued)

Table 1 (continued)

Error type			Human errors in this accident
Unsafe supervision	Inadequate supervision		The liquid discharging operation was a common operation which should be conducted every seven to ten days in this plant. Continuous failures during this operation reflected relaxed following of procedure and lack of management in this plant. Inadequate safety education
	Planned inappropriate operations		When the operator worked, there was nobody monitoring the temperature, so there was nobody who adjusted or reported the high temperature
	Failed to correct a problem		Failure to correct the personnel arrangement when it was known that there was only one operator on site
	Supervisory violations		None identified
Organizational influences	Resource management		Inadequate safety management human resource in case of enterprise's size expanding Inappropriate layoffs. Many experienced staff were laid off from 2001 to 2002
	Organizational climate		Focus on punishment Lack of employee involvement in management
	Organizational process		Failure to point out the matters needing attention and the existing risks during operation in the procedures. Possible consequences in case of high temperature were not mentioned in any procedures either. Unreasonable time scheduling of frontline employees

4.1 Unsafe Acts

On the day of the accident, the operator was off work for some reason, and the team leader worked as a substitution. Normally, the team leader possess better working skill than other workers. However, the team leader failed to follow the correct procedure in a normal operation, which reflected his poor skill. So, it was concluded that there was a skilled-based error. The errors committed by the team leader were strictly unpermitted in this operation. So, these errors were classified into exceptional violations.

4.2 Preconditions for Unsafe Acts

The preconditions for unsafe acts include three main factors: environmental ones, individual ones and personnel factors. There was no environmental factors contributing to this accident and the conditions of the operator was not mentioned in any literature. In fact it is rarely identified in accident reports in China. There was obvious human errors in crew resource management of personnel factors. The first human error was that there was only one operator in the whole process from 10:10 am to 1:37 pm, which led to the process lack of control. To be worse, there was no real time information collection on the abnormal situation on site. The unsafe acts or violations, unsafe work conditions of equipment during process could not be fed back to the corresponding decision makers to correct errors.

4.3 Unsafe Supervision

There are three categories of unsafe supervision existing in this accident, which are inadequate supervision, planned inappropriate operations and failed to correct a problem. The liquid discharging operation was a common operation which should be conducted every seven to ten days in this plant. Continuous failures during this operation reflected deficiency in following of procedure and omissions of management in this plant. And, the errors in operation showed inadequacy in safety education. Accident investigation found that employees in this plant were reluctant to join in safety education organized. During safety education, employees could not concentrated on it and could not really master the skills or procedures delivered. These two human errors were classified into inadequate supervisions in this research.

When the operator was working, there was nobody monitoring the temperature, so there was nobody who adjusted or reported the high temperature. We concluded that there was an inappropriate operation arrangement. And, in the whole process, there was nobody who corrected the fault operation and inappropriate operation, which caused the out of control of the productive process.

4.4 Organizational Influences

The human errors above stemmed from the organizational influences of the plant. In resource management, there were two human errors. The first one was inadequacy of safety management human resource. The size of this plant expanded very quickly in several years previous to the accident. However, the amount of safety managers increased slightly. The safety management on site was mainly conducted by its headquarters. The second human error was related to the onsite employees. During 2001 to 2002, more than 30 thousand staff were laid off. And these staff were mostly experienced but not very young employees. The rich experience were taken away as they were laid off.

There was not very good organizational climate in this plant. Firstly, the plant possessed a climate which was focused on punishment. With this climate employees were not active in pointing out errors of others or false decisions of mangers. On the other hand, employees were not involved in any management or decision making in this plant, which was detrimental to risk management.

In organizational process, there were deficiencies in operation procedures. Matters needing attention, existing risks during operation and possible consequences in case of high temperature were not mentioned in any procedures. The time scheduling of frontline employee was also not appropriate. The employees work almost every weekend. In this case, they had no opportunity to rest, which might trigger adverse mental and psychological state.

5 Discussion

In analysis results, there were some human factors which were not identified. However, it might be exist. For example, there is no human factors of conditions of operators in this analysis result. However, there is a high possibility that conditions of operators contributed to this accident. Our analysis is according to literatures. So, we can't deduce any information which was not mentioned in them. From another point of view, the accident causation model which was taken when investigating determined what we would find in the accident analysis.

In analyzing unsafe acts, it is difficult to attribute the human factors to routine violation or exceptional violation because of no further information. Considering that the operation in this accident is very common in daily work, the author classified this human factor into exceptional violation.

In fact, there are still some factors leading to this accident which could not be classified into the HFACS framework. For example there are outside factors which contribute to this accident. In the government supervision and management, Bi-benzene Plant in Jilin is supervised and management by Jilin safety administration, which means its safety issues have no relation with other administrations. However the catastrophic consequence include environment pollution, which should be administrated by environmental departments. Another outside factor is the safety assessment of the plant. In China, safety assessment is indispensable for a petro-chemical plant. However, the plant got accepted risk assessment conclusions with many hazards unidentified or controlled. In fact, modified HFACS including outside factors has been developed in previous studies [2].

In this accident, there was no factors of equipment which led to its happen. However, in petro-chemical industry, there are accidents caused by unsafe conditions of equipment, in analysis we could classify it into environmental factors in preconditions for unsafe acts or include unsafe conditions of equipment into a modified HFACC model for petro-chemical industry.

6 Conclusion

The case discussed here outlines a series of human factors that led to a catastrophic accident. The results showed that human factors played a great role in the genesis of this accident. And, the feasibility of applying HFACS in petro-chemical industry was indisputable. So, it is recommended to include HFACS to accident investigation in petro-chemical industry.

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References

1. Hollnagel, E.: Barriers and Accident Prevention. Ashgate, Aldershot (2004)
2. Chauvina, C., Lardjaneb, S., Morela, G. etc.: Human and organizational factors in maritime accidents: Analysis of collisions at sea using HFACS. Accid. Anal. Prev. **59**, 26–37 (2013)
3. Patterson, J.M., Shappell, S.A.: Operator error and system efficiencies: analysis of 508 mining incidents and accidents from Queensland, Australia using HFACS. Accid. Anal. Prev. **42**, 1379–1385 (2010)
4. Celik, M., Cebi, S.: Analytical HFACS for investigating human errors in shipping accidents. Accid. Anal. Prev. **41**, 66–75 (2009)
5. Mitchell, R., Williamson, A., Molesworth, B.: Application of a human factors classification framework for patient safety to identify precursor and contributing factors to adverse clinical incidents in hospital. Appl. Ergon. **52**, 185–195 (2016)
6. Spiess, B.D., Rotruck J., McCarthy H., etc.: Human factors analysis of a near-miss event: oxygen supply failure during cardiopulmonary bypass. J. Cardiothorac. Vasc. Anesth. **29**, 204–209 (2015)
7. Ergai, A., Cohen, T., Sharp, J. etc.: Assessment of the human factors analysis and classification system (HFACS): intra-rater and inter-rater reliability. Saf. Sci. **82**, 393–398 (2016)
8. Shappell, S., Detwiler, C., Holcomb, K. etc.: Human error and commercial aviation accidents: a comprehensive, fine grained analysis using HFACS. Hum. Factors. **49**, 227–242 (2007)
9. Li, J.: The hints from the explosion event for Bi-benzene plant of Jilin petrol chemical branch company. Thesis of Jilin University. Jilin, China (2007)

Participatory Ergonomic Approach for Workplace Improvements: A Case Study in an Industrial Plant

Hélia Fonseca, Nuno Santos, Isabel Loureiro and Pedro Arezes

Abstract This paper aims to describe the development of an ergonomic program based on the principles of Participatory Ergonomics, in order to implement workplace improvements. A case study was conducted in an industrial plant where several musculoskeletal disorders were previously identified as being the main cause of a high absenteeism. As a result of the ergonomic intervention program, several different improvements measures were implemented, improving several workplace aspects, namely workers' posture and, consequently, their working conditions. The obtained results indicate that there was a significant ergonomic improvement in tasks where the proposed measures have been implemented. The workers' satisfaction has increased considerably after the implementation of the suggested measures. Finally, it was possible to conclude that based in the success of this project, the same approach can also be extended to the remaining company's workplaces.

Keywords Ergonomics · Improvements · Participatory ergonomics · Workers' involvement · Evaluation · Effectiveness

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1 Introduction

The way companies works is more important than ever to ensure success and future sustainability. Many businesses realize that real success requires continuous improvement in several key-areas, including business performance, costs, quality, occupational safety and health, and environmental protection. Human component has taken an important role in almost industries. The study of the influence of Human factors in industries aims to guarantee that working conditions are as adequate as possible, ensuring workers' motivation, while preventing diseases and accidents. By doing so, healthy and motivated workers will be more willing to increase productivity.

Participatory Ergonomics (PE) is an intervention strategy to reduce risks related to physical load. Usually, there are several reasons for its implementation. First, it addresses one of the categories of occupational risks with the greatest impact on workers' health, both in terms of incidence, prevalence, or disability [1]. Additionally, the basic principle of PE is to enable workers to participate in the identification of risks resulting from exposure to physical loads in the workplace, as well as to propose and evaluate appropriate corrective measures for each situation. Finally, it enables solutions' development without interfering with the technical procedures.

According to Martin et al. [2], a participatory approach can encourage sustainability by using industry and workplace knowledge with design skill to meet all objectives, including the goal of sustainability. The most effective business system is the one that achieves all the sustainability' standards such as, economics, environmental, production, quality and occupational health, as well as meeting the needs of all the stakeholders.

Nowadays, industries are under a lot of pressure for several reasons as increasing of demands force manufacturers to improve the flow of assembly orders together with a more efficient process. This kind of pressure on the organization is likely to increase workers mental and physical stresses [3]. In order to solve or minimize these problems a participatory approach can be developed. Wilson and Haines [4] defined PE as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals". This active participation of workers in their workplace decisions, with the support of the organization headed by their supervisors and managers, has as main benefit the improvement of working conditions.

Theberge et al. [5] suggest PE as an intervention strategy in which workers are involved in planning and control of a portion of its own working activities. PE lists the different aspects of the organization of work, whether physical or social although the implementation of this kind of strategy is (and must be) unique to each particular situation and organization [6, 7].

The positive effects of Participatory Ergonomics targeted on the European Foundation for the Improvement of Living and Work Conditions (1999) reports. According to Vink et al. [8] report' analysis direct participation in production organizations most often leads to quality improvements (90 % of the cases), to reduction of cycle time (60 % of the cases), and to a cost reduction (60 % of the cases).

Tompa et al. [9], in a study carried out in a textile plant, suggested that PE interventions can be cost beneficial from the company perspective. In this study, even though proposals were typically low-cost and low-tech interventions benefits were achieved on both the health and financial fronts. A successful Participatory Ergonomics program should be systematic, focused and integrated into existing processes and operations and it must be also viewed as a good business decision for it to succeed [10].

It seems to there is a consensus in literature that PE methodology should always have an assumption, which is the creation of an ergonomic 'team' (steering group). This group will guide the intervention process. Typically this group comprises employees (or their representatives), managers, ergonomists, health and safety personnel, and research experts and will allow the Ergonomics to be high beyond the singular work situation and may interfere in the organizational structure [11].

Once formed, teams undergo training by an expert to become familiar with the basic ergonomic principles [1, 12].

The participatory and integrative approach has a stepwise background. For example, Vink et al. [13], divided the step-by-step approach in nine major steps: introduction, analysis, idea generation, idea selection, prototyping, testing, adjusting, implementation and evaluation. Indeed, active participation of end-users and management is very important for the 'involvement' process. On the other hand, the 'process' success is dependent on a good inventory of the problems, a structured stepwise approach, a steering group (with well-defined responsibilities for each member of the group) and a good check/monitoring of the effects [8].

The current study aims to develop an ergonomic program based on the principles of Participatory Ergonomics, in order to implement workplace improvements. It was conducted in a textile plant where several MSD were previously identified as being the main cause of a high absenteeism. The purpose of this research is to show that the active participation of all stakeholders in workplace design is essential, and this kind of approach provides a strong rationale for the use of Participatory Ergonomic principles in the development of safety work systems.

2 Methodology

2.1 Sample

This project was developed in a production area of a textile industry for automotive components, located in the North of Portugal. The manufacturing process includes textile reinforcements of tires, which is a key element in the tire manufacturing. Three stages with strict production criteria are established: twisting, weaving and dipping. Twisters are the machines responsible for twist of yarns, obtaining rope with improved characteristics. The cord resulting from twisting is rolled into tubes, of plastic or cardboard, forming bobbins that are the feedstock and will be transferred to one of two possible stages. In one of the stages, the cord can go directly to the dipping machine where the impregnation and drying of the cord is performed.

The machines work continuously, 24 h a day, 7 days per week. There are three different 8 h shifts. On average, workers have 25.1 years old (standard deviation = 3.7) and a vast majority are male (95.65 %). The majority (63.2 %) work in the company between 1 to 5 years. The second most reported range is the category one more than 5 years (31.6 %).

The workplace of dipping cord was selected to the Participatory Ergonomic program implementation, since this area, according to previous internal reports, is associated to a high-risk level of MSDs.

2.2 Participatory Ergonomics—Project Implementation

To implement the ergonomics participatory project, three fundamental stages were defined: pre-intervention, intervention and post-intervention.

A summary of the various stages of the program, as well as their objectives and target groups, is presented in Fig. 1.

A brief description of each stage is provided. The complexity of this process (project implementation) requires a sequence, in which ideas are introduced within the lead teams (pre-intervention stage). Therefore, at the beginning of the project, authors addressed the nature of the work to the Management Board and Engineering Departments, where the scope of the project was discussed as well as several steps and timeline. Following this formal presentation, it was then scheduled several communication activities to the plant operators, where fundamental and basics knowledge's about Ergonomics were exploited and tackled (mainly: ergonomics concepts, risk factors, exposure effects and safety) intertwined with an introduction to the project scope (Participatory Ergonomics) and all the different phases to be developed. Two communications sessions were booked, covering the four shifts of the studied workplace, where 24 persons were informed about the project's motivations and goals.

The intervention stage starts with an assessment of all the risks inherent to each workplace, enabling a simple and fast evaluation of the root causes. This information was collected by a diagnostic questionnaire applied to all workers that participated on the program. The questionnaire was based on the ERGOPAR [14] method, whereas the workers' identification was done according the Company guidelines. The main purpose of the questionnaire was to identify symptoms and ergonomic risk factors existing in the selected jobs for analysis. The questionnaire was divided in three main parts. The first part (workers' characterization) was related to certain variables such as gender, age, shift, type of contract and professional seniority. In the second part of the questionnaire, it was possible to assess the

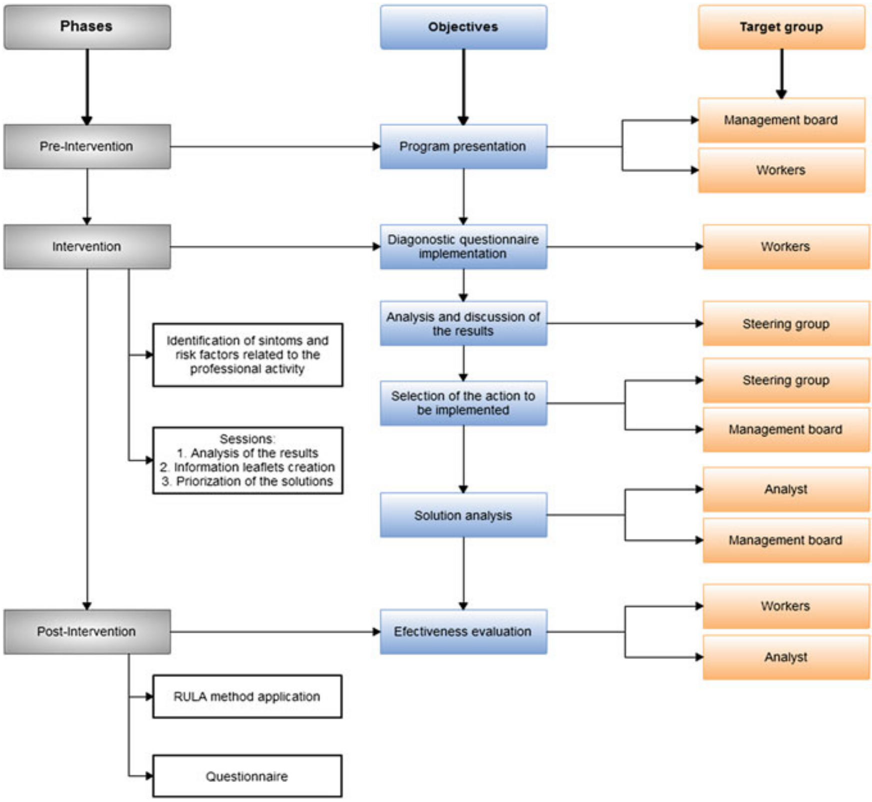


Fig. 1 Overview of the participatory ergonomics program

possible damage related to occupational health. Workers were asked to indicate, for each body area, if they felt or not discomfort or pain when performing the different tasks. In the third part, workers responded to questions about their usual postures and actions adopted when carrying out their tasks to perceive the ergonomic risk factors.

All data were collected in a spreadsheet for a more specific analysis of the results in the IBM SPSS Statistics 22, a software package used for statistical analysis.

After concluding the initial assessment phase, it was time to provide meaningful interpretations for the results and naturally start to act on the optimization of the issues highlighted by the study (treatment stage). In order to achieve this objective, the initial step was to produce a refined action plan with several proposals to tackle the workplace problems. From an ergonomic point of view, the main focus during an assembly line design should be on the worker. This is why these workplaces re-design should fit each worker and not the other way around. Therefore, an early involvement of the operators on this exercise is crucial since the optimum working environment is mostly determined on the perception that the operators have from their own working place.

The participation of the operators within the project activities is done via a "steering group" that generates a "decision context/environmental" where the intervention strategy to be applied in each workplace is proposed, extensively discussed and the key actions and monitoring mechanisms are agreed between all.

The "steering group" is defined as a specific and multidisciplinary project team with an important role of acting during the conception and problem solving activities of the project. Furthermore, several assumptions were taken under consideration, namely: (1) experience with the selected workplaces; (2) size of the "steering group" should be as such that everyone could have an important and active role (5 to 10 persons); (3) participation in the group should be voluntary; (4) the team should comprise workers from the different shifts.

With these requirements in mind, the "steering group" was then created and consisted in 8 operators, covering all shifts of the workplace, as well as the staff from the Ergonomics team of Quality and Safety Department. It should be noted that the team contained operators with different functions in the company (planning, quality and maintenance). During the entire project the Engineering Department was also briefed about the status of the project.

It was carried out three different sessions across the entire length of the project, with the following subjects under discussion:

- The first session had consisted in the analysis of the results from the questionnaire and an information leaflet was produced, stating all the risks identified during the survey for the workplace;
- In the second session, all the information that have been gathered was organized in a table with corresponding tasks addressed to each of risks. In addition to this, preventive measures were discussed and grouped by main challenges, being all accepted and listed;
- In the third, and last, session, an evaluation, prioritization and selection of solutions were technically validated and the relevant ones chosen for practical implementation.

After the selection of measures to be implemented, these were introduced in the company suggestion system to require the approval of the Quality, Production, Engineering, Health and Safety, as well as the cell leader linked to the area where the idea would be applied. For their development and determining the recommendable dimensions it was necessary to perform the anthropometric calculations based on the anthropometric data of the adult Portuguese population, according to Arezes et al. [15], and it was considered either the 95th or 5th percentile, i.e. covering 95 % of the population that would be satisfied with the proposed dimensions.

Post-intervention stage occurs following the initial assessment exercise and with the objective of monitoring all the improvements that were previously identified, suggesting that all the achieved results may now converge towards the direction of project target.

In order to analyze the effectiveness of the measures, two scenarios were established: scenario 1—corresponding to the present situation; and scenario 2—after the implementation process—and two approaches were used:

1. Assesses of postural loading
2. Identification per corporal segment of the level of reported pain.

Due to the type of work demand, Rapid Upper Limb Assessment method—RULA [16] was used to assess the risk associated to workers' postures. The risk and action levels were calculated according to Table 1 and compared against the initial results.

The operator's body postures were also extensively observed and recorded by means of pictures and/or videos. Thereafter, scores were given according to four different risk levels and corresponding colors (green illustrates a small risk, yellow a medium risk, orange a high risk and finally red representing a very high risk), based on the different main body areas under evaluation in order to better understand the impact of each improvement proposal.

The identification per corporal segment (neck, shoulders, arms, wrists, trunk and legs) of the level of reported pain regarding the two scenarios was made. For this purpose, a map was developed as presented in Fig. 2. In order to actively help in the final project assessment, a questionnaire was then created, distributed and explained to each of the workers (23 individuals) how to fill it, where each of the tasks were scored according to the type of pain and intensity, for the before and after scenarios. Workers have to score each body area in a scale of pain intensity ranging between 1 and 5.

Additionally, the risk and action levels were re-calculated and compared against the initial results. This analysis constitutes a unique way of investigate if the chosen actions had the expected impacted in increasing the ergonomic levels of any given workplace. Results obtained from the two scenarios were compared though a visual representation of each segment and with data analysis though a non-parametric test, Wilcoxon signed-rank test for two dependent samples (IBM SPSS Statistics 22 software). A significance level of 5 % was considered.

Table 1 Action levels of RULA method (adapted from McAtamney and Nigel Corlett [16])

Action level	Action
A	A score of 1 or 2 indicates that posture is acceptable if it is not maintained or repeated for long periods
B	A score of 3 or 4 indicates that further investigation is needed and changes may be required
C	A score of 5 or 6 indicates that investigation and changes are required soon
D	A score of 7 indicates that investigation and changes are required immediately

3 Results and Discussion

Nineteen workers participated in the intervention phase responding to the diagnostics questionnaire. Workers indicated, for each body area, their level of discomfort or pain when performing the different tasks.

As shown in Fig. 3, elbows were the only body area with no associated pain. Neck, shoulders, and lumbar spine, were identified as the most reported painful areas, while body down extremities were mostly associated with a discomfort level.

The great majority of workers (74 %) considers that their jobs were physical high demanding (Fig. 4).

After analysis and discussion of the results with the steering group, three different sessions were hold helping the identification of the measures to be implemented in short-term or medium/long term. Management board has validated the proposal measures presented in Table 2. Status of the implementation process is also presented. Note that ongoing process, although not been selected to immediately implementation, was introduced in the ideas system of company for medium/long term implementation.

An example of implemented measures, regarding the raise of the base of metal boxes and bench with wheels, is presented in Fig. 5.

In order to measure the effectiveness of implemented measures, RULA method was applied for each of the tasks under analysis. Risk levels were assigned to different body areas and a general assessment of the improvement rate regarding the new postures was performed.

Table 3 identifies the four-risk level obtained from RULA and correspondent percentage of occurrence. It is important to highlight that before implementation 33.33 % of the risk level was on the high category and in the "after" situation this category dropped to 2.3 %. The lowest level increased 34.43 %, being a direct

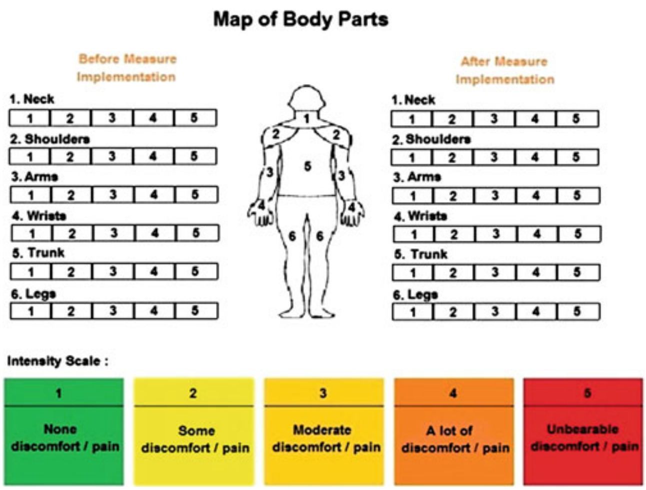


Fig. 2 Map of body parts (adapted from Corlett and Wilson [17])

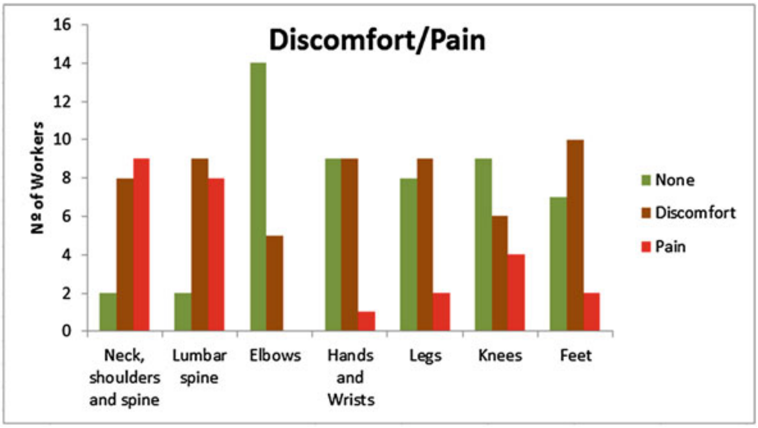
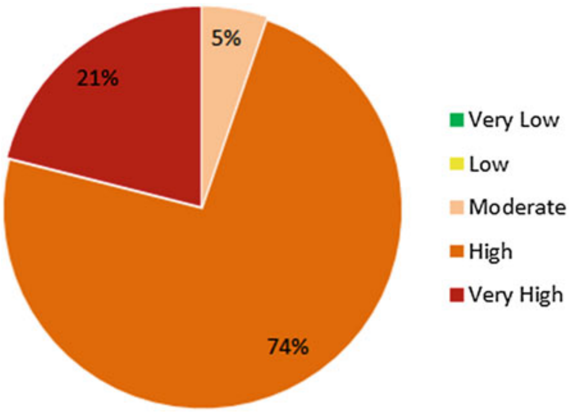


Fig. 3 Level of reported discomfort/pain per body area

Fig. 4 Physical demands of jobs according to workers' perception



consequence of the measures implemented on the different workplaces, improving the postures adopted by the worker when performing the different tasks.

Regarding the statistical analysis performed on the questionnaire post-intervention phase, results showed a significant improvement in all tasks, concerning the intensity level of reported discomfort/pain felt by workers.

The statistical analysis (Wilcoxon signed-rank test) of the self-symptoms results reported by workers "before" and "after" the implementation of measure presented in Fig. 5a) is shown in Table 4.

According to workers' opinion, by raising the handle height the level of reported discomfort/pain is alleviated in all evaluated areas of the body. However, the trunk is the most benefited body area going from an average level of discomfort of 3.87 to 2.48, corresponding to a "moderate" level of discomfort/pain according to the

Table 2 Proposal measures: objectives, technical changes and status

Measures	Objective	Technical changes	Status
Acquisition of an electric high lift pallet truck	Load and unload creels and transport pallets easily	Permits that works adjust the high of lift the bobbins during loading and unloading creels	Ongoing
Development of benches with wheels	Sit while cleaning twisters pots and the wire avoiding poor postures	The workers doesn′t need to get up while they are performing tasks. The seat height should not exceed 38.4 cm	Finished
Development of a platform (bench)	Reach the upper level of the creels just to easily pass the wire and perform safely	Bench height may not exceed the height of the bottom level of the creels (45 cm). The platform height should be between 53.6 and 67.9 cm	Finished
Development adapted bench	Clean the dipping machine stove rolls on a mesh floor	The seat height should not exceed 38.4 cm	Finished
Extend the ramp of the carpet ramp	Lower the handle height during the task of unload twisters	The handle height of the carpet ramp should be between 117.1 and 131.4 cm	Finished
Modify the table of scale	Twisters-raise the table height	The handle height of the table + scale should be the high of the carpet	Ongoing
Raise the base of the metal boxes	Dipping machine—raising the handle height	Minimum height of bottom level is 62.8 cm and maximum height of upper level is 155 cm	Finished
Create support for compressed air hose	To dipping machine	Design of support in development stage	Ongoing

Fig. 5 Before/After implementation of a base of metal boxes (**a**) and a bench with wheels (**b**)

Table 3 Risk levels associated with different body areas and % of occurrence before and after the implementation of measures

Risk level	Before (%)	After (%)
Very high 🔴	33.33	2.78
High 🟠	11.11	8.33
Moderate 🟡	38.89	52.78
Low 🟢	16.67	36.11

Table 4 Descriptive statistics per body area (questionnaire post-intervention)

Body area	Before average	After average	Wilcoxon statistics
Neck	2.96	2.26	2.859**
Shoulders	3.43	2.48	3.372**
Arms	3.30	2.39	3.384**
Wrists	3.04	2.35	3.066**
Trunk	3.87	2.48	3.895**
Legs	3.04	2.39	2.877**

** $p < 0.05$

intensity scale presented in Fig. 2. The differences between "before" and "after" are statistically significant to a level of significance of 5 % ($p < 0.05$) for all body areas.

It should be noted some difficulties in implementing a program based on Participatory Ergonomics and advices for this type of approach, namely:

- It is a slow and time-consuming process because of the need to build trust and credibility among all participants and at all levels of the organization;
- It requires a high and constant effort to raise awareness to the participation of all stakeholders, and it is necessary that, during the process, to consult regularly if workers wish to continue with their participatory role given that the levels of interest and motivation can change throughout the process;
- Even after the training sessions, workers may not understand some ergonomic aspects, which could mislead in some of the suggested measures;
- Sometimes there are difficulties in obtaining financial support, as it is undeniable that a process that takes time to get results can be seen as an unprofitable investment;
- The investigator's role is fundamental in order to demonstrate the benefits that such approach can bring, both for workers and organization in the short, medium and long-terms.

4 Conclusions

The current study shows that Participatory Ergonomics can be an effective strategy in reducing the workers' exposure to WMSDs risk factors of. Furthermore, it strengthens the importance of employees' participation at all stages of the process. Indeed, workers know their workplaces better than anyone, and this knowledge allows them to develop a deeper understanding of both ergonomic problems and potential solutions.

The objectivity of the program was also essential to the success of the implementation process, as it allowed keep people committed to the proposed goals.

According to RULA method, the obtained results indicate that there was a significant ergonomic improvement in tasks where measures have been implemented. Results also showed that workers felt a significant improvement regarding the level of reported discomfort/pain.

Finally, based on the results, Management Board decided that the very same approach should be extend to all sections of the company,

Aside all the relevant contributions, this study also has its own limitations. The main one, inherent to the research method, is the difficulty in generalizing the results. Therefore, it shall be taken into account that, when analyzing the results, the implementation of Participatory Ergonomics program described here is only a case study on a specific type of organization, a multinational company with a high-level of safety culture. Consequently, due to the limited scope of the study, and the nature of action research, the implementation and results of Participatory Ergonomics program are not easily generalized to other contexts.

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References

1. Rivilis, I., Van Eerd, D., Cullen, K., Cole, D.C., Irvin, E., Tyson, J., Mahood, Q.: Effectiveness of participatory ergonomic interventions on health outcomes: a systematic review. Appl. Ergon. **39**(3), 342–358 (2008)
2. Martin, K., Legg, S., Brown, C.: Designing for sustainability: ergonomics–carpe diem. Ergonomics **56**(3), 365–388 (2013)
3. De Looze, M.P., Van Rhijn, J.W., Van Deursen, J., Tuinzaad, G.H., Reijneveld, C.N.: A participatory and integrative approach to improve productivity and ergonomics in assembly. Prod. Plan. Control **14**(2), 174–181 (2003)
4. Wilson, H., Haines, J.R.: Participatory ergonomics. In: Salvendy, G. (ed.) Handbook of Human Factors and Ergonomics (2nd ed.), pp. 490–513. Wiley, New York (1997)
5. Theberge, N., Granzow, K., Cole, D., Laing, A.: Negotiating participation: understanding the 'how' in an ergonomic change team. Appl. Ergon. **37**(2), 239–248 (2006)

6. Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W.S., Wilson, J.R., van der Doelen, B.: A strategy for human factors/ergonomics: developing the discipline and profession. Ergonomics **55**(4), 377–395 (2012)
7. Stanton, N., Hedge, A., Brookhuis, K., Salas, E., Hendrick, H.: Handbook of Human Factors and Ergonomics Methods. CRC Press, Boca Raton (2005)
8. Vink, P., Koningsveld, E., Molenbroek, J.: Positive outcomes of participatory ergonomics in terms of greater comfort and higher productivity. Appl. Ergon. **37**(4), 537–546 (2006)
9. Tompa, E., Dolinschi, R., Natale, J.: Economic evaluation of a participatory ergonomics intervention in a textile plant. Appl. Ergon. **44**(3), 480–487 (2013)
10. Jatczak, M.: Key Factors for Successful Implementation of a Participatory (2008)
11. Bolis, I.: Contribuições da ergonomia para a melhoria do trabalho e para o processo de emancipação dos sujeitos," p. 180 (2011)
12. Wells, R., Norman, R., Frazer, M., Laing, A., Cole, D., Kerr, M., Services, S.C.: University of Waterloo ergonomics program implementation blueprint, no. (2003)
13. Vink, P., Imada, A.S., Zink, K.J.: Defining stakeholder involvement in participatory design processes. Appl. Ergon. **39**(4), 519–526 (2008)
14. A. y S. (ISTAS-C. Instituto Sindical de Trabajo, "Recursos de apoyo al tutor en la aplicación del Método ERGOPAR Versión 2.0," 2014. Available: http://ergopar.istas.net/recursos/. Accessed 15 Jan 2015
15. Arezes, P., da Costa, L.G., Miguel, A.S., Barroso, M., Cordeiro, P.: Base de dados antropométricos de uma população laboral. Revista Ingenium, Ordem dos Engenheiros **II**(88), 64–69 (2005)
16. McAtamney, L., Nigel, E.: Corlett, "RULA: a survey method for the investigation of work-related upper limb disorders.". Appl. Ergon. **24**(2), 91–99 (1993)
17. Corlett, N., Wilson, J.: Evaluation of Human Work: A Practical Ergonomics Methodology, 2 ed. Taylor & Francis, London (1995)

Friendly Fatigue Alert Mobile Apps to Help Aviation Workers Prevent, Identify and Manage Alertness and Fatigue

Rosa M. Arnaldo, Fernando Gomez Comendador, Luis Pérez Sanz and Alvaro Rodriguez Sanz

Abstract Fatigue is currently one of the hottest topic in transport safety research, since it has been recognized as one of the key factors in several industrial incidents/accidents. The aeronautical industry is currently working in developing standards and regulation for FRMS, Fatigue Management Risk Systems, with the aim of helping aeronautical organizations to reduce the hazards associated with fatigued workers. The implementation of such systems is difficult and requires high effort in training, dissemination and awareness. They may greatly benefit from the development of curricula and training materials widely available through internet but also from SW or mobile applications for workers, and also for organizations, that helps them to identify fatigue situations and manage derived risk. This paper presents an initiative carried out by students of the UPM Master in Air Transport System to develop "Friendly Fatigue Alert" mobile applications, designed specifically to help workers manage alertness and fatigue that will allow workers to estimate, detect, measure and mitigate their fatigue.

Keywords Fatigue · Alertness · Aviation · Mobile applications · Fatigue risk management systems

1 Fatigue Management in Aviation

In the aviation industry, 24-h operations are a must and shift work is a necessary component of operations. Irregular work schedules, night and sometimes extended shifts, operations through multiple time zones and high cognitive workload are integral part of the business. Flight crews, aircraft mechanics, air traffic controllers, handling operators and workers in the aviation chain assembly are prone to fatigue due to the nature of their professions.

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ICAO, the International Civil Aviation Organization, defines Fatigue as "*a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness*, *circadian phase*, *or workload* (*mental and/or physical activity*) *that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties*" [1].

Fatigue is a snowballing process that continues to construct through the day, and from day to day, if not lightened by sufficient rest, sleep, and nutrition. Fatigue is both a warning sign of poor sleep and health management, and also an activator of other safety risk. Fatigue affects negatively a person's ability to stay awake, alert, and attentive to the demands of safety critical works. Moreover, fatigue damages our capacity to judge just how fatigued we really are. Fatigue goes along with an increasing bodily discomfort [2] and a decline in cognitive performance [3]. Fatigue impairs the executive functions of the brain including motivation, initiative, reasoning, short-term memory, communication, decision-making, and perceptual tasks requiring interpretation and response [4]. It also diminishes mood while increasing indifference [5].

The turn down in brain functions and performance becomes in an increase in errors and accidents [6–10]. It is therefore a serious issue affecting the safety of the travelling public in all modes of transportation, and specifically aviation. Not in vane "Fatigue has been on of the NTBS 'Most Wanted List' of transportation safety improvements every year since the list's inception in 1990." The NTSB Most Wanted List highlights safety issues identified from the NTSB's accident investigations to increase awareness about the issues and promote recommended safety solutions [11].

Despite research carried out on systems, methods and tools for preventing, detecting and predicting human fatigue, the challenge is that fatigue cannot be entirely be eradicated from 24/7 aviation operation, so aviation companies need to apply proactive and adaptive approaches to manage and mitigate fatigue.

The traditional ways to manage fatigue in aviation had been prescriptive flight and duty time limitations and rest requirements. Today however, the aeronautical industry has adopted a data-driven approach for the continuous monitoring of fatigue-related safety risks, called Fatigue Risk Management System (FRMS). An FRMS is defined as a "*data-driven means of continuously monitoring and managing fatigue-related safety risks*, *based upon scientific principles and knowledge as well as operational experience*, *that aims to ensure relevant personnel are performing at adequate levels of alertness*" [12]. Based upon scientific principles and knowledge, as well as operational experience, it aims to ensure that relevant personnel are performing at adequate levels of alertness. There are *four basic tools for an FRMS* to be effective:

1. *Fatigue-Related Data*. It should be data-driven, based on scientific principles and involving continuous monitoring of work schedules and fatigue reports.
2. *Fatigue Analysis Methods*. It should use well known and accepted models that incorporates the latest scientific research on human circadian systems, sleep, and performance capability, and can be useful for rapidly estimating fatigue levels [13].

3. *Identification and Management of Aviation Fatigue Drivers*. It should act on operational drivers of fatigue in any aviation environment: duty periods; rest breaks; additional duties; recovery days, utilization of available rest opportunities,…
4. *Application of Fatigue Mitigation Procedures*. It should employ multiple layers of defense: adjust scheduling rules to provide recovery sleep opportunities; maximizing use of available sleep opportunities to reduce cumulative fatigue,…

Additionally in this context employees/operators have *three main responsibilities* to contribute to an effective FRMS: get enough sleep, plan this sleep ahead of time and sincerely report on fatigue. Each person has a single sleep profile to maintain alertness and performance, and it is its own responsibility to get the sleep needed and to take additional sleep when they feel fatigued or unfit for duty. Getting adequate sleep requires planning with future duty times in mind. Additionally it is key that the employee identifies and reports his or her state of fatigue properly.

The implementation of effective FRMS requires all the support and resources available. Organizations and employees may greatly benefit from the potential of new technologies in achieving their common goal of preventing, detecting and predicting human fatigue, and applying proactive and adaptive measurements to manage and mitigate the fatigue derived risk.

This paper presents an initiative carried out by students of the UPM Master in Air Transport System to develop mobile applications that allows workers to estimate, detect, measure and mitigate their fatigue.

"Friendly Fatigue Alert" apps have been designed specifically to help workers to manage alertness and fatigue. These apps could also support a future crowd sourcing activity aimed at collecting fatigue data across multiple regions and aeronautic business models world-wide. People (workers) using the project smart phones applications for fatigue can be invited to participate in a Fatigue Data Collection program. The data could be used for correlation of so-called mathematical fatigue models as well as assess current state and compare between different types of operation.

2 Organization of the Work and Methodology

Air Transport Systems Master program students from the ETSIAE (Aeronautical and Space Technical Engineering School) at the UPM (Universidad Polytechnic de Madrid) have faced the challenge of developing "Friendly Fatigue Alert" apps specifically designed to help workers to manage their alertness and fatigue.

This Masters' Degree is oriented at research and professional activities in the areas of analysis and architectural design of air transport systems. Its main aim is research applied to the improvement in operational safety, efficiency and the capacity of air transport and its infrastructure, by using information technologies and the analysis of systems centered on the human factor. The Master Degree includes a track focused on Aviation Safety that allows students to acquire the knowledge, technical skills and practical experience, necessary to practice safety in an aviation environment.

Master students receive courses on subject such as Operational Safety in Aviation, Safety Management Systems, Optimization and Estimation Theory, Aircraft and safety Occurrences Investigation, Safety Data Analysis, Risk of Collision and Safety Modeling, System Safety Assessment and Risk Mitigation, and Human Factors in Aviation. This Master track is designed for students who wish to further improve their knowledge and experience of aviation safety.

The development of "Friendly Fatigue Alert" apps has been settled as a classroom cooperative competition among groups of students along the whole semester, where students strive to in by developing the smartest and most useful fatigue app. This initiative have been sponsored by LISA the "Laboratory of Ideas for Safety in Aviation", a partnership between UPM and other relevant research agents in the Aviation Safety Arena like CRIDA, IBERIA, AESA, etc. to promote the exchange of innovative ideas & collaborative initiatives to address the safety challenges of aviation. The Laboratory of Ideas for Safety pretends to offer a platform where entities engaged in the development of research activities that seek to improve safety standards in aviation can foster collaboration in educational, scientific and technical related initiatives.

Students groups have to accomplish two main objectives as part of their assignment. They have to design and develop a prototype of a smart and useful app to help aviation workers to estimate, detect, measure and mitigate their fatigue. At the same time they have to incorporate in the design of such applications the Human Factors principles learned in the Master program. Each group of student was assigned a tutor to supervise their work and to provide them with guidance and advice through tutorial sessions organized every two weeks. The student work was also organized, split and distributed in 4 main deliveries along the semester so they had to accomplish intermediate tasks, as indicated in the Fig. 1.

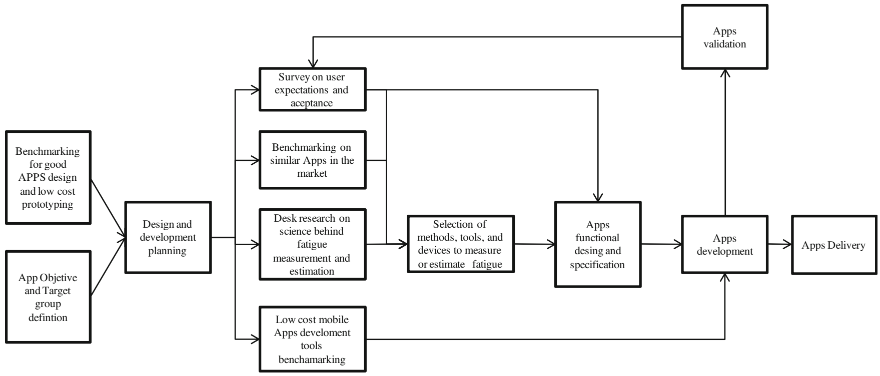

Fig. 1 Methodology for the development of friendly fatigue apps

3 Capturing Users Expectations

One of the main tasks developed by the students was an online survey to verify up to what extent possible target groups might be interested in the concept for the Friendly Fatigue App, and what might be their expectations and requirements as future users.

To carry out this survey each group of students have followed 4 steps: survey design, survey on line implementation, survey disseminations and analysis of the survey results. Target groups and rate of respondents varied among the groups of students. To illustrate the process Table 1 presents part of the questions in one survey addressed to the target group of "pilots" that obtained 66 answers and the main conclusions obtained from their analysis.

4 The Science Behind Fatigue Measurement

As students have learned, there is no a single simple measure for detecting and predicting human fatigue, just different ways of estimating or monitoring the level of fatigue. The evaluation of fatigue in the laboratory implies the combination of many different measurements in the same experiment to build up a complete picture and there tends to be a strong correlation between the different measures. The detection of fatigue in an operational context entails totally different requirements such as the need to select a very limited number of measures and the adaptation to practical constraints. Table 2 illustrates a classification on the main methods for measuring and monitoring fatigue in aviation operations.

4.1 Subjective Fatigue and Sleepiness Ratings

Among the subjective methods there are several well-established and validated subjective measures, including:

- The *Visual analogue scales* (*VAS*) is a scale of 9 levels ranging from 1 to 9 (1 = "Extremely alert", 9 = "extremely sleepy, fighting sleep"), where odd levels have a verbal description associated [14–16].
- The *Karolinska Sleepiness Scale* (*KSS*) is a one-dimensional scale ranging from 1 ("very alert") to 9 ("very sleepy, great effort to keep awake") [17, 18]. A value of 7 or higher on the KSS is associated with intrusions of sleep and an increased risk of impaired performance.
- The *Samn-Perelli seven-point fatigue scale* (*SPS*) is a 7-point scale with scores ranging from 1 ("fully alert, wide awake") to 7 ("completely exhausted, unable to function effectively") [19–21]. 5 and 6 are 'Fatigue Class II', i.e. "flying duty permissible but not recommended". 7 is 'Fatigue Class I', i.e., "Severe fatigue. Performance impaired. Flying not recommended. Safety of flight in jeopardy."

Table 1 Example of user's expectation survey

Survey questions	Answer analysis
Do you think convenient the design and development of a mobile application (app) able to measure the level of fatigue flight crews?	• Yes: 98.5 % • No: 1.5 %
Would you consider the use of lightweight rubber bracelet (smartband) as a means of fatigue data collection for flight crews?	• Yes: 77.3 % • No: 22.7 %
What features would expect in a mobile application for flight crews fatigue detection?	• Fatigue estimated from flight scheduling: 83.3 % • Recommendations for optimal sleep planning: 63.6 % • Anticipated alert of flight crew state of fatigue: 72.7 % • Daily activity statistics (steps, sleep, calories,…) 71.2 % • Evaluations of perceived fatigue before flight: 95.5 % • Eyes strain detection: 57.6 % • Evaluations of actual fatigue based on performance: 53 % • De-identified fatigue reporting to the company FRMS: 63.6 % • Countermeasures to mitigate fatigue: 57.6 %
Would he agree to answer a fatigue questionnaire trough a mobile application?	• Yes: 87.9 % • No: 12.1 %
Would you prefer a free or paid friendly fatigue mobile application?	• Yes: 87.9 % • No: 12.1 %
What recommendations would you suggest for the design of the mobile application?	• Developed by people with operational experience • Paid and developed by the airline • Accepted by national supervisory authorities to verify fulfillment of flight time limitations • To be used for the flight preparation (meteo and aeronautical information, briefing, etc.) • User friendly and simple • That highlight the relevance of fatigue in aviation safety • Feed with actual flight times • Certified by aeronautical authorities • Provide a level of risk before a flight • No time demanding • No intrusive • Usable also for daily activity control

Table 2 Main methods for measuring and monitoring fatigue

Subjective methods	Fatigue	Sleep	
	VAS KSS Samn-Perelli	Sleep diaries	
Objectives methods	Circadian rhythms	Sleep	Performance
	Temperature Biological testing	Actigraphy Polysomnography	Simple mental tasks Complex behaviors

Subjective sleepiness and fatigue ratings are cheap and easy to collect and analyze, although do not always reliably reflect objective measures of performance impairment or sleep loss, particularly if a person suffered sleep restriction on consecutive nights.

4.2 Objective Performance Measurement

A range of objective performance tests are used in laboratory studies, however strict requirements needs to be considered when choosing performance tests for monitoring operators fatigue and sleepiness during real time (particularly flight) operations. One performance test that meets these criteria is the Psychomotor Vigilance Task or PVT [22, 23]. In the most widely used version of the PVT, the test lasts for 10 min and on a purpose-built hand-held device, although some recent studies [24] are using a 5-min version of the PVT programmed on a PDA. It requires a operator's constant attention and does not measure situation awareness and decision-making.

4.3 Monitoring Sleep

Sleep can be monitored during operations using subjective sleep diaries and/or by objective measures such as actigraphy or polysomnography:

- *Sleep Diaries*: Sleep diaries ask operators to record, for each sleep period, where they sleep; what time they go to bed and get up; how much sleep they think they get; and how well they think they sleep. Sleep diaries are cheap compared to objective forms of sleep monitoring, although they are less reliable.
- *Actigraphy*: An actigraph is a small device wrist worn that monitors activity and can give an indication of when an individual may be asleep and estimate the timing of periods of sleep and its quality. They are small and unobtrusive to

wear; easy to administer and can pick up unintentional sleeps, but they monitor activity (not sleep) and cannot distinguish being asleep vs being awake but not moving.

- *Polysomnography*: Polysomnography is the accepted gold standard for monitoring sleep and for knowing the internal structure of sleep and its quality. It involves sticking removable electrodes to the scalp and face to measure three different types of electrical activity: brainwaves (EEG), eye movements (EOG) and muscle tone (EMG). It monitors waking alertness, subsequent fatigue levels, and recovery from a series of duties.

4.4 Monitoring the Circadian Body Clock Cycle

The circadian body clock cycle is a key contributing factor to fatigue, but it is difficult to monitor during operations. In the laboratory, the cycle of the body clock is usually monitored by measuring two of the overt rhythms that it drives: (1) the daily rhythm in core body temperature; and (2) the daily rhythm in levels of the hormone melatonin, which is secreted by the pineal gland at night. Melatonin levels can be measured from blood, saliva, or urine samples collected at regular intervals.

Today is generally impracticable to measure it during operation, although a number of groups are actively working on new technologies for monitoring the circadian body clock cycle, but as yet none of these has been validated or demonstrated to be robust enough and practical for use during flight operations.

4.5 Biomathematical Models for Predicting Fatigue

Most biomathematical models are based on 2- or 3-process models [25–27], and may also be ‘task related’, in that they consider aspects of the type of task/s to be performed during the work period.

The Two-Process Model, developed on the basis of many laboratory experiments, explains timing and duration of sleep as a result of the interaction between two processes: (1) Process S (Sleep), also called homeostatic pressure, where sleep onset occurs when process S reaches a high threshold (H) and wake-up occurs when S drops below a low (L) threshold. (2) Process C (for Clock/Circadian) is a sinusoidal function that programs sleep to occur during night time and to stop during the daytime.

The Three-Process Model of Alertness predicts the level of alertness and by adding the process W (Waking), relating to sleep inertia (transient state of lowered arousal occurring immediately after awakening from sleep and producing a temporary decrement in performance).

An exception is the Fatigue Risk Index (FRI), which is based instead on empirical data from shiftwork and aviation, constructed from three separate components: (1) a cumulative component based on the pattern of work leading up to any given shift; (2) a duty-timing component concerned with the effect of start time, shift length and the time of day; and (3) a job type/breaks component, which relates to the task or activity performed and the breaks scheduled during the shift.

5 Selecting a Method for Measuring Fatigue in Operation

Students have had to revise the state of the art of human fatigue estimation methods and select the combinations of techniques that best suit the purpose of their apps. In this situation, as in many other industrial engineering applications the final decision is based on the evaluation of a number of alternatives in terms of a number of criteria.

This problem may become a very difficult one when the criteria are expressed in different units or the pertinent data are difficult to be quantified. To deal with these difficulties students have applied the Analytic Hierarchy Process (AHP) as an effective approach in dealing with this kind of decision problems [28]. Table 3 shows the criteria selected by one of the groups of participants for the application of this method, and the ranking of fatigue measurement methods resulting from the Analytic Hierarchy Process and the criteria previously identified.

Table 3 Criteria for application of the analytic hierarchy process and resulting prioritization

AHP selection criteria and weighting factors		Prioritized methods	
AHP selection criteria	Normalized weighting factors (%)	Order	Method
Diagnostic capability	30	1°	Objective performance measurement PVT
Level of intrusiveness	30	2°	Monitoring sleep: actigraphy
Necessary for carrying out the test time	20	3°	Subjective fatigue and sleepiness ratings
Sensitivity	10	4°	Biomathematical models for predicting fatigue
Continuity in the collection	10	5°	Monitoring the circadian body clock cycle

6 Conclusions and Further Work

Up to 15 groups of students have participated in this competition with the aim of developing Friendly Fatigue Apps for aeronautical professionals with a wide range of results.

In general all the groups achieve the goal of designing and developing a prototype functionally capable up to certain extent of providing indications about operators fatigue. Being this a classroom exercise, some phases in the process, such as SW development and validation of the applications, are not of a professional standard.

However the different phases of the project have shown the relevance and interests of the concept for several target of user groups, including not only operator but also companies and regulators. The project have also put of manifest the technological viability of this type of applications as a standard and useful way of measuring/estimating fatigue and present the information to the affected operators in a way that might help them to reduce their negative impact.

The experience have confirmed the initial idea that Friendly Fatigue mobile Apps can become a powerful tools that serves several purposes for an aeronautical company and its FRM and safety departments, as well as their professionals, becoming a key asset in:

- Fatigue prediction—by automatically adjust to changes in the settings, the work schedule, and a operators sleep history, to predict poor alertness with alertness colors, and creating an important awareness that leads to better sleep and activity management, when preparing for duty.
- Fatigue mitigation—If used by operators to find tailored mitigation strategies and learn more on how different factors, like light exposure, affect fatigue.
- Fatigue reporting—It might simplifies fatigue reporting, by automatically populating most information in the report, and sending it off as an email.
- Data collection—Reducing the workload and cost for collecting fatigue data and increasing the demographic representative of the gathered data.
- Finding scheduling options—It makes it straightforward to create and compare several different patterns (such as consecutive early/late duties, west before east, consecutive night duties).
- Education—Being a good tool for training operators and safety professionals in fatigue risk.

References

1. ICAO: Manual for the Oversight of Fatigue Management Approaches, 2nd edn. ICAO (2016) (unedited)
2. Bartlett, F.: Fatigue in the Air Pilot, pp. 1–10. Flying Personnel Research Committee No. 488 (1942)

3. Evans, S.M., Mackie, R.R., Wylie, C.D.: Fatigue Effects on Human Performance in Combat: A Literature Review. United States Army, Research Institute for Behavioral and Social Sciences. ARI Research Note 91-90 (1991)
4. Craig, A., Cooper, R.E.: Symptoms of acute and Chronic fatigue. In: Smith, A.P., Jones, D.M. (eds.) Handbook of Human Performance, vol. 3; State and Trait. Chap. 11. Academic Press, New York, NY, pp. 289–339 (1992)
5. Firth-Cozens, J.: Stress, psychological problems, and clinical performance. In: Vincent, C., Ennis, M., Audley, R.J. (eds.) Medical Accidents. Chap. 9. Oxford University Press, New York, NY, pp. 131–149 (1993)
6. Carskadon, M.A., Dement, W.C.: Effects of total sleep loss on sleep tendency. Percept. Motor Skills **48**, 495–506 (1979)
7. Dinges, D.F., Kribbs, N.B.: Performing while sleepy: effects of experimentally-induced sleepiness. In: Monk, T.H. (ed.) Sleep, Sleepiness and Performance. Wiley, Chichester, England, pp 97–128 (1991)
8. Dinges, D.F., Pack, F., Williams, K., Gillen, K.A., Powell, J.W., Ott, G.E., Aptowicz, C., Pack, A.I.: Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4–5 hours per night. Sleep **20**, 267–277 (1997)
9. Durmer, J.S., Dinges, D.F.: Neurocognitive consequences of sleep deprivation. Semin. Neurol. **25**, 117–129 (2005)
10. Bonnet, M.H., Arand, D.L.: We are chronically sleep deprived. Sleep **18**(10), 908–911 (1995)
11. NTSB: http://www.ntsb.gov/safety/mwl/Pages/default.aspx (2016)
12. IATA: Fatigue Management Guide for Airline Operators, 2nd edn. IATA (2015)
13. Van Dongen, H.P.A, Kerkhof, G.A.: Human Sleep and Cognition, Part II: Clinical and Applied Research (2014)
14. Gillberg, M., Kecklund, G., Åkerstedt, T.: Relations between performance and subjective ratings of sleepiness during a night awake. Sleep **17**(3), 236–241 (1994)
15. Harma, M., Sallinen, M., Ranta, R., Mutanen, P., Muller, K.: The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. J. Sleep Res. **11**(2), 141–151 (2002)
16. Gillberg, M.: Subjective alertness and sleep quality in connection with permanent 12-hour day and night shifts. Scand. J. Work Environ. Health **24**(Suppl 3), 76–80 (1998)
17. Åkerstedt, T., Gillberg, M.: Subjective and objective sleepiness in the active individual. Int. J. Neurosci. **52**, 29–37 (1990)
18. Kaida, K., Takahashi, M., Åkerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., Fukasawa, K.: Validation of the Karolinska sleepiness scale against performance and EEG variables. Clin. Neurophysiol. **117**(7), 1574–1581 (2006)
19. Samn, S.W., Perelli, L.P.: Estimating aircrew fatigue: a technique with implications to airlift operations. In: Brooks AFB, TX. USAF School of Aerospace Medicine. Technical Report No. SAM-TR-82-21 (1982)
20. Samel, A., Wegmann, H.M., Vejvoda, M., Drescher, J., Gundel, A., Manzey, D., Wenzel, J.: Two-crew operations: stress and fatigue during long-haul night flights. Aviat. Space Environ. Med. **68**, 679–687 (1997)
21. Samel, A., Wegmann, H.M., Vejvoda, M.: Aircrew fatigue in long-haul operations. Accid. Anal. Prev. **29**(4), 439–452 (1997)
22. Dinges, D.F., Powell, J.P.: Microcomputer analysis of performance on a portable, simple visual RT task during sustained operation. Behav. Res. Meth. Instrum. Comput. **17**, 652–655 (1985)
23. Balkin, T.J., Bliese, P.D., Belenky, G., Sing, H., Thorne, D.R., Thomas, M., Redmond, D.P., Russo, M., Wesensten, N.J.: Comparative utility of instruments for monitoring sleepiness-related performance decrements in the operational environment. J. Sleep Res. **13**, 219–222 (2004)
24. Lamond, N., Petrelli, R., Dawson, D., Roach, G.D.: The impact of layover length on the fatigue and recovery of long-haul flight crew. In: Proceedings of the Fatigue in Transportation Conference (Session 13c), Seattle, 11–25 Sept 2005. US Department of Transport

25. Borbély, A.A.: A two process model of sleep regulation. Hum. Neurobiol. **1**(3), 195–204 (1982)
26. Akerstedt, T., Folkard, S.: Validation of the S and C components of the three-process model of alertness regulation. Sleep **18**(1), 1–6 (1995)
27. Akerstedt, T., Folkard, S.: Predicting duration of sleep from the three process model of alertness regulation. Occup. Environ. Med. **53**, 136–141 (1996)
28. Evangelos Triantaphyllou, E.: Using the analytical hierarchy process for decision making in engineering applications: some challenges. Int. J. Ind. Eng. Appl. Pract. **2**(1), 35–44 (1995)

Part IV
Safety Assessment

Ergonomics Design in Secure e-Healthcare Information System

Goran Jakimovski and Danco Davcev

Abstract Medical data is more and more offloaded onto servers and cloud systems to enable fast access to patient's medical record by creating Electronic Health Records (EHR). Since almost each patient has mobile devices with bio sensors, mobile devices are often connected to the EHRs and transfer data between Medical Cloud and mobile devices. Since medical data is sensitive by nature and must be secured, different approaches are used to achieve basic and advanced level of protection of these data. The main contribution in this paper is the proposed multi-layered security model, along with the ergonomic analysis of the system to provide better healthcare system for patients and medical personnel. Our QoE metrics and analysis is used to analyze and accommodate the system on users' needs.

Keywords Ergonomic analysis · NFC · Mobile devices · MRI secure medical mobile cloud

1 Introduction

Medical data recently is being transferred or offloaded onto cloud computing systems so that patient can access their medical profiles faster and easier. Nowadays patients have mobile devices with bio-metrical scanners; mobile devices get connected to the Electronic Health Records (EHRs) and transfer data between Medical Cloud (MC) and mobile devices. Since medical data is sensitive by nature

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and must be secured, different approaches are used to achieve basic and advanced level of protection of these data. The main contribution in this paper is the ergonomics design of the security model stack based on NFC tagging and encryption. We are using Quality of Experience (QoE) metrics to analyze and improve system based on users' perspective.

Doctors, nurses, surgeons and specialists can use the medical cloud system in conjunction with their NFC-equipped devices to run tests, give diagnostics and store medical information in the MC. In our case, we are using sensor information about patient's blood pressure, temperature and outdoor pollution. Doctors can access the entire medical history of their own patients or patients that the system has granted them access to. The system uses strict role-based approach to access medical profiles. In [1], NFC is used to tag prescription pills of patients to maintain correct amount of pill consumption. It uses smart devices equipped with NFC-tagging and automates the process of taking pills. That way, patients can improve their healthcare by correctly taking their pills. Another usage of smart devices is presented in [2], where using the smart-phone's camera, the author is sending cardiogram information of the patient. Using this method, the Medical System can use Electrocardiogram data of the patient using day-to-day sensors.

In [3], the authors in the very beginning emphasize that mhealth services need reliable communication techniques to offer acceptable Quality of Experience (QoE) for doctors in the transfer of biomedical data. These services play very important role in health-care and provide tools for home assistance, remote patient monitoring, and disease management. Within the proposed CONCERTO solution to m-health system, the medical health files are divided into source (area of the incident) and remote hospital area. Data is being transferred and streamed between these areas in order to increase the ease of access and reliability of multimedia medical data. The division is mainly logical, dividing heavy medical data such as video streaming where additional coding and analysis is needed from generating continuous data from sensors where data is heavy in a fixed time slot. In our paper, besides reliability, we are proposing a security model for increased medical data security and protection.

Doctors, nurses, surgeons and specialists can use the medical cloud system in conjunction with their NFC-equipped devices to run tests and give diagnostics. In our case, we are using MRI images to detect possible bone fractures and sensor information about patient's blood pressure. Doctors can access the entire medical history of their patients. In [1], NFC is used to tag prescription pills of patients to maintain correct amount of pill consumption. It uses smart devices equipped with NFC-tagging and automates the process of taking pills. That way, patients can improve their healthcare by correctly taking their pills. Another usage of smart devices is presented in [2], where using the smart-phone's camera, the author is sending cardiogram information of the patient. Using this method, the Medical System can use Electrocardiogram data of the patient using day-to-day sensors.

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In order for the system to be convenient for medical data generation, analysis, storing and online access, the system has to address the issue of data security, integrity and privacy. The first issue that an online medical healthcare system has to solve is the security and privacy of patients due to patient-doctor confidentiality and manipulation of healthcare data by unauthorized person. This could lead to bad healthcare and possible death of patients. In [4, 5], the medical record system is secured using encryption and middleware software for privacy policy and profile management. Additionally, in [5] the system uses encryption to address the network security issue. In [6–8], the entire system's security is boosted using NFC tagging and identification control (this lowers the risk of data manipulation and maintains healthcare data integrity and reliability).

Our contribution is creating and testing a secure medical data Cloud system that patients can securely use to improve their medical experience and health. We are testing our system by using NFC reader and NFC-equipped mobile device to send sensor information securely to the EHR. The cloud system then analyses the information and sends back the data to the Mobile device using the same communication protocol, [9–12]. Section 2 presents the model of the system, how the system is implemented and the connecting parts, whereas Sect. 3 presents a brief case study that illustrates the functionality of the system. When replacing a current working system with a new online/electronic system users often face hard time in adapting to the system and its needs. That is why Sect. 4 presents the ergonomic analysis of the case study presented in Sect. 3 and an evaluation of the system from users' perspective. Section 5 concludes the paper.

2 Model of Secure e-Healthcare Information System

The Secure Medical Mobile Cloud Model (SMMCM) is a scalable online medical model for analyzing, storing and providing access to EHR. NFC helps to authenticate users with the TAG NFC protocol (reader mode). Users of the MC can require access to the services and according to his/her permissions to send a command. The model uses Multi-layer security system to ensure safety of users and EHR. The first layer is the authentication using NFC to identify users. The next layer is used for encryption of offline data stored on the NFC-enabled mobile

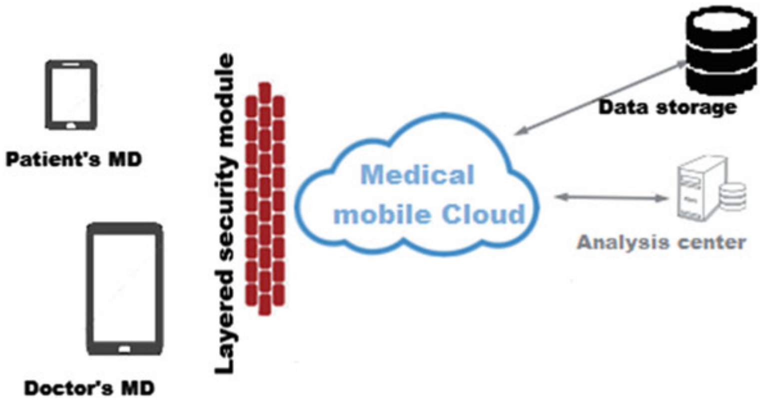

Fig. 1 Medical mobile cloud model

device. The third and the forth layer are used for key-based encryption of data, where K1 and K2 keys protect data integrity. The last layer is used for defining strict boundaries between user profiles. The model is presented on Fig. 1. Although the SMMCM has its own data storage, Fig. 1 shows that SMMCM can communicate with external data storage agents or analysis centres to offload their workload. The communication with external data storages and analysis centres is done behind the Layered security module, which means that the Layered security module is used with NFC-enabled user (patient and medical personnel) mobile devices, [13, 14].

The model is based on the patients' needs, that is, all the actions taken within the system are related to patients and to make the health system more efficient. Each user has an NFC card that can be used in all three modes of operation. Patients, using the NFC, can request diagnostics or scans to be sent on their mobile devices. Also, patients can read their entire medical profile, sort their prescriptions and manage their health-life directly from their NFC-enabled mobile devices. If the mobile device is equipped with sensors, the NFC card can be programmed to use these bio sensors for real-time health analysis.

Since the model is patient-centric and medical information is highly sensitive by nature, more and more patients and medical personnel are concerned about safety, protection and reliability of medical data in the system. Users are reluctant to let their medical data be stored on a data cloud system, [15]. Several solutions are proposed to provide and maintain safety of medical data in the cloud. We propose a multi-layer data security module, where safety of data is addressed from different stages. The layers of this module are presented in Fig. 2. The first layer is the authentication, where we propose using the NFC tagging system to identify patients and medical personnel, [12]. This layer provides encryption algorithms that protect data and user authentication that the medical mobile application requires in order to obtain information. This authentication can be done using password, passphrase or fingerprint ID (if available).

Fig. 2 Layered security stack of the MMC model

Layered security module
1. Authentication using NFC tagging
2. Encryption of (offline) data
3. First level key encryption
4. Second level key encryption
5. Profile-based restrictions

Once the user is identified, the system uses the second layer to protect offline data using the key used to authenticate the user. The offline data stored in the NFC-enabled medical mobile device is the NFC tag of the user, blood type, recent allergies and other critical data for fast access. This data can be read by an ParamedicApp or the user by using his/her key. This layer is useful in cases if the device gets stolen or is hacked into. Before any data is sent to the SMMCM, it is encrypted with the First level key encryption. This encryption is known by the patient and by the SMMCM and can only be decrypted by the SMMCM and the patient. This security level is established when the Medical Mobile device is first introduced in the SMMCM, where the administrator of the system generates keys for the specific device and the SMMCM. The second stage of the encryption encrypts the data with another key. The data was previously encrypted in the first stage is additionally encrypted in the second stage. The second stage encryption is done for the network and is used just for data transfer. The cloud server that the SMMCM is using has interface that decrypts the data in the second level encryption. This means that the second hand encryption is not affiliated with the SMMCM but with the machine and the network. The last level is defining strict boundaries between user profiles, define regulations about user privileges.

Using this multi-layer security module, attackers will have difficulty in violating the security of the data transferred and data stored. One of the possible reasons why attackers would want to change medical information of patients would be to deteriorate patients' health of rival hospitals or by protesters to make a statement. Additionally, attackers can attack the Medical Cloud to gain access to medical records of patients for analysis and statistics to companies. These records are usually sold by hospital with approval of the patients. The first layer addresses the access and restricts patients and medical personnel on using their NFC tags to authenticate in the Medical Cloud model. Using this layer, the Cloud model can be certain that there is no "man in the middle" attack or other intrusion. Also, NFC tags can serve as a means to provide non-repudiation in the model.

3 Case Study of the Model

In the case study of this paper we are presenting a scenario in which we are using the NFC enabled mobile device to send sensor information of the patient to send to the Electronic Health records and store the information for further analysis. We are

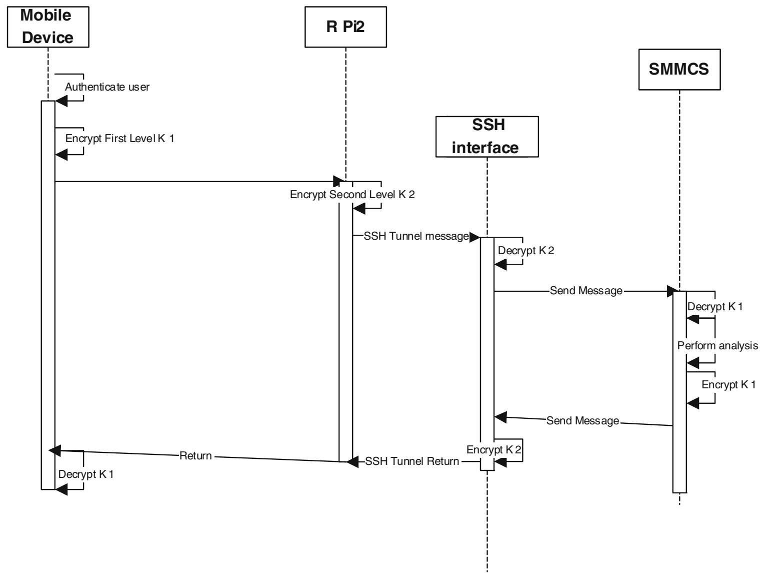

Fig. 3 Sequence diagram of the information flow

using NFC enabled mobile device (in our case Samsung Galaxy S5), and NFC reader in card emulation mode. Figure 3 shows the sequence diagram of the case scenario and the timed flow of data between objects shown in Fig. 4. The mobile device is first authenticating in the system via NFC tagging, so the system knows which patient is supplying the information. Then, using NFC transfer mode, the mobile device communicates to the MMCS using several connection points. The first connection point is between the mobile phone and the NFC reader using NFC communication protocol to transfer data. The second connection point is between the NFC reader and the Raspberry Pi 2 board. The Raspberry Pi 2 board is used to connect the NFC reader online and send data to the MMCS. This connection point uses USB cable to connect the NFC reader with the Raspberry Pi 2.

The third connection point is between the Raspberry Pi 2 board and the MMCS, where using additional hardware, the board communicates with the Cloud system using Secure Shell (SSH). The first communication point is implementing the first layer of the security stack presented in Sect. 2, where users authenticate in the system and send data with NFC. The second communication point is considered secure because it is wired USB communication. The second layer of the security system is implemented using the Raspberry Pi 2, where data is encrypted before sending it to the MMCS. The encryption is done in two stages; first stage where data is encrypted using K1 key and the second stage is using SSH cryptographic tunneling. When data is sent through the third communication point it is secured and can only be read by the MMCS.

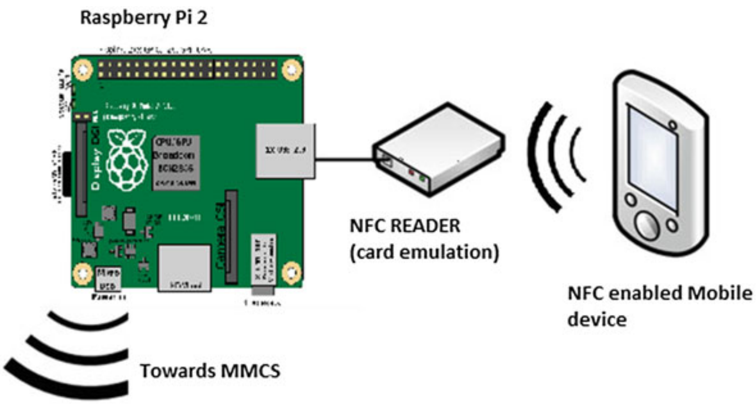

Fig. 4 Communication flow of the case study

Sensor information is usually considered as light data since it only transfers numbers and text. The communication scenario described earlier is used in the case study to test how data is stored from sensors in the MMCS. Figure 5 presents the application and which bio sensors are used in the scenario. The PatientApp uses bio sensors from the mobile device to upload medical data to the Medical Mobile Cloud system. In this case scenario, the PatientApp sends air pressure and patient's heart rate. If the mobile device is not equipped with hearth rate sensor, it can use the camera to approximately measure heart rate. In Fig. 4 we can see how this data is uploaded to the Cloud system.

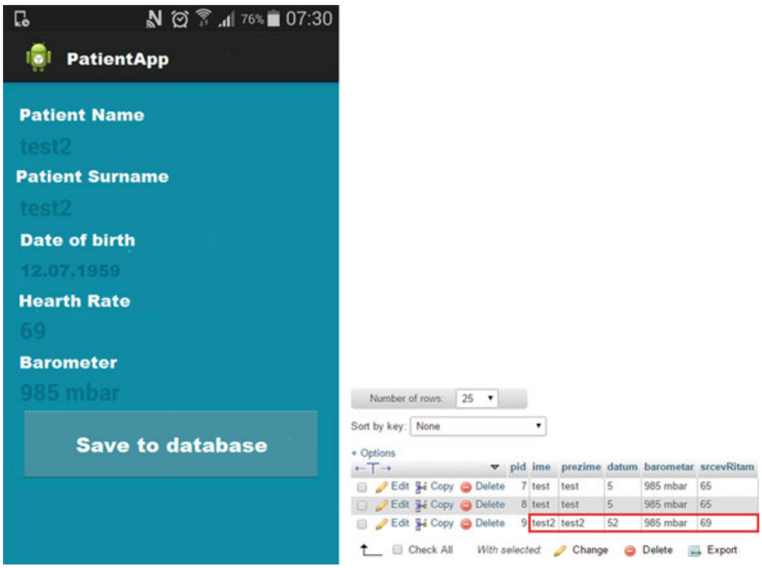

Fig. 5 Results of the case study

Sensor information usually considered as light data, as it only transfers numbers and text. The communication scenario described earlier is used in the case study to test how data is stored from sensors in the MMCS. Figure 5 presents the application and which bio sensors are used in the scenario.

From Fig. 5 we can see the results are transferred from the PatientApp to the SMMCM without error and written in the Patient's database. In between, we can see the way the data is being encrypted and decrypted based on the scenario depicted in Fig. 4. During the transfer of data, it can be intercepted by a third party and it can be read. If the third party is no near the system or the mobile device, it can intercept the data when it is encoded with key K2 and cannot decode it. If the third party changes the K2 encoded data, the SMMCM and the mobile device will not be able to decode it and could detect malicious data.

Third party can intercept the data encoded with K1 if the attacker is near the device and uses its own Raspberry Pi 2 and NFC reader. That is why K1 key is used to add additional security to data transfer. This would mean that if the attacker has a hold of the medical mobile device, it can try to get information using his own K2 encoder. But the data is previously encoded with K1 that only the mobile device and SMMCM have and can decode.

4 Ergonomics Analysis Based on QOE Metrics

Electronic online Medical systems are always discredited by patients and medical personnel. Patients are reluctant to share their information electronically and medical personnel are usually distrusting of the e-health system and consider it as a additional time-consuming task, [16]. Nowadays e-health systems need to be better than the existing health systems already installed and used by medical and patient users alike. Electronic healthcare has to provide faster service to doctors, patients, surgeons and nurses, to ease the appointment and appointment scheduling, to have accurate and fast access to medical files and adequate presentation of multi-media medical information such as X-RAY scans and MRI. But most importantly, e-healthcare systems have to be secure and patients and medical personnel to feel safe to share medical information in such fashion.

That is why an ergonomic security analysis (ESA) was conducted on our MC using QoE metrics based on patents' and medical personnel surveys. This analysis is used to evaluate the MC from security point of view. Our main objective of (ESA) was to evaluate whether the NFC-based MC has improved the willingness of patients and medical personnel to use our SMMCM and feel safe while doing so. A group of 30 medical personnel and 20 patients were the subject of the ESA. The questions used in the ergonomic survey are presented below and are divided into two categories, the first for the medical personnel and the second for the patients. The main objective of the ESA is to evaluate and adapt the system to user's needs. This means that we tested the SMMCM to see if the users feel safe enough to store and analyze their data (Table 1).

Table 1 Ergonomic analysis of the SMMCM based on the medical personnel

	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7	Question 8
Medical P1	Once/twice a month	2–3 accesses a week; not having mobile device	5 cases so far; patient not in the system	No	In few seconds	30 s most to get multimedia; perfect image	To some extent yes; most of the time don't use it	Safer than before
Medical P2	Never	Sometimes slow but can always access data	None	No	If can be accessed then right away	Ok image, readable	Not misleading	Pretty safe
Medical P3	Once or twice so far	3 times, personal error	Few times a month	No	Instantly	Quality almost as from scanner	Almost accurate	Safe enough
Nurse N1	Never	Usually in the morning for maintenance	2–3 a week; not having NFC card	Yes; human error when entering information	10–30 s	–	–	I think so; yes
Surgeon S1	Never	Never	One or two maybe	No	Fast access or no access	Great quality	If you know how to read it	Maybe
Specialist	Three times —personal	Never	None	No	In few seconds	If loaded, OK quality	Helpful to some extent	Yes

Survey questions for the medical personnel:

1. How often have you accessed wrong data or have noticed inaccurate data?
2. How often has the system been unusable? (malfunction, maintenance, not having mobile device)
3. How many lost appointments due to system being unusable? (malfunction or not carrying nfc medical mobile device)
4. Have you noticed inconsistent data or information that might have been altered by a third party?
5. How fast can light (non-multimedia) data be accessed?
6. How adequate is the display of multimedia medical information?
7. Was the medical online analysis helpful?
8. Is the system safe? (based on personal non-expert-in-field opinion)

The tested medical personnel was chosen for the survey and prepared for the survey before it was executed. Some of the questions were revealed before the survey so the tested medical personnel can take notes and be prepared to answer afterwards. They were told to keep track of the missing appointments and have paper-based records kept to compare them with the e-health system for inconsistencies. After the survey, they were asked to give performance mark of the system on each question separately (1–10). The results are presented in Fig. 6. Based on the histogram in Fig. 6 we can see that medical personnel are more than satisfied of using the system. There were minor notes for improvement which include bypass of the NFC-authentication if a patient forgets or doesn't have his NFC-equipped mobile device.

Survey questions for patients:

1. Has the SMMCM improved the healthcare experience?
2. Are appointments on time and does the system put additional time pressure in the appointment process?
3. Is the access to personal medical records easy and safe? Can someone else access your medical profile without consent?

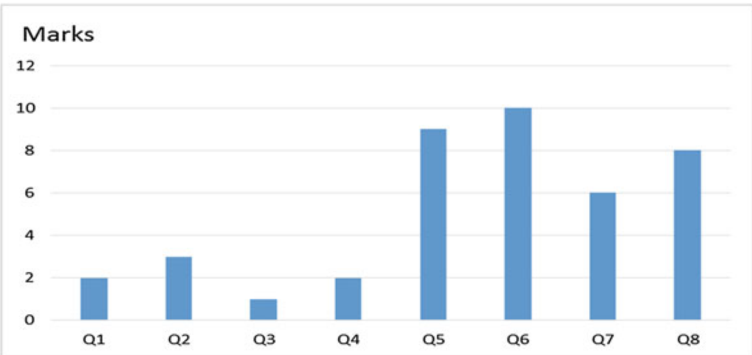

Fig. 6 Results of the ESA of medical personnel

4. How often have you noticed irregularities in medical data or inaccurate information?
5. How often have you been rejected by the system and the healthcare? (malfunction, not having NFC medical mobile device)?

The patent's for Table 2, were selected because they had different medical issues and were testing the system from different institutions in the healthcare. Asthmatic and diabetic patients are considered as recurring patients and test the system more frequently than other patients. Patients with heart problems are less recurring but test specific aspects of the healthcare system, whereas patients with hemorrhoids are frequent testers of the system. Common cold patients are least frequent and test the system once in a while but make excessive tests on the part of the system that does the appointments and prescriptions. The overall marks of the entire test case group are presented in Fig. 7. More than 70 % of the patients were satisfied from the system and consider it an improvement of the healthcare system and its security. Almost all of the patients were satisfied with the second and third layer of the security, where they used passcode to encrypt and decrypt their access to the SMMCM.

Table 2 Ergonomic analysis of the SMMCM based on the patients

	Question 1	Question 2	Question 3	Question 4	Question 5
Asthmatic patient	Yes, a lot	Not on time, but manageable	Easy access and safe	Never	Few times
Heart patient	Slightly	Many schedules with no show	Easy access and maybe safe	Never	Once
Common cold patient	The appointment	On time	Accessible and safe	Never	Never
Hemorrhoids patient	Maybe	Fast and on time	Easy access distributable	Once due to malfunction	Never
Diabetes patient	In some areas yes, in others no	Have to wait for months for specialist appointment	Easy access and safe	Never	Every third check up

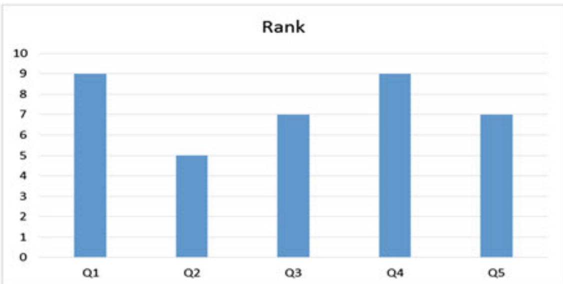

Fig. 7 Results of the patient's ESA

5 Conclusion

The QoE metrics used in the survey include ESA of medical personnel and patients. All tests were done by all users and were pre-prepared for the ergonomic analysis. The number of users varies because not all users have NFC or sensors. The results show that users feel mainly safe to use MC because only minor security flaws were detected. The main disadvantage is the lack of equipment required for full access to SMMCM services.

Additionally, the appointment system needs to be modified in order to avoid so many no-shows and shorten the amount of time a patient has to wait for specialist appointment. Although this flaw is due to misuse of patients and lack of specialists, we plan to improve it by forcing patients to reapprove the appointment the day before or release the slot for someone else. Also, we plan to improve the system and let patients do certain medical test and appointments only by authenticating with their fingerprint. That way, the problem with not wearing medical mobile device can be solved.

References

1. Crema, C., Depari, A., Flammini, A., Lavarini, M., Sisinni, E., Vezzoli, A.: A smartphone-enhanced pill-dispenser providing patient identification and in-take recognition. In: Medical Measurements and Applications (MeMeA), 2015 IEEE International Symposium, pp. 484–489, 7–9 May 2015
2. Martin, E., Nugent, C., Bond, R., Finlay, D., Breen, C.: Diagnosis of the electrocardiogram using a Smartphone. In: 2014 IEEE 27th International Symposium on Computer-Based Medical Systems, pp. 491–492 (2014)
3. Iacobelli, L., Panza, G., Piri, E., Vehkaperä, J.: An architecture for m-health services: the CONCERTO project solution. In: 2015 European Conference on Networks and Communications, pp. 118–122 (2015)
4. Kovachev, D., Klamma, R.: Framework for computation offloading in mobile cloud computing. Int. J. Interact. Multimedia Artif. Intell. IJIMAI **1**(7), 6–15 (2012). doi:10.9781/ijimai.2012.171
5. Sawand, A., Djahel, S., Zhang, Z., Naït-Abdesselam, F.: Toward Energy-Efficient and Trustworthy eHealth Monitoring System, CIC ICCC2014, pp. 46–65 (2015)
6. Mobile Cloud Computing Forum: http://www.mobilecloudcomputingforum.com/ (2013)
7. Wang, S., Dey, S.: Adaptive mobile cloud computing to enable rich mobile multimedia applications. IEEE Trans. Multimedia **15**(4), 870–883 (2013)
8. Lai, C.F., Vasilakos, A.V.: Mobile multimedia services over cloud computing. In: E-Letter 2010, vol. 5(6). Multimedia Communications Technical Committee, IEEE Communications Society (2010)
9. La, H.J., Kim, S.D.: A conceptual framework for provisioning context-aware mobile cloud services. In: IEEE Cloud, pp. 466–473. IEEE. ISBN: 978-1-4244-8207-8 (2010)
10. Wenwu, Z., Chong, L., Jianfeng, W., Shipeng, L.: Multimedia cloud computing. In: IEEE Sig. Process. Mag. **28**(3), 59–69. ISSN:1053-5888 (2011). doi:10.1109/MSP.2011.940269
11. Kovachev, D., Yu, T., Klamma, R.: Adaptive computation offloading from mobile devices into the cloud. In: Proceedings of the 2012 IEEE 10th International Symposium on Parallel and

Distributed Processing with Applications (ISPA'12), pp 784–791. IEEE Computer Society, Washington, DC, USA (2012). doi:http://dx.doi.org/10.1109/ISPA.2012.115

12. 3D Camera: http://www.androidpit.com/en/android/market/apps/app/com.ens.threedeecamera.lite/. 3D-Camera (2013)
13. Constantinescu, L., Kim, J., Feng, D.: SparkMed: a framework for dynamic integration of multimedia medical data into distributed m-health systems. IEEE Trans. Inf. Technol. Biomed. **16**(1), 40–52 (2012)
14. Hoang, D., Chen, L.: Health records protection in cloud environment. In: 2014 IEEE 13th International Symposium on Network Computing and Applications, pp. 85–90 (2014)
15. Weider, Y., Davuluri, L., Radhakrishnan, M., Runiassy, M.: A security oriented design (SOD) framework for ehealth systems. In: 2014 IEEE 38th Annual International Computers, Software and Applications Conference Workshops, pp. 122–127 (2014)
16. Catelani, M., Ciani, L., Risaliti, L.: Risk assessment in the use of medical devices: a proposal to evaluate the impact of the human factor. In: Medical Measurements and Applications (MeMeA), 2014 IEEE International Symposium on, Lisboa, pp. 1–6 (2014)

Ergonomic Work Analysis of a Pathological Anatomy Service in a Portuguese Hospital

Filipa Carvalho, Rui B. Melo and Valdemar Costa

Abstract Awkward and uncomfortable postures when maintained for long periods of time could stress and fatigue supporting muscles and tendons, leading to the development of musculoskeletal disorders (MSD). An Ergonomic Work Analysis was required to assess and evaluate the working conditions in a pathological anatomy laboratory. The objectives of this study were: assess the actual working conditions of the professionals in that service; establish relationships between them and the complaints presented; identify and select the most painful task/workstation, characterize this task/workstation in terms of the associated MSD development risk and, finally, identify and propose some preventive measures. The Rapid Upper Limb Assessment was used and the results revealed that the risk for the development of MSD is present in all tasks. The three most critical tasks were identified. Considering the self-reported physical symptoms, the results were similar with the other studies reported.

Keywords Musculoskeletal disorders (MSD) · Rapid upper limb assessment (RULA) · Binocular microscopes · Microtomes · Embedding centres

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1 Introduction

Awkward and uncomfortable postures are recognized as harmful in particular if they are maintained for long periods of time. These postures are usual among pathologists and other technicians due to some particularities of the tasks they are required to complete, namely while using binocular microscopes, microtomes and embedding centres. The association of prolonged microscope use with the development of chronic pain syndromes has been recognized for nearly 3 decades [1]. This situation is common in these professionals due to the number of risk factors associated with the tasks performed by them every day such as: the force, the posture, the repetition required by the task and the level of precision and attention required. In other words, all these situations may stress and fatigue supporting muscles and tendons, leading to the development of musculoskeletal disorders (MSD) [2].

Therefore, an Ergonomic Work Analysis was required to assess and evaluate the working conditions in a pathological anatomy laboratory.

This study integrates five main objectives:

- Assess the actual working conditions of the professionals in that service;
- Establish relationships between them and the complaints presented;
- Identify and select the most painful task/workstation;
- Characterize this task/workstation in terms of the associated MSD development risk and, finally;
- Identify and propose some preventive measures.

2 Materials and Methods

2.1 Stages of the Study

This study comprised 3 fundamental stages which integrate different kinds of objectives. The first stage named—Characterization of the Work Situations—integrated the three first objectives, the second stage named—MSD risk characterization—integrated the fourth objective and, the last stage named—Preventive measures—integrated the fifth and last objective.

- 1st stage—Characterization of Work Situation—included characterization of both the operators and the service and a task analysis, e.g., task identification and characterization, in terms of prescribed objectives as well as in terms of general executing conditions (this step without much rigor).
- 2st stage—MSD risk characterization—included the application of Rapid Upper Limb Assessment (RULA) find if the risk for the development of MSD was

presented in the selected tasks. Other analyses were included to better characterize the workstation associated with the tasks selected.
- 3rd stage—Preventive measures—Included some of different kinds of preventive measures such as technical and organizational measures.

2.2 Data Collection and Procedures

For data collection, we used different methods, tools and equipment, in accordance with the specificity of stage of the study.

1st Stage The study began with the characterization of the work situation and workers relying on different methods: Conversation or dialogues with workers which were crucial for the identification of relevant information which was included in a questionnaire specifically developed to further characterize the work situation; Documental Analysis (e.g.: task procedures, service organization chart, material safety sheet, tools instructions,…); Free and systematized observations; As we said before for a better characterization of the situation, a questionnaire was specifically developed. The questionnaire was applied during the 1st stage of the study and it intended to identify key parameters for the workers' characterization, evaluate their perception of the real working conditions, as well as to identify self-reported symptoms of annoyance, discomfort and physical pain, eyestrain and mental fatigue. The questionnaire results and the sensibility of the workers were important to select the tasks to integrate in the 2nd stage of the study. The questionnaire developed results from an adaptation of the questionnaire proposed by Carvalho [3] and the questionnaire used by Serranheira et al. [4].

To participate in this study a previous verbal consent of the operators involved was obtained. The workers responded to the questionnaire independently and anonymously. All workers (N = 40) involved in that service were invited to participate in this stage of the study. Therefore, different types of workers' activities and their workstations were observed, resulting in 32 workstations analyzed.

2nd Stage To provide a better characterization of the workplace associated to the tasks selected, the noise, the lighting and the thermal environment variables were measured. Therefore, the environmental variables only were assessed after the tasks had been selected and during this particular stage of the study.

Noise was measured with a Bruel & Kjaer Sound meter, 2260 model, which was carefully placed near the operator's ear. The device was subjected to verification in the workplace before each series of measurements. Both Continuous A-Weighted Sound Pressure Level (dB(A)) and Maximum Peak Level (dB(C)) were measured. The noise was assessed in a total of 8 workstations. Among these workstations we have: 3 that implicate the use of microtomes; 3 that implicate the use of microscope, and 2 embedding centres.

Fig. 1 Flowchart illustrating the RULA methodology applied

The illuminance (lux) level was assessed with a digital Krochmann lux meter, 106E model, which was strategically put on the surface of the workstations. In particular near the place where the subtasks or technical actions that involve high levels of precision and attention were accomplished, in each task. The illuminance was assessed in a total of 13 workstations. Among these workstations we have: 3 that implicate the use of microtomes; 8 that implicate the use of microscope, and 2 embedding centres.

Finally, the thermal variables (dry (Ta) and wet air temperatures) were assessed with a THIES sling psychrometer—450 model. Air humidity (Hr) was computed from these two variables; for each workspace, three measurements were made with the equipment on the center of the workspace (medical office or laboratory) and the average value was used as reference. The thermal evaluations were made in 3 medical offices, the cytology laboratory and the histology laboratory.

For dimensional characterization of the workstations, associated with the tasks selected, several dimensions of the work surface and of the equipment used were collected resorting to a measuring tape.

Image and video recording were included to collect images related to work activity. For this purpose a digital camera with 13 megapixel and 1920 × 1080 (16:9) resolution was used.

To characterize the associated risk of MSD development, by each task selected, the Rapid Upper Limb Assessment (RULA) was used. A complete description of the RULA method can be found in the works written by McAtamney and Corlett [5, 6].

In terms of methodology RULA was applied considering the flowchart illustrated in Fig. 1.

At the end we used the average scores obtained for each task/subtask considered. This method was applied 167 times and 13 workstations were analyzed in terms of the biomechanical load. Among these workstations we had: 2 that use embedding centres, 5 that implicate the use of microtomes; 6 that implicate the use of microscope.

2.3 Data Processing

For data processing, we resorted to the Statistical Package for the Social Sciences (SPSS©). Descriptive analyzes were performed using location (Mean, Mode, Percentiles) and dispersion (ranges, standard deviation) parameters.

Table 1 Illuminance level (lux) recommended considering the different kind of exigence in workstation

Task	Illuminance level (lux) EN 12464-1 de 2002	Illuminance level (lux) NF_X35-103
Laboratory (general illuminance)	500	750
Task with high visual and attentional demand	1000	1500

The Action Level 2 of RULA method, which represents the final Grand Score Rula (GSR) equal to Score 3 or 4, was considered the level from which a high level of MSD development is present.

For each task assessed the load ranking was based on biomechanical criteria. With this purpose, The Score A and Score B, available with RULA application, were highlighted. The Score A gives us the biomechanical load considering how much the upper limbs (the upper arm, lower arm, wrist and wrist twist) are involved in doing the task and Score B gives us the biomechanical load considering the use of neck, trunk and legs.

To evaluate the noise level, the values recommended by NBR 10152:1987 [7]—a Brazilian standard—were used. For this standard, 50 dB(A) is considered the value from which the workers exposed will be experiencing acoustic discomfort.

To interpret the illuminance (lux) level, the values recommended by BS EN 12464-1:2002 [8]—a British standard—was used and after all, the values were corrected by the level proposed by NF_X35-103—a French standard [9]. These corrections considered variables such as: age (>45), reflection and contrast factors, error relevance, task frequency, lack of natural lighting. Table 1 shows the recommended values by each standard used.

To interpret the thermal variables we used the values proposed by Portuguese legislation: Dec-Lei no. 243/86 de 20 Agosto [10], which recommends:

- 18 °C ≤ Ta ≤ 22 °C;
- 50 % ≤ Hr ≤ 70 %.

3 Results and Discussion

3.1 Workers' Characterization

75 % of the professionals working in that service agreed to participate in the study, which represented 30 out of the 40 workers. Out of these workers (N = 30), 28 were female and 2 were male. Considering the age, these workers had an average of 44 years old (28–65 years). More than 50 % of the workers had more than 45 years old (Fig. 2); in terms of Seniority, this service has a high level of seniority (60 % of the workers had more than 10 years—Fig. 3).

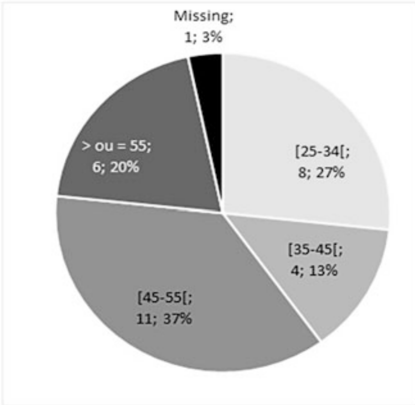

Fig. 2 Workers' distribution by age groups

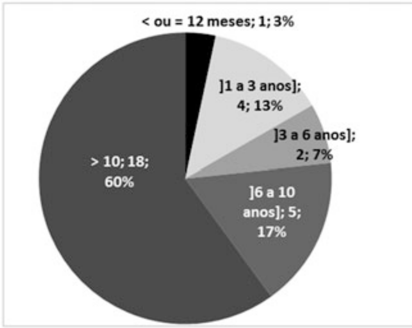

Fig. 3 Workers' distribution by Seniority groups

3.2 Work Organization

In terms of work organization this service has no rigid schedule, working between 8:30 and 17:30; All workers did work breaks, where they had the freedom to choose the duration and frequency and 60 % of the workers did overtime, at least, one time per week.

3.3 Workers' Job—Task Associated

In terms of Workers' Job and Task associated 23 % of the workers that participated in the study were pathologists, which are the workers responsible for Observation and Diagnosis under the microscope; 43 % were Diagnostic and therapeutic technicians, which were responsible for preparing all the procedures to make possible the Observation and diagnosis of histological and cytological analysis and may also assist in performing autopsies; 27 % were Technical assistants, which were responsible for all Lab secretarial work and, finally, 7 % were Operational technicians, which were responsible for Cleaning of work equipment and lab benches.

3.4 Self-reported Symptoms Results

Considering the self-reported symptoms (annoyance, discomfort and pain) it was possible to identify the main corporal regions affected with a high level of prevalence of symptoms for the total jobs integrated in that service: cervical (66.7 %) dorsal (43.3 %) and lumbar (53.3 %) spine, right shoulder (43.3 %), right wrist (46.7 %) and right hand (53.3 %). These results are similar to the results reported by other studies [1, 11]. Figure 4 shows the main regions where complaints prevail by each workers' jobs. Considering that for the Operational technicians, only one answer was obtained for this part of questionnaire, we decided not to include them in this analysis to assure the confidentiality of data.

Considering visual and mental fatigue, 87 and 73 %, respectively, were reported by workers. 54 % of the workers that reported visual fatigue considered that this symptoms had some impact in perception of information. In terms of Visual Fatigue, the main symptoms appointed were: Blurred vision; Itchy eyes and, Red eye. In terms of Mental Fatigue, the main symptoms referred were: Decreased concentration and attention; Mood swings/ irritability and, Extended outage in time.

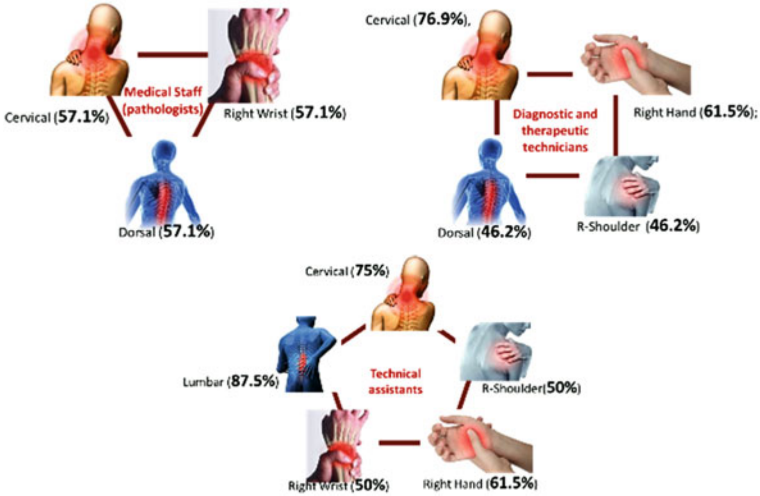

Fig. 4 Main corporal regions with prevalence of complains

3.5 Association Between Age/Seniority/Job and Annoyance/Discomfort/Pain, Visual Fatigue and Mental Fatigue

In all categories of Age groups, Seniority groups or Job, the workers experience some kinds of Annoyance/discomfort or/pain, Visual fatigue and Mental Fatigue (Figs. 5, 6 and 7). Considering these results we can assume that Age, Seniority and Job seem to have no specific association with the presence of symptoms of Annoyance/discomfort/pain, Visual and Mental fatigue but suggest that the work conditions is an important variable that could be responsible for that.

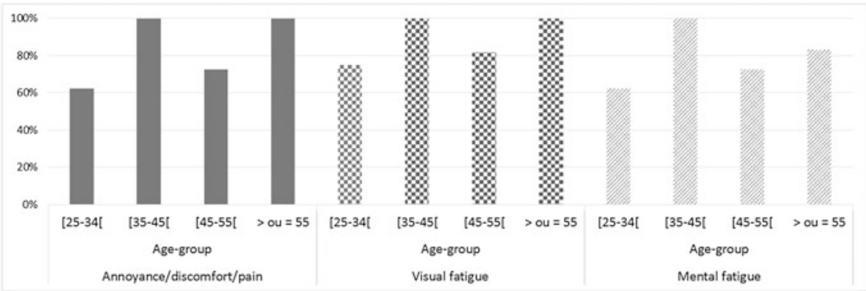

Fig. 5 Physical complaints (annoyance/discomfort/pain)/Visual Fatigue and Mental Fatigue by Group age

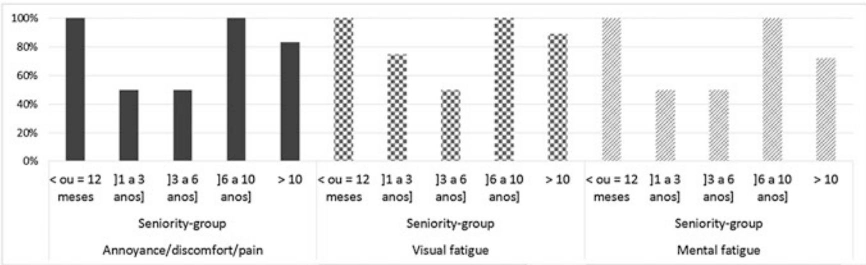

Fig. 6 Physical complaints (annoyance/discomfort/pain)/Visual Fatigue and Mental Fatigue by Group seniority

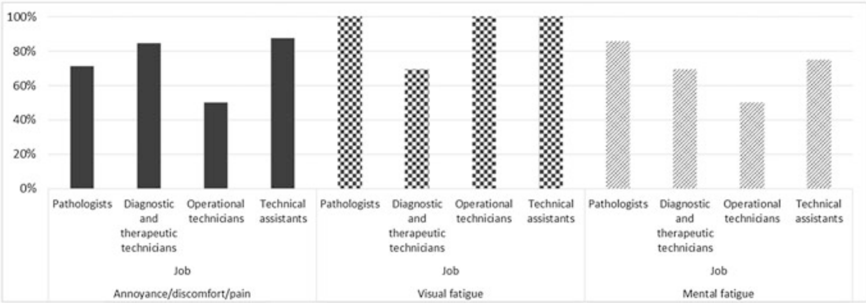

Fig. 7 Physical complaints (annoyance/discomfort/pain)/Visual Fatigue and Mental Fatigue by Job

3.6 Critical Tasks Selected and Tasks' Characterization

Three most critical tasks were identified: Microscope Observation and Diagnosis; inclusion of fragments in paraplast blocks and Cutting paraplast blocks in microtomes (2nd Cut). The main reasons pointed were: static position maintained throughout the working day; high liability associated with the diagnosis; high manual accuracy and visual attentional demand; inadequate chairs and microscopes and, lighting problems. Table 2 synthesize the main characteristics of the tasks selected regarding some of the parameters considered and main critical movements/postures or constraints observed.

3.7 Environmental Results

Considering the noise assessment, even though the results obtained do not represent risk for workers' health, they can experience acoustic discomfort (L_{Aeq} > 50 dB(A)).

Considering the task accomplished in that service, the results of dry temperature were higher than the recommended values.

In terms of illumination, 17 % of the measures made revealed that the Illuminance level (lux) obtained were higher than recommended. The main reason appointed was lack of protection on the windows. In the other all cases the Illuminance level (lux) obtained was not sufficient for the tasks developed.

These results may justify complaints presented by workers, which consider that:

- 43 % considered noise was very uncomfortable or uncomfortable;
- 43 % considered lighting was nothing suitable or unsuitable;
- 36.6 % considered thermal environmental was very uncomfortable or uncomfortable.

Table 2 Synthesis of main characteristics of the tasks selected regarding some of the parameters considered and mains critical movements/postures or constraints observed

	Task assessed		
	Microscope observation and diagnosis	Inclusion of fragments in paraplast blocks	Cutting paraplast blocks in microtomes (2nd cut)
Number of workstations assessed	6	2	5
Work cycle time (average)	Variable	50 s	60 s
Task duration	≥8 h/day	1.5–3 h/day	1.5–4 h/day
N of Technical actions (TA)	7	11	13
Workstation height	Very variable	97.6–101.5 cm	≈89.3 cm
Equipment used	Chair and desk; microscope Computer; keyboard, mouse	Chairs and embedding centres	Chairs, benches and microtomes (with several different characteristics)
Main constraints observed	– Some microscopes don't permit any regulation – High flexion of the neck – Compression of soft tissues (wrist and forearm) – Suspended arm – Some operators need footrest – Inadequate regulation of the equipment to the workers	– Shoulder abduction for almost the entire work cycle time – High amplitude of flexion in reach sub-tasks – Pronation during the whole working cycle (left hand) with high level in some TA – Pincer grip of both hands – Compression of soft tissues (wrist and forearm) – Suspended arm during all the task time	– High level of reach in some TA – Different kind of regulations and cut mechanisms; – Medium-high flexion of the neck to see the cuts – Simultaneous trunk rotation and side flection (left side) to do some TA – Suspended arm – Lack of rested back posture, workers didn't lean against the chair

3.8 RULA Results

Considering the RULA results, the risk for the development of MSD is present in all tasks (GSR > 3). The inclusion of fragments in paraplast blocks was the task with the lowest Grand Score Rula (GSR = 3.385). However it was the task that presented a higher value for Score A (Score A = 3.9), which means more stress on the upper limbs. Cutting paraplast blocks in microtomes (2nd Cut) was the task with

Table 3 Synthesis of scores and average score obtained with RULA by Task

Task	ID	Score A (upper arm)		Score B (neck, trunk, legs)		Grand score RULA	
		χ score	$\bar{\chi}$	χ score	$\bar{\chi}$	χ score	$\bar{\chi}$
Inclusion of fragments in paraplast blocks	1	3.92	3.90	2.83	3.03	3.33	3.39
	2	3.89		3.22		3.44	
Cutting paraplast blocks in microtomes (2nd cut)	1	3.47	3.85	3.29	3.29	3.59	3.76
	2	3.95		2.84		3.42	
	3	4.05		3.05		3.82	
	4	3.9		4.1		4.3	
	5	3.88		3.18		3.69	
Microscope observation and diagnosis	1	3.5	3.73	2.38	3.25	3.13	3.70
	2	3.81		3.81		4	
	3	3.4		3.3		3.4	
	4	3.56		2.56		3.22	
	5	4.67		4.67		5	
	6	3.46		2.8		3.46	

higher Grand Score Rula (GRS = 3.764), the most prejudicial for neck, trunk and legs (Score B = 3.292) and the 2nd worst for upper limbs (Score A = 3.85). Microscope Observation and Diagnosis was the task that obtained lower Score A (Score A = 3.73) and the 2nd task that obtained higher value in Score B (3.253) and in Grand Score Rula (GSR = 3.702). Table 3 synthetizes the scores obtained with RULA by task.

4 Solutions Proposed

Some organizational and technical solutions were proposed to reduce the results obtained and complaints presented by workers.

4.1 Organizational Solutions

Workers Training Employers should train workers to be aware of their posture and better understand the MSD problematics. For this reason, workers should be encouraged to:

- Adopt neutral postures;
- Keep frequently used instruments and work materials within close reach;

- Diversify activities, change position, and take short breaks, at least, every 60 min to rest muscles and increase blood circulation;
- Adjust, when possible, the position of work, the work surface, or the chair so that you can sit in an upright, supported position;
- Sit close to the work area, keep objects close and adjust the chair to match the height of the bench.

When worker needs to work with both, Computers and Microscops, more attention should be given, to

- Sitting close to the work surface;
- Adjusting chair, workbench, or microscope as needed to maintain an upright head position;
- Elevatting, tilting or moving the microscope close to the edge of the counter to avoid bending their neck;
- Taking short breaks. Every 15 min, close the eyes or focus on something in the distance;
- Avoid leaning on hard edges;
- Using Pad forearms and edges;
- Keeping elbows close to their sides;
- Keeping scopes repaired and clean;
- Placing monitor so the top of the screen is approximately at eye level;
- Using footrests, where possible, in order to allow changing leg positions throughout the day.

Note: Where there are multi-users in the same workstation, more attention should be given to its adjustment.

4.2 Technical Solutions

Changes in Layout

- Where possible, position computer workstations in corners or other areas away from doors, entrances and passageways;
- Monitor and keyboards should be positioned perpendicular to the windows;
- Increase the luminous flux of localized illumination in embedding centres so that the level, in work surface, be around 1500 lux;
- Replace yellow bulbs, in embedding centres, with white bulbs, which have better color rendering index;
- Decrease the luminance of the work surface used in microtomes, with a dark-colored film;
- Control the illuminance level (lux) using blinds or curtains;
- Redesign the workplaces considering, when possible, that, workers should sit parallel to windows rather than facing them or sitting with their backs to them;

- Remove the drawers blocks under desks ensuring that the undersurface of the desk, both front to back and side to side, allows users to move their legs freely and change position without hindrance;
- Incorporate handle in order to maintain a neutral wrist position, on manual microtome used in one of tasks.

Choosing New Equipment Always when needing new equipment some attention should be payed to these tips:

- Choose adjustable microscopes (with tilting and telescoping eyepieces) or adapt existing microscopes with longer ocular tubes, platform adapters, etc.;
- Choose chairs/desks and adjustable equipment;
- Provide a foot rest to help workers adjust their body position.

5 Conclusions

This study has revealed that the work done in this pathological anatomy service entails risks for its employees who may be responsible for the development of musculoskeletal disorders. These results are similar with the results reported by other studies [1, 11].

Workers should be trained regarding MSD risk factors, as well as on how to fit the workstation to their needs. Some guidelines to regulate the equipment used or to buy the new one are among the advice given.

References

1. George, E.: Occupational hazard for pathologists: microscope use and musculoskeletal disorders. Am. J. Clin. Pathol. **133**, 543–548 (2010)
2. Navsafecen: Ergonomic microscopes reduce the risk of musculoskeletal disorders at naval health research center's respiratory disease laboratory, http://www.public.navy.mil/navsafecen/Documents/SuccessStories/082_Ergo_Scopes.pdf
3. Carvalho, F.: Estudo comparativo entre diferentes métodos de avaliação de risco, em situação real de trabalho (2007)
4. Serranheira, F., Pereira, M., Santos, C.S., Cabrita, M.: Auto-referência de sintomas de lesões músculo-esqueléticas ligadas ao trabalho (LMELT) numa grande empresa em Portugal. Saúde Ocup. Rev. Port. Saúde Pública. **21**, 37–47 (2003)
5. Mcatamney, L., Corlett, E.N.: RULA: a survey method for the investigation of world-related upper limb disorders. **24**, 91–99 (1993)
6. McAtamney, L., Corlett, N.: Rapid upper limb assessment (RULA). In: Stanton, N., Hedge, A., Brookhuis, K., Salas, E., Hendrick, H. (eds.) Handbook of Human Factors and Ergonomics Methods. pp. 7–1–7–11. CRC PRESS, Florida, USA (2005)
7. ABNT: NBR 10152:1987—Níveis de ruído para conforto acústico. ABNT—Associação Brasileira de Normas Técnicas, Rio de Janeiro (1987)

8. BS EN 12464-1:2002—Light and lighting. Lighting of work places. Indoor work places. Br. Stand. Inst. (2002)
9. NF X35-103 Juin 2013—Ergonomie—Principes d'ergonomie applicables à l'éclairage des lieux de travail. AFNOR (2013)
10. Decreto-Lei n.o 243/86 de 20 de Agosto—Regulamento Geral de Higiene e Segurança do Trabalho nos estabelecimentos Comerciais, de Escritórios e Serviços. Diário da República—I —n.o 190. 1a Serie, 2099–20105 (1986)
11. Sillanpää, J., Nyberg, M., Laippala, P.: A new table for work with a microscope, a solution to ergonomic problems. Appl. Ergon. **34**, 621–628 (2003)

Defining the Angles' Range in Ergonomics Assessment Using 3D Cameras and Surface EMG

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Abstract Work-related Musculoskeletal Disorders (WMSDs) are pathologies of great impact in the working population. The main risk factor in the onset of these diseases are the postures adopted and held by the workers or, in other words, the critical joint angles adopted by them during significant time periods. Large exposure periods usually occur in the workplace. The influence of the postures adopted at the workplace has been studied by several authors who have developed different methodologies for the corresponding risk assessment (e.g., OWAS, RULA, REBA, LUBA, PATH, etc.). There is also a European standard, the EN 1005-4:2005 that is applied to the evaluation of working postures and movements in relation to machinery. The main problem while using these methodologies is the difficulty of knowing the specific angle adopted at a given joint. Currently, this is not a problem since some new technology enables accurate position sensing of any body part. Nowadays, 3D cameras can recreate the specific body segment in the three planes of space with high accuracy by using passive markers that are placed in different anatomical references, allowing to obtain the speed, trajectory, and angles variation data. Additionally, through the use of surface electromyography (sEMG) it is also possible to obtain data about different muscle activation patterns. This paper intends to present a comparative analysis of the angles used by major research methodologies in the field of WMSDs. It tries to establish the reference ranges of angles with their corresponding score for a later ergonomics assessment. The idea is to use that reference with new technologies as 3D cameras and surface EMG, in order to accurately assess and score postures adopted in every workplace.

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Keywords WMSDs · Postural analysis · Manual handling · Physical work load · 3D cameras · Surface EMG

1 Introduction

WMSDs are the most prevalent occupational diseases in Europe. Exposure to awkward postures is one of the major physical risks in the workplace [1] and is one of the most important factors related to WMSDs [2, 3]. Several authors have proposed methodologies in this area including: "Ovako Working Posture Analyzing System"(OWAS) [4], a practical method designed to identify and evaluate postures encountered in the workplace; "Rapid Upper Limb Assessment" (RULA) [5], a method used in ergonomics research focusing on the assessment of the upper limbs; "Rapid Entire Body Analysis"; (REBA) [6], a tool for analyzing posture; "Loading on the Upper Body Assessment" (LUBA) [7], an assessment technique used to evaluate and re-design static work stations in industry, "Posture, Activity, Tools and Handling"; (PATH) [8], a sampling based approach to ergonomic job analysis for non-repetitive work; "Portable Ergonomic Observation"(PEO) [9], a method for analyzing postures at work; "Portable Ergonomic Observation Method for Computerized On-Line Recording of Postures and Manual Handling" (SWAT) [10], a method used in ergonomic observation.

Apart from a variety of published methods to assess risk, it is also important to refer that there is a European standard, the EN 1005-4: 2005 + A1: 2008 "Safety of machinery. Human physical performance. Part.4: Evaluation of working postures and movements in relation to machinery".

Based on these methods, one of the most important data is the information about the angles of the workers' relevant joints. The purpose of this paper is to analyze the results, in terms of angles' measurement, provided by some of these observational methods in order to exploit them by using some new technologies available for ergonomic evaluation. This will allow to achieve greater reliability in the results of evaluations of static jobs without repeated movements, by using techniques such as photogrammetry and surface electromyography.

2 Materials and Methods

This paper has considered observational methods of ergonomic evaluation in which forced posture was used as a risk factor.

Of the many existing methods, only those with a valid link or association with WRMSD's or which have a potential for researchers were used [11, 12].

Five general methods were selected and applied: (1) OWAS; (2) REBA; (3) PATH; (4) PEO; and (5) RULA. They have been applied by following the

Table 1 Body areas considered by each considered method

Method	Wrist	Elbow	Shoulder	Cervical	Lumbar
OWAS			X		X
REBA	X	X	X	X	X
PATH			X	X	X
PEO				X	X
RULA	X	X	X	X	X

European standard regarding working postures and movements, the EN 1005-4: 2005.

The muscle groups used in the research methods were different as there are differences within each group. The body areas and the associated major muscle groups that are overloaded in the workplace were selected for this analysis, namely: wrist, elbow, the upper extremity of the shoulder, the vertebral and lumbar parts of the back. Table 1 shows the muscle groups that were used in the various methods in the sample.

3 Results

The selected methods use different intervals of joint angles, and each of them provides a specific score for each position analyzed. A given posture is assigned to a specific working position and it is analyzed with different criteria. The limits of these score intervals are highly variable, since they depend of the evaluation of the angles covered by these intervals which changes the scoring in each method used.

As shown in Tables 2, 3, 4, 5 and 6, the variability in the angular ranges of the various methods is very high and, therefore, the result obtained by applying them can be also very variable.

Table 2 Joint angles considered in wrist flexion

Method	0	−15°	15°
REBA	X		X
RULA	X	X	X

Both REBA and RULA also take into account, without quantifying, if there is radial or ulnar deviation or if pronation or supination are detected

Table 3 Joint angles considered in elbow flexion

Method	0	60º	100°
REBA	X	X	X
RULA	X	X	X

This angles are for the bending posture of the elbows. RULA method also considers whether the arms cross the midline plane of the body or if the forearm is positioned outside the same 45° range

Table 4 Joint angles considered in shoulder flexion

Method	−20°	20°	45°	60°	90°
OWAS					X
RULA	X	X	X		X
REBA	X	X	X		X
PATH					X
PEO					X

The RULA method takes into account, not quantitatively, if the shoulder is raised, if abduction occurs, or if the arms are supported. The REBA method considers, qualitatively, any abduction or rotation that exists

Table 5 Joint angles considered in neck flexion

Method	0°	10°	20°	30°	40°
RULA	X	X	X		
REBA	X		X		
PATH				X	
PEO			X		

The RULA and Reba methods take into account, not quantitatively, if the neck is rotated or tilted sideways. The Path method takes into account the lateral deviation and rotation with limits of 30° and 45°. Finally the PEO method has a limit of 45° for rotation

Table 6 Joint angles considered in back flexion

Method	−20°	0°	20°	45°	60°
RULA		X	X		X
REBA	X	X	X		X
PATH			X	X	
PEO		X	X		X

The RULA, method takes into account, not quantitatively if your back is turned and tilted sideways. The PATH method has limits of 20° to the lateral tilt and rotation. Finally the PEO method has a limit of 45° for rotation

4 Discussion

All observational ergonomic evaluation methods require the determination of the adopted joint angles. For some of them, when analyzing the working day, the analysis of many positions is required for most of the method application. In other cases, during shorter exposure time, only those most demanding postures, from a physical point of view, are analyzed, i.e. those that can originate fatigue.

This entails the need to know the value of the angle of each joint and for each position to be analyzed in all three spatial dimensions.

In practice, while using these methods, ergonomists and/or health and safety professionals or practitioners use photographs and videos and this support involves a more or less important deviation from the real result of each observed angle.

Additionally, in many studies and research programs, conscious that it is impossible to observe postures while working with exactness, limits have been established based not on fatigue produced on the joints, but on the observational limits themselves [4].

A second difficulty in observation must be mentioned too, which is to not consider individual factors, such as those inherent to the individual. Fundamentally it means the characteristics of each individual (age, sex, anthropometrics, habits, fitness, influential chronic diseases such as diabetes, rheumatoid arthritis, etc.). Any of these factors can accelerate a problem and therefore the adoption of joint angles closest to the neutral position. Ultimately, the result of the evaluation of the job would depend on the worker occupying the workplace at a given moment.

As a general principle, which should be analyses carefully for some specific situations, an ergonomic evaluation method must be simple, it should be designed to be used by untrained staff, and must provide clear and specific answers that should offer possibilities for ergonomic correction [13]. The reality is that most of the methods are conditioned by two opposing characteristics, on one hand they have to be easy to use and in the other hand, they should be highly sensitive for be accuracy, which increases difficulty [9].

To achieve higher sensitivity and reliability in the results, some methods have included the possibility to use direct measurement techniques such as electromyography (EMG) or electrogoniometry. Despite that, this application has rarely been used to facilitate any type of recording for several reasons, such as the difficulties associated with worker mobility, and the cost and existence of obstacles in the workplace. Nevertheless, in the future the use of bioinstrumentation will increase [8], since it is the only way to get reliable data in the obtained results.

4.1 Angular Analysis

What is clear, and more than demonstrated in scientific literature, is that the postures adopted by a worker because of the equipment, tools and furniture are one of the most important factors in the development of WMSDs. With respect to the angular values, listed in Tables 2, 3, 4, 5 and 6, the sources are:

- In the case of the wrist, joint ranges ((−15)–0; 0–15) were developed in the publication HSE [14];
- Forearm ranges (0–60, 60–100) were developed by Grandjean [15] and Tichauer [16];
- The ranges of motion of the arm (0–20; 20–45; 45–90) were studied by Tichauer [16], Chaffin [17], Herberts [18], Hagberg [19], Schuldt [20] and Harms

Table 7 Joint angles of flexion considered

Joint	−20°	−15°	0°	10°	15°	20°	30°	40°	45°	60°	90°	100°
Wrist		X	X		X							
Elbow			X							X		X
Shoulder	X					X			X	X	X	
Neck			X	X		X	X	X				
Back	X		X			X			X	X		

Ringdahl [21]. Meanwhile, the value of 60 is included in the European standard EN 1005-4;

- With regard to vertebra flexion ranges (0–10, 10–20) were analyzed by Chaffin [17] and Kilbom [22, 23], the value 30° by Keyserling [24] and the value 40° in the European standard EN 1005-4;
- Finally, the trunk flexion joint has limits of (0–20; 20–60) determined by Drury [25], Grandjean [15, 26] (−20) and included by Hignett [6] and the value (45°) by Keyserling [24].

An ergonomic assessment, from the perspective of the postures taken by the joints involved in the risk of WMSDs, consists in determining an adopted angle and its subsequent inclusion in one of the reference intervals so that it can be assigned a score on a previously established criteria based on epidemiological studies or research.

Angles considered by the methods of the sample are shown in Table 7 and the assigned scores depend on each method and each interval considered, based on studies or previous research.

There are two main issues to consider at this respect: the determination of an adopted posture (angle) and the penalization that is assigned to that angle (score).

4.2 *Performing an Ergonomic Assessment Accurately*

An ergonomic evaluation, to ensure a minimum of reliability, must be based on four separate approaches [27]:

(a) Visual observation, in which an ergonomist, evaluates either in 2D in a sagittal plane or a frontal plane, those relevant aspects of the task analyzed, going beyond frequencies, angles or times;
(b) Quantitative measurement of kinematic parameters: movements, joint angles, times and frequencies;
(c) A biomechanical analysis (strengths and its effects on the task);
(d) A muscle EMG study to determine quantitatively the effort or muscle fatigue that is caused by the task.

Therefore, if what is intended is to assess static work looking at frequencies and negative forces regarding the effect of postures, the assessment should be based on two main actions, a quantitative measurement of joints, and the objective assessment of muscle fatigue.

Using 3D Photogrammetry. Photogrammetry is a science that obtains information from physical objects using the processes of recording, measuring and interpreting photographic images. From the perspective of biomechanics, the human body can be represented as a system of articulated segments and photogrammetry allows, during movement thereof, us to estimate the kinematic variables (mass, center of mass position, moments of inertia [28]), and place them continuously in space.

The Standardization and Terminology Committee (STC) of the International Society of Biomechanics (ISB) has developed a set of rules to correctly report the movement of each joint. In 1993 the Joint Coordinate System (JCS) was approved as a rule, initially proposed by Grood and Suntay [29]. This standard refers some anatomic markers to be used on the spine, full body, shoulder, elbow, wrist and [30] and [31].

By using photogrammetry, scientific evidence obtained from the markers that define each muscle group can give us, in a precise way, the angle of each joint.

Currently, 3D scanning of the human body is used in many fields of knowledge [32], including but not limited to: ergonomics, medicine, clothing sizes, industry, etc. There are many examples that have used photogrammetry to perform a biomechanical analysis of a joint [33] for a particular task, but for the moment its use is more widespread in injury recovery, improving athletic performance and prosthesis design or other sports items.

In any case, once the movement of muscle groups has been recorded, we have all the necessary data for calculating the kinematic variables and to produce a graphical representation. Some software currently available can provide kinematic point data (position, velocity, acceleration, angle angular velocity, and angular acceleration), distances, and rigid body dynamics (translation and rotation), based on previous records of the task. With great accuracy, it is possible to determine the movement and position of a rigid body defined by the applied body markers.

Using EMG. Surface electromyography (sEMG) is a technique that quantifies the physical demands on the body and detects both the effort expended and muscle fatigue. It is a sensitive and specific reproducible diagnostic technique, [34, 35]. Many researchers use it to detect muscle hyperactivity/hypoactivity, muscle imbalances and generally any responses by the muscles to performing mechanical work.

All values obtained from the sEMG require standardization comparison: angle if static test, range of motion in the case of dynamic test speed, applied load, duration, previous state muscle and, of course, electrode placement. On this last point, the SENIAM project (Surface Electromyography for the Non-Invasive Assessment of Muscles) is used by researchers in Europe as it establishes a series of recommendations on the location of the sensors to evaluate electrical response of the major joints (shoulder, neck, trunk, elbow, wrist, knee and ankle).

Therefore, with the application of this technique it is possible to determine the correlation between the load and the muscle fatigue or in other words, between their spatial positions, if there is no existence of external load, and fatigue. This shows that sEMG can be considered as a very important tool in ergonomic research [36–38].

5 Conclusions

Traditional methods of postures' evaluating at the workplace have always been limited by the type of observation made (visual, photographs, video, etc.).

Most of the methods rely on a score assignment to each posture of the body zone and these evaluations are mostly established based on angular intervals. In some cases, it is necessary to take into account the limits of human observation.

Photogrammetry allows the spatial location of any muscle group and therefore it can be a reliable technique to determine the angle taken by a joint. On the other hand, regarding the assessment of posture, sEMG allows a quantitative analysis of muscle activity and thus an objective determination of muscle fatigue.

With the combination of both previous mentioned tools, it is possible to define a joint posture with great accuracy and the muscle response can be objectively assessed. With this scenario, there will be no need to use ranks or scores that penalize unfavorable situations. At this respect, it is important to mention that, as indicated in previous studies, it has been shown that it is necessary to have a synchronization unit for the digital signal photogrammetry. This must be aligned with the wave of the potential provided by the sEMG. Thus, there will be a muscular response value for each position, i.e. a continuous assessment over time.

Ideally, an ergonomic evaluation should be performed on the field, in the workplace. Even though the operational difficulties of making EMG studies during a work activity are great, they may open a line of research in finding a relationship between posture and muscular effort. This would avoid the necessity for EMG testing on the workplace by just filming the worker with simple portable wireless cameras.

References

1. Publications Office of the European Union, Luxembourg, Eurofound: Fifth European Working Conditions Survey. ISBN 978-92-897-1062-6. (2012)
2. Hunting, W., Lauble, T.H., Grandjean, E.: Constrained postures of VDU operators. In: Grandjean, E., Vigliani, E. (eds.) Ergonomic Aspects of Visual Display Terminals, pp. 175–184. Taylor & Francis, London (1980)
3. Westgaard, R.H., Aara, Ê.S.A.: Postural muscle strain as a causal factor in the development of musculo-skeletal illness. Appl. Ergon. **15**, 162–174 (1984)

4. Karhu, O., Kansi, P., Kuorinka, I.: Correcting working postures in industry: a practical method for analysis. Appl. Ergon. **8**(4), 199–201 (1977)
5. McAtamney, L.Y., Corlett, E.N.A.: Survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
6. Hignetta, S., McAtamneyb, L.: Rapid entire body assessment. Appl. Ergon. **31**, 201–205 (2000)
7. Kee, D., Karwowski, W.: An assessment technique for postural loading on the upper body based on joint motion discomfort and maximum holding time. Appl. Ergon. **32**, 357–366 (2001)
8. Buchholz, B., Paquet, V., Punnet, L., Lee, D., Moir, S.: A work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. Appl. Ergon. **27**(3), 177–127 (1996)
9. Fransson-Hall, C., Gloria, R., Kilbom, A., Winkel, J.: A portable ergonomic observation method for computerized on-line recording of postures and manual handling. Appl. Ergon. **26** (2), 93–100 (1995)
10. Swat, K., Krzychowicz, G.: Computer-aided working posture analysis system for workplace designers. Int. J. Ind. Ergon. **18**, 15–26 (1996)
11. Takala, E.-P., Pehkonen, I., Forsman, M., Hansson, G.-A., Mathiassen, S.E., Neumann, W.P., Sjogaard, G., Veiersted, K.B., Westgaard, R.H., Winkel, J.: Systematic evaluation of observational methods assessing biomechanical exposures at work. Scand. J. Work Environ. Health **36**(1), 3–24 (2010)
12. Ketola, R., Toivonen, R., Viikari-Juntura, E.: Interobserver Repeatability and Validity of an Observation Method to Assess Physical Loads Imposed on the Upper Extremities. Taylor & Francis, Published online (2010)
13. McPhee, B.J.: Work-related musculoskeletal disorders of the neck and upper extremities in workers engaged in light, highly repetitive work. In: U OsterholzW KarmautB HullmaB Ritz. In: Proceedings of the International Symposium Work-related Musculoskeletal Disorders. Bonn, Germany (1987)
14. Health and Safety Executive: Guidelines on the prevention of work related upper limb disorders HMSO. London (1990)
15. Grandjean, E.: Fitting the Task to the Man, pp. 24, 48, 51, 107. Taylor & Francis, London (1988)
16. Tichauer, E.R.: Some aspects of stress on forearm and hand in industry. J. Occup. Med. **8**, 63–71 (1966)
17. Chaffin, D.B.: Localized muscle fatigue - definition and measurement. J. Occup. Med. **15**, 346–354 (1973)
18. Herberts, P., Kadefors, R., Broman, H.: Arm positioning in manual tasks. An electromyographic study of localised muscle fatigue. Ergonomics, **23**, 655–665 (1981)
19. Hagberg, M.: Electromyographic signs of shoulder muscular fatigue in two elevated arm positions. Am. J. Phys. Med. Rehabil. **60**(3), 111–121 (1981)
20. Schuldt, K., Ekholm, J., Harms-Ringdahi, K., Arborelius, U.P., Nemeth, G.: Influence of sitting postures on neck and shoulder EMG during arm-hand work movements. Clin. Biomech. **2**, 126–139 (1987)
21. Harms-Ringdahl, K., Schiildt, K.: Neck and shoulder load and load-elicited pain in sitting work postures. Ergonomics: the physiotherapist in the workplace Churchill Livingstone, Edinburgh, pp. 133–148 (1990)
22. Kilbom, A., Persson, I., Jonsson, B.G.: Risk factors for work related disorders of the neck and shoulder—with special emphasis on working postures and movements'. In: Corlett, E.N., Wilson, J.R., Manenica, J. (eds.) The Ergonomics of Working Posture, pp. 44–53. Taylor & Francis, London (1986)
23. Kilbom, A., Persson, I., Jonsson, B.G.: Disorders of the cervicobrachial region among female workers in the electronics industry. lnt. J. lnd. Ergon. **1**, 37–47 (1986)
24. Keyserling, W.M.: Postural analysis of the trunk and shoulders in simulated real time. Ergonomics **29**, 569–583 (1986)

25. Drury, C.G.: A biomechanical evaluation of the repetitive motion injury potential of industrial jobs. Semin. Occup. Med. **2**(1), 41–47 (1987)
26. Grandjean, E., Hunting, W., Piderman, M.: VDT workstation design: preferred settings and their effects'. Hum. Factors **25**, 161–175 (1983)
27. Martínez, F., Gómez, F., Romero, E.: Análisis de vídeo para estimación del movimiento humano: una revisión. Rev. Med. **17**(1), 953–1006 (2009)
28. Kawamura, C. M., Morais Filho, M.C., Barreto, M.M., Paula Asa, S.K., Juliano, Y., Novo, N. F.: Comparison between visual and three-dimensional gait analysis in patients with spastic diplegic cerebral palsy. Gait & Posture. **25**, 18–24 (2007)
29. Grood, E.S., Suntay, W.J.: A joint coordinate system for the clinical description of three-dimensional motions: application to the knee. J. Biomech. Eng. **105**, 136–144 (1983)
30. Wu, G., et al.: ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion-part I: ankle, hip, and spine. J. Biomech. **35**, 543–548 (2002)
31. Wu, G., et al.: ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion-part II: shoulder, elbow, wrist and hand. J. Biomech. **38**, 981–992 (2005)
32. Percoco, G.: Digital close range photogrammetry for 3D body scanning for custom-made garments. Photogram. Rec. **26**(133), 73–90 (2011)
33. Lópeza, C.L., Ribas, J.: Análisis biomecánico de la articulación de la muñeca en el paleo en kayak: modelo dinámico. Sernab. Rev Andal Med Deporte **2**(3), 102–107 (2009)
34. Buxbaum, J., Mylinski, N., Parente, F.R.: Surface EMG reliability using spectral analysis. J. Oral Rehabil. **23**(11), 771–775 (1996)
35. Gallo, L.M., Guerra, P.O., Palla, S.: Automatic on line one-channel recognition of asseter activity. J. Dent. Res. **77**(7), 1539–1546 (1988)
36. Hgg, G.M., Luttmann, A., Jager, M.: Methodologies for evaluating electromyographic field data in ergonomics. J. Electromyogr. Kinesiol. **10**, 301–312 (2000)
37. Pang, M., Guo, S., Huang, O., Ishihara, H., Hirata, H.: Electromyography-based quantitative representation method for upper-limb elbow joint angle in sagittal plane. J. Med. Biol. Eng. **35**, 165–177 (2015)
38. Wang, J., Bartuzi, P., Roman-Liu, D.: Influence of upper extremity position on EMG signal measures calculated in time, frequency and time-frequency domains. Acta Bioeng. Biomech. Orig. Paper. **15**(4) (2013)

Application of TRIZ Methodology for Ergonomic Problem Solving in a Continuous Improvement Environment

João F. Alves, Helena V.G. Navas and Isabel L. Nunes

Abstract This paper discusses a case from an automotive industry plant where ergonomic problems were identified corresponding to inadequate postures resulting from operations performed above the workers' head height. Company's economic situation didn't allowed to consider the automation of the operation despite the recognized need to reduce or, ideally, to eliminate the risk to operators. In this context the use of the TRIZ methodology offers an opportunity to identify potential solutions. Therefore, the TRIZ's Su-Field Analysis was used, with the support of an adapted Contradiction Matrix. This approach allowed obtaining a more structured solution, combining Ergonomics with Lean management principles. The outcome of implementing the proposed solution was the elimination of wastes and the improvement of workplaces' ergonomic quality. Furthermore, the study provided some insights on ways of eliminating or reducing existing Occupational Safety issues in the near future.

Keywords Occupational safety · Problem solving · Su-Field analysis

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1 Introduction

Some industries still have a large dependence on manpower. For instance, in automotive manufacturing not all the tasks are performed by robots. Besides the reasons related with the high costs of automating some processes, some operations are very difficult to automate with the available technology, namely the ones related with the assembly/trimming processes. However, this draw upon manpower may have unexpected costs, since any ergonomics inadequacies in medium and long term may cause musculoskeletal disorders [1].

One of the purposes of Lean philosophy in manufacturing is to reduce the variability of processes, turning the planning process much more accurate and allowing the reduction of waste. Several authors refer that lean implementation can take a toll on workers since its goal is to maximize production minimizing resources, which can affect working conditions and promote work-related musculoskeletal disorders (WRMD) [2]. WRMD, which are associated with repetitive and strenuous working conditions, continue to represent one of the biggest occupational problems in companies causing absenteeism [3]. WRMD are caused by physical, psychosocial, and individual risk factors. Psychosocial and individual risk factors are assumed as transversally contributing factors, which are not important enough to produce by themselves a WRMD but can have a synergistic effect when associated with physical risk factors. On the other hand, there is evidence that the presence of some specific physical risk factors is enough for the development of a specific WRMD [4].

This paper describes a case from an automotive industry plant where ergonomic problems were identified, and discusses the use of the TRIZ methodology to identify potential solutions.

2 Application of Su-Field Analysis to Eliminate Risk Factors

The workstation under study belongs to the assembly line of an automotive plant where some complaints of WRMD were recorded. Among other operations, the workers in this workstation install the seats, the tipper system and some other trims under and around the cabin (body). In order to have access to the bottom of the cabin's body, the cabin is lifted by a mechanical system and held by two supports which ensure the necessary stability and, in case of failure of the lifting system, prevents the cabin's from smashing the operator that is working underneath it (Fig. 1).

The RULA method was used to evaluate the operators' postures, and some issues concerning the work done under the cabin were identified. The evaluation result obtained was within the third of four levels, which indicated the need of a more accurate analysis and a short-term modification of the working conditions.

Fig. 1 Overview of the workstation

Following what RULA method [5] pointed out in order to reduce or, ideally, eliminate the ergonomics risk factors the first step consists of analysing the workstation and, based on the results, act in order to promote harmless working conditions.

2.1 Reduce the Physical Risk Factor in a Workstation Using Substance-Field Analysis

The RULA evaluation and the analysis performed suggest the need to change to the working conditions. In this case two operators share the workstation, each one with a different body structure. Ergonomic principles state that the workstation has to adapt to the operator and not otherwise [6]. However, when there are two different operators with different heights, it becomes problematic to ergonomically optimize the workstation. As Altshuller (the creator of the Theory of Inventive Problem Solving, better known by its Russia acronym TRIZ) would say, there is a contradiction. There is a problem and there is not an obvious solution. The problem consists in an impossibility to simultaneously adapt a workstation to both operators.

2.2 Workstation

As mentioned before, the cause of the ergonomic inadequacies are related with the operator's posture when working at the raised cabin's body. Some of the operations can be seen in Fig. 2.

When performing such operations, most of the time the worker has to hold the arms above the shoulder line, and sometimes works with the torso side bended or twisted. All these conditions can be considered as physical risk factors to WRMD.

The analysis suggests that the problem becomes more severe as the height of the cabin increases, forcing workers to stretch further to reach it.

Fig. 2 Examples of operations performed with the arms above the shoulder line and with the torso side bend

Fig. 3 Tipper system used for working under the body [7]

In this particular case, there is already a commercial solution available to improve the working conditions (as illustrated in Fig. 3), but it would represent a significant investment, which was not feasible to the company considering its financial situation.

This solution could represent a great improvement and it would most probably solve the ergonomic inadequacies. Despite the company couldn't adopt it, its managers recognized the need to reduce or, ideally, eliminate the risk to operators. In this context the use of the TRIZ methodology offers an opportunity to identify potential solutions.

2.3 *Su-Field Analysis of the System*

Altshuller, as an engineer, lived most of his time focused in the development of a theory, called TRIZ, which would facilitate problem solving in an inventive way. One of the tools created by him was the Su-Field Analysis which turns a specific problem into a generic problem graphically represented, and then applies the generalized solutions to reach a generic and, therefore, specific solution.

After identifying the main problem it is now possible to start solving it. In order to do it the Su-Field can be applied [8].

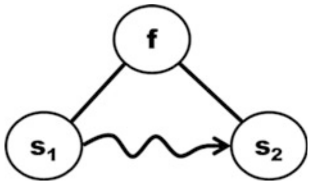


Fig. 4 Graphic representation of the initial state of the system by the Su-Field Analysis

The Su-Field analysis represents a complete system in a form of triangle, represented by a field (F) and two substances (S) (see Fig. 4).

In this specific case, "s_1" represents the cabin before the workstation, "s_2" represents the cabin at the end of the workstation and "f" represents all the tasks performed in the workstation. In an ideal situation, a straight line would represent the connection between "s_1" and "s_2". However this system has an ergonomic inadequacy identified by RULA method, which is showed in the Su-Field Analysis by a curved line.

In order to solve the ergonomic inadequacy, the seven general solutions can be applied. It is important to understand how these changes can affect the system and focus in a specific field or substance. In this case, both substances (s_1 and s_2) should not be the object of alterations, although it is possible to manage the task performed in the workstation.

2.3.1 First Change of the System (f → f′) – Reduce the Cabin's Height Position by 30 Cm (1 ft.)

As previously identified, there is a problem with the height of the cabin (workstation), so the first change to the system consists in reducing cabin's height by 30 cm (about 1 ft.).

As it can be observed in Fig. 5 there is a gain concerning ergonomics: the operator assumes a more natural posture. Nevertheless in Fig. 6 the operator assumes a less natural posture, with a slight flexion of the legs and the bending of the torso. This leads to new requirement, which is to position the cabin at two different heights.

On the other hand, it is important to evaluate the impact of the height reduction to the second operator that works on the same workstation (Fig. 7).

The working posture of the second worker with the lower cabin's position worsened, but it is possible to identify some operations where this reduction does not represent an increase of the physical risk factors.

After reducing cabin's position height, there is still an issue concerning the simultaneous work of the two operators because both of them have different needs regarding each operation and body structure. Therefore, the graphic illustration of the system by Su-Field Analysis is still represented by a complete system with undesired effects (Fig. 8).

Fig. 5 Postures after the reduction of the cabin's height (operations previously performed under the cabin with the arms over the head)

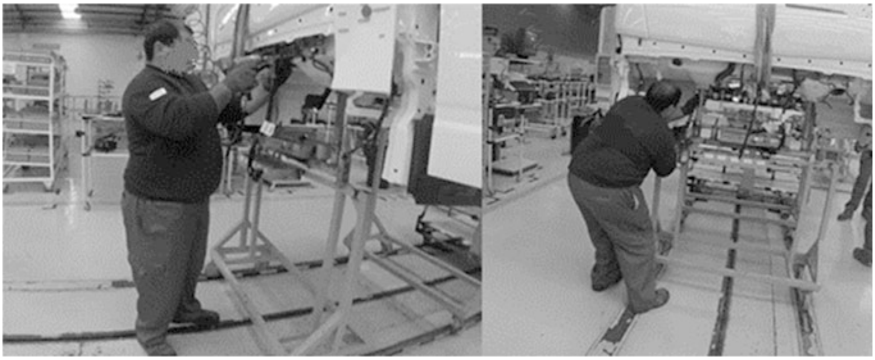
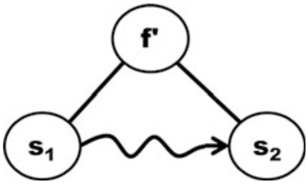


Fig. 6 Operator posture for operations performed in the cabin front: posture on the left improved and the posture on the right degraded

Fig. 7 Postures of the operator that shares the workstation after reducing cabin's height

Fig. 8 Graphic representation after the first change of the system by the Su-Field Analysis



2.3.2 Second Change of the System—Eliminate Redundant Operations

The main problem with physical risk factors is the time that the operators are exposed to a specific posture during their task. In order to reduce this risk and afterwards balance the operations, it is crucial to identify and reduce the duration of some operations, namely the ones that are redundant.

Along with the first analysis of the workstation, it was possible to identify some redundant operations, more specifically when checking the torque of screws or nuts. This situation occurred due to an incorrect read of the tensor (nutrunner) caused by the deposit of paint in the threaded elements. To solve this problem, after using the tensor (nutrunner) it is used a dynamometric tool to reconfirm the torque that was previously presented by the other tool. Afterwards, the screw or nut tighten is painted with the purpose of knowing that the torque was checked (Fig. 9).

In order to eliminate a significant amount of time of the operation, another method can be applied: the Contradiction Matrix [9] of Altshuller. The basis of this problem is the duration, but in the same conditions, the reduction of time would imply a downgrade of precision, which is not a solution. That is, to improve one parameter (speed), there is a degradation of another parameter (manufacturing precision). Thus, to contradict this situation, the Contradiction Matrix presents a set

Fig. 9 Set of redundant operations performed with the arms above the head

Table 1 Adapted contradiction matrix of the second change of the system

		29—Manufacturing precision
9—Speed		10, 28, 32, 25
Legend:	10. Prior action 25. Self-service, self-organization	28. Replacement of a mechanical system 32. Changing colour or optical properties

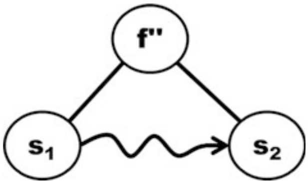


Fig. 10 Graphic representation after the second change of the system by the Su-Field Analysis

of possible actions (called Inventive Principles) that can mitigate the direct effect of improving one parameter in another one (Table 1).

Among the inventive principles presented above, the “prior action” seems to be a good and suitable solution. For example, a plastic part could be applied to cover the threaded elements, preventing paint to get in. During the operations, the plastic part would have to be removed, but it would take much less time than the current method used.

This would result in a reduction of the operation’s time and the risks factors associated. However, there is still one issue to solve: the operations are not balanced yet. So, the graphic illustration of the problem by Su-Field Analysis is still represented by a complete system with undesired effects (Fig. 10).

2.3.3 Third Change of the System—Balancing Operations

Based on the previous premise that only the field (F) is the focus of modification, the third change aims for a balance of operations capable of having the two operators working in good ergonomic conditions. This requires a dynamic positioning of the cabin in the x-axis (vertical movement) which allows adapting the workstation to each body structure. In this case, it is essential to evaluate the viability of this dynamic positioning and then balance the operations of both operators in terms of their body structures and the best cabin height for each operation per operator.

Table 2 presents the tasks of both operators (in this case referred as “X” and “Y”) and their respective operations. These operations are classified as “A”, “B” or “C” according to the previous analysis of the workstation, in which “A” refers to the initial cabin’s position, “B” refers to the lower height cabin’s position and “C” refers to operations not affected by the cabin’s position.

Table 2 List of coded operations per operator ("X" and "Y")

Task of operator "X"			Task of operator "Y"		
Operation's code	Duration (s)	Cabin's position	Operation's code	Duration (s)	Cabin's position
R1	45	B	L1	17	C
R2	29	B	L2	76	C
R3	45	A	L3	27	B
R4	74	B	L4	37	A
R5	37	A	L5	88	A
R6	53	B	L6	32	B
R7	17	B	L7	44	A
R8	16	A	L8	43	A
R9	33	B	L9	64	A
R10	142	A	L10	45	A
R11	22	C	L11	75	A
R12	120	C	L12	20	C
R13	58	C	L13	40	C

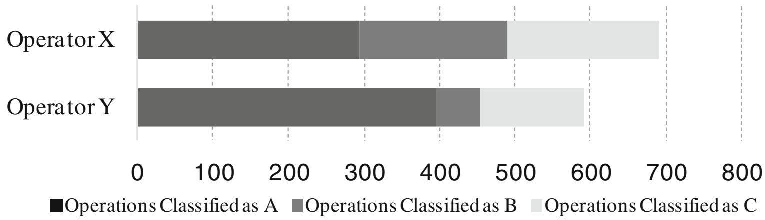


Fig. 11 Sum of operations per classification for each operator

The operations were summed per classification to confirm the viability of proceeding with the balance of operations according to the cabin's position (Fig. 11).

Analysing Fig. 11 it seems possible to rearrange the operations. The existence of operations classified as "C", which are not affected by the cabin's position, can absorb the difference of sums per classification to each operator. To support the rearrange of operations a pictorial code with the same colours of Figs. 11 and 12 can be used. Figure 12 represents the initial order of operations and shows the impossibility to establish good ergonomic conditions to both operators.

This rearrange of operations has to take into consideration a few rules, namely the precedence of operations, the space to work of each operator so that they do not interfere with each other and that operations classified as "A" or "B" can only occur simultaneously with operations with the same classification or "C" (Fig. 13).

After the rearrangement of operations it is clear that it is possible to operate with two different cabin positions. Nevertheless, the current system is not prepared for a dynamic positioning of the cabin during the operations. The system can move the

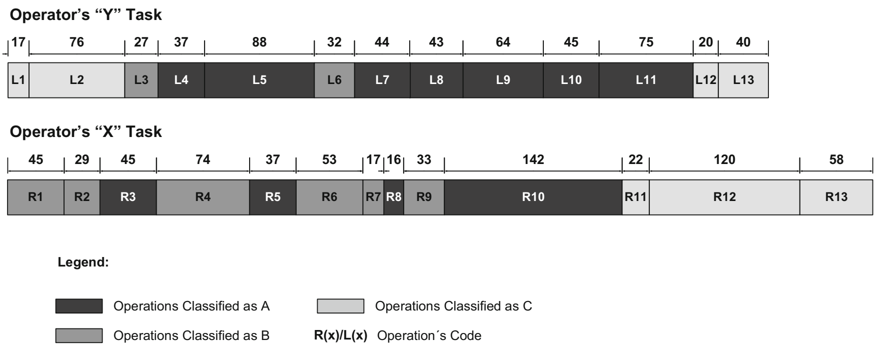


Fig. 12 Initial order of operations per operator with the respective classification color and operation code

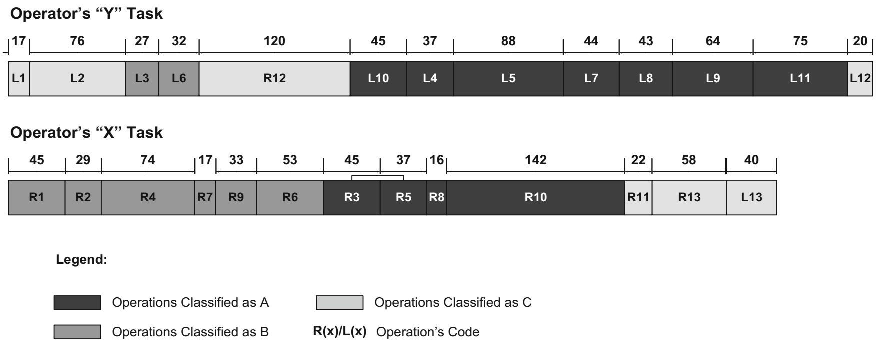
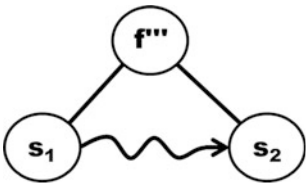


Fig. 13 Rearranged operations based on the cabin´s position per operator

Fig. 14 Graphic representation after the third change of the system by the Su-Field Analysis



cabin in the x-axis, but it cannot adapt the height of the workstation to all operators' body structure because of the support used to give stability to the cabin. In this case, the graphic illustration of the problem through Su-Field Analysis is still represented by a complete system with undesired effects (Fig. 14).

2.3.4 Forth Change of the System—Organizational Changes

Assuming that all the possible changes in the existent field were made, another solution is to introduce a new field, with the capacity to mitigate the hazards of the existing field (f‴).

It is important to understand how to eliminate physical risk factors. There are some strategic changes that can be done such as reduce repetitions [10, 11], find the right working position, reduce the amount of force, reduce duration, improve the working environment and tackle the underlying effects of work or conditions. A fraction of these measures have already been implemented with the Su-Field Analysis, but not all of them.

Reduce repetitions, improve working environment, and tackle the underlying effects of work or conditions are three important modifications to the system. In fact, implementing these measures can also result in an improvement of the psychological well-being.

First, to reduce the frequency of repetitions it is possible to create a qualification matrix that allows workers to rotate among workstations with different physical needs. Secondly, it is important to inform and educate workers and staff about ergonomics and the consequences of neglecting it. Finally, it is also essential to promote an adaptable workstation (Fig. 15).

Instead of a static support, which only grants one height position, a dynamic one allows adapting the height of the cabin to every operator's body structure. This feature permits a short setup time between operations. The spring, an Acceleration Sensitive Damping shock absorber, in the center has a double function, supports the upper part of the structure and lets it move according to the needs of the workstation. In addition, in case the cabin falls, the shock absorber will prevent worker injuries.

With the addition of this last field, the system is now complete without any undesired effects (Fig. 16).

Fig. 15 Proposal of a new dynamic support for the cabin

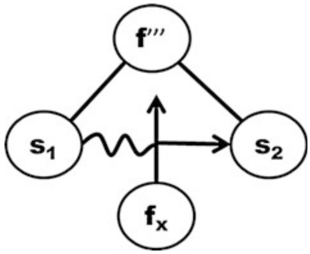


Fig. 16 Graphic representation after the fourth and last change of the system by the Su-Field Analysis

The application of the Su-Field Analysis contributes to a structured and inventive solution obtained by simple steps, gathering knowledge of different scientific areas and adapting a general solution to a specific problem [12].

3 Conclusion

The TRIZ methodology, with its strong theme of innovation, can contribute to accelerating the resolution of problems in industrial design activities. TRIZ analytical tools are very useful for schematization of project tasks, structural analysis, identification and formalization of contradictions and problematical situations and its solving.

The application of the Su-Field Analysis just by itself does not present a solution. As a tool of TRIZ, it encourages to go beyond of a specific scientific field and to build a structured solution, step-by-step. Its application with the support and synergy of lean tools and a basic knowledge of ergonomics, grants a strong solution, which allows, what at a first glance seems a huge problem, to be solved fairly easily.

Acknowledgments The present authors would like to thank the Faculty of Science and Technology of The New University of Lisbon and the Portuguese Foundation for Science and Technology through the Strategic Project no. PEst-OE/EME/UI0667/2011. Their support is helping to make possible our research work.

References

1. Salvendy, G., Karwowski, W.: Ergonomics in Manufacturing: Raising Productivity through Workplace Improvement. Society of Manufacturing Engineers, Dearborn, Michigan (1998)
2. Freitas, D., Nunes, V., Nunes, I.L.: Integrating lean six sigma and ergonomics—a case study. In: Arezes P., et al. (eds.) Occupational Safety and Hygiene III, pp. 441–445. Taylor & Francis Group, London (2015) (ISBN 978-1-138-02765-7)
3. Nunes, I.L.: FAST ERGO_X—a tool for ergonomic auditing and work-related musculoskeletal disorders prevention. WORK J. Prev. Assess. Rehabil. **34**(2), 133–148 (2009) (ISSN 1051-9815)

4. Nunes, I.L., Knowledge acquisition for the development of an upper-body work-related musculoskeletal disorders analysis tool. Hum. Factors Ergon. Manuf. Serv. Ind. **17**(2), 149–162. (2007). doi:10.1002/hfm.20070 (ISSN 1520-6564)
5. McAtamney, L., Corlett, E.N.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**, 91–99 (1993)
6. IEA—definition and domains of ergonomics. http://www.iea.cc/whats/index.html
7. ADP—Manufacturing Electrified Vehicles in Wolfsburg in Automotive Design and Production. http://www.autofieldguide.com/articles/manufacturing-electrified-vehicles-in-wolfsburg
8. Mao, X., Zhang, X., Abourizk, S.: Solutions for Su-Field Analysis. TRIZ J. http://www.triz-journal.com/generalized-solutions-for-su-field-analysis/
9. Terninko, J., Zusman, A.: Systematic Innovation. An Introdution to TRIZ. St. Lucie Press, Boca Raton, Florida (1998)
10. HSE—Human factors: design. http://www.hse.gov.uk/humanfactors/topics/design.htm
11. HSE—Reducing the risk of upper limb disorders (ULDs) in the workplace. http://www.hse.gov.uk/msd/uld/employers/howtoreducerisk.htm
12. Navas, H.V.G.: TRIZ: Design problem solving with systematic innovation. Adv. Ind. Design Eng. (2013). doi:10.5772/55979, http://www.intechopen.com/books/advances-in-industrial-design-engineering/triz-design-problem-solving-with-systematic-innovation (ISBN 978-953-51-1016-3, InTech)

Ergonomic Assessment of Assembly Tasks in a Mexican Automotive Industry

Luis Cuautle-Gutiérrez, Jesús Juárez-Peñuela and Luis Alberto Uribe-Pacheco

Abstract According to the Mexican National Institute of Statistics and Geography (INEGI), the automotive industry contributes with the 25 % of the Gross Domestic Product of the State of Puebla. In this matter, Puebla has 160 companies and employs 56,000 workers. The lower back pain represents the first cause of absenteeism in work places at Mexico. This situation is generated by materials handling or load lifting. The research was made in the assembly of a component of the vehicle powertrain in a Mexican metallurgical factory. Two assemblies were assessed with ergonomics tools in order to identify overload lifting and repetitive movements' risks. In addition, Methods Time Measurement techniques were considered to calculate the cycle time in the work stations studied and its relationship with ergonomics. The improvements resulted in a production increase of 6.89 % and 45 shifts less.

Keywords Ergonomics · Ergonomic assessment · Productivity

1 Introduction

According to the Mexican National Institute of Statistics and Geography (INEGI), the automotive industry contribute with the 25 % of the Gross Domestic Product of the State of Puebla and it represents the second sector with more value of Mexico with an annual production of 115,324.7 million of pesos. In this matter, Puebla has

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160 companies and employs 56,000 workers. The main vehicle producers are the German brands: Volkswagen de Mexico and AUDI and among the principal suppliers are companies such as Kiekert, LuK, Plastic Omnium, Brose, Allgaier, and ThyssenKrupp.

The lower back pain represents the first cause of absenteeism in work places in Mexico. This situation is generated by Manual Material Handling (MMH) or load lifting. Nowadays, there are not laws or regulations that force companies to include ergonomics in the design of their tasks. Besides, Mexican companies do not have enough occupational health and ergonomic committees to coordinate actions to prevent, reduce and control risk factors, or if they have it, their scopes and results are too limited.

2 Research in a Mexican Automotive Industry

The research was made in the assembly of a component of the vehicle powertrain in a Mexican metallurgical factory during eight weeks. First we considered a sub assembly (trolley) and the final product, the level actuator. Both processes were assessed with ergonomics tools in order to identify overload lifting and repetitive movement's risks. One of the main objectives was to link Ergonomics with MTM to determine work method improvements and assess the tasks' ergonomic aspects, especially frequency rates (repetition), awkward postures and load lifting.

In terms of productivity, the problem consist in the decrease of production in manual stations in the trolley line (Op. 10, 30 and 70), and operations 50 and 100 for the lever actuator line. In both lines there are extensive use of upper limbs (fingers, hands and arms) and load lifting.

The methodology used to solve this situation consisted in the following steps: determine the cycle time of the operations of interest using MTM, based on this study, determine the motion wastes and ergonomic risks, optimize or eliminate them. Jointly, workplace ergonomic assessment studies were conducted, experimentation of the possible solutions, analysis of the results, proposals, improvement, and documentation.

2.1 Actuator Line

This production line works two shifts and 24 days per month. For each work station considered in this assembly, the cycle time was calculated using MTM, see Table 1.

Therefore, the stations number 100 and 240 were considered in the first stage of the process to improve them. Also station number 10/20 was part of the research because of ergonomics and production management interests.

Table 1 Workstation cycle times

Workstation	Type	Cycle time (s)
10/20	Manual	11.58
30	Machine	6.11
40	Machine	9.71
50	Manual	11.69
60	Machine	10.57
70	Machine	7.31
100	Manual	14.37
110	Manual	7.87
120	Machine	10.22
130	Machine	7.69
135	Machine	6.79
140	Machine	12
220	Manual	10.08
230	Machine	11.15
240	Machine	12.84
260	Manual	9.65

The current production capability of the actuator line was estimated in 1775 pieces in the first shift and 1712 pieces in the second shift. This represents a 90,120 pieces per month production capability.

In terms of ergonomics and using OWAS, a posture of the worker with harmful effects on the musculoskeletal system was identified in station 10/20. With the purchase of a lifting device, this task changed to a more comfortable condition, see Fig. 1.

Meanwhile in workstation 100, it was noticed that the plates rack had to be filled manually several times during the shift because the sensor was programmed to stop

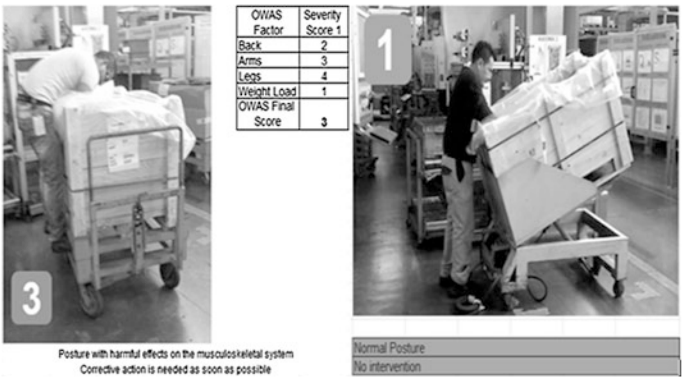

Fig. 1 Operation 10/20 OWAS

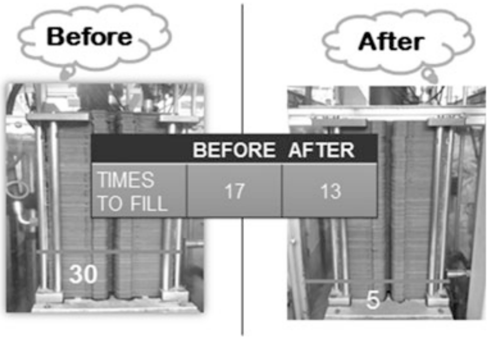

Fig. 2 Workstation 100 improvement

the machine when the number of plates drops to 30 units. The position of the sensor was changed so the machine stops when the number of plates is 5 instead of 30, this helped to reduce the amount of meter the worker had to walk and, and also reduce the number of filling operations from 17 to 13 per shift, see Fig. 2.

On the other hand in workstation 240, actuator images were searched for comparison to a master piece. The quest was performed in an 800 GB file that belongs to the production of one month. With a new program in the camera, a file per day was done, see Fig. 3. This improvement reduced the search of images and the release time of the production.

At the end of this study, the cycle time of each work station was estimated, see Fig. 4. Therefore, an increase of 2125 pieces in the first shift and 2050 pieces in the second shift was obtained. It represents 420 more pieces per day or 10,080 pieces per month.

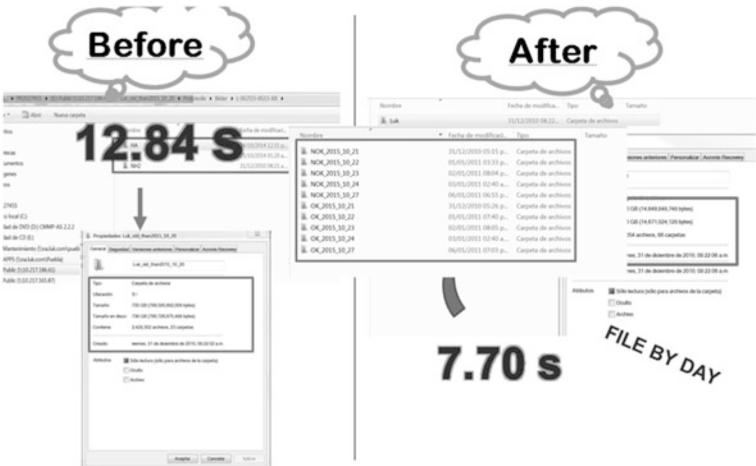

Fig. 3 Workstation 240 upgrade

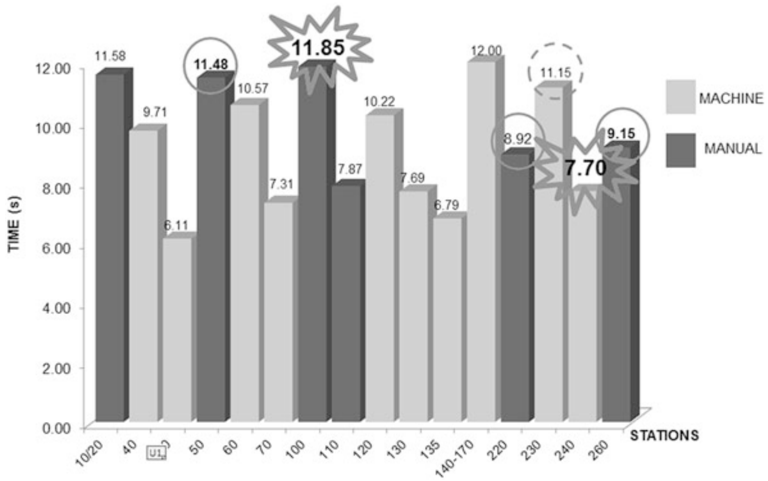

Fig. 4 MTM time analysis actuator line (after improvement)

2.2 *Trolley Line*

In this process, the cycle time were measured for each work station. The results are shown in Table 2. So, the stations number 10, 30, and 70 were analyzed for improvements. Thus, trolley line current production capability was established as 3553 pieces per day working two shifts or 85,272 items fabricated per month.

The purpose in workstation 10 was to decrease the cycle time. To achieve this, the therbligs were identified and reduced. The proposal method was simulated with CATIA V5 software. It is expected that the current cycle time of 9.49 s falls to an 8.15 s lapse, see Fig. 5. The same goal was pursuit in workstation 30. Using the same criteria of workstation 10, the cycle time was reduced 1.44 s.

Operation 50 could not be improved, due to the machine restrictions; in fact this is the line bottleneck.

In workstation 70, after filling a tray with 60 pieces, the worker takes the load and put it on a trolley. She performs this movement three times. To do this, she twists the spine.

Table 2 Work station cycle times in trolley line

Workstation number	Type	Cycle time (s)
10	Manual	9.49
20	Manual	12
30	Manual	14.47
50	Machine	14.69
60	Machine	9.45
70	Manual	6.50

Fig. 5 Workstation 10 cycle time reduction

	Before
OWAS	4
REBA	10
RULA	7
Disc Compressive Force	3386 N
Strain Index	0.56
NIOSH Origin	0.56
NIOSH (Destination)	1.04

Quick Exposure Check (Station 70) Before				
	Low	Moderate	High	Very High
Trunk/Back		28		
Shoulder/Arm		24		
Wrist/Hand		22		
Neck	6			
Speed of work		4		
Stress		4		

Fig. 6 Workstation 70 ergonomic study (before)

In Fig. 6, the activity shows moderate levels in trunk/back, shoulder/arm, wrist/hand, speed of work, and stress. Besides, the neck presents a low risk. To get more detail on this task, complimentary studies were done. Among the tools employed stand out RULA, REBA, OWAS, QEC, Job Strain Index and NIOSH formula, the results are shown in the same figure.

By studying the operation, it was concluded to build a rack and put it in the workstation next to the worker. In that way, each tray finished can be situated in the rack. In Fig. 7, the rack design as well as the decrease in the cycle time is shown.

In terms of ergonomics, the posture and repetition issues were taken to a warning zone (yellow) in the three studies performed: OWAS; REBA, and RULA. The job

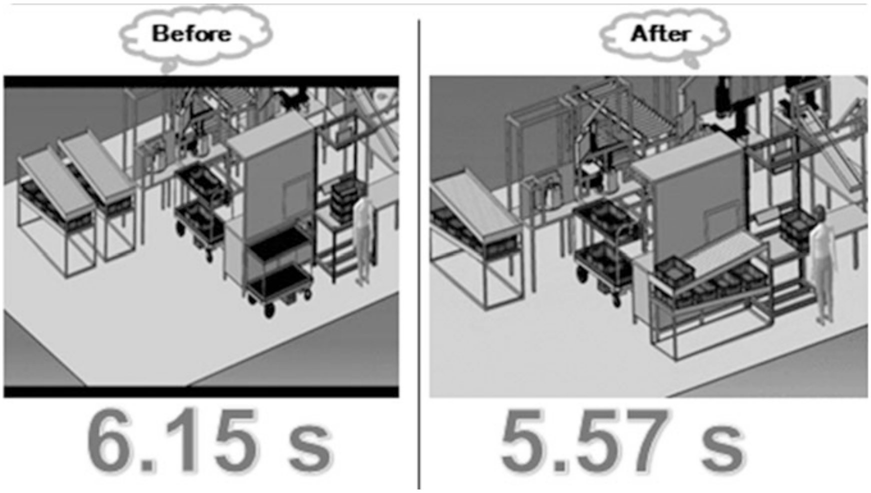

Fig. 7 Workstation 70 proposal and result

Purpose	Tool	Before	After	
Posture/ Repetition	OWAS	4	2	✓
	REBA	10	4	✓
	RULA	7	3	✓
	Job Strain Index (JSI)	0.56	0.38	✓
Load Lifting	NIOSH (Origin)	0.56	0.56	
	NIOSH (Destination)	1.04	0.59	✓
	Disc Compressive Force	3386 N	1228 N	✓

Quick Exposure Check (St. 70) *Future*				
	Low	Moderate	High	Very High
Trunk/Back	20			
Shoulder/Arm		24		
Wrist/Hand		22		
Neck	4			
Speed of work	1			
Stress	1			

Fig. 8 Workstation 70 results comparison

strain index decreased to a 0.38 value. About load lifting, the greatest achievement was to change from a load of 3386 N to a 1228 N. The QEC study also remarks good benefits Fig. 8.

After the implementation, the new cycle times in the trolley line were calculated. Figure 9 shows the results. These time represent an increase of 1838 pieces in the first shift and 1960 in the second one, It is estimated that these improvements can make possible to produce 5880 more pieces per month.

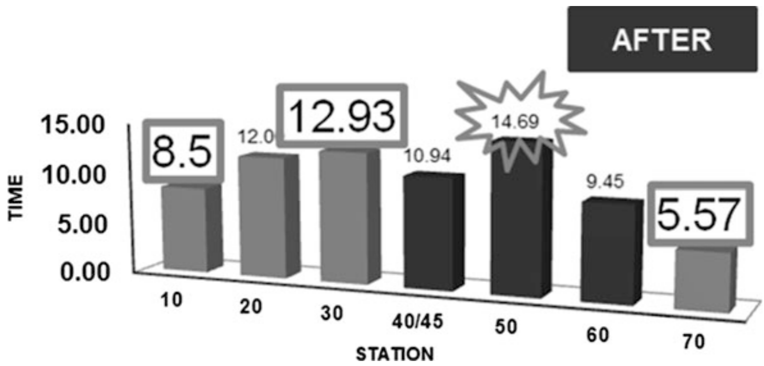

Fig. 9 Final work station cycle times in trolley line

3 Conclusions

The research was performed within the eight weeks planned. It allowed increasing the number of pieces fabricated in trolley and lever actuator assembly lines. The final gain is of 245 more pieces per day, it means a 6.89 % increase in production. This study saved the metallurgical company 1.25 h each day and in financial matters the gain of production represented an increase of 4 %.

Also it shows that all the productivity should not be used alone, it is needed to combine them, in order to get an effective improvement, not only MTM studies or ergonomic assessment tools, but an holistic approach, so at the end, it was possible to reduce ergonomic risks and improve number of finished product in both lines.

To assure the success of this ergonomic initiatives it is also needed the full commitment of all the organization levels, to push the changes and the required investments.

Work-Related Musculoskeletal Symptoms Among Small Scale Gold Miners and Extraction Workers in the Philippines

Benette P. Custodio, Aura C. Matias and Virginia J. Soriano

Abstract It is estimated that in about 30 countries, approximately 13 million people are directly engaged in small scale mining. Small scale mining activities centre on the production of gold in many countries, including the Philippines. These activities heavily rely on manual labour that include frequent or heavy lifting, pushing or pulling heavy objects, prolonged awkward postures, vibrations, and repetitive, forceful, or prolonged exertion of the hands. Thus, workers are exposed to risk factors associated with Work-related Musculoskeletal Disorder (WMSD). This study aims to estimate the prevalence of Work-related musculoskeletal disorders (WMSD) in small scale gold mining and extraction in the Philippines through the occurrence of Work-related Musculoskeletal Symptoms (WMSS). A survey, using modified Nordic questionnaire, of 124 miners from different mining sites showed 95 % of the interviewees perceived WMSS in at least one part of their bodies, with highest prevalence in lower back (65 %), shoulders (60 %), and neck (54 %).

Keywords Ergonomics · Work-related musculoskeletal disorders · Philippine small scale gold mining

1 Introduction

1.1 Small Scale Gold Mining

The extraction and processing of minerals in small scale has provided jobs for millions of people and sufficient revenue for the governments in developing nations. It is estimated that in about 30 countries, approximately 13 million

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people are directly engaged in small-scale mining [1]. A situationer from the Philippine Department of Environment and Natural Resources reported an estimate of 20,000–25,000 small scale miners in the Philippines as of December 2009.

In many countries, small scale mining activities center on the production of gold. Gold constitutes two-thirds of production in Ghana and Ecuador, and almost a hundred percent in Peru [1]. In the Philippines, the law limits small scale mining to gold, silver, and chromite, and 90 % is dedicated to gold.

The gold sold to Bangko Sentral ng Pilipinas by the small scale mining exceeded those of the large scale companies in the year 2001–2005, and 2008. Although, there is a decrease in the amount of gold sold to the BSP in the recent years, small scale gold mining in the Philippines is still prevalent. These activities heavily rely on manual labour that include frequent or heavy lifting, pushing or pulling heavy objects, prolonged awkward postures, vibrations, and repetitive, forceful, or prolonged exertion of the hands. Thus, workers are exposed to risk factors associated with Work-related Musculoskeletal Disorder (WMSD).

1.2 Statement of the Problem

There is no data and statistics available regarding the prevalence of Work-related musculoskeletal disorders (WMSD) in small scale gold mining and extraction in the Philippines.

1.3 Objectives of the Study

The study aims to provide baseline statistics of the the prevalence of Work-related musculoskeletal disorders (WMSD) in small scale gold mining and extraction in the Philippines that can be used for creating concrete policies and actions for prevention.

1.4 Scope and Limitations

The study is focused on small scale gold mining and extraction in the Philippines specifically, underground mining, and gravity concentration and cyanidation for gold extraction which are the most common method used by the small scale miners.

Underwater/compressor mining as well as mercury amalgamation for gold extraction are not considered since it is prohibited by the government.

The study is limited to the study sites of the Mineral Extraction with Responsibility and Sustainability (MINERS) Program PROJECT G: The Gold and Copper Chase (Life Cycle Analysis of Sustainable Small Scale Production Systems).

Work-related Musculoskeletal Symptoms (WMSS) were gathered to characterize Work-related Musculoskeletal Disorders (WMSDs).

2 Methodology

A survey, using a modified Nordic questionnaire, was conducted to gather data on the WMSS of the miners and extraction workers. It incorporated questions on the presence of symptoms such as pain, numbness, tingling, aching, stiffness or burning perceived during the last 12 months in each body part including arms and legs, and a 5-point scale rating on the frequency and severity of symptoms present [2].

Analysis of the prevalence included the evaluation of correlated body parts with respect to frequency and severity of WMSS. Spearman's rank correlation coefficient, which is a nonparametric measure of statistical dependence between two variables and is appropriate for both continuous and ordinal variables, was used [3]. Spearman's rank correlation coefficient above +0.3 and below −0.3 indicate the presence of a positive and negative correlation, respectively. Coefficients were calculated using Minitab. In addition, cluster analysis was used to generate groupings of correlated parts. The results of cluster analysis were summarized using a dendrogram. In a dendrogram, distance is plotted on one axis, while the sample units are given on the remaining axis. It shows how sample units are combined into clusters, the height of each branching point corresponds to the distance at which two clusters are joined.

3 Results and Discussion

Based on the survey, 95 % of the interviewees perceived WMSS in at least one part of their bodies. Lower back (65.32 %), shoulders (59.68 %), and neck (54.03 %) have the highest prevalence of WMSS in the samples (see Table 1). These correspond to the parts where repetitive, forceful, or prolonged exertion and postures is focused. Such activities include heavy lifting of sack of ores, carrying the ores on the shoulders, and stooping forward inside the mine.

Frequencies of WMSS are skewed towards 4 and 5 rating, while severities are approximately normal with a mode of 3 for the cases were WMSS is present (see Figs. 1 and 2). These indicate medium severity but frequent occurrence of symptoms.

Table 1 Prevalence percentage of WMSS

Body parts	Prevalence (%)
Lower back	65.32
Shoulders	59.68
Neck	54.03
Upper back	44.35
Arms	38.71
Hips	35.48
Knees	32.26
Hands/Wrists	29.84
Thighs	26.61
Legs	26.61
Feet/Ankle	21.77
Elbow	14.52

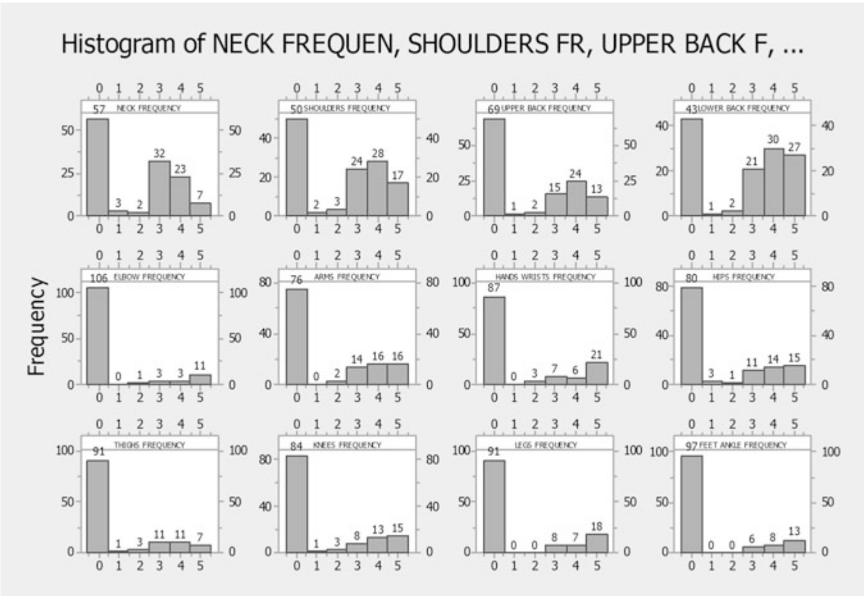

Fig. 1 Histogram of body part frequencies

The Spearmans's rank correlation coefficient generated by Minitab showed that WMSS of body parts are correlated (see Tables 2 and 3). Upper body parts are correlated, as well as the limbs/ extremities. Dendogram generated by the cluster analysis in Minitab showed three clusters: upper body, middle body, and extremities (see Fig. 3).

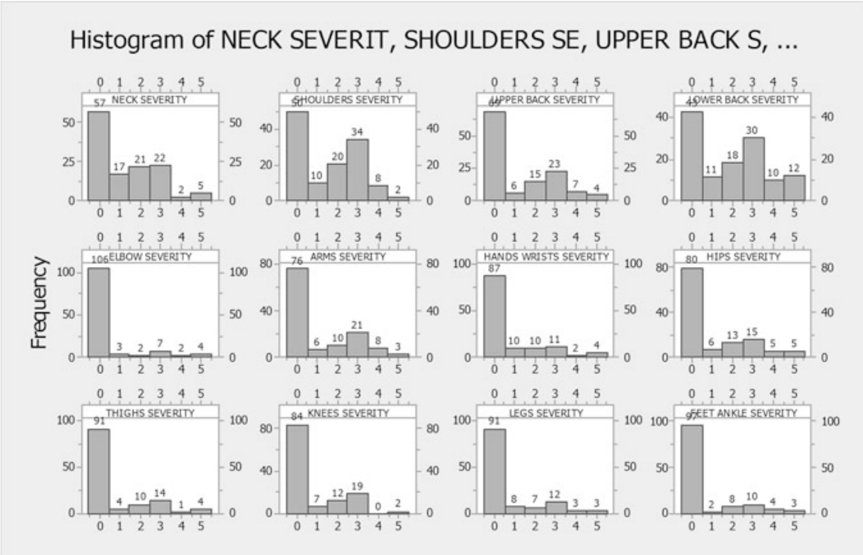

Fig. 2 Histogram of body part severities

Table 2 Correlation matrix of WMSS (severity) of body parts

	NECK FREQUENCY	SHOULDERS FREQUENCY	UPPER BACK FREQUENCY	LOWER BACK FREQUENCY	ELBOW FREQUENCY	ARMS FREQUENCY	HANDS WRISTS FREQUENCY	HIPS FREQUENCY	THIGHS FREQUENCY	KNEES FREQUENCY	LEGS FREQUENCY
SHOULDERS FREQUENCY	0.443										
UPPER BACK FREQUENCY	0.367	0.531									
LOWER BACK FREQUENCY	0.208	0.334	0.249								
ELBOW FREQUENCY	0.253	0.342	0.407	0.296							
ARMS FREQUENCY	0.237	0.415	0.366	0.182	0.306						
HANDS WRISTS FREQUENCY	0.254	0.308	0.286	0.41	0.345	0.461					
HIPS FREQUENCY	0.243	0.283	0.335	0.327	0.35	0.286	0.317				
THIGHS FREQUENCY	0.3	0.394	0.323	0.276	0.232	0.379	0.37	0.232			
KNEES FREQUENCY	0.176	0.248	0.369	0.414	0.295	0.272	0.353	0.288	0.239		
LEGS FREQUENCY	0.238	0.221	0.285	0.243	0.315	0.403	0.398	0.119	0.386	0.473	
FEET ANKLE FREQUENCY	0.291	0.28	0.33	0.29	0.371	0.279	0.316	0.282	0.265	0.433	0.37

Table 3 Correlation matrix of WMSS (frequency) of body parts

	NECK SEVERITY	SHOULDERS SEVERITY	UPPER BACK SEVERITY	LOWER BACK SEVERITY	ELBOW SEVERITY	ARMS SEVERITY	HANDS WRISTS SEVERITY	HIPS SEVERITY	THIGHS SEVERITY	KNEES SEVERITY	LEGS SEVERITY
SHOULDERS SEVERITY	0.345										
UPPER BACK SEVERITY	0.334	0.49									
LOWER BACK SEVERITY	0.149	0.215	0.194								
ELBOW SEVERITY	0.199	0.351	0.354	0.234							
ARMS SEVERITY	0.239	0.427	0.341	0.118	0.316						
HANDS WRISTS SEVERITY	0.214	0.263	0.184	0.348	0.292	0.382					
HIPS SEVERITY	0.19	0.183	0.282	0.228	0.297	0.229	0.218				
THIGHS SEVERITY	0.363	0.444	0.312	0.228	0.261	0.352	0.314	0.145			
KNEES SEVERITY	0.082	0.156	0.28	0.314	0.252	0.238	0.289	0.22	0.194		
LEGS SEVERITY	0.224	0.211	0.237	0.139	0.299	0.375	0.315	0.051	0.375	0.424	
FEET ANKLE SEVERITY	0.249	0.255	0.238	0.291	0.297	0.236	0.253	0.171	0.201	0.36	0.332

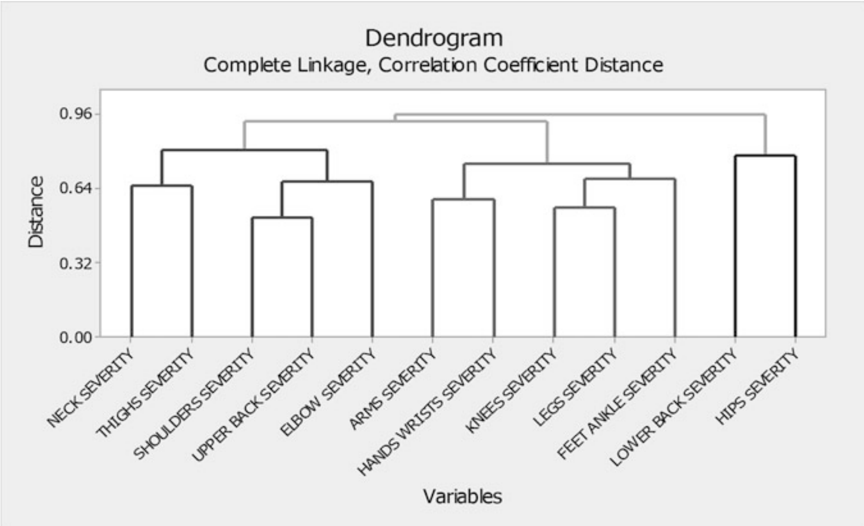

Fig. 3 Dendogram from cluster analysis of WMSS (severity) of body parts

4 Conclusion and Recommendation

The study has determined that 95 % of the 124 interviewees perceived WMSS in at least one part of their bodies with highest prevalence in lower back (65 %), shoulders (60 %), and neck (54 %). Evaluating the correlation of the severity of symptoms provided the clusters of the upper body, middle body, and extremities.

This proves the prevalence of Work-related Musculoskeletal Disorder (WMSD) in small scale gold mining and extraction in the Philippines. Thus, small scale gold miners and extraction workers in the Philippines are exposed to the risks associated to WMSD.

Risk factor exposure is an early warning of a more serious problem of physical symptoms that can lead to serious injury, in addition, can inhibit production. Long-term exposure to risk factors reduces the quality of life. Thus, reducing risks or exposure to risks, which involves (1) awareness of risk factors, (2) ability to recognize and categorize these factors, and (3) examination of options to reduce the frequency or duration of exposure to the risk factors, is vital [4].

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References

1. Hentschel, T., Hruschka, F., Priester, M.: Artisanal and small-scale mining challenges and opportunities. In: International Institute for Environment and Development and WBCSD, pp. 1–17. Russell Press Ltd, Nottingham, UK (2003). ISBN 1 84369 470 0
2. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., Jørgensen, K.: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. **18**(3), 233–237 (1987)
3. Daniel, W.: Applied Nonparametric Statistics: Spearman Rank Correlation Coefficient. 2nd ed, pp. 358–365. PWS-Kent, Boston (1990)
4. Wiehagen, W., Turin, F.: Ergonomic Assessment of Musculoskeletal Risk Factors at Four Mine Sites: Underground Coal, Surface Copper, Surface Phosphate, and Underground Limestone. National Institute for Occupational, Safety and Health (NIOSH) (2004)

Work Movements: Balance Between Freedom and Guidance on an Assembly Task in a Furniture Manufacturer

Symone A. Miguez, M. Susan Hallbeck and Peter Vink

Abstract This study demonstrates that the ergonomic analyses of work must consider why a worker adopts certain movements (gestures) when performing assembly tasks. It discusses the balance between allowing the worker to freely choose the way of assembling goods and providing guidance. On two assembly tasks in a furniture manufacturer, this research performs an ergonomic analysis in which worker movements are emphasized and it investigates the impact of these strategies on the ergonomic risk and on the worker's health. Data collection instruments included direct observation, unstructured interviews and film footage. The ergonomic analyses show that the work environments are ergonomic, but workers adopt their own movements, unaware that these are awkward postures. Guidance proved to be effective in improving ergonomic risks. This article highlights the significance of understanding work movement, its implications in the corporate training programs as well as in the ergonomic risks and in the worker's health.

Keywords Ergonomics · Assembly line · Modus operandi · Ergonomic risk · Training · Assembly line · Work-related musculoskeletal disorders (WRMSDs)

1 Introduction

In the last decades, many changes have occurred in workplace. Many of them still happen within the production processes in companies, which are always aiming to increase productivity and to provide competitive costs, both while retaining quality.

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In Brazil, companies in several sectors fall within this scenario and generate a considerable number of jobs. As an example, one could cite the furniture industry. In 2013, there were 2580 furniture manufacturers solely in the southern region of the country, creating 44,574 jobs and 93 million pieces of furniture, which were worth 1.8 billion US dollars. The furniture industry in the south of Brazil represents 13.8 % of the all companies in the country. In 2015, the revenue of the furniture industry in Rio Grande do Sul was 2.1 billion dollars and the revenue of the domestic market in Brazil was 35.74 billion dollars [1]. Several Brazilian furniture manufacturers have been modernizing their facilities through automation, however, a great deal of assembly line tasks are manual ones and many require ergonomic intervention.

Lim and Hoffmann's studies [2] revealed that research on manual assembly tasks has historically emphasized (a) time and motion studies (b) sequence and cognition of assembly tasks, (c) subjective difficulty of component assembly tasks, (d) effects of the structure of the assembly line on worker's performance, (e) personal preferences on the layout of work stations, and (f) the impact of following manual assembly instructions on the worker's performance. Despite all of these different research scopes and studies, Lim and Hoffmann [2] believed there was the need to investigate one more aspect within the field: what would happen if the worker could choose his or her own way of working. Hence, the aforementioned researchers conducted a study that revealed that the 40 participants adopted different assembly patterns, even when assembling a simple product.

The different strategies adopted by the worker when performing manual tasks have made us reflect upon and explore the balance between freedom of choice and providing instructions when assembling goods. Moreover, this study analyzed the movements adopted when performing tasks, considering the impacts on the health of the worker.

The complexity of this issue makes us think about the definitions of work movements and those of modus operandi/work style. In addition, it makes us wonder whether these terms are synonyms or different concepts.

According to Pastre e Guimarães [3], modus operandi or work style is the way a worker perform his/her tasks and it may vary according to the experience of the professional. Moreover, the modus operandi may be altered by formal training on how to perform the tasks. On the other hand, Vidal [4] conceives modus operandi as a response of the worker to the need of reconciling the task (request), the means of work and the way of performing the task.

Lémonie and Chassaing [5] define work movements as natural and complex movements that are strategies employed by the worker to respond to work demands. They are a key tool for the worker and possess three important functions, to: (1) promote efficiency, (2) preserve the worker's health and (3) integrate productivity and quality.

Therefore, it seems clear that the definition of modus operandi and that of work movement both state that the worker uses his body (arm, torso, head, etc.) in order to create regulatory strategies when performing manual tasks so they can respond to work demands in situations where the actual work differs from the one requested.

Furthermore, the strategy of adopting movements aims at preserving the health of the worker in terms of work-related musculoskeletal disorders [6].

The literature also discusses the relevance of encouraging workers to identify the "one best movement" according to their individual experience when performing the same task. The practical knowledge resulting from this should then be included and shared within follow-up training sessions [5, 7].

In this study we employ the term *work movement* because we see it as being more pertinent to our research.

In April 2015, during a symposium presentation, one of the authors administered a questionnaire about work movements to 18 professionals in the field of ergonomics (physical therapists, ergonomists and university professors). The questionnaire contained 5 multiple-choice questions (Appendix) and the results showed that 12 participants declared to have knowledge of work movements and 6 declared to not know about the issue. However, 58 % of the subjects believe that work movement is a strategy used to avoid musculoskeletal discomfort and to gain time so production demands can be met. Besides the conceptual issues, it is pertinent to point out that the queried professionals know about work movements, but do not take them into account when performing their ergonomic work analyses.

The focus of the majority of ergonomic analyses is on biomechanics and kinesiology; they tend to not take into account the reasons why the movements are performed this or that way. Thus, the present study aims to raise awareness of the importance of movements in task performance, as well as how simple instructions can make a difference in the ergonomic risk at the workstation and prevent work-related musculoskeletal disorders.

2 Methods

The present study was carried out at a large office furniture manufacturer in the countryside of the state of São Paulo, Brazil. The factory is 92,000 ft^2 and it employs 500 people.

2.1 Criterion for Choosing the Sample

Initially, we performed direct observation of the activities and informally interviewed the workers from the woodwork and assembly areas in order to select the sample for the research study. Among the 20 workers from those areas, two of them, one from each area, were invited to participate in the study because they adopted different movements from the remaining workers. Both of them were production assistants.

2.2 Instruments

We carried out ergonomic analyses of the tasks before and after providing the two workers with instructions about the most appropriate movements in the two covered areas, woodwork and assembly. We used RULA (Rapid Upper Limb Assessment), developed by McAtamney and Corlett [8] to categorize the ergonomic risk. This instrument allows for a quantitative assessment of the biomechanical load in the upper and lower limbs, neck and torso of a task. RULA is an assessment instrument recognized by the international system ISO 11228-3-2006 and its score ranges from 1 to 7 in order to define an action level for musculoskeletal risk.

3 Approach and Results

3.1 Job Content and Movements

Woodwork Area

Description of Task before Ergonomic Instructions regarding Work Movements. The production assistant gets the parts that have been cut without waiting for the belt to bring them to the edge of the counter. The worker therefore makes movements that are not recommended by the biomechanics and kinesiology studies, namely, he flexes his trunk and reaches to the extreme posture with his arms in order to reach the parts (Fig. 1). It is at RULA level 3: The worker is working in a poor posture, with a risk of injury from the work posture. The reasons for this need to be investigated and changes and changed in the near future to prevent injury.

Description of Task after Ergonomic Instructions regarding Work Movements. After the ergonomic instructions provided by the ergonomist, the worker

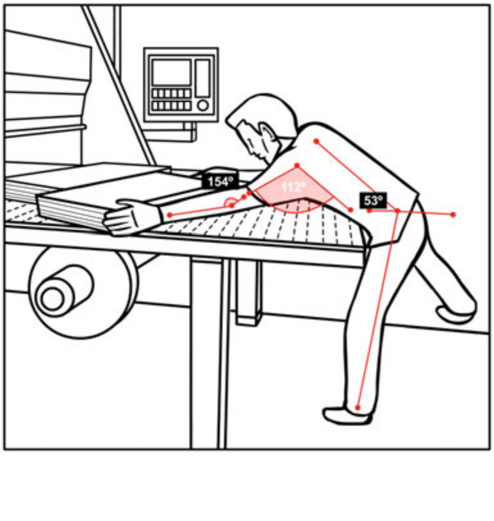


Fig. 1 RULA score action level 3

understood the need to wait for the part to arrive to the edge of the counter. It is clearly noticeable that there is no longer the need to adopt work movements that may contribute to the development of work-related musculoskeletal disorders (Fig. 2). It is rated as a RULA level 1: The person is working in the best posture with little or no risk of injury from their work posture.

Assembly Area

Description of Task before Ergonomic Instructions regarding Work Movements. The production assistant places the rubber floor glides on the base of the chair. She adopts movements that are not recommended by the biomechanics and kinesiology studies, namely, she flexes her back and arms in order to perform the task (Fig. 3). RULA score result was Action level 3, indicating that further investigation and

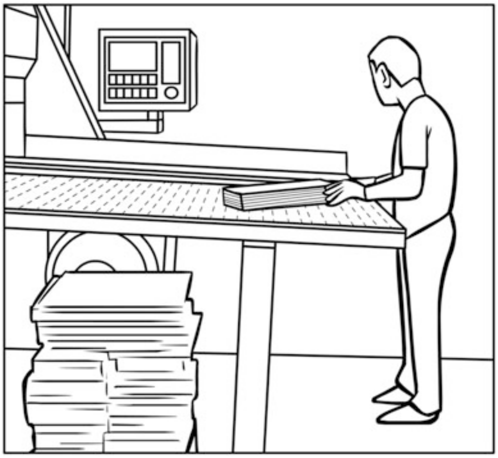


Fig. 2 RULA score action level 1

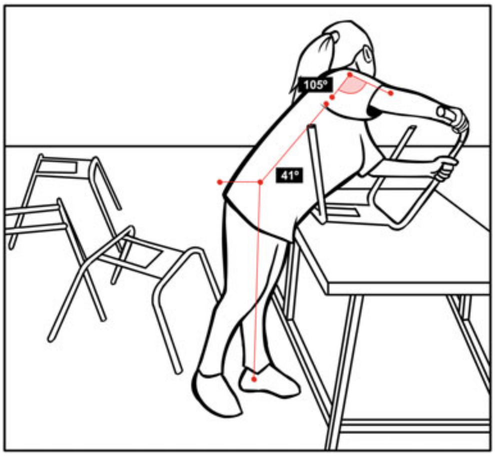
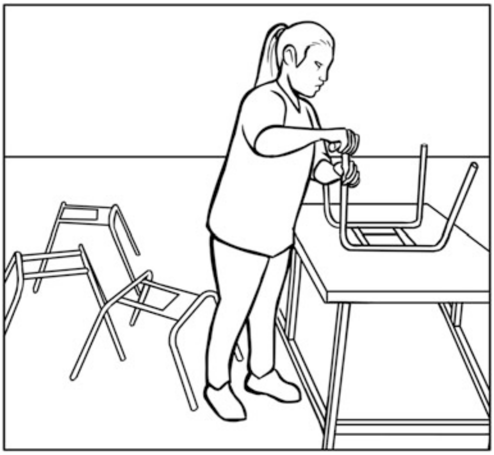


Fig. 3 RULA score action level 3

Fig. 4 RULA score action level 3



changes are needed. In this case, the layout of the workstation is proper and it does not require that the worker use her body—work movements—in order to attend to the production demand.

Description of Task before Ergonomic Instructions regarding Work Movements. After the ergonomic instructions were provided by the ergonomist, the worker abandoned the movements that did not follow biomechanical or kinesiological standards (Fig. 4). Similar to the woodworking case, the RULA score was Action Level 1, indicating that the posture is acceptable if it is not maintained or repeated for long periods of time.

4 Discussion

The variability of work movements is fundamental for the worker to be able to respond to task demands [4]. This fact was confirmed in informal, unstructured interviews with the workers, who claim the adoption of those movements' speeds up their work. The work movements analyzed in the woodwork and assembly areas met the production demand but were unnecessary and generated ergonomic risk when assessed through RULA, whose initial, pre-instruction action level score was 3 for both investigated areas (Figs. 1 and 3).

In reality, our observation of the tasks identified a moderate ergonomic risk for shoulders and trunk. Despite the moderate ergonomic risk, found during the ergonomic analysis, we found that only a few workers complained of WRMSDs in their shoulders and trunk. This result is aligned with results from studies published by other scholars. Pastre and Guimarães [3] show that work movements can contribute to explaining cases in which some workers performing the same tasks and having the same production goals complain of WRMSDs in the upper limbs but others do not. However, most workers in this study are young, which may justify the lack of complaints about musculoskeletal discomforts.

Our experience tells us that, in order for health complaints to be considered WRMSDs, one must also take into account the work cycle frequency in which the movements are made and whether or not these movements are continuous.

The results of this study demonstrate that, at times, the freedom to adopt movements with no ergonomic guidelines may not bring balance between the production demand and the health of the worker.

5 Limitations and Strengths

The strengths of this research are: (a) the workers' participation during the entire data collection process; (b) the worker's acceptance of the instructions provided by the ergonomist in regard to the need and the possibility of adopting new movements when performing a task; (c) the worker's understanding that adequate movements prevent musculoskeletal discomfort associated with work and (d) implementation of ergonomic improvements at no cost.

A possible limitation of the study is the relatively small size of the sample of subjects, however, they are deemed suitable for the research object in question.

6 Conclusion

When performing ergonomic analyses, we must take the work movements into consideration and ask ourselves: Why does the worker perform the task the way s/he does? Do all workers make the same movement(s) when performing this task? Does the workstation layout prevent the worker from making movements that do not compromise his/her posture? Are the movements made in order to meet the high production demand? All these questions must be considered by the ergonomist since each worker has his/her own personal story to perform the work.

People arrive at their workstations with their genetic capital, which may contain physical and mental misuse abuse during their lives. They also come with their lifestyle, including aspects involving their personal and ethical conduct and educational background and that will influence the way they deal with their work demands [9].

Based on the results from this study and the authors' experience, we can conclude that:

- When there are problems in the organization of work and in the production process, for instance, work demands beyond the worker's capacity, the variability in work movements are fundamental for the worker to be able to respond to those demands;

- The company must structure its objectives and production goals in a way that the worker can achieve the expected results without resorting to his/her own body (movements) as a regulatory strategy when performing tasks;
- The choice of the worker to adopt movements when performing a task must be complemented with in loco ergonomic training and/or instructions provided by a qualified professional. It is important to point out that providing instructions does not mean standardizing work movements;
- Allowing the worker to perform his/her tasks without previous ergonomic advice may impact the ergonomic risk of the activity and, consequently, the worker's health, contributing to the development of WRMSDs;
- It is not possible to predict all the work movements that the worker will make. Nonetheless, this study demonstrated that it is possible to raise awareness about ergonomic concepts in regard to the adoption of movements that mitigate WRMSDs;
- Ergonomic instructions about movements are efficient and many times cost-free ergonomic improvements, especially if the company employs an ergonomics professional or hires an ergonomics consultancy firm;
- Workers may adopt involuntary movements not required to perform the task. We observed that the workstations in the woodwork and assembly areas were adequate for performing the tasks and did not pose ergonomic risks. It was the voluntary movement spontaneously adopted by the worker that generated the ergonomic risk.

Finally, we conclude by citing Guerin et al. "Understand work, to transform it" [10]. This idea synthesizes the importance and the challenge of considering work movements when performing an ergonomic analysis of work. Besides biomechanical issues, any such analysis must attend to cognitive, organizational and sociotechnical issues involving work and work movements. We believe that the freedom to choose the movements will only be positive if ergonomic guidelines are provided as a balance between the worker's health with the production demand.

Acknowledgments The authors are grateful to all professionals and the furniture company, which allowed us to bring about this reflection over such a relevant issue and we also thank Fernando Giatti for his help with data collection and analysis.

Appendix: Questionnaire

Questionnaire Work Gesture

First Name : Last name :

Age : Profession :

1. How do you define work gesture?
( ) worker’s lack of experience
( ) strategy assumed by the worker
( ) company’s lack of training
2. You would say that work gesture is:
( ) an strategy used by the company to gain time
( ) an strategy to avoid work-related musculoskeletal disorders
( ) Others/please define:
3. Do you believe the work gesture increases the criticality of the workplace?
( ) No. Why?
( ) Yes. Why?
4. Do you believe that work gesture is negative or positive?
( ) Negative
( ) Positive
( ) Others. Please comment.
5. Which intervention strategies do you believe are adequate for work gestures?
( ) Lectures
( ) One-on-one meetings
( ) Others. Please define.

References

1. Association of furniture industries of south state. http://www.movergs.com.br/dados-setor-moveleiro
2. Lim, J.T.A., Hoffmann, E.R.: Strategies in performing a manual assembly task. Int. J. Ind. Ergon. **50**, 121–129 (2015)
3. Pastre, T.M., Guimarães, L.B.M.: Ergonomia de Processo. FEENG- Fundação Empresa Escola de Engenharia da UFRGS, 4st edn. Porto Alegre (2004)
4. Vidal, M.C.: Ergonomia na Empresa: Útil, Prática e Aplicada. Virtual Científica, 4st edn. Rio de Janeiro (2002)
5. Lémonie,Y., Chassaing, K.: Construtive Ergonomics. In: Falzon, P. (ed.) 1st edn. CRC Press. Taylor & Francis Group, New York (2015)
6. Madeleine, P.: On functional motor adaptations: from the quantification of motor strategies to prevent of musculoskeletal disorders in the neck—shoulder region. Acta Physiol. **199**, 1–46 (2010)
7. Pastré, P.: Didactique Professionnelle et Développement. Psychologie Française **42**(1), 89–100 (1997)
8. McAtamney, L., Corlett, L.E.: A survey method for the investigation of work—related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
9. Wisner, A.: A inteligência no Trabalho. Fundacentro, São Paulo (1994)
10. Guérin, F., Lavile, A., Daniellou, F., Duraffourg, J., Kerguelen, A.: Compreeender o Trabalho para Transformá-lo: A prática da Ergonomia. Edgar Blucher, São Paulo (2001)

A Method to Calculate the Accident Probabilities in Construction Industry Using a Poisson Distribution Model

Senem Bilir and G. Emre Gurcanli

Abstract Occupational accidents not only lead to serious damages or loss of life and money, but also cause a serious reduction of the productivity. Existing occupational health and safety practices are not sufficient to prevent the construction accidents in Turkey. Especially, in construction industry the accident rate is five times higher than the employment rate. Benefiting from more realistic and objective risk assessment methods can help to reduce the accident rates. Therefore, accident probabilities should be calculated objectively without considering personal experiences or subjective assessments. In this study an objective and quantitative accident probability calculation approach is proposed. Firstly, the accident probability is redefined. Based on this definition the accident probability became a function of accident rates and worker exposure values. The accident rates were calculated from statistics of real accidents. In order to determine accident rates expert witness reports that were examined for 13 years (2000–2013) and the statistics that were presented by Social Security Institution were used. In total 623 expert witness reports that belonging the actual construction work accidents between 2000 and 2013 were analyzed. The exposure values were calculated from the man—hour values that were taken from project schedules and planning tables. Then, accident probabilities were calculated by using a Poisson distribution model where accident rates and exposure values were used as a distribution parameter. Within the scope of this study, instead of focusing all construction activities it was decided to focus on 5 main activities which show the highest accident rate in order to provide better results to prevent accidents. These five main activities were chosen as; Excavation, Reinforced Concrete Works, Masonry, Plaster and Painting Works, Roof Works. In an industry like construction industry where the accidents are recorded in non-specific standards, it is very difficult to represent probability of

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accidents with a known distribution model. Thanks to the approach presented in this study it was possible to provide an objective method to obtain accident probabilities using Poisson distribution.

Keywords Accident frequency · Poisson distribution · Safety management

1 Introduction

Current occupational health and safety practices are not sufficient to prevent the accidents in Turkey. Especially during the last decade, due to the fast growth in construction sector accident rates increased significantly. Based on the National Social Security Institution data set between 2000 and 2013 the annual average number of employees is 19.948.586 while 1.148.586 of them belong to the construction sector [1]. As it is seen in Table 1 during last 13 years the construction sector occupies the 6 % of the total employment in the country. In between 2000 and 2013 the total number of accidents which results in injuries is 1805 while is it 397 (22 %) for the construction sector [1].

The most striking fact from Table 1 is that in Turkey the average number fatal occupational accidents is 1120 whereas in construction sector the average number of fatal occupational accidents is 350. In other words, the construction sector occupies the 6 % of the employment in Turkey but in terms of fatal occupational accidents it occupies 31 % of the total fatal accidents. By looking at the occupational accident and lost working day figures in Turkey it can be concluded that present hazard analysis and risk assessment methods are not sufficient. With this study in order to prevent work-related accidents in the construction industry, an objective probability parameter was developed which is focusing on construction activity in conventional construction projects, using accident rates and worker exposure values.

2 Scope and Method

The construction sector is mainly project based where each project is unique during planning and implementation. In order to use the proposed probability parameter in different projects in construction industry, the probability is designed as activity based. For removing the subjectivity of the study it is planned to use the real accident rate data and man—hour values. For this purpose, 623 expert witness reports belonging the actual construction work accidents between 2000 and 2013 were analyzed. Most common types of accidents and most prevalent activities in which these accidents occur are identified with this analysis. Within the scope of the

Table 1 Social security institute occupational accident statistics 2000–2013

Year	Total employment	Const. industry employment	Const. employment/total employment %	Number of injuries	Number of injuries in const. industry	%	Number of fatalities	Number of fatalities in const. industry	%
2000	21,755,771	761,452	0.04	1818	399	0.22	1173	379	0.32
2001	21,308,813	681,882	0.03	2183	517	0.24	1008	341	0.34
2002	21,625,121	713,629	0.03	1820	439	0.24	872	319	0.37
2003	21,434,438	685,902	0.03	1421	354	0.25	810	274	0.34
2004	19,793,053	752,136	0.04	1693	345	0.2	841	263	0.31
2005	19,861,660	933,498	0.05	1639	322	0.2	1072	290	0.27
2006	20,443,500	1,185,723	0.06	2267	425	0.19	1592	397	0.25
2007	20,799,500	1,247,970	0.06	1550	361	0.23	1043	359	0.34
2008	21,360,138	1,238,888	0.06	1452	373	0.26	865	297	0.34
2009	21,167,207	1,227,698	0.06	1668	282	0.17	1171	156	0.13
2010	22,714,286	1,431,000	0.06	1976	319	0.16	1434	475	0.33
2011	22,585,714	1,581,000	0.07	2093	405	0.19	1700	570	0.34
2012	11,939,620	1,789,487	0.15	2036	563	0.28	744	256	0.34
2013	12,484,113	1,849,942	0.15	1660	459	0.28	1360	521	0.38
Ort	19,948,067	1,148,586	0.06	1805	397	0.22	1120	350	0.31
Σ					5563			4897	

paper, instead of focusing all construction activities it is decided to focus on 5 main activities which show the highest accident rate in order to provide better results to prevent accidents. These five main activities are respectively; Excavation, Reinforced Concrete Works, Masonry, Plaster and Painting Works, Roof Works. In this paper only the reinforced concrete activity will be investigated due to the page limitation.

Also, "occupational accidents and occupational diseases statistics" which were published between 2000 and 2013 by Social Security Institution (SSI) were examined and combined with the results obtained by examining the expert witness reports. As an outcome, activity based and accident type based accident rates were obtained. In addition, the exposure value is determined by using the traditional 20 construction projects work programs and the planning tables. Exposure is calculated using the number of workers in the construction and working duration. Accident probabilities were calculated with the help of a Poisson distribution model, accident rates which are obtained from actual accidents and exposure values which are calculated from work programs and the planning tables.

3 Activity Based Accident Intensity Calculation

In construction works there are numerous risky situations. Therefore, in order to determine the risks in all activities risk analysis should be performed. In this section the risk analysis is performed with the assumption that no safety precaution is considered at all. While performing the risk analysis 623 expert witness reports were investigated which belong to the occupational accidents in construction sector between the years 2000 and 2013. In Table 2 the risk analysis for the reinforced concrete activity is provided.

While performing the accident density analysis again 623 expert witness reports were used. In this analysis expert witness reports investigated by concentrating on 5

Table 2 Reinforced concrete processing risk analysis

Activity	Risk number	Risk code	Risk name
Reinforced concrete works	1	R01	Fall from height
Reinforced concrete works	2	R02	Struck by flying/falling object
Reinforced concrete works	3	R06	Other accidents
Reinforced concrete works	4	R03	Building/Structure collapse
Reinforced concrete works	5	R09	Hazards due to machine and tool usage
Reinforced concrete works	6	R04	Contact with electricity
Reinforced concrete works	7	R11	Struck by a moving vehicle
Reinforced concrete works	8	R07	Struck by a moving vehicle

Table 3 Reinforced concrete processing accident intensities

Activity	Risk number	Risk code	Risk name	Number of fatalities	Number of injuries	Total Number of accidents
Reinforced concrete works	1	R01	Fall from height	70	20	90
Reinforced concrete works	2	R02	Struck by flying/falling object	16	4	20
Reinforced concrete works	3	R06	Other accidents	5	1	6
Reinforced concrete works	4	R03	Building/structure collapse	9	4	13
Reinforced concrete works	5	R09	Hazards due to machine and tool usage	0	1	1
Reinforced concrete works	6	R04	Contact with electricity	2	2	4
Reinforced concrete works	7	R11	Struck by a moving vehicle	6	2	8
Reinforced concrete works	8	R07	Struck by a moving vehicle	2	0	2
Total				110	34	144

different activities and 12 different accident types and accident density values are obtained. In Table 3, the accident intensity values that are obtained from the expert witness reports for the 8 risks that exits in the reinforced concrete activity are given. By looking at Table 3 it can be said that the most frequent accident types in reinforced concrete activity are “Fall from height, Struck by flying/falling object, Other accidents, Building/Structure collapse, Hazards due to machine and tool usage, Contact with electricity, Struck by a moving vehicle, Struck by a moving vehicle”. The accident intensity for the reinforced concrete activity in provided in graphical form in Fig. 1 (Tables 4 and 5).

The accident intensities will be used to calculate the activity based accident rates. It has been observed that the 70.8 % total number of occupational accidents in construction sector come from the 5 activities that will be used in this paper.

4 Activity Based Accident Rate Calculation

In this paper, occupational accidents that occurred after year 2000 were taken considering the improvements in construction techniques and technologies. In this scope, “work place and employee statistics” and “occupational accident statistics” archive of Social Security Institute were analyzed and from this archive construction sector employment data, number of accidents that result in permanent injuries and number of fatal accidents were obtained for the between 2000 and 2013. In this

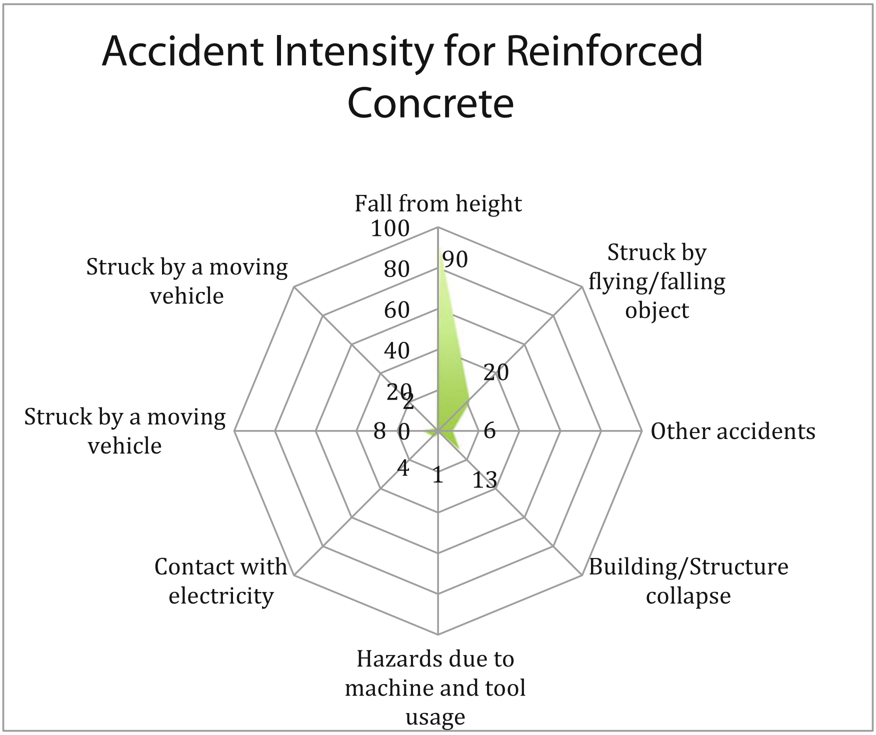

Fig. 1 Accident intensity for reinforced concrete

Table 4 Accident intensity investigation for 5 chosen activities

Activity	Fatalities	Ratio of fatalities (%)	Injuries	Ratio of injuries (%)	Total number of accidents	Ratio of total number of accidents (%)
Excavation	43	9	20	9	63	9
Reinforced Concrete	110	23.5	34	16	144	21.1
Plastering and painting	60	12.8	49	23.1	109	16
Masonry	62	13.2	27	12.7	89	13.1
Roof	65	13.9	12	5.7	77	11.3
Total	340	72.5	142	67	482	70.8

study it was assumed that construction workers work 45 h/week and 50 weeks/year.

While calculating the averaged accident rate for 13 years the construction work volume (work-hour) were calculated for each year. For each year the 70.8 % of accident rate was calculated and were used in the following calculations. After

Table 5 Distribution occupational accidents in between 5 activities based on 623 expert witness reposts

Activity	Fatalities	Ratio of fatalities (%)	Injuries	Ratio of injuries (%)	Total number of accidents	Ratio of total number of accidents (%)
Excavation	43	0.126	20	0.141	63	0.131
Reinforced concrete	110	0.324	34	0.239	144	0.299
Plastering and painting	60	0.176	49	0.345	109	0.226
Masonry	62	0.182	27	0.19	89	0.185
Roof	65	0.191	12	0.085	77	0.16
Total	340	1	142	1	482	1

dividing the number of accidents by the work volume the accident rates for each year were calculated. The accident rates were averaged for 13 years and the calculated value was used as the accident rate for the following calculations. In Turkey, for the chosen activities the averaged accident rate was found as 2.26×10^{-7} accidents per 100,000 h construction work.

In 5 construction activities the number of injuries, fatal accidents and total accidents are provided. With 0.229 accident ratio the most dangerous activity is found as reinforced concrete works. At this stage for each activity the accident rates were calculated considering the distribution of accidents in these 5 activities. For the reinforced concrete works the accident rates were given in Table 6. The accident rate for reinforced concrete works were found as 6.747×10^{-8} (accident/105 work-hours). The accident rate was distributed to risk categories and accident rate for each risk category in reinforced concrete works were calculated.

5 Activity Based Exposure Calculation

In available risk assessment methods exposure values are either not included or used as a constant for each risk type [2–6]. It is crucial to obtain an exposure concept which uses activities and man-hour values in construction projects. In this study the exposure values were calculated in daily basis. The daily worked hours was taken as 9 and number or workers were taken from project planning tables. The exposure values were calculated as:

$$\text{Exposure} = \text{Daily working hours} \times \text{Number of workers} \quad (1)$$

Table 6 Reinforced concrete process accident rates

Activity	Average accident rate for 5 activities	Ratio of reinforced concrete to total number of accidents (%)	Rate of reinforced concrete	Risk number	Risk code	Risk name	Number of accidents for reinforced concrete	Ratio of accidents for reinforced concrete	Rate of accidents for reinforced concrete
Reinforced concrete	2.26E−07	2.99E−01	6.75E−08	1	R01	Fall from height	90	0.625	4.217E−08
				2	R02	Struck by flying/falling object	20	0.139	9.371E−09
				3	R06	Other accidents	6	0.042	2.811E−09
				4	R03	Building/structure collapse	13	0.09	6.091E−09
				5	R09	Hazards due to machine and tool usage	1	0.007	4.686E−10
				6	R04	Contact with electricity	4	0.028	1.874E−09
				7	R11	Struck by a moving vehicle	8	0.056	3.749E−09
				8	R07	Struck by a moving vehicle	2	0.014	9.37E−10

Table 7 Accident probability calculation for foundation pour activity

Sub-activity name	Risk code	Risk name	Accident rate	Daily working hour (h)	Number of workers	Exposure	Accident rate x exposure	Accident probability	Accident probability × 1.000.000
Foundation pour	R05	Fall from height	4.21714E−08	9	7	63	2.6568E−06	2.65679E−06	2.657
	R01	Struck by flying/falling object	9.37142E−09	9	7	63	5.904E−07	5.90399E−07	0.590
	R02	Other accidents	2.81143E−09	9	7	63	1.7712E−07	1.7712E−07	0.177
	R03	Building/structure collapse	6.09143E−09	9	7	63	3.8376E−07	3.8376E−07	0.384
	R04	Hazards due to machine and tool usage	4.68571E−10	9	7	63	2.952E−08	2.952E−08	0.030
	R07	Contact with electricity	1.87428E−09	9	7	63	1.1808E−07	1.1808E−07	0.118
	R10	Struck by a moving vehicle	3.74857E−09	9	7	63	2.3616E−07	2.3616E−07	0.236
	R12	Struck by a moving vehicle	9.37142E−10	9	7	63	5.904E−08	5.904E−08	0.059

6 Accident Probability Calculation

In this study Poisson distribution model was used to calculate the accident probability. In order to use Poisson distribution for a data set two pre-requests exist. First, the realization rate of the event should be available. In this study the realization rates in order word the accident rates were calculated in previous chapters. Second, events should be independent. In construction works accident are independent from each other.

In Poisson distribution the probability of realization of event X for k times is calculated from:

$$\Pr(X = k) = \frac{\lambda^k e^{-\lambda}}{k!} \tag{2}$$

where λ = AR × E (Accident Rate × Exposure), k: number of accidents.

In proposed risk assessment method, it is assumed the precautions are not taken in construction are and the risk assessment is performed during the planning stage. The risk assessment during planning stage aims to have zero accidents during the project timeline. Therefore, the probability of having zero accident is calculated and it is subtracted from 1 in order to calculate the probability of accident realization $(1 - P(X = 0))$.

In Table 7 the calculation of accident probability of each activity is shown. It can be said that the accident probabilities are quite accurate because they are calculated using the real accident data and the exposure values are calculated from the real project planning tables.

7 Results

So far, in risk assessment methods accident probabilities are determined by way of various types of accidents probability scales based on expert opinion. Calculating the probability of an accident, as in this study, without the need for personal experiences and opinions, in an objective manner have enabled it to determine the probability of accidents.

In this study, the man-hour values were drawn from project planning table while calculating the probability values. The variations in project scales results in variations in exposure values. Therefore, if the probability of an accident calculated using the exposure value, probability values is required to make the project independent of the absolute scale. Another plus to calculate the probability of an accident with the help of the Poisson distribution in all likelihood of accidents value is between 0 and 1. This way, the likelihood of accidents values are becoming independent of the size of the project.

References

1. SII. Social Insurance Institution Occupational Accidents Statistics Report. 10 12 2013. Retrieved from http://www.isteguvenlik.tc/SGK2012IsKazaIstatistik.pdf (2012) (in Turkish)
2. Casanovas, M.M., Armengou, J., Ramos, G.: Occupational risk ındex for assessment of risk in construction work by activity. J. Constr. Eng. Manage. **140**, 04013035-1–04013035-9 (2014)
3. Gangolells, M., Casals, M., Forcada, N., Roca, X., Fuertes, A.: Mitigating construction safety risks using prevention through design. J. Saf. Res. **41**, 107–122 (2010)
4. Hallowell, M., Gambatese, J.: Activity-based safety risk quantification for concrete formwork construction. J. Constr. Eng. Manage. **135**(10), 990–998 (2009)
5. Hallowell, M.: Risk-based framework for safety investment in construction organizations. J. Constr. Eng. Manage. **137**(8), 592–599 (2011)
6. Jannadi, O., Almishari, S.: Risk assessment in construction. J. Constr. Eng. Manage. **129**(5), 492–500 (2003)

Salivary Cortisol Analysis in Shift Workers

Antônio Moro, Pedro Reis, Israel Santos, Alexandre Pinto and Diogo Reis

Abstract Night work is responsible not only for changes in sleep, but major changes in the production of cortisol. The shiftwork has become shared these days; however, this practice affects the health of workers. The objective of this study was to investigate the influence of shift work in the prevalence of morbidity in vigilant workers. The sample consisted of 21 guards of a company's electricity branch in the city of Foz do Iguaçu, Paraná, Brazil. After signing the informed consent form, the questionnaire research of stress symptoms for adults was applied. The collection of the hormone cortisol has been through a salive up early in the 1st round (6:30–7:05) and at the end of the morning shift (5:30–6:05). Analyses of the hormone cortisol was in the laboratory, through the electrochemiluminescence method. The data showed 66.8 % with bad and very bad sleep in the morning shift, 72 % said fatigue and insomnia, irritability 81 and 91 % drowsiness. The damage to family, health and social showed 90.6, 71.5 and 85.8 % respectively. It was observed that in the group for 71 % in stress resistance phase. The values of salivary cortisol hormone achieved total range of 0.06–0.73 mg/dL, indicating low values for the vigil. In conclusion, the shift work contributes to the emergence of stress, depression, affecting the health and quality of life of vigilant and provides a change in the secretion of the cortisol hormone.

Keywords Shiftwork · Quality of life · Stress · Salivary cortisol

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1 Introduction

The existence of work shifts, increasingly common in the contemporary society, is linked to the need to meet the demands of businesses for continuous period of 24 h. In addition, other issues related to the requirements for employability and compliance with activities, requiring the individual to work night-shifts [1].

The amount of shift workers in recent years had a marked growth, due to the great demand for services for longer periods [2]. This reality can be justified by the society growing demand of 24 h available services due to the population continuous needs for certain services. Justify the necessity of third shits [3].

Currently, work shifts had become common in various areas of services, especially health care, safety and transportation. Although there is a constant need for such types of services, there is no concern about possible biopsychosocial impacts on those employed in this type of shift regiment [4].

The so-called “24-h society” emerged from the need for relentless pursuit of welfare and financial stability, associated with the pursuit of profits by companies. This term is relatively new, used to describe a practice that was already seen since the early days and is gaining more space in everyday life, especially when related to certain professional areas, for example the surveillance work [5].

According to Regis Filho, the stress originated from the desynchronization of the circadian rhythm, the change in social and family life and sleep deprivation, are factors that support the disturbance of the psychological and physical state of the night-shift workers. This fact is associated with production of the cortisol hormone by humans [6]. Thus, the production of the cortisol hormone, which is produced by the adrenal glands, follows a natural circadian cycle.

However, this cycle may be disturbed for night-shifters, given that it increases its production in the last stages of sleep in order to prepare the body to wakefulness [7]. Therefore, the concentration of cortisol upon awakening is highest and will decrease during the day, reaching lower concentrations before bedtime.

Authors described the importance of monitoring and analysis of cortisol during the circadian rhythm, and its effects on cognition, stress, anxiety, depression and panic attacks, especially in individuals with sleep deprivation, night shifters and chronic fatigue [2].

Cortisol is known as the stress hormone [8]. Its concentrations in the blood can change in both physical and psychological stressful situations. Cortisol hormone has anti-inflammatory, metabolic (gluconeogenesis) and is an immunosuppressant functions.

Thus, the present study aimed to determine the impact of shift-working on morbidity, health and performance of service providers working in uninterrupted-shift regiment activities.

2 Method

This descriptive cross-sectional study was conducted between September and October of 2014, with 21 security officers of a power company in the city of Foz do Iguaçu, Paraná, Brazil. There were alternating and uninterrupted shifts during the 24 h, with 6 h daily arranged in four shifts, morning shift from 6 am to 12 pm (six in the morning to noon); afternoon shift from 12 pm to 6 pm; Night shift from 6 pm to 12 am; Overnight shift from 12 am to 6 am (midnight to six in the morning). All subjects signed the consent form according to the ethical recommendations for research with human beings.

Data were collected through a questionnaire from the application of the Inventory of Stress Symptoms for Adults (ISSL), and saliva samples from Salivette® tubes for measurement of salivary cortisol (Fig. 1). The questionnaire featured three stress phases, in which the first consists of 15 items related to physical or psychological symptoms that the employee has experienced in the past 24 h.

The second phase presents 10 physical 5 psychological symptoms, associated with symptoms experienced in the past week. The third phase consists of 12 physical and 11 psychological symptoms experienced in the past month.

The salivary cortisol samples were collected in two different periods, one held during the early morning shift (between 06h30 and 07h05 am) of September 3rd, 2014. The second sample was collected at the end of the overnight shift (between 05h30am and 06h05am) of October 2nd, 2014. The Salivette® tube for salivary sample collection is an affordable way and allows easy and clean sampling. The plastic tubes have cotton rollers with high capacity of saliva absorption and capable of storing acceptable cortisol concentrations.

Fig. 1 Salivette® tubes used to collect saliva and subsequently analysis of cortisol

The volunteers were instructed to not perform oral hygiene or ingest food or drinks (except water) for a period of 30 min prior to collection of sample. The procedure for collecting the samples started with positioning the cotton roll from the Salivette tube on one side of the oral cavity, in order to stimulate salivary flow for about 5 min. After the collecting period the cotton roll was removed using the Salivette tube to avoid possible contamination. The tube was closed as quickly as possible and then disposed in a cooler containing dry ice, to slow down the process of degradation and decomposition of the saliva.

Samples were stored under refrigeration and sent to a laboratory for analysis, within less than two hours after the end of the collection, ensuring reliability for analysis. Refrigerated centrifugation for separation of saliva in which they were processed through electrochemiluminescence method (ECLIA). This method uses light emission which is modulated with application of suitably oxidation potential or reduction on an electrode immersed in solution containing radiation emitting molecules. Normal reference values for 07:00 am are 5.5 to 30.0 mg/dL.

3 Results

Firstly it will be presented the results regarding the quality of sleep, symptoms of discomfort, health status, leisure, social and family interaction, and stress level, followed by the results of the level of salivary cortisol concentration.

Regarding the quality of sleep, respondents from the morning shift reported 66.8 % of their sleep as POOR and VERY POOR, which is justified by the shift schedule start at 06h00 am, forcing the individual to wake up at around 05h00 am. This fact is evidenced when the individual wakes up at an earlier time but does not anticipate bedtime to compensate for the loss of sleep. Therefore the sleep quality is impaired primarily for the morning shifters [6].

The night shifters, comprising the schedule of 6 pm to 12 am, reported 62 % of their sleep as EXCELENT, and the afternoon shift (12 pm to 6 pm) rated as GOOD with 52.4 %. According to Silva (2010), the afternoon shift enables a more flexible schedule for sleep and wake up times. Due to the obligation to comply with the scheduled shift, workers can apply chronobiological principles to determine the best time to sleep [9].

With regard to fatigue and insomnia, respondents indicated a 72 % occurrence of these disorders, 91 % incidence of drowsiness and 81 % irritability. These values indicate high levels of symptomatology associated with continuous and rotating shift schedules. These percentages can be an indicative that the quality of sleep is affected by night shifts, and the symptoms recorded after rest and sleep confirmed that the employee remains tired, discouraged, and sleepy.

Results from studies indicate that morning and overnight shift workers sleep in segmented schedules, alternating between periods of sleep and periods of wakefulness, which could be the cause of insomnia and/or difficulty sleeping [6]. Thus, the data presented suggests that the quality of sleep is poor, and it generates fatigue, insomnia, anxiety and irritability, changes in emotional state, gastrointestinal disorders, constipation and heart problems.

Regarding family relationships, health status, leisure and social interaction, 90.6 % of the workers “strongly agree” and “agree to some extent” that quality of sleep can influence these respective areas. Concerning health status, the options “strongly agree” and “agree to some extent” reached a total of 71.5 %, and leisure and social interaction alone were 85.8 %.

The high degree of complaints reported by respondents may be explained by Goh and collaborators study, in which shift-work results in mismatch between the external factors and the internal biological clock, causing a desynchronization of circadian rhythms [10]. Observing this scenario where workers report the negative factor of working in shift regiment, it is possible to identify feelings of isolation and social disadvantage among night workers, especially when working weekends.

In relation to the stress phase, from 21 participants, 05 (29 %) reported no stress and 16 (71 %) reported stress resistance, where this phase is characterized by an attempt to resist the stress factors and may evolve to the exhaustion phase, in which is considered by Lipp a phase where stress can cause disease (pathological). The exhaustion stage is a time when the individual may be very depressed and unable to work [6].

The stress resistance phase was evidenced in this study group compared with the other phases, indicating that this workers are highly susceptible of increased stress levels. Noting that the psychological and physical symptoms are characteristic in very stressful jobs [11–13].

Cortisol helps the body to control stress, reduce inflammation, contribute to the functioning of the immune system and maintains constant blood sugar levels, and blood pressure. Some factors can interfere in the process, such as fever, inflammation, pain, stress and hypoglycemia. Cortisol and the adrenal-corticotrophic hormone (ACTH) usually present circadian variations with higher peaks in the morning, decreasing throughout the day.

Thus, the reference values for the collection of salivary cortisol, according to the laboratory responsible for the analysis include values of 5.5–30.0 g/dL for the morning; 2.0–14.5 g/dL for afternoon; 2.0–14.5 g/dL. at night. Figure 2 shows the relationship between the two periods of data collection, which presents low levels of salivary cortisol for the morning and overnight shifts, specially for the overnight shift.

Fujiwara and collaborators study shows that salivary cortisol concentration was significantly lower in the group with higher stress levels than in the low stress level group [9]. The low Cortisol levels may indicate circadian rhythm disorder induced by stress at work. Corroborating with the findings in the present study, Yang and collaborators also found low cortisol levels in emergency nurses [5].

The salivary Cortisol measured by descriptive analysis, according to Fig. 2, the present value in the range of 0.06–0.73 mg/dL, which are below the normal

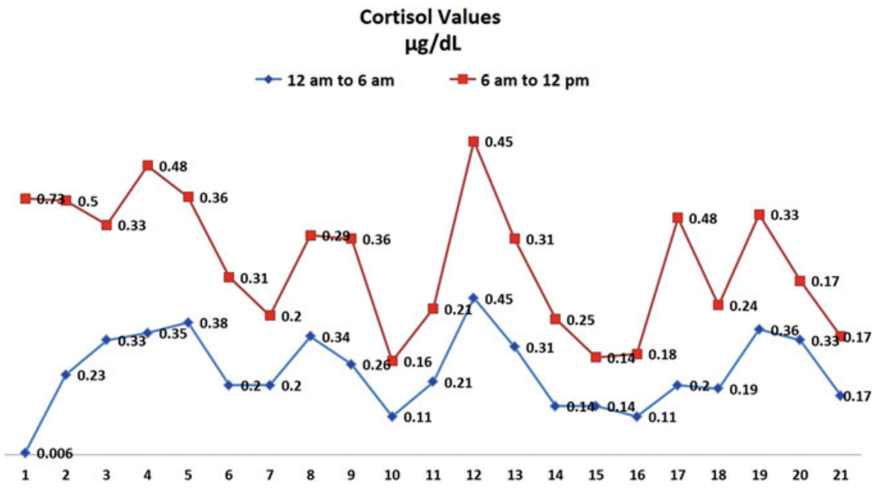

Fig. 2 Graph of cortisol concentration for the two shifts

reference values. The minimum values were from 0.06 mg/dL to 0.14 μg/dL, with the maximum values of 0.45 g/dL and 0.73 mg/dL; the average was 0.24 mg/dL to 0.32 mg/dL; the median was 0.21 μg/dL–0.31 g/dL and the standard deviation was 1.52–1.56 g/dL.

During pathological processes, whether arising from physical or psychological stress, communication between the central nervous system and the immune system is of vital importance. Thus, hypothalamus optimal function is critical, which is an important center for the coordination of neuroendocrine functions, controlling blood concentrations of stress hormones, particularly cortisol and gonadal hormones, such as testosterone and estradiol [11, 14].

Chemical releases arising from stress contribute significantly to pathological development, especially when the body can no longer self regulate to avoid invaders. Cortisol primarily acts by combating inflammation in acute stress, and in the chronic phase of stress hormone will increase significantly in the body, affecting the immune cells, thus resulting in the illness.

Therefore, low cortisol levels during wakefulness is a strong indicator of stress is due mainly by desynchronization sleep wake cycle and circadi-year rate, the average values found in the present study was 0.24 mg/dL–0.32 g/dL. These values lower line of reference for 07:00 am should be above 5.5–30.0 g/dL.

The dysregulation of cortisol have also been proposed as a possible contributor to morbidity, mortality and severity of the disease process [15]. Thus, a cause and effect relationship between circadian rhythms and shift work presents significant decreased levels of secretion of cortisol in fatigued individuals.

4 Conclusion

In this scenario, with working hours of continuous shifts in a society that operates 24 h a day, there are difficulties adapting to alternating shifts, with negative implications for health, family relationships, and limiting recreational activities and social life.

Through the information gathered by the questionnaire, the inventory on stress symptoms and salivary cortisol collection, it was possible to identify disorders associated with shift work. According to the interviewees, sleep disorders such as drowsiness, fatigue, insomnia and irritability, were the highlights of their sleep perception during and after work.

In conclusion, the results demonstrate the impact in health and quality of life, with those individuals also predisposed to psychosocial problems, due to the differences between their schedule and their families, regarding daily activities and the time available for social interaction.

References

1. Goh, H.H., et al.: Circadian disturbances after night-shift work onboard a naval ship. Mil. Med. **165**(2), 101 (2000)
2. Fischer, F.M.: What do petrochemical workers healthcare, and truck drivers have in common? Evaluation of sleep and alertness in Brazilian shift workers. Cadernos de Saúde Pública, Rio de Janeiro (2004)
3. Scott, A.J.: Shift work and health. Occup. Environ. Med. **27**(4), 1057 (2000)
4. McEwen, B.S.: Protective and damaging effects of stress mediators. N. Engl. J. Med. **1**(338), 171–179 (1998)
5. Toledo, R.C., Souza, V.A., Dias, B.V.B.: Alterações psicofisiológicas relacionadas ao trabalho noturno na área de enfermagem. Revista Multidisciplinar da Saúde. Ano **II**(04), 38–48 (2010)
6. Regis Filho, G.I.: Síndrome da má-adaptação ao trabalho em turnos: uma abordagem ergonômica. Editora da UNIVALI, Itajaí (2000)
7. Lipp, M.E.N.: Stress no trabalho: Implicações para a pessoa e para a empresa. In: Sobrinho, F. P.N., Nassaralla, I. (Orgs.) Pedagogia Institucional: Fatores humanos nas organizações, Rio de Janeiro (2005)
8. Rocha, M.C.P., Martino, M.M.F.: O estresse e qualidade de sono do enfermeiro nos diferentes turnos hospitalares. Rev. Esc. Enfermagem, USP. **44**(2), 280–286 (2010)
9. Fujiwara, K., et al.: Urinary catecholamines and salivary cortisol on worksdays and days off in relation to job straim among female health care providers. Scand. J. Work Environ. Health **30**, 129–138 (2004)
10. Yang, Y., et al.: Salivary cortisol levels na work-related stress among emergency department nurses. J. Occup. Environ. Med. **33**, 1011–1018 (2001)
11. Iida, I.: Ergonomia - Projeto e Produção. Editora Edgard Blucher, São Paulo (2005)
12. Johnson, E.O., et al.: Mechanisms of stress: a dynamic overview of hormonal and behavioral homeostasis. Neurosci. Biobehav. Rev. **16**(2), 115–130 (1992)

13. Rosa, P.L.F.S.: Percepção da duração do sono e da fadiga entre trabalhadores de enfermagem. Revista Enfermagem, UERJ, Rio de Janeiro (2007)
14. Ahlgren, A., Akerstedt, T., Kecklund, G.: Individual differences in the diurnal cortisol response to stress. Chronobiol. Int. **21**(1), 913–922 (2004)
15. Silva, E.C.G., et al.: Impactos gerados pelo trabalho em turnos. Revista Perspectivas On Line **4** (13), 65–86 (2010)

Evaluation of the Perception of Knowledge and Occupational Exposure to Xylene, Toluene and Ethylbenzene for the Furniture Industry Workers

Manuel Pedroso and Mónica Dias-Teixeira

Abstract The study of perception and risk of occupational exposure to xylene, toluene and ethylbenzene by workers of furniture factories in the districts of Aveiro, Coimbra and Viseu, intends to separately evaluate the perceived risk and real risk of exposure to these chemicals in the workplace. The cross-sectional study using a questionnaire was applied in April and May of 2014 to workers of furniture factories, with a sample of 142 respondents from 28 companies. The results of this study show that 55 % use the suction booths without proper maintenance. The ambient air samples were collected between July and November 2014 and held 108 crops of air for the determination of toluene, xylene and ethylbenzene. The results of measurements of concentrations of COV's in different companies showed that the arithmetic mean of certain concentrations was 51 ppm for toluene, ethylbenzene to 23 ppm and 57 ppm for xylene isomers.

Keywords Volatile organic compounds (COV's) · Furniture · Toluene · Xylene · Ethylbenzene

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1 Introduction

The International Safety Chemical Program composed by the World Health Organization (WHO), United Nations (UN) and International Labour Organization (ILO), estimated at about 100,000 the number of pure chemicals and 4 million compounds with commercial use [1].

Existing chemicals in the workplace occupation is the most extensive professional risk factor among many factors affecting human health [2].

The attention to allergenic effects of chemicals, endocrine disruptors, carcinogenic, mutagenic and teratogenic has increased, the answers follow different patterns of dose-response curve of the deterministic type.

The increased complexity of the chemicals, much due to commercial requirements and preferences, caused an increase in the number of individuals with concurrent exposures to various chemicals from various sources, alone or interacting, creating new and increased risk situations. To these factors we can add a technological development line that is the use of substances at the level of nanotechnology.

It is therefore essential to know all the factors that somehow can influence the protection of the workers health. Among these, it highlights the adverse effects of the substances used, the evaluation result and the control measures adopted, biological monitoring to estimate the occupational risk and the adoption of effective measures to protect the health of exposed persons.

The hydrocarbon part of the core group of volatile organic compounds into the atmosphere [3], and their indoor concentrations are two times higher than in external environments [4].

Risk analysis of exposure to chemicals associated with the development of professional activities includes determining the concentration of the agents in the air of the workplaces. This concentration, when representative of occupational exposure in the study, is compared with reference values representing exposure thresholds corresponding to acceptable risk levels.

These reference values, called “exposure limit values”, are established for each identified chemical agent and are risk criteria in the evaluation of the risk of exposure to chemical agents. These limits described in the Portuguese standard NP 1796: 2014 are based on the figures proposed by the American Conference of Governmental Industrial Hygienists [5].

Painters were exposed to a wide range of complex mixtures that include a number of known carcinogenic and mutagenic chemicals including organic solvents and dye products. The findings are consistent with previous work showing an increased risk for urological and hematic cancers among painters. The study, however, found an excess of cases of multiple myeloma among painters, whereas other workers found an excess of leukemia [6].

Thetkathuek et al. were analyzed the exposure factors that may lead to neuropsychological symptoms among 92 workers who were exposed to xylene and toluene and 100 workers who were not exposed to the solvents. The analysis of the airborne xylene and toluene concentration for the exposed group indicates that workers exposed to xylene had a mean exposure of 2.7 parts per million (ppm). The mean toluene exposure was 9.5 ppm [7].

In Pathological Anatomy laboratories, can be found concentrations between 162.2 and 181.1 ppm for xylene isomers and between 155.3 and 196.8 for ethylbenzene [8].

Moch Sahri and Noeroel Widajati, studied the evaluation of toluene exposure in workers at industrial Area of Sidoarjo, Indonesia. Levels of toluene in workplace air at all companies were below the ratified governmental regulatory threshold value (<50 ppm) with the maximum level of 28.1 ppm [9].

Also Decharat studied the exposure of Paint Workers at Steel Furniture Manufacturers in Thailand and concluded the median of the 87 airborne toluene levels was 55 ppm [10].

2 Methodology

To develop this work, two different methodological approaches were applied. Initially proceeded to the application of a questionnaire and then to the air quality assessments.

One hundred and forty-two employees participated in this study. They belong to all companies (28 companies) with more than 15 employees of the districts of Aveiro, Coimbra and Viseu in the furniture industry within the economic activity codes 31010—furniture manufacturing office and shop, 31020—manufacturing kitchen furniture and 31091—wood furniture manufacturing for other purposes.

The questionnaire was personally distributed to the population under study, in April and May 2014. This took about 10 min after which it was immediately returned. The survey data were collected and analyzed using SPSS (®) version 21.

Measurements of VOCs were performed in ambient air at 36 workplaces, in total 108 air samples, in paint|burnish, varnishes and plugged pores application workplaces.

The ambient air samples were collected between July and November 2014. The procedure was to collect three samples using activated carbon tubes (SKC—Anasorb® CSC: coconut charcoal, 20/40 mesh, 50/100 mg) activated and an independent sampling pump (SKC standard model—224-44EX). Both ends of the cartridges were cut. The applied flow rate varied between 0.13 and 0.19 L min^{-1} for 15 min. The personal sampler was placed on the worker's lapel in which it was performed air sampling in the breathing zone. The sampling time (15 min) was controlled with the aid of a stopwatch (Oregon Scientific).

3 Results and Discussion

3.1 Results of the Questionnaire

The knowledge concerning the risks of exposure to organic solvents, 63 % consider that this risk was derived from exposure to inks/burnish, 71 % consider that risk in exposure to varnish and 65 % to plugged pores. Regarding exposure to xylene, 27 % respond that there is the risk, and 24 % toluene.

About 33 % of employees agree that there is no risk of exposure to paints/wood stains, varnishes and plugged pores if it is for a short time while 43 % disagree; 55 % of employees stated that the masks that gave them the most appropriate; only 39 % of workers were provided with a protective suit.

About 50.7 % of workers indicate that they always use a protective mask in the handling of the paint/wood stains, varnishes and plugged pores. It added the fact that on average they do not know when to replace the mask filters. Although 65.5 % of the workers mentioned that there was a strong smell of chemicals in their jobs.

Approximately 57.7 % agrees and 16.2 % fully agrees that protective gloves were provided by their employer. They claim to wear the protective gloves and say that the contact of the skin with these products is dangerous. However, 57.1 % of the employees agrees and 10.7 % fully agrees that the provided gloves were the best suited for the job, revealing the lack of knowledge as to which are the appropriate gloves for the handling of these chemical products.

In terms of physiological effects it turns out that 45 % of respondents stated that this exhibition provokes irritation in the respiratory tract (nose and throat); 18 % of workers reported episodes of dizziness in the workplace; and 52 % had the skin dehydrated and irritated.

An additional worrying situation is the fact that 25.9 % of the workers report headaches. The workers (49.2 %) mention that there is an intense uproar at the workplace, which makes this a troubling fusion. As it has been demonstrated in a study by Morata et al. [11] and another by Jonhson [12], there is a synergetic effect between noise and the exposure to toluene. Another study conducted by Cary et al. [13], shows that the workers exposed to toluene suffer from hearing loss, in the sensibility to the threshold of pure sounds, and at least some hearing damage when simultaneously exposed to chemicals and the noise [14].

Nearly 15.7 % of the workers admit to sometimes ignoring the safety rules, 10.8 % always, and 5.7 % most times, which altogether represents 32.2 %, concluding there is a behavior problem among the employees, even though they know the safety rules.

3.2 Measurements of VOCs in Ambient Air

The results of measurements of concentrations of COVs in different companies showed that the arithmetic mean of certain concentrations was 51 ppm for toluene, 23 ppm to ethylbenzene and 57 ppm for xylene isomers.

The values were higher when compared with other study conducted in Paços de Ferreira, in 2007 by the Portuguese Authority for Working Conditions (ACT) in the same field companies. In which it detected an average concentration of 18.7 ppm toluene, ethylbenzene 5.2 ppm and 19.7 ppm xylene [15].

The maximum concentration determined in this study was 168 ppm for toluene 56 ppm for ethylbenzene and 119 ppm for xylene.

The levels found were much higher than those found in a study conducted in two paint factories in Thailand, whose concentrations are around 0.1 and 13.1 ppm for xylene and between 0.5 and 48.7 ppm for toluene [7].

In the studied companies, xylene was detected in greater abundance in the air of the jobs analyzed.

In pathology laboratories there can be found concentrations between 162.2 and 181.1 ppm for isomers of xylene, and between 155.3 and 196.8 ppm for ethylbenzene [8].

The results obtained in the furniture industries were lower than those detected in the laboratory. These results were expectable because in the laboratory are used VOC concentrations, quite high and with a high purity as in the industrial environment xylene, toluene and ethylbenzene are chemicals that make up the paint/wood stains, varnishes and plugged pores much lower concentrations.

From measurements made, 56 % of the analyzed samples are above the TWA for xylene isomers established in Decree-Law no 24/2012 of 06 February (50 ppm) and 8 % is above the TWA NP 1796: 2014 is 100 ppm. The level of short-term exposures (CD) 16 % of the measurements are higher than 100 ppm, value established in Decree-Law no 24/2012 of 06 February for the VLE-CD and only 2 % of evaluations are found above the limit values, i.e., 150 ppm according to the NP 1796: 2014.

Relative to toluene, 39 % of the measurements show values of concentrations above the TWA, i.e. 50 ppm, according to Decree-Law no 24/2012 of 06 February and there's even more than 44 % of workplaces that have concentrations above 20 ppm, average exposure limit value weighted established in the Portuguese Standard 1796: 2014 (NP 1796: 2014). Thus, 83 % of workplaces have toluene concentration values above the established in the NP 1796: 2014.

With regard to short-term exposures (CD) it is observed that 12 % of 15-min measurements are higher than the TLV-CD, i.e. 100 ppm established in Decree-Law no 24/2012, of 06 February.

Regarding ethylbenzene, the concentrations present no higher than the TWA established by Decree-Law no 24/2012, of February 06 is 100 ppm, however, it turns out that 56 % of values are above 20 ppm recommended in the NP 1796: 2014.

Knowing the effects of xylene, toluene and ethylbenzene exposure in the organs/human physiological systems, referred in the norm NP 1796: 2014 we can establish that xylene causes hearing disorders, kidney injuries and irritation in the upper respiratory tract, toluene affects the sight (eyes), causes lesions in the feminine reproductive system and abortion, and ethylbenzene causes hearing disorders, kidney injuries and irritation in the upper respiratory tract. Literature, specifically in DLEP 39—Documentación Toxicológica para el Estabelecimiento del Limite de Exposición Profissional del Tolueno [16] indicates that toluene causes effects in the upper respiratory tract and affects the central nervous system, among others. Therefore, considering this additional effect amid xylene, toluene and ethylbenzene isomers, present in the analyzed workplace's air, (picture 25), we can verify that 92 % of the mixture's exposure exceeds the limit (>1) and only 8 % is below the limit (<1). The average is 2.6 having even found jobs where maximum concentration was 5.5. These data demonstrate that employees will most likely come to suffer from functional disorders NP 1796: 2014.

In a study conducted to 96 employees of seven companies of paint and printing, located in Sidoarjo Indonesia, investigators concluded that only 5 % of the workers presented rated values of hippuric acid (determined by spectrophotometry) above the biological limit when the concentration of toluene in the workplace air was below 28.1 ppm [9].

4 Conclusions

Workers of paint application industry/wood stains, varnishes and plugged pores although knowing that these products carry risks to their health, unaware of their composition, which consists of xylenes, toluene and ethylbenzene. These workers, however, rely on the effectiveness of masks provided by the company, recorded up pathophysiological changes due to inadequate equipment of the type of personal protective equipment.

The workers of the studied furniture manufacturing companies show a low perception related to the risk exposure to toluene, ethylbenzene and xylene too.

Given the VOC concentrations detected we can infer that:

- 56 % of the studied workplaces have xylene concentration higher than the TWA established in Decree-Law no 24/2012 of 06 February (50 ppm) and 8 % are above the TWA NP 1796: 2014 (100 ppm).
- 39 % of the studied workplaces have higher toluene concentrations to TWA established in Decree-Law no 24/2012 of 06 February (50 ppm) and 44 % are above the TWA NP 1796: 2014 (20 ppm).

In any employment detected ethylbenzene concentrations exceed the TWA set out in Decree-Law no 24/2012 of 06 February (100 ppm), nevertheless, it turns out that 56 % of jobs show concentrations exceeding the TWA recommended in the NP 1796: 2014 (20 ppm).

With this study, we can conclude that exposure to paints/wood stains, varnishes and plugged pores, made from various substances by VOCs, most notably toluene and xylene constituting these two substances as risk factors for the health of furniture manufacturing workers.

References

1. International Programme on Chemical Safety.: Environmental Health Criteria; 210: Principles for the assessment of risks to human health from exposure to chemicals. Geneva: WHO (1999)
2. Prista, J., Uva, A.S.: Aspectos Gerais de Toxicologia para Médicos do Trabalho. Lisboa: Escola Nacional de Saúde Pública Obras Avulsas nº 6 (2002)
3. Kalabokas, P.D., Hatzianestis, J., Bartzis, J.G., Papagiannakopoulos, P.: Atmospheric concentrations of saturated and aromatic hydrocarbons around a Greek oil refinery. Atmos. Environ. **35**, 2545–2555 (2001)
4. Godish, T.: Air Quality. 2th edn. Lewis Publishers (1991)
5. American Conference of Governmental Industrial Hygienists: TLV's and BEI's based on the documentation of the threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati (2014)
6. Bethwaite, P.B., Pearce, N., Fraser, J.: Cancer risks in painters: study based on the New Zealand cancer registry. Br. J. Ind. Med. **47**, 742–746 (1990)
7. Thetkathuek, A., Jaidee, W., Saowakhontha, S., Ekburanawat, W.: Neuropsychological symptoms among workers exposed to toluene and xylene in two paint manufacturing factories in Eastern Thailand. Adv. Prev. Med. (2015)
8. Dias-Teixeira, A., Dias-Teixeira, M., Rangel, R., Tiritan, E., Gonçalves, V., Domingues V.: Development and validation of HPLC-DAD method for the simultaneous determination of creatinine and metabolites of xylene, toluene and ethylbenzene in urine. Paper presented at the SETAC europe: 20th annual meeting, Seville (2010)
9. Sahri, M., Widajati, N.: Evaluation of toluene exposure in workers at industrial area of Sidoarjo, Indonesia by measurement of urinary hippuric acid. Asia Pac. J. Med. Toxicol. **2**, 145–149 (2013)
10. Decharat, S.: Hippuric acid levels in paint workers at steel furniture manufacturers in Thailand. Saf. Health Work, 227–233 (2014)
11. Morata, T.C., et al.: Effects of occupational exposure to organic solvents and noise on hearing. Scand. J. Work Environ. Health **19**(4), 245–254 (1993)
12. Jonhson, A.C.: The ototoxic effects the toluene and influence of noise, acetylsalicylic acid, or genotype. A study and rats and mice. Scand. Audiol. **S39**, 1–40 (1993)
13. Cary, R., Clarke, S., Delic, J.: Effects of combined exposure to noise and toxic substances—critical review of the literature. Ann. Occup. Hyg. **41**(4), 455–465 (1997)
14. Pereira, D.A.: Solventes ototóxicos: efeitos do tolueno e estireno na perda auditiva. Universitas Ciências da Saúde **01**(01), 01–12 (2003)
15. Mayan, O., Gonçalves, I., Trigo, L., Neves, P., Gonçalves, C., Guimarães, F., Rodrigues, S., Martins, M.: Condições de trabalho na indústria de mobiliário de madeira. Autoridade para as condições do trabalho, Lisboa (2011)
16. Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT).: DLEP 39 – Documentación Toxicológica para el Estabelecimiento del Limite de Exposición Profissional del Tolueno. España (2017)

Health Promoting Games as Part of the Strategy of the Organization

Katarzyna Lis, Ewelina Wierzejska and Alicja Rytelewska

Abstract This article aims to discuss health promoting games as part of the strategy of the organization, models of safety culture levels and a proposal for a new approach There are several methods enabling organizational development. One of them can be incorporating workplace health promotion into organizational philosophy and methodology. Health of the employees can be perceived as a cost-effective investment, and modern interventions targeting employee health are very often connected with the application of IT. Moreover, strategic games are gaining popularity as activities used to enhance the effects of organizational activities aimed at human resources development.

Keywords Workplace health promotion · Strategic management · Occupational health · Games

1 Introduction

Strategic management is one of the key areas of organization management. Every manager wishes to become expert in this field as it guarantees appropriate decisions made with regard to organization development. It is not an easy task though. It requires appropriate knowledge, abilities and experience. Additionally, making

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decisions connected with strategic management requires carrying out a number of analyses allowing for the determination of organizational goals. It is said, therefore, that strategic management is now a firmly established field in the study of business and organizations [1].

The aim of the article is to discuss health promoting games as part of the strategy of the organization, models of safety culture levels and the proposal of a new approach towards health at workplace.

The article is divided into eight sections. The first section is introduction of the paper. The second section is related to evolution of strategic management in the organizations over the years. The third section presents health as an investment in human resources. The fourth section describes the systemic approach to occupational health and safety. The fifth section presents the meaning of workplace health promotion. The sixth section discusses possible health promoting and disease preventing interventions. The seventh section is devoted to possible workplace health promotion implementations though internet and games. The eighth section are conclusions.

2 Evolution of Strategic Management

Until the beginning of the 1960s, the concept of strategic management was not commonly applied in organizations. Most decisions were taken ad hoc and were based more often on business traditions than on analyses (see Fig. 1). Only the discovery made by Henderson's, who was intrigued by differential unit costs among companies using similar technologies, marked a breakthrough in the field of business strategy concept. The development of strategic management was reflected later in the 1960s in the publication of a few significant papers regarding the area, at that time referred to as Business Policy, which was considered the pioneer of strategic management. Its gradual transformation into the new branch called 'strategic management' dates back to the second half of the 1970s [2]. This new approach was formulated mainly in the papers by Chandler, Ansoff and Drucker, and was then developed by Ackoff, Andrews, Porter, Mintzberg and others.

At first, the innovative approach was mainly advocated for organizations that were planning their long-term strategic activities (planning model of strategy [3]). It was based on organizational structure designs, which were created on the basis of a strategy, relied on management decentralization and reformulation of managerial functions towards long-term planning, coordination of organizational activities and diagnosis of the whole organization [4–6]. The planning model was the first to consider the necessity of long-term strategic planning in management. Its assumptions were rational but unfortunately, the theoretical and rigid rules were not always suitable to be put into business practice of an organization, which was functioning in a changing environment. The environment put the pressure on the planning model to change. It led to the development of a new concept of a so called evolution model. Its basic assumption was to take into account some not completely

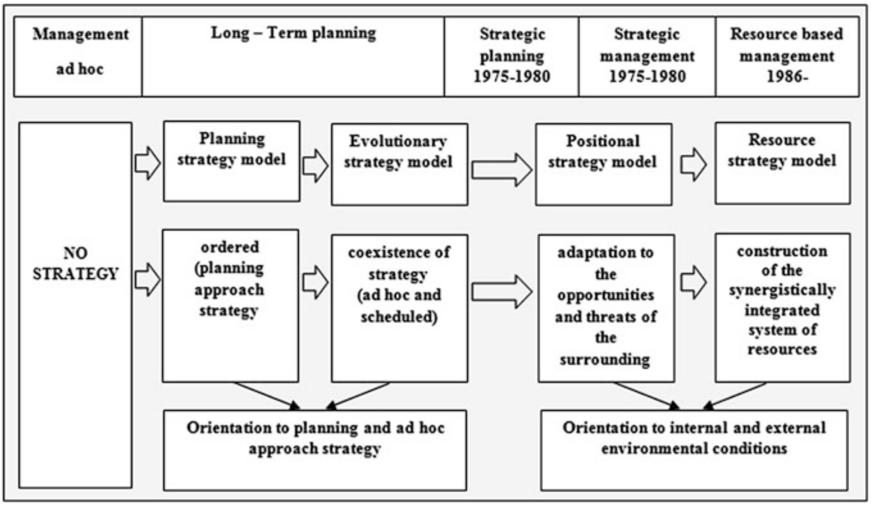

Fig. 1 Strategic management development [7]

rational behaviors of the organization. This assumption allowed for insufficient information and the related decision limitations of the managing staff. The necessity was recognized for some organization-oriented activities, planned not only on the basis of the previously determined strategy but also on the basis of dynamically taken decisions. Organization's surrounding environment is continually changing.

A breakthrough moment in strategic management development was published in 1965 in the paper by Learned, Christiansen, Andrews, Guth (Harvard Business School). This paper presented the major assumptions of the concept of strategic management in organizations. These views were reflected in a new, market-oriented model of strategy formulation in an organization – a position model. In accordance with its assumptions, the goal of the organization strategy should be to develop a competitive advantage (or a system of advantages) understood as the achievement of a more beneficial position on the market in comparison to other companies – competitors.

The creation and development of strategic approach in management was connected with industrial, informational and structural changes of the global economics especially with sudden acceleration in the dynamics of these changes. This was affected by intensification of the following phenomena: market globalization, tendency to decomposition, destabilization and changes of the surroundings, and management decentralization [8]. Among internal factors that have changed the strategy of the organization the following ones are mentioned: organization diversification, acceleration of innovative processes, sudden increase in information space [9]. The greatest development of the concept was accomplished due to the crisis in the 1970s. It influenced greatly the development of strategic management. At that time organizations and even whole governments of developed countries coped with the, unheard of since the Great Depression, period of stormy changes that hindered business activities of organizations.

As a result, organization managers started to seek new methods of effective company management. Researchers also had to take action aimed at the development of new technologies used in strategic planning due to the fact that the methods used at that time were outdated and inadequate for that economic situation [10].

In 1973 and 1979 new methods of management of big diversified organizations were created following, among other things, counteractions of the oil crisis. In the second half of the 1970s these actions were perceived as a great success, which sparked the creation of a new movement evolving from organization policies, referred to as strategic management.

Also, in the last few years, as a result of economic changes organizations and their surroundings have undergone significant transformations. Changes in the functioning and surrounding environment of companies, banks and other economic institutions and organizations, undertaken in the course of the progressing economic transformation, resulted in the development of many new phenomena and processes, both in macro- and micro-regions of work management. These changes were related to the new role of national governments and also to the changing status of organizations. The greatest transformations took place in organization management systems, in human resources management systems, in the perception of work as a valuable asset, in employees', managers' and employers' attitudes [11].

Effective management of organizations became top priority in the period of economic crisis. The need arose to reconstruct the concept of organizational functioning towards the dynamically changing conditions of the surrounding environment [12]. Therefore, also strategic management underwent a dramatic revolution, which was reflected in many new concepts of management. New and more effective methods of organization management were being sought after, especially in terms of opportunities recognized within the organization and its surroundings. Employees' ingenuity and creativity began to be highly valued and human resources management became one of the priorities. It needs to be stressed that despite many changes which resulted from economic transformations the concept of strategic management was still associated with the definition of strategic goals which are based on detailed strategic analysis of the whole organization and its surroundings. It is top managers or even management board who are responsible for the preparation and implementation of an appropriate strategy of organization. It is assumed that most often it involves the basic issues, determining company competitiveness and development pace, directions and methods [13]. The issue of effective implementation of a strategy poses a great challenge both for management theorists and practitioners. New trends and concepts have appeared which define the methods of implementing changes in companies. They define the ways of pursuing goals or determine to the means of encouraging all organization members to proceed in the same direction [14]. The analysis of opportunities and threats of the company is a key element of a strategy. The overriding reason for opportunity exploration enabling company development is its strategic activity, which is based, on the creation of a new, innovative project [15]. It is possible because of redefinition the main key assumptions of organization businesses [16]. Some researches provides a new concept of reistic approach to work, which assumes the equivalence of all elements for the effects of work. The concept has been compared with existing methodological approaches to work and to the social-economic conception, which exclude the exclusiveness of human agent [17]. They argued that the economic efficiency perspective needs to be broadened with organizational dimensions of evaluation. They presented an evolution of economic criteria from the market-based to the organizational and resources-related and the common dimensions and relationships, including human capital [18]. It should be underlined that particular results of enterprises may assume various forms, such as: new inter-organizational ventures, innovations, changes at various levels within organization structure, more dynamic development of an organization, higher strategic value (new competitive advantage), new organization value (better method of activity organization), new social value (new attitude towards human factor), more competent participants within an organization, new products, markets, industries, technologies. It needs to be stressed that the key organization value is created thanks to the development of an organization and its participants. It has been noted that the organization has a significant influence on its resources, including human resources, which may be shaped and controlled. Adequately utilized resources of an organization potentially constitute its source of competitive advantage and the resource-based view is still very influential in strategic management [1].

There are several methods enabling organizational development. Among them, strategic games are gaining popularity as activities used for the improvement of effects of inter-organizational activities aimed at human resources development. Researchers have demonstrated the ability of simulation games to engage people in the learning process while also developing a range of key skills and attitudes [19].

3 Health as an Investment

Health of the employees can be perceived as a cost-effective investment, which was presented by Chapman [20] and discussed in the European Commission document entitled “Investing in Health” [21]. Healthy workforce is not only productive and efficient but also investing in the health of staff helps to retain them and enable to remain active longer. Longer occupational activity is important for employers who want to keep highly qualified staff and also for employees who need to be active longer these days because of the demographic situation in most highly developed countries. Therefore, what can be perceived as an improvement of the population’s health, can also be named an investment in one of the most important organization’s assets—human resources.

Shurcke [23] discusses the four main channels by which health of individuals can contribute to the economy in rich countries (see Fig. 2).

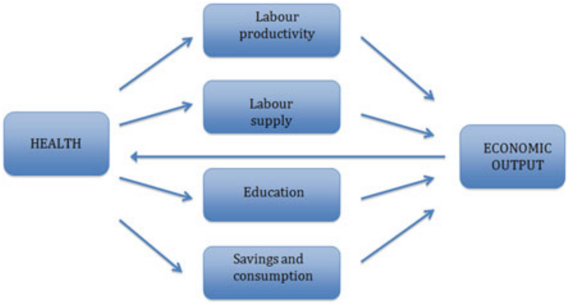

Fig. 2 Mechanisms linking health and economic input [22]

4 Systemic Approach to OHS Management in the Context of Health Promotion

Until mid-90s of the 20th century, organizations approached occupational health and safety only in a traditional manner, i.e. they only took actions necessary to comply with the legal requirements. Thereafter, organizations began to implement OHS management systems showing a systemic approach to occupational health and safety, which led to, among other things, an increasing interest in employees' health. The systemic approach was introduced in a different manner in different countries, by way of standardization, implementing new legislation or arrangements at the level of federal states (e.g. Lands in Germany).

The first countries to publish their own standards include:

- Great Britain—BS 8800 published in 1996 by British Standards Institution (BSI) [24];
- Australia and New Zealand—AS/NZS 4804:1997 "OHS Management Systems" developed by Australian and New Zealand Technical Committee [25];
- Holland—NPR 5001:1997 "Guide to OHS management systems" [26].

In Germany the guidelines for implementing OHS management systems are regulated by the individual Lands e.g. Hessia or Bavaria.

In order to unify the approach to the OHS systemic strategy, international normative documents were issued—Occupational Health and Safety Assessment Scheme (OHSAS)—regulating the requirements and guidelines for OHS management systems. Moreover, in 2001 the International Labour Organization (ILO) developed, on the basis of ILO Convention no. 155 and 161, the guidelines for OHS management systems ILO-OSH 2001. Polish organizations apply the PN-N-18001 standard which transposes the guidelines of the International Labour Organization to the national level [27].

Organizations applying an OHS management system show a higher level of safety culture, which, according to Obłój's concept of strategic resource, meets the three basic conditions:

- is of an aggregate nature;
- is characterised by heterogeneity;
- is used to the maximum as a material for natural processes in the organization and its environment.

The aggregate nature of the safety culture is shown by "collective programming of the mind", which means that it covers the whole phenomenon that constitutes something more than just a sum of its constituents [28]. The set of shared convictions makes the entity's organizational activities coherent and uniform.

The heterogeneity of the safety culture is a result of the internal complexity of the individual employees' safety cultures. Thus, both the safety culture as well as the organizational culture of a contemporary organization should be heterogeneous, which conditions its flexibility, easy adaptation to the requirements of the fast changing environment, and even getting ahead of changes in the environment [29].

The last condition pertains to applying the safety culture as a material for natural processes in the organization and the environment. The safety culture impact on the organization's internal processes consists in mitigating the occupational risk, helping to eliminate the internal uncertainty, ensuring internal integration. As a result of cooperation and collaboration of all the participants, some specified organizational solutions are adopted and they make it possible to implement the strategy in the organization. Behavioral standards observed within an organization are a significant factor that impacts the strategic behaviors and a factor that conditions the strategic program implementation effectiveness [30].

Health promotion among employees, being a strategic program, is an organization's activity under the OHS management system. Despite burdening the organization with the costs of health promotion, this activity results in benefits for the organization as well as for the individual employees and their families, as well as insurance companies.

In order to implement health promotion programs within an organization, it is necessary to engage the top management and to convince the employees to get involved in the program and care for their own health [31]. In the context of the society ageing and extending the retirement age, this is an indispensable condition for maintaining the occupational activity [32].

5 Workplace Health Promotion

Health promotion is presented in Ottawa Charter [33] as a process that helps individuals to control and improve their health. The process takes place in a "setting" which is perceived as a place where we live, work and play. Therefore, it is crucial to create health promoting setting at work, where we spend a significant part of our lives. The Health Promoting Workplace is a holistic settings-based approach that integrates healthy solutions in the workplace and creates conditions for workers that enable them to control and improve their health.

In the literature, workplace health promotion is defined in both traditional and contemporary manner. In the traditional context, workplace health promotion is understood as "a system of activities implemented for and in cooperation with the employees employed at the workplace, which potentially aim at enhancing and developing their health". The system is not imposed on the employer by legal regulations [34]. The contemporary and systemic approach, however, stipulates that workplace health promotion, according to the Luxembourg Declaration, is a strategy of supporting economic growth of organizations achieved via coordinated investments in enhancing health of their staff (see also Sect. 3).

Workplace health promotion refers to a wide range of factors, including [35]:

- principles and methods of management which stipulate that employees constitute an indispensable factor of the organization's success, rather than perceiving them only in terms of costs;
- corporate culture and corresponding leadership principles which include employee participation, increase motivation and a sense of responsibility for all the employees;
- principles of work organization which ensure that employees appropriately balance occupational requirements, and have a possibility to regulate their work, the skills level and social support;
- personnel policy which incorporates health promotion issues;
- integrated services regarding health protection and occupational safety.

The main aspect of workplace health promotion involves influencing the employees' healthy life style outside the workplace, also in the area of behaviors connected with working, which may have an impact on health and safety at the workplace.

Organizations that engage themselves in workplace health promotion activities develop programs that promote health at the workplace. In the literature, such programs are referred to as "the process of creating and implementing, possibly on multiple levels of the workplace organization (and its environment), a harmonized policy of material, organizational, cultural and mental transformations that enable and facilitate the individuals, groups and formal structures to diagnose and assess the health situation, negotiating and making decisions, initiatives and activities that have a positive effect on health, and stimulating, supporting and enhancing their activity aimed at health protection, enhancement and development, at the same time facilitating the achievement of fundamental values and goals of the organization" [36].

6 Workplace Health Interventions

Programs that turn a workplace into a health promoting setting aim at keeping employees healthy, detecting potential disorders or improving their quality of life.

The workplace interventions can be divided into those focused on promotion or prevention or both promotion and prevention (see Table 1), which are said to be the most effective by Matson-Koffman [37].

It is very important to see that health promoting interventions should include 2 types of measures: educational (knowledge and skills) and environmental (conditions to improve workers' health). As far as educational component is concerned, there are examples such as:

- promotional activities (films, seminars);
- raising awareness (posters, pamphlets, brochures, newsletters, games);
- health education on alcohol consumption, smoking, stress, weight control, nutrition;
- policy changes (smoking);
- feedback (cholesterol, glucose, blood pressure);
- counseling activities (smoking, weight control).

The environmental modification is usually connected with:

- inclusion of healthy food in a canteen;
- encouraging the use of stairs;
- labeling of products;
- changing the food choice in a cafeteria (low-fat foods, fruit and vegetables);
- changing the products in vending machines.

As Engbers et al. [38] pointed out, the effectiveness of the above listed incentives may differ, but it is crucial to combine the two components (education and conditions) to increase the positive effects of the programs.

Table 1 The workplace interventions

Health promotion	Health education and conditions that help to improve health	Investing in healthy behaviors	e.g. healthy diet and physical activity
Prevention of diseases	I LEVEL OF PREVENTION: Primary prevention	Measures to avoid the development of a disease	e.g. vaccinations, coping with stress
	II LEVEL OF PREVENTION: Secondary Prevention	Activities aimed at early disease detection, thereby increasing opportunities for interventions to prevent progression of the disease and emergence of symptoms	e.g. check-ups, cancer screening
	III LEVEL OF PREVENTION: Tertiary Prevention	Activities aimed at the reduction of the negative impact of an already established disease by restoring function and reducing complications	e.g. adjusting the workplace for the persons with disabilities

7 Health Promotion, Internet and Games

Workplace health promotion programs are most often implemented by way of training sessions where relevant contents are communicated using different means. Nowadays, a significant source of knowledge is the internet. As shown in the survey done by PBI, it is the internet that is most often consulted by internet users (88 % of them) when they need to find information on health, diseases and treatment methods. Only the second most popular source of information is doctors and other health care professionals (73 % responses).

As the public has increasing skills in using computers and the internet, it is reasonable to use this communication means for the purposes of workplace health promotion. In modern organizations, e-learning is becoming a standard due to:

- reduction of training costs as a result of eliminating conference room rental fees, travel and training time,
- possibility for the training to take place in convenient time within specified timelines,
- possibility to directly modify the training contents so that they are always up to date,
- easy administration of the training, possibility to monitor the training process and progress made by the participants, by way of detailed statistics.

However, the drawback of this kind of training is, first and foremost, the need to have efficient IT infrastructure; besides, e-learning participants tend to be less motivated compared to regular training sessions. The problems connected with the decreased involvement result from the lack of emotions and social bonds in the course of learning. This problem may be solved by strategic games which, compared to an e-learning course by itself, provide an opportunity to develop interpersonal relations and increase concentration. Even if we are losing, we grow fonder of the persons who are playing with us, sociologists suggest. Games let us acquire some skills through learning by playing, which means fun. Therefore, games are the tools that may stimulate participants to learn and to solve problems.

An interesting example of using a strategic game to cope with stress in case of getting trapped in a mine and to learn how to behave in case the mine roof collapses is *Harry's Hard Choices* developed in 2012 at the University of Arizona. The players, along with the said Harry, have only partial data at their disposal, and depending on the decisions taken, they implement the chosen scenario of the game. Due to playing *Harry's Hard Choices* employees:

- learn how to cope with stress in difficult situations;
- get familiar with correct procedures applicable in difficult situations;
- automate their choices in dangerous situations and learn how to make safe decisions.

Such strategic games enable employees to match theoretical knowledge with practical skills in similar to real-life environment. Moreover, similar games may be applied to teach correct behaviors that promote employees' health, first and foremost their mental health when exposed to stress conditions.

8 Conclusions

Effective management of organizations became top priority in times of austerity.

Strategic management is firmly established field in the study of business and organizations. Employees' ingenuity and creativity began to be highly valued and human resources management became one of the priorities. Health of the employees also started to be perceived as a cost-effective investment. In order to implement health promotion programs within an organization, it is necessary to engage the management and to convince the employees to get involved in the program and care for their own health. The key aspect of workplace health promotion is influencing the employees' healthy life style outside the workplace, also in the area of behaviors connected with work setting, which may have an influence on their health and safety at the workplace. The best workplace health promotion programs comprise two elements, which are: education (knowledge and skills) and conditions (infrastructure and environmental change) as presented in Sect. 6.

Games may be applied to teach correct behaviors that promote employees' health and verify individuals' knowledge on health and what is most important help to develop skills that can be applied when needed.

References

1. Polowczyk, J.: Strategic management at the beginning of the XXI century: the impact of crisis turbulences. In: Poznań Univ. Econ. Rev. **12** (3), 81–98. University of Economic, Poznań (2012)
2. Matyja, M.: Ekonomika organizacji przemysłowej zarządzaniu strategicznym. Acta Universitati, Ludzienisi, Folia oeconomica, Łódź (2011)
3. Obłój, K.: Strategia organizacji. PWE, Warszawa (1998)
4. Chandler, A.D.: Strategy and Structure. MIT Press, Cambridge (1962)
5. Ansoff, H.I.: Zarządzanie strategiczne. PWE, Warszawa (1985)
6. Learned, E.P., Christensen, C.R., Andrews, K.R., Guth, W.D.: Business Policy: Text and Cases, Richard D. Irwin. Homew. J. Manag. 2 (1965)
7. Murawska, M.: Zarządzanie strategiczne niematerialnymi zasobami przedsiębiorstwa. Fundacja Promocji i Akredytacji Kierunków Ekonomicznych, Warszawa (2008)
8. Moszkowicz, M.: Strategia przedsiębiorstwa okresu przemian. PWE, Warszawa (2000)
9. Gołębiewski, T.: Zarządzanie strategiczne. Planowanie i kontrola, Difin, Warszawa (2001)
10. Mintzberg H.: The fall and rise of strategic planning. Harv. Bus. Rev. (1994)
11. Jarmołowicz, W., Woźniak-Jęchorek, B.: Przebudowa instytucjonalna polskiej gospodarki. In: Jarmołowicz W. Szarzec K. (eds.), Liberalne przesłanki polskiej transformacji gospodarczej, PWE, Warszawa (2011)

12. Galata, S.: Strategiczne zarządzanie organizacjami. Wiedza, intuicja, strategie, etyka, Wydawnictwo Difin, Warszawa (2004)
13. Pierścionek, Z.: Strategie konkurencji i rozwoju przedsiębiorstw. Wydawnictwo naukowe PWN, Warszawa (2006)
14. Trocki, M., Sońta-Drączkowska, E.: Strategiczne zarządzanie projektami. Wyd. Bizarre, Warszawa (2009)
15. Low, M.B., MacMillan, I.C.: Entrepreneurship: past research and future challenges (1988)
16. Guth, W.D., Ginsberg, A.: Guest editor's introduction: corporate entrepreneurship. Strateg. Manag. J. **4**, 5–16 (1990)
17. Rymaniak, J.: Work in organization: key factors of the reistic approach. In: Vink, P. (ed.) Advances in Social and Organizational Factors, pp. 567–572. CRC Press, Taylor & Francis Group, Roca Baton, FL (2012)
18. Rymaniak, J.: Capability, Profit or Waste? Organizational-economic dilemmas criteria for measuring the effectiveness of enterprise. In: Trzcieliński, S., Karwowski, W. (eds.), Advances in the Ergonomics in Manufacturing: Managing the Enterprise of the Future, Published by AHFE Conference @ Jagiellonian University, Kraków, pp. 203–213 (2014)
19. Brennan, R., Vos, L.: Effects of participation in a simulation game on marketing students' numeracy and financial skills. J. Market. Edu. **35**(3), 259–270 (2013)
20. Chapman, L.S.: Meta-evaluation of worksite health promotion economic return studies: 2005 update. Am. J. Health Promot. **19**(6), 1–11 (2005)
21. Investing in Health, Commission Staff Working Document, Social Investment Package, Brussels (2013)
22. Bloom, D.E., Canning, D.: The health and the wealth of nations. Science **26**, 599–622 (2000)
23. Suhrcke, M., McKee, M., Stuckler, D., Sauto Arce, R., Tsolova, S., Mortensen, J.: The contribution of health to the economy in the European Union. Public Health **120**(11), 994–1001 (2006)
24. BS 8800 Guide to occupational health and safety management systems (1996)
25. AS/NZS 4804 Occupational health and safety management systems—general guidelines on principles, systems and supporting techniques (1997)
26. NPR 5001 Guide to occupational health and safety management systems. Technical Report. Nederlands Normalisatie-institut, September (1997)
27. Górny A.: The work environment in the structure of management system. In: Car Z., Kudláček J., Szalay T. (eds.) Proceedings of International Conference on Innovative Technologies, IN-TECH 2013, pp. 217–220, Faculty of Engineering University of Rijeka, Rijeka (2013)
28. Hofstede, G.: Kultury i Organizacje. Zaprogramowanie umysłu, PWE, Warszawa (2000)
29. Pierzchawka, S.: Kultura elastycznej organizacji, In: Zarządzanie przedsiębiorstwem w turbulentnym otoczeniu. Ku superelastycznej organizacji, Krupski R. (ed), PWE, Warszawa, pp. 270–272 (2005)
30. Stańda, A.: Kultura organizacyjna w perspektywie strategicznej, In: Zeszyty Naukowe Nr 33, Współczesne tendencje w zarządzaniu, Zimniewicz K. (ed), Wydawnictwo AE w Poznaniu, Poznań, pp. 89–99 (2003)
31. Geller, E.S.: The psychology of safety. Chilton Book Company Randor, Pennsylvania (1996)
32. Lis, K.: The labour market and material environment design. In: Vink, P. (ed.) Advances in Social and Organizational Factors, pp. 603–612. CRC Press Taylor & Francis Group, Boca Raton (2012)
33. WHO/HPR/HEP/95.1.: Ottawa charter for health promotion. In: First International Conference on Health Promotion. Ottawa (1986)
34. Gniazdowski, A.: Promocja zdrowia w miejscu pracy. Teoria i zagadnienia praktyczne, Instytut Medycyny Pracy, Łódź (1997)
35. Wojtaszczyk, P.: Promocja zdrowia w miejscu pracy w koncepcji społecznej odpowiedzialności biznesu (CSR). Med. Pr. **59**(3), 255–261 (2008)
36. Puchalski K.: Aktywność dużych zakładów pracy w Polsce w dziedzinie promocji zdrowia, In: Postępy w profilaktyce i leczeniu przewlekłych chorób niezakaźnych. Part 2. Materials from IV CINDI Seminar. Spała, 28–29 X. 1999. Łódź, pp. 203-209 (2000)

37. Matson-Koffman, D.M., Goetzel, R.Z., Anwuri, V.V., Shore, K.K., Orenstein, D., LaPier, T.: Heart healthy and stroke free: successful business strategies to prevent cardiovascular disease. Am. J. Prev. Med. **29**(5 Suppl 1), 113–121 (2005)
38. Engbers, L.H., van Poppel, M.N., Chin, A., Paw, M.J., van Mechelen, W.: Worksite health promotion programs with environmental changes: a systematic review. Am. J. Prev. Med. **29** (1), 61–70 (2005)

Cytotoxic Drug Manipulation and Its Impact on Occupational Safety of Hospital Workers

João Silva, Pedro M. Arezes, Rudolf Schierl and Nélson Costa

Abstract In order to study environmental contamination by cytostatic drugs in a Portuguese hospital two wipe sampling campaigns were conducted in 2010 (12 samples) and 2015 (44 samples). Platinum containing drugs and fluorouracil were chosen because both were administered in high amounts. The detection limit was 0.01 pg/cm^2 for platinum and 0.1 pg/cm^2 for fluorouracil. The detected contamination on specific locations in the pharmacy and in the day hospital was higher in 2010. More detailed sampling in 2015 confirmed that optimization of working procedures and introduction of closed transfer system resulted in lower contamination by platinum drugs and fluorouracil. But there is still a need for continuing those processes.

Keywords Occupational safety · Hospitals · Cytostatic agents · Hospital workers · Environmental contamination

1 Introduction

Improving working conditions has been the object of study of many experts in various fields. In hospitals, occupational environment is a concerning for factor risk management, not to ensure the fulfilment of all legal obligations but also because health care professionals, who manipulate cytostatic agents, are exposed to chemical risks that can contribute to their health deterioration, due to everyday contact and exposure time [1].

Cytostatic agents are substances capable of inhibiting or preventing neoplastic cell evolution, reducing malignant cells proliferation and acting on specific stages

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of cellular cycle, particularly on those involved in cell division processes. They feature distinct physical–chemical tasks and act through very different means [2].

Health care professionals who manipulate cytostatic agents may be exposed to chemical risk through several routes, among which stand out the following [3]: Inhalation, cutaneous route, ingestion and accidental injection. Contaminations by these products can be taken up and may generate genotoxic effects. However, due to the implementing of current safety regulations, there have been records of improvements in various countries [4]. This improvement occurred after NIOSH had proposed risk control measures for professionals who manipulate cytostatic agents [5].

Platinum and 5-fluorouracil are the selected for the study, due to their broad application in various neoplasia types, being used to treat many of the most frequent cancers. They can be used in combination with other anticancerogenic medicines [6, 7].

This is a topic which is not very much considered in Portugal, probably due to the inexistence of quantifying laboratory equipment and absence of a specific legal context for the problem that is contamination risk by contact with cytostatic agents. Thus, it is pertinent to study the real impact caused on the occupational environment in Portuguese hospital units where cytostatic agents are regularly manipulated, since the present bibliography consists on exposures in international hospital units and points out various risk situations, mainly in places of cytostatic agents manipulation/preparation and administration (hospital pharmacies and ambulatory care) [8–11].

The number of new cancer cases are increasing every day, and therefore also the number of patients and preparations [12], which is reflected on a greater need for hospitals preparing and administering cytostatic agents and subsequently, involving a larger number of employees. The importance for the professionals' health in these types of services, associated to the fact of the present study having been performed on a single health unit [1], adds relevance to this subject.

2 Methods

Performing this research implied a set of previous actions for its achievement. Thus, written contact was established with the hospital unit's administration in the sense of obtaining authorization for developing the project in its facilities. After receiving affirmative reply, the process of contacting headship and for meeting scheduling with collaborators was carried out. These meetings took place with the headship and employees of the intervening services, i.e., hospital pharmacy, day hospital and control group, for presenting the research project to be carried out and their involvement level. The project was disseminated to collaborators by headship through an institutional email message.

2.1 Observing and Procedures Recording

The project's presentation was followed afterwards by the performing at the hospital pharmacy and day hospital of four observation sessions of procedures and practices, their respective recording and procedures guidelines consultation at the health unit. The first session was aimed at observing procedures and equipment at the hospital pharmacy and day hospital in medical oncology. The second session was aimed at recording procedures and practices in different functions. The third observation session consisted on concluding the procedures and practices recording in different functions. Lastly, the fourth observation served in verifying workplaces in loco to thereby determine sampling points in hospital pharmacies and oncological medicine hospitals.

2.2 Sample Collection Technique

Samples were collected at the hospital pharmacy and day hospital in medical oncology from the hospital unit located in northern Portugal region.

The applied technique for sample collection was the "*wipe sampling*" technique method, used by [8] in studies developed for 5-fluorouracil (5FU) and platinum (Pt) purposes.

"*Wipe sampling*" was applied in this research at the selected hospital B. Sampling purposes and places were determined in accordance with the risk management official. Among the several places, it was defined a set of these at the hospital pharmacy and oncological medicine day hospital (Table 1).

The basis for choosing these sampling spots was the fact of them being susceptible to a high chemical contamination, [13], leaving these organisations' health care professionals exposed to risk and eventual damage.

The research of platinum (Pt) surface contaminations as a marker for platinum-drugs (Cis-, Carbo-, Oxaliplatin) was carried out using paper filters and sample containers along with hydrogen chloride (HCl) in suited percentage of 0,1% as moistening agent, which is included in the "wipe-kit". The same procedure was used for investigations of 5-fluorouracil surface contaminating area, except with methanol (MeOH) as moistening agent.

After the sample collection, they were properly sealed, equipped with cool bags and sent to the "*Institute for Occupational and Environmental Medicine*", University Hospital of Munich for analysing the contamination level at the hospital pharmacy and day hospital in medical oncology of Hospital Unit B, located in Northern Portugal region. Using this technique implies a good logistical planning, to the extent that time between collecting and reaching the laboratory cannot exceed 48 h.

Table 1 Hospital B sampling places

Place reference	Section	Specific place or equipment	Wipe characteristics
1	Hospital Pharmacy	Laminar flow hood (inside with gutter)	$30 \times 20\ cm^2$
2	Hospital Pharmacy	Floor in front of LFH	$(40 \times 40)\ cm^2$
3	Hospital Pharmacy	Transfer chamber	$(20 \times 20)\ cm^2$
4	Hospital Pharmacy	3 stainless trays	$(30 \times 30)\ cm^2$
5	Hospital Pharmacy	Reception table	$(20 \times 20)\ cm^2$
6	Hospital Pharmacy	Packing table	$(20 \times 20)\ cm^2$
7	Hospital Pharmacy	Transport bag	$(30 \times 30)\ cm^2 +$ $(70 \times 23) \times 2\ cm^2$
8	Hospital Pharmacy	Waste trolley bin	$(28 \times 28) \times 2\ cm^2 +$ $(128 \times 4)\ cm^2$
9	Hospital Pharmacy	Storage location (Carbo/Platinum/5-FU)	$(30 \times 20)\ cm^2$
10	Hospital Pharmacy	Computers Area	$(20 \times 20)\ cm^2$
11	Hospital Pharmacy	Floor next to computers	$(30 \times 30)\ cm^2$
12	Hospital Pharmacy	Laminar flow hood–inside–T=Ø	$(30 \times 20)\ cm^2$
13	Hospital Pharmacy	Laminar flow hood–inside–T=finish	$(30 \times 20)\ cm^2$
14	Hospital Pharmacy	Storage	$(30 \times 20)\ cm^2$
15	Day Hospital	Reception table	$30 \times 20\ cm^2$
16	Day Hospital	Stainless steel tablet	$(30 \times 30)\ cm^2$
17	Day Hospital	Transport cart	$(30 \times 30)\ cm^2$
18	Day Hospital	Waste trolley bin	$(28 \times 28) \times 2\ cm^2 +$ $(128 \times 4)\ cm^2$
19	Day Hospital	Support treatments	$(11 \times 13) \times 2\ cm^2 +$ $(30 \times 20)\ cm^2$
20	Day Hospital	Armchair	$(42 \times 7) \times 2\ cm^2 +$ $(30 \times 30)\ cm^2$
21	Day Hospital	Bathroom door handle (outside)	$(15 \times 30)\ cm^2$
22	Day Hospital	Bathroom floor	$(20 \times 20)\ cm^2$

3 Results and Discussion

Samples from 2010 were collected from six points for platinum and 5-fluorouracil, whereas samples from 2015 were collected from 22 points for each of the drugs. Thus, there is a difference in the number of sampling points between the second and the first collection, although two points of the first collection (laminar flow hood support table and patient support table) were not sampled in the second collection since they were inexistent within the current work context. The results of the samples collected in March 2010 and September 2015 at the hospital pharmacy are shown in Table 2 for both drugs being studied.

The results of the samples collected in March 2010 and September 2015 at the day hospital are shown in Table 3 for both drugs being studied.

The TLV proposed by [8] were derived on a statistical basis from a large dataset. Values below TLV-1 (Pt: 0.6 pg/cm^2, 5-FU: 5.0 pg/cm^2) got a "green" traffic light, which means they are in a normal range. Values above TLV-2 (Pt: 4.0 pg/cm^2, 5-FU: 30.0 pg/cm^2) got a "red" traffic light, which means they are too high and there is a need for action. Values between TLV-1 and TLV-2 got a "yellow" traffic light and are suspicious. The sampling results from the year 2010 with many "red" values confirmed the intervention priority at the workplace. Thus, for platinum (Pt), there are four critical points (**) and important to know: inside the laminar flow hood (LFH), floor in front of the laminar flow hood, transfer chamber and patient support table.

Table 2 Platinum and 5-Fluorouracil (5-FU) contamination in Hospital B Pharmacy according to threshold limit values (TLV) as defined by [8]

Cytostatic drug	2010		2015	
	Platinum	5-FU	Platinum	5-FU
Location of sampling	pg/cm^2	pg/cm^2	pg/cm^2	pg/cm^2
Laminar flow hood, inside	292.5	4375.0	0.1	14.2
Laminar flow hood support table	4.0*	5.0		
Laminar flow hood–inside–T=Ø			0.3	4.5
Laminar flow hood–inside–T=finish			0.3	179.3**
Floor in front of LFH (left side)	1457.5**	193.0**	0.2	10.1*
Transfer chamber (left side)	13**	199.3**	0.2	17.0*
3 stainless trays (30 × 30) cm^2			3.0*	12.0*
Reception table (left side)			0.5	3.8
Packing table (left side)			0.3	0.8
Transport bag (30 × 30) cm^2			0.0	1.1
Waste trolley bin			0.0	1.7
Storage location (platinum/5-FU)			0.8*	48.7**
Computers Area			0.1	1.0
Floor next to computers (30 × 30) cm^2			0.1	nn

* >TLV-1, ** >TLV-2; nn < 0,1 ng FU/sample

Table 3 Platinum and 5-Fluorouracil (5-FU) contamination in Day Hospital B according to threshold limit values (TLV) as defined by [8]

Cytostatic drug	2010		2015	
	Platinum	5-FU	Platinum	5-FU
Location of sampling	pg/cm^2	pg/cm^2	pg/cm^2	pg/cm^2
Reception Table (30 × 20) cm^2	3.5*	8.0*	0.1	nn
Patient table	15.8**	10.3*		
Stainless steel tablet (30 × 30) cm^2			0.1	nn
Transport cart (30 × 30) cm^2			0.2	0.8
Waste trolley bin (28 × 28) × 2 cm^2			0	3.1
Support treatments			38.5**	162.2**
Armchair			1.9*	9.4*
Bathroom door handle			7.3**	6.2*
Bathroom floor (left)			750**	146.8**
Storage (30 × 20) cm^2			0.1	nn

* >TLV-1, ** >TLV-2. nn <0,1 ng FU/sample

The remaining points (LFH support table and administration room work desk), are less critical (*), nonetheless, they should also be intervened since they exceed admissible values.

Also 5-fluorouracil FU shows three critical points which are inside the laminar flow hood (LFH), floor in front of the laminar flow hood and transfer chamber.

It should be noted that the existence of two less critical points (administration room work desk and patient support table should also be intervened, since there were detected values higher than admissible ones.

In the study performed in 2015 for platinum at the hospital pharmacy there are two observed places with one star (stainless trays and carbo/platinum shelves). The day hospital in oncology shows three critical places marked by two stars (bathroom floor, bathroom door inside handle and treatment support) and one place marked by a single star (armchair). These places require priority intervention in a sequential manner from two to one star.

5-fluorouracil analysis shows a larger number of places with concentrations in need of intervention since they exceed admissible values. Thus, at the hospital pharmacy there are two critical places marked by two stars (shelves and laminar flow hood, after performing of functions) and four places marked by one star (laminar flow hood with gutter, floor in front of laminar flow hood, transfer chamber and stainless trays). At the day hospital in medical oncology there are two places marked by two stars (treatment support and bathroom floor) and two places marked by one star (armchair and bathroom door outside handle).

Comparing results from the 2015 study with the ones from the 2010 study, we verify that regarding platinum (Pt), all common places were not marked, whereas the 5-fluorouracil (FU) results were marked by one star. It is important to note that the results gathered from the 2015 study show much lower concentrations when compared with the previous study, whether in the hospital pharmacy or in the day hospital in medical oncology. These values should be associated to various factors among which stand out the following:

Improve procedures in the hospital pharmacy and day hospital in medical oncology, such as using protection equipment and using drug transferring closed system apparatus and centralised preparation.

There have also occurred changes at the physical facilities, especially because it is new, as well as all equipment installed in the preparation room and at the day hospital in medical oncology.

At the hospital pharmacy, there have occurred changes at the preparation professional's level, with the replacing of nurses by pharmacists and pharmacy technicians.

In the day hospital in medical oncology there have also been changes with the use of the drug transferring closed system apparatus [14, 15] and the fact that nursing staff who participated in the 2010 study continue performing their duties in 2015, reveals that they are professionals with experience in manipulating cytostatic agents [12], which can significantly reduce the probability of occurring errors.

4 Conclusion

The problem focus is due to the fact that for the first time in Portugal there have been two studies performed in the same hospital unit, allowing for a comparison. The first study was performed in May 2010 and the second one was performed in September 2015. Comparing both studies resulted in significant improvements in reducing cytostatic agents' contamination, preparation and administration.

Thus, these values should be associated with procedures improvement, greater awareness for this problem and changes made in hospital pharmacy by replacing nursing staff with pharmacists and pharmacy technicians. For the nursing stuff at the day hospital in medical oncology which uses the drug transferring closed system apparatus, it is revealed that they are professionals with experience in manipulating cytostatic agents, as they participated in the 2010 study, as well as in the 2015 study.

However, there are still high concentrations for 5-FU and platinum on the hospital pharmacy's shelves and in treatment support, bathroom door handles and bathroom floor of the oncological medicine day hospital.

As intervention measures to reduce these concentrations, there must be a change of gloves for contacting with the hospital pharmacy's shelves. In the same manner, the cleaning of door handles and bathroom floors at the oncological medicine day hospital must be performed with greater frequency. In treatment support, the use of gloves must be mandatory as well as their frequent exchange.

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References

1. Silva, J.: Manipulação de citostáticos num hospital: estudo do impacto sobre a contaminação do ambiente ocupacional. Master thesis, Minho University (2011)
2. MSC, Ministério de Sanidad Y Consumo: Protocolo de Vigilância Sanitária Especifica para los trabajadores expuestos a Agentes Citostáticos. Page 14, Madrid (2003)
3. Polovich, M.: Developing a hazardous drug safe-handling program. Commun. Oncol. **2** (2005)
4. Suspiro, A., Prista, J.: Exposição ocupacional a citostáticos e efeitos sobre a saúde. Revista Portuguesa de Saude Publica **30**(1), 76–88 (2012)
5. NIOSH, National Institute for Occupational Safety and Health: Preventing occupational exposures to antineoplastic and other hazardous drugs in health care settings (2004)
6. Sessink, P.J.M., Bos, R.P.: Drugs hazardous to healthcare workers. Evaluation of methods for monitoring occupational exposure to cytostatic drugs. Drug Saf. **20**(4), 347–359 (1999)
7. Infarmed, Medicamentos antineoplásicos e imunomoduladores. http://www.infarmed.pt/formulario/navegacao.php?paiid=266. Last accessed 2014/04/18 (2014)
8. Schierl, R., Böhlandt, A., Nowak, D.: Guidance values for surface monitoring of antineoplastic drugs in german pharmacies. Ann. Occup. Hyg. **53**(7), 703–711 (2009)
9. Kopjar, N. Garaj-Vrhovac, V. Kasuba, V. Rozgaj, R. Ramic, S. Pavlica, V. Zeljezic, D.: Assessment of genotoxic risk in Croation health care workers occupationally exposed to cytotoxic drugs: a multi-biomaker approach. ScienceDirect revista, 414–431 (2009)
10. Bouraoui, S. Brahem, A. Tabka, F. Mrizek, N. Saad, A. Elghezal, H.: Assessment of chromosomal aberrations, micronuclei and proliferation rate índex in peripheral lyphocytes from Tunisian nurses handling cytotoxic drugs. ScienceDirect revista, 250–257 (2011)
11. Kopp, B., Schierl, R., Nowak, D.: Evaluation of working practices and surface contamination with antineoplastic drugs in outpatient oncology health care settings. Int. Arch. Occup. Environ. Health **86**(1), 47–55 (2013)
12. Connor, T.H., McDiarmid, M.A.: Preventing occupational exposures to antineoplastic drugs in health care settings. CA Cancer J. Clin. **56**(6), 354–365 (2006)
13. Brouwers, E.E.M., Huitema, A.D.R., Bakker, E.N., Douma, J.W., Schimmel, K.J.M., van Weringh, G., Beijnen, J.H.: Monitoring of platinum surface contamination in seven Dutch hospital pharmacies using inductively coupled plasma mass spectrometry. Int. Arch. Occup. Environ. Health **80**(8), 689–699 (2007)
14. Nygren, O., Gustavsson, B., Ström, L., Eriksson, R., Jarneborn, L., Friberg, A.: Exposure to anti-cancer drugs during preparation and administration. Investigations of an open and a closed system. J. Environ. Monit. JEM **4**(5), 739–742 (2002)
15. Clark, B.A, & Sessink, P.J.: Use of a closed system drug-transfer device eliminates surface contamination with antineoplastic agents. J. Oncol. Pharm. Pract. **19**(2), 99–104 (2013)