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THE AGEING WORKFORCE: A CASE STUDY

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ABSTRACT

Digital human modelling (DHM) most frequently models humans that are able-bodied and of working age. However, increased life expectancy is resulting in employment above ‘normal’ retirement age, often reflected in legislation changing state pension age and freedom for workers to work as long as wish. The resulting older workforce has many positive aspects including increased experience, wisdom, loyalty and motivation, but negative effects such as the loss of capabilities in strength, mobility, vision and hearing will also be present. Inclusive design aims to accommodate more of the workforce in the design of workplaces so it is essential that design methods are able to cope with the ageing workforce. A case study was conducted in a furniture manufacturing company, particularly to investigate the usefulness of a DHM-based inclusive design method in determining working strategies that are suitable for older workers in terms of work productivity, well-being and safety.

Keywords: Workforce, Ageing Inclusive Design.

1 INTRODUCTION

Digital human modelling tools have been used in many areas of application, but rarely specifically for older people or those with disabilities. HADRIAN (Human Anthropometric Data Requirements Investigation and Analysis) works in conjunction with the long-standing digital human modelling tool SAMMIE in attempts to improve this situation. HADRIAN has task analysis capabilities and a database of individuals who have physical disabilities or are older. HADRIAN was initially used to study Activities of Daily Living as part of the Extending QUAlity Life programme (Case *et al*., 2001, Porter *et al*., 2004). (Figure 1). Transport issues have also been investigated as part of the AUNT-SUE (Accessibility and User Needs in Transport –Sustainable User Environments) programme. Figure 2 illustrates a case study undertaken with the London Docklands Light Railway. (Summerskill *et al*., 2009, Marshall *et al*., 2010).

Figure 1: Collecting task behaviour knowledge in the laboratory and simulating it in the HADRIAN digital human modelling tool. (Case *et al*., 2001, Porter *et al*., 2004).

Figure 2: Transport accessibility (Summerskill *et al*., 2009, Marshall *et al*., 2010).

Recent work has been concerned with industrial environments, focused on the ageing workforce. A substantial case study in a furniture manufacturing company was undertaken to understand how age-induced reduced mobility impacts manual assembly tasks (Case *et al*., 2011). Figure 3 illustrates the simulation of working postures that are potentially difficult or impossible for older workers.

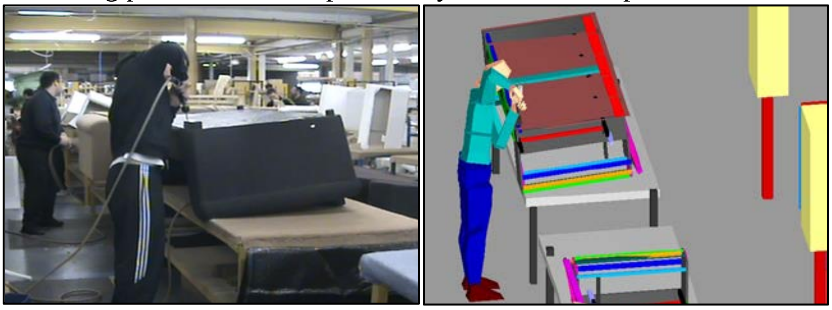

Figure 3: Evaluation of working postures in furniture manufacture (Case *et al*., 2011).

2 LITERATURE SURVEY

Diversity refers to differences between individuals because of their gender, age, functional capability, cultural background, experience and education (Williams and O'Reilly 1998). There are multiple dimensions of diversity but age, race, gender, disability and national origin are frequently considered (Shore *et al.* 2009). The focus of this research is on age as a major dimension of diversity. The world is experiencing a significant increase in the proportion of older people with about 759 million people aged 60 or above in 2010, estimated to increase to 2 billion by 2050. It is estimated that one out of 5 persons will be of age 60 years or above by 2050 and this will significantly increase the dependency ratio (the proportion of economically inactive versus active population). The UK population is also ageing (O.N.S. 2009) with an increase of 1.7 million people aged 65 and over in last 25 years. Age affects humans in different ways including physical, physiological, cognitive, psychological, attitudinal and psychosocial aspects. There is a need to understand all these changes so that the challenges faced by older workers might be addressed in a logical way. However, physical, physiological and cognitive issues are the primary concern for designers and ergonomists. Functional capacity declines with age and becomes critical for workers aged over 50. Musculoskeletal strength starts to decline after the age of 30, and a 60 year old has muscular strength which is approximately 70% of a 30 year old (Sturnieks, St George and Lord 2008). Balance disorders and risks of falls and injuries lead to a decline in work performance (Wanger *et al.* 1994) and joint mobility reduces considerably with age (Chung and Wang 2009). Reaction time variability is higher in older people and directly affects work performance (Hultsch, MacDonald and Dixon 2002). Similarly there are relationships between functional capacity, vision and tasks performed by older workers (Sue 2008).

To conclude, in the light of above discussion, it is very important to understand all the physical, physiological, psychological and cognitive changes that result from ageing. On the other hand, there are a number of other factors like experience, decision-making, loyalty to the organization, sense of responsibility and critical thinking which make older people a real asset for organizations. The removal of an experienced and skillful older worker is not simply the loss of one person; it is also a drainage of skills, knowledge, experience and relationships and to regain these attributes, needs resources in the form of money and time (Dychtwald, Erickson, and Morison 2004).

3 METHOD

Digital human modelling was used for the concept validation of using a human modelling based inclusive design strategy in a manufacturing assembly environment. Data captured at a furniture manufacturing company was used for human modelling based risk assessment of the working strategies adopted. Assembly workers were recorded to capture a variety of working strategies, methods and procedures. Selected snap-shots of a variety of workers performing similar tasks were used for the purpose of analysis. The SAMMIE human modelling tool was used to generate a CAD model of the working environment that includes the sofas that are being assembled, tools used during the assembly operations and other relevant objects. Selected postures recorded in the factory were replicated by human models in SAMMIE. Joint mobility data of 31 workers who were older than 40 years was used to assess suitability of working postures or strategies. Joint mobility constraints for arm flexion/extension, abduction/adduction, medial/lateral rotation; shoulder flexion/extension, abduction/adduction; elbow flexion/extension, pronation/supination; wrist flexion/extension, abduction/adduction were used as criteria for the acceptability of postures.

4 FURNITURE COMPANY CASE STUDY

Figure 4 shows three workers carrying out the same assembly operation. It is clear that they are performing their task in very different ways, in terms of tool handling, tool orientation, object or product orientation and body posture. The orientation of the object (sofa) and holding of a tool (drill) account for significant differences in adopted postures. The most difficult posture is adopted by worker 3 (method 3), where the position of the upper-arm, lower-arm, neck and orientation of the hand might be the assessment criteria for the acceptability of this method’s inclusiveness. It is also clear that the positions of the upper-arm and lower-arm of worker 3 are the most awkward and differentiating features and have a direct relationship with joint mobility of the workers.

Digital human modelling tools are capable of predicting risk involved during work, with an acceptable level of reliability. Use of the computer-based digital human modelling tool SAMMIE can provide information about the acceptability of these working strategies regarding their inclusiveness for older workers. During this experimentation, all 31 workers were evaluated performing each working method. In this way, 93 (31x3) scenarios were created and attempts were made to replicate actual working postures of older workers. The differences in joint mobility capabilities means it is unlikely that all older workers can adopt all these working postures. The joint constraints of a fully capable SAMMIE human model set the criteria for comparison of these (actual working postures with joint constraints of fully capable SAMMIE human model) and older workers (with limited and varying levels of joint mobility).

Complex body movements that contain both simultaneous bend and twist have a high level of risk at work and these must be avoided. Clearly, worker 3 (method 3) adopted a complex and relatively difficult trunk/back posture, due to the orientation of the sofa. The orientation of the sofa for workers 1 and 2 was different, and this determined the view and height of the object (position of the working object with reference to face, shoulders etc.). Difficulty in viewing the working object and inappropriate height led worker 3 to adopt an awkward working posture where the neck is bent, the trunk/back is bent and twisted and one elbow is above shoulder level. In comparison with worker 3, worker 2 performed better in terms of level of risk, but worker 1 seemed very relaxed and comfortable during his work. Moreover, the working strategies of worker 1 and 2 were different in tool and object holding, and positions of the shoulder were different. All these aspects can be seen in Figure 4.

Differences in these work organization issues lead to entirely different working strategies where adopted postures demand different joint mobility capabilities. For example, the positions of the upper-arm and lower-arm are found to be different for these three working methods. Figure 4 also illustrates that working method 3 imposes the highest level of joint mobility requirements, where the lower arm bend (R) demands a 141^0 extension which is high as compared with the other two methods (129^0 and 136^0). Similarly, right upper-arm swing value (113^0) is also significantly higher than that of method 1 and 2 (47^0 and 92^0). So, these pre-defined joint mobility requirements can be used as criteria to investigate the acceptability of any method for a broad range of the population. During experimentation, 93 working postures were analysed where each older worker (virtual human with actual joint constraints of an older worker from the HADRIAN database) was tested against the three different working methods shown in Figure 4. Figures 5-7 show examples of posture replication by SAMMIE (middle) and an older worker (right) against working methods 1-3. The joint mobility requirements for a fully capable human (SAMMIE) for replication of an adopted posture, set a criterion for the acceptability of a method for any individual and older workers in general.

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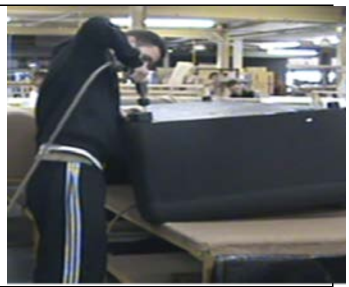
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">Worker 1. Method 1. Tool held by both hands; Both arms are below shoulder level; No bend or twist in trunk; Neck is straight; Object is at appropriate height</td><td colspan="3">Worker 2. Method 2. Tool held in one hand (other hand grips the object); Both arms are nearly at shoulder level; Trunk has little bent or twisted; Neck is twisted; Object is at appropriate height</td><td colspan="3">Worker 3. Method 3. Tool held in one hand (other hand grips the object); One arm above shoulder level; Trunk bent/twisted; Neck bent /twisted; Object at lower height</td></tr>
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Figure 4: Three workers performing same task with different methods

5 RESULTS

This section is a description of the design evaluation process through the SAMMIE human modelling system. Figure 8 shows a worker (number 19 in the HADRIAN database) performing the same activity in three different ways. The aim is to assess his ability to perform these activities based on his limited joint mobility as he is 73 years old. It has already been stated that methods 1 and 2 impose relatively less joint mobility requirements as compared with method 3. Here, figure 8 clearly indicates that worker 19 can easily accomplish this assembly task by adopting method 1. However, the same worker is unable to successfully complete the same assembly task element through methods 2 and 3. The red highlighting indicates violation of joint constraints and unacceptability of these two methods for this worker. It can be concluded that a person with limited joint mobility can do the task using method 1, but the other two methods are unacceptable due to high joint mobility requirements.

Figure 5: Using SAMMIE human modelling system to assess task inclusiveness for method 1

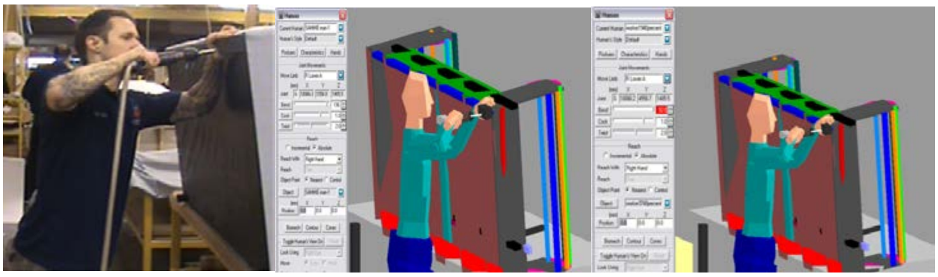

Figure 6: Using SAMMIE human modelling system to assess task inclusiveness for method 2

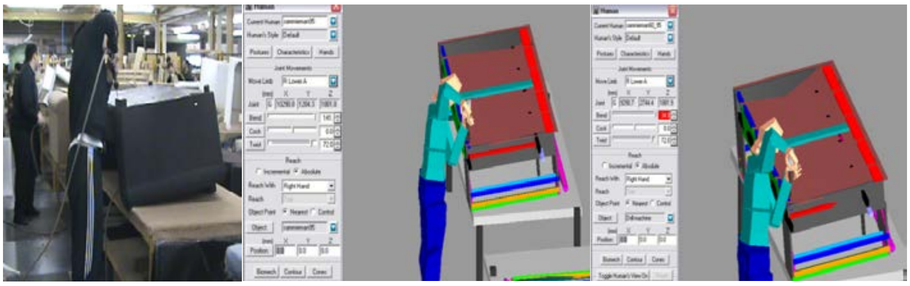

Figure 7: Using SAMMIE human modelling system to assess task inclusiveness for method 3

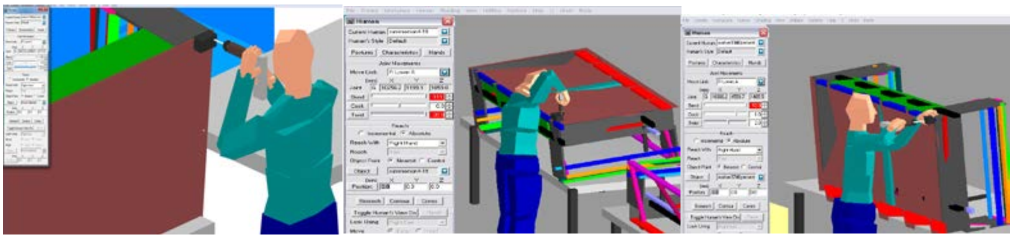

Figure 8: HADRIAN database worker 19; design inclusion for work performing methods 1-3

As described above, the database has been used to define 31 older workers (>40 years of age) with individual joint constraints and then tested against these three working methods for the same assembly activity. The results indicate that work method 1 is acceptable for 84% of the older workers, which is the highest proportion as compared with 48% and 19% for methods 2 and 3 respectively. Only 5 out of 31 older workers were found to be excluded with method 1, whereas 16 and 25 were excluded for methods 2 and 3 respectively. The above results indicate the usefulness of the DHM-based inclusive design method where designers and ergonomists can promote such work practices that are equally acceptable for a broad range of the population, older people in this example.

6 STRENGTHS AND LIMITATIONS

This case study has shown a great potential for using the digital human modelling technique for the promotion of an inclusive design approach in industrial applications. In the future, workforce diversity will increase and people with different backgrounds, cultures, sizes, shapes, age and expereinces will be sharing the same workplaces. The inclusive design method provides an opportunity to address all these issues proactively so that safe, healthy and productive workplaces might be assured. In future, organizations will have to think more seriously about these human variability issues, so that they can retain their skilled and experienced workforce, which will be a key driving force for achieving organizational sustainability. This study provides an idea of how the proposed inclusive design method can work for the benefit of individuals and organizations, in terms of workplace safety, productivity and human well-being. It also highlights the importance of the availability of more realistic human capabilities data (physical, physiological and cognitive) and use of that in an appropriate design tool. On the other hand, validation of the proposed method has been carried out only for furniture manufacturing assembly activities. There is a need to validate the method against more industrial applications where its usefulness can be assessed against a variety of applications. Moreover, this case study has only used the physical capabilities context of human working capabilities, but the concept should also be validated for more complex dimensions of human capability such as physiological, psychological and cognitive abilities. Similarly, older workers' capability data is not limited to joint mobility; there are many other functional capabilities that decline with age, so other available data should also be used to promote healthy and safe working of the ageing workforce. Initially, the proposed method has been validated through SAMMIE, where older worker's joint mobility data has been used manually. There is a need to enhance the automated task evaluation capability of HADRIAN from simple activities to more complex industrial activities like manual assembly operations.

7 CONCLUSIONS

A digital human modelling based inclusive design approach is considered useful for addressing work-related issues of a diverse workforce, especially older workers. Like joint mobility data, other functional capabilities data can be collected and used for assessing whether or not working conditions, environments and strategies are suitable for a broad range of the population. This proactive design approach benefits individuals and organizations by securing safe working conditions where people, with their existing differences, can perform at their best. In this way, global workforce challenges of diversity and ageing can be addressed by promoting such design practices. However, still there is a need to capture more data about the human differences and effectively utilize that in appropriate tools, so that more realistic work strategies can be implemented.

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