

ADDRESSING HUMAN VARIABILITY AND WORK PERFORMANCE THROUGH AN INCLUSIVE DESIGN METHOD

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ABSTRACT

Humans are vital in meeting production requirements in manufacturing systems, but performance is strongly influenced by factors including experience, age, skill, physical and cognitive abilities and attitudes towards work. Typical manufacturing system design processes do not adequately account for these variability issues and an 'inclusive design' approach is proposed to address the problem. The diversity of the global workforce is described and the importance of older workers as an increasingly larger proportion of the workforce is emphasised. The decline in physical capabilities of older workers creates a mismatch between job demands and working capabilities, and this is described in the context of assembly. An inclusive design approach based on the HADRIAN digital human modeling approach is proposed to offer a more productive, safe and healthy working environment. It is suggested that healthy and safe working conditions give benefits in terms of workforce satisfaction, reduced turnover, higher productivity and improved quality.

Keywords: Human variability, work performance, inclusive design.

1 INTRODUCTION

Organizations are continuously struggling to improve their products, methods, work practices and procedures. In spite of highly automated manufacturing systems, the importance of humans cannot be ignored as a key resource. These days, like many others, a manufacturing organization's workforce is becoming more diverse in terms of age, gender, skill and cultural background. All these factors potentially lead to inconsistencies in manufacturing system performance. Ignoring these human variability issues during the manufacturing system design process eventually leads to the setting of unrealistic and overestimated production capacities of manufacturing systems. There is a need to understand all possible factors that might cause a variation in human performance and how designers can accommodate human variability issues so that more reliable, safe and consistent manufacturing systems might be assured.

2 WORKFORCE DIVERSITY

Diversity refers to differences between individuals because of their gender, age, functional capability, cultural background, experience and education (Williams, 1998). Workforce diversity comes with a number of potential benefits and challenges as it increases work performance inconsistencies because of human variability issues. Effective diversity management can provide an opportunity for better work perfor-

mance by utilizing more diverse ideas in decision making. However, failure to manage a diverse workforce may lead to an environment of conflicts, frustration and sense of insecurity that can promote absenteeism, high turnover, job dissatisfaction and lower work commitment (Richard, 2000, Shore, 2009). So, it becomes very important to understand relationships between different dimensions of diversity and their potential impact on work performance of individuals and organizations. Moreover, diversity management demands the implementation of working methods and strategies that might promote positive and prevent negative outcomes.

3 HUMAN VARIABILITY AND WORK ORGANIZATION

Humans are different in a number of ways because of their differences in genetics, body shapes, sizes, physical abilities, motor skills etc. These variations significantly influence the capability to perform tasks. Frequently this important factor of human variability and its relationship with work performance is not considered during the planning phase of any system design process. There is a need to conceptualize these potential variations and consider them during a work organization process. Work organization is defined as the way work is structured, distributed, processed and supervised (Carayon, 2000). According to the National Institute of Occupational Safety and Health (2000), work organization deals with subjects like scheduling, job design, interpersonal issues, career concerns, management style and organizational characteristics. It is simply clear that all these methods, issues and strategies are directly influenced by human variability. For example, the job design process considers a variety of aspects like task complexity, level of skill and effort required, and degree of control. Furthermore, human variability has a direct link with all these aspects because they are reflected in changes in working strategies adopted by different workers. A change in working strategy raises human variability issues. In a similar fashion, all other domains of work organization are directly linked with human variability and create many challenges for designers, engineers and ergonomists. There is a need to recommend such working procedures, methods or strategies that might minimize the effects of human variability

4 AGEING AND WORK PERFORMANCE

It is evident from the literature that the world is experiencing a significant increase in the proportion of the population that is older. United Nations statistics (Figure 1) show that there were about 759 million people aged 60 or above in 2010, and it is further projected that this figure will increase to 2 billion by 2050. Moreover, this trend is more prominent in the developing world (U.N.O., 2009).

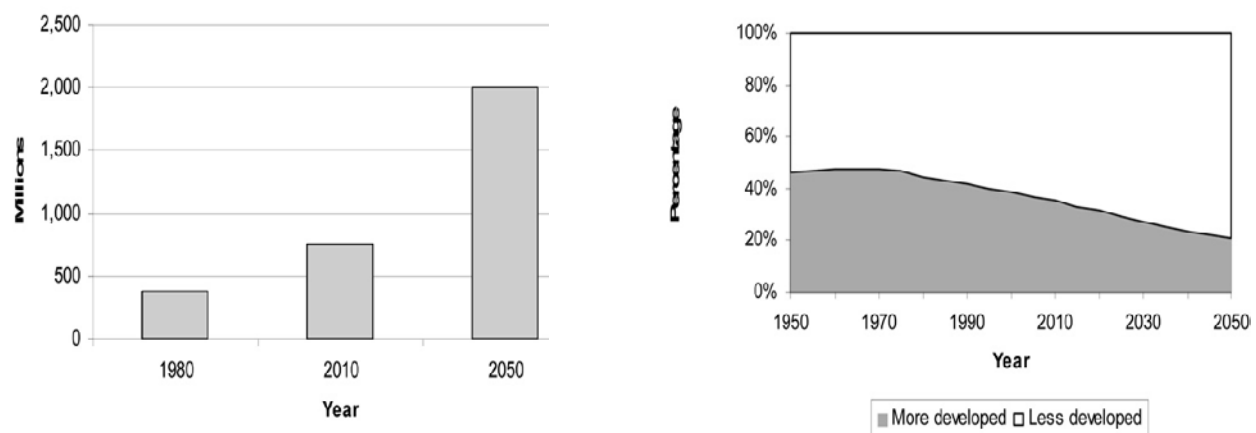


Figure 1: World population aged 60 and over: 1980, 2010, and 2050 (left) and increasing proportion of over 60s in the less developed world (right) (U.N.O., 2009)

The above demographics clearly identify the need for the effective utilization of this valuable human capital. The current global economic crisis also attracts the attention for accommodating and holding older

and experienced workers for a longer time, so that this resource might be utilized for national and global economic growth. However, retention of older workers gives rise to potential benefits and challenges for the organizations. Experience, knowledge and skills of older workers are considered prominent factors that attract positive inclination of employers and older workers are considered as an asset for the organization. However, decline in their physical and physiological capabilities generate many challenges. For example, functional capability mainly depends on muscular strength of the body and this starts declining after the age of 30. Muscular strength of a 60 year-old person is approximately 70% of that of a 30 year-old (Wanger, 1994). Flexibility also decreases with age and is closely linked with balance disorders which leads to a decline in work performance in sitting, standing, moving and leaning positions. Moreover, investigations show that age adversely affects joint mobility and this decline directly influences work performance as most manual activities require fast, accurate and repetitive movements of different parts of the body (Chung, 2009, Sturnieks, 2008, Chiacchiero, 2010). Similarly, more reaction time variability has been found in older people as compared with younger ones, and this directly influences work performance. However, decline in reaction time is more prominent in older women as compared with older men. Aerobic capacity is affected by age, and comprehensive physiological investigations are recommended before assigning any task to an older person. However, physically active older workers are better able to manage physically demanding tasks, as compared with the less active. (McArdle, 2001, Ilmarinen, 1980, Astrand, 2003). These, and similar, facts significantly increase design complexity when designers try to design workplaces, products and processes that are equally viable for older population as they are for the younger. (Hultsch, 2002, Der, 2006).

The above discussion reveals the need for understanding the effects of ageing and the potential impact on work performance. A realistic understanding of both positives and negatives about older workers can provide an opportunity for designers to address design needs of this part of the workforce. Otherwise, unrealistic and over ambitious production targets create a mismatch between job demands and working capabilities of older workers. Such situations can ultimately result in an unsatisfied, over stressed, frustrated and less loyal workforce that results in a decrease in individual and organizational work performance.

5 INCLUSIVE DESIGN METHOD

The inclusive design method aims to address the design needs of a broader range of the population where an effort is made to understand existing differences among humans because of their age, gender, size, shape and working capabilities. However, 100 percent design inclusion is not possible as human variability results in a number of challenges, where it becomes difficult for designers, engineers and ergonomists to accommodate all varying design needs into a single design solution. Nevertheless, the inclusive design methodology significantly contributes in the promotion of such design scenarios that are equally viable for a broad range of the population.

Previously, an inclusive design tool called HADRIAN was developed to check design inclusiveness of any proposed design at an early design stage. It is based on the SAMMIE digital human modelling system, where a database of 100 people of different age groups, sizes, shapes and level of disability, is used for the assessment of any proposed design (Marshall, 2010). It contains physical and behavioural data of individuals and presents this graphically so that designers can access and understand all available information (Figure 2). A key feature of this database is the definition of basic task elements of an activity and an automated evaluation process that provides information on what percentage of the population is excluded. Interestingly, it also provides an opportunity to explore why an individual is unable to perform a task successfully, and the individual's background dataset displays capability information of that particular individual so the designer can easily understand how to accommodate an excluded individual. In this way, HADRIAN not only displays information about who is excluded but also indicates how to modify and re-design so that the workplace can be used for a broad range of population. HADRIAN has previously been used primarily in transport and domestic environments and more recently attention has been given to the use of this inclusive design methodology for industrial applications like manufacturing assembly activities. The next section describes how this method is being developed and used to address the design

needs of a diversified industrial workforce where human variability issues might be understood and addressed at some pre-design stage.

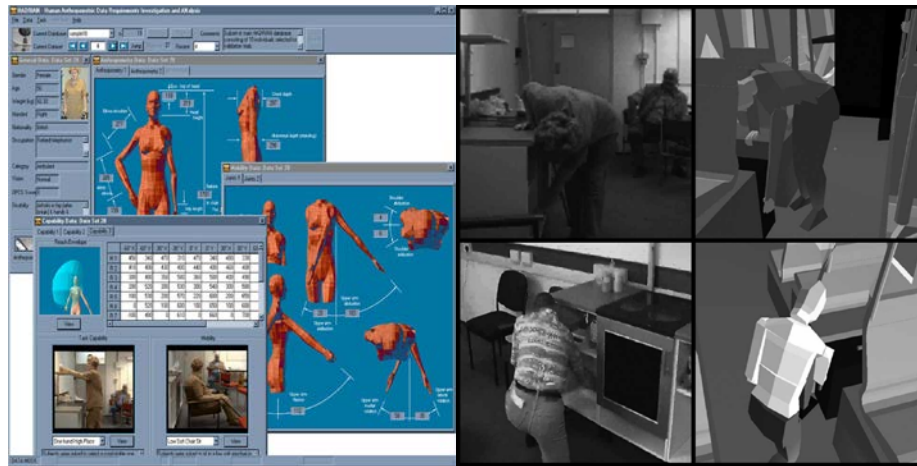


Figure 2: Screen short of a part of the HADRAIN (left) and task driven evaluation (right)

6 MANUFACTURING ASSEMBLY ACTIVITIES

In spite of highly automated manufacturing systems, a considerable proportion of manufacturing assembly activities are carried out manually. Today's highly competitive markets demand an optimal use of human capital so that organizations can carry on their business and manufacturing organizations strive to achieve their maximum in terms of product quality and productivity. On the other hand, assembly activities are mainly accomplished manually where a skillful and dedicated workforce becomes essential for meeting these objectives. As mentioned earlier, human variability creates a number of issues that affect human work performance. Frequently, designers and planners do not consider human variability issues during the design process and later on this can cause serious problems related to quality, productivity, safety and reliability. There is a need to understand naturally existing human variations and their potential impact on work performance. The HADRIAN inclusive design method is considered helpful as it aims to use realistic data about individuals' working capabilities, behaviours and strategies for the assessment of any product, process, service or workstation design. For example, evidence suggests that joint range of motion decreases with an increase in age. Most manufacturing assembly activities consist of task elements where joint mobility requirements play an important role for successful completion of the overall task. It might be possible that any working strategy adopted by an individual is not suitable for an older worker because of joint mobility constraints. So, it becomes very important to understand differences in strategies adopted by a number of workers and to select an optimal strategy in terms of physical load, repetitiveness, postural comfort and work safety. In this way, the inclusive design HADRIAN methodology might be used to evaluate different working strategies so as to select the best one that might be equally useful for a broad range of workers in spite of all existing differences. Designers can expect useful recommendations that can promote less harmful and more productive working strategies equally acceptable for a broad range of workers. This can also lead to some better and more realistic standardization processes for manufacturing assembly activities.



7 OBSERVATIONS AND ANALYSIS

A furniture manufacturing company was selected for the purpose of validation and implementation of this proposed 'inclusive design' strategy. For the purpose of understanding differences in adopted working

strategies, a team of 12 workers was selected who belonged to different age groups and had varying levels of skill and experience. The subjects were observed and video recorded multiple carrying out sets of similar manual assembly activities. It was clearly found that there were significant variations in working procedures and strategies that directly or indirectly affected individual and organizational work performance. For example, it was observed that there were some strategies or procedures where object and tool handling is significantly more time consuming and physically demanding as compared to others, for the same task element. Ergonomic risk assessment of such adopted strategies indicated a straightforward need for immediate corrective actions. On the other hand, other workers were found to perform the same task elements in an entirely different ways, which were time efficient and involved less risk exposure. Figure 3 shows three workers performing the same task element in three different ways. Object and tool handling strategies were significantly different clearly indicating that variations in working strategies and procedures play a vital role in one's work performance. The preliminary investigations explored variations in skill and experience basically and their influence on working strategies in terms of variations in tool holding, object handling and process sequencing. Here the objective of 'inclusive design' method would be to find and implement an optimal working method that is equally acceptable and productive for a broad range of workers in spite of their existing differences.

Figure 3: Three workers performing same task in three different ways

Manual assembly activities require some complex, repetitive and fast movements depending the level of complexity and work pace. Physical capabilities general and joint mobility in particular, greatly affects one's suitability for such activities. The literature shows that joint



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mobility decreases as we get older. So, acceptability of any adopted work strategy can be checked and validated if we have knowledge of joint mobility data for individuals and an appropriate design assessment tool that can use this data for analysis.

The use of a digital human modeling (DHM) strategy (HADRIAN) makes it possible to utilize individual capabilities and behavioral data at earlier design stage where inclusiveness of any adopted working strategy can be validated. Ongoing research focuses on the validation of this DHM based 'inclusive design' strategy for industrial activities; manual assembly activities. It is hoped that the proposed 'inclusive design' method will be equally useful for industrial applications, where it can address global workforce challenges and underlying human variability issues.

8 CONCLUSION

Demographic changes show that the global workforce is becoming more diverse in terms of age, gender, background, skill and experience. Whilst workforce diversity provides some positive opportunities in terms of variety of skill, a large pool of novel ideas and improved critical thinking, it also results in challenges like the management of a variety of skills, variations in functional capabilities and difference in attitudes and working behaviours. All these issues potentially increase overall human variability issues that directly influence work performance at individual and organizational levels. The HADRIAN methodology has been proposed for the promotion of such design practices that can minimize human variability is-

sues and their effects on work performance. Future research will be concerned with manufacturing assembly activities where an assembly-based task element can be included within the HADRIAN design system.

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