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WORKFORCE AGEING, THE NEED FOR AN INCLUSIVE DESIGN APPROACH IN MANUFACTURING INDUSTRY

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Abstract. *Demographic trends clearly indicate that the number of people over 60 years of age is increasing in most developing countries, while the availability of a young workforce is decreasing due to falling birth rates. Successful global competition drives the need to ensure the availability of a skilled workforce which accommodates older workers, is a real challenge for industrial organizations. An Inclusive Design approach is considered helpful in the assessment of workstations, product or service design requirements and the establishment of realistic production standards during the design development phase in any manufacturing industry. The approach can be used for a variety of industrial applications especially in manufacturing tasks such as assembly, maintenance, lifting, loading, unloading, transporting and machine operating activities. This paper reveals the need for an Inclusive Design approach that can potentially increase the productive time of the older workforce which can then make a valuable contribution to the economy. The paper also describes initial research which involves the re-analysis of a very large UK survey on ageing and disability and new data on joint mobility and its significance to the ageing workforce.*

1 INTRODUCTION

The issue of the ageing workforce is beginning to have an impact on the thinking of governments, trades unions, manufacturing industry and perhaps most significantly the workers themselves. Clear global demographic trends indicate that industrial and economic development leads to older populations and increasingly this is seen as being unsustainable economically without reversing the trend for a decreasing younger part of the population supporting the increasing older part. One solution currently being implemented by several governments is an increase in the retirement age. For this to be effective there needs to be a strategy for dealing with the issues it raises. Many of these issues arise out of an increase in physical disabilities with age and so it is necessary to understand these challenges whilst not losing sight of the fact that some cognitive and behavioural functions might actually improve with age. If the challenges are to be met by appropriate design of workplaces and tasks then an Inclusive Design approach needs to be adopted. Inclusive Design aims to substantially increase the accommodation levels of designs, particularly for older and disabled people, whilst providing designs that are also desirable to the younger and more able-bodied population. Inclusive Design requires design approaches that are more sophisticated in their approach in comparison with methods that are aimed at designing for more narrowly defined populations.

2 DEMOGRAPHICS

Demographic trends clearly indicate that the percentage of older people is increasing considerably over time. According to the United Nations Organization, “one of every ten persons is now 60 years or above; by 2050, one out of five will be 60 years or older; and by 2050, one out of three persons will be 60 years or older” [1]. The UK population is ageing and there has been an increase of 1.7 million people aged 65 and over in last 25 years. However, the percentage of the population aged less than 16 decreased from 21% to 19% between 1984 and 2009. This trend is predicted to continue together with a marked increase in those over 85 and a decrease in the ratio of women to men in the over 65 year age group [2]. The UK population trends show that it has an ageing population, but ageing less rapidly as compared to other European countries such as Germany and Italy. In common with other European countries, life expectancy in the UK is increasing, but the UK has higher fertility and immigration rates [3]. In Europe, the median age of the population was 29.7 in 1995, had risen to 39 years by 2005, and is forecast to be approximately 47.1 years in 2050. The same trend is also followed in Asia and Oceania where the percentage over 65 years of age in 2005 was 6.4% and 10.0% respectively and is predicted to increase to 17.5% and 19.3% respectively by 2050. It is also estimated that there will be an overall increase of more than 100% (11.4% to 25.4%) in the dependency ratio (per 100 people) of older people throughout the world from 2005 to 2050. So, there is clear evidence of a significant increase in the average age of the global workforce in many countries of Europe, North America and Australasia and also developed Asian countries such as Japan and Singapore. Figure 1 clearly indicates that there is a considerable increase in the percentage of the people aged 65 and over, in all parts of the world, but particularly in Asia, Europe and America [1].

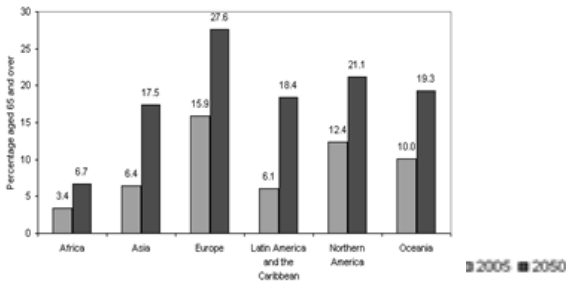


Figure 1: Percentage aged 65 and above in 2005 and 2050 [1]

3 CHALLENGES FOR AN AGEING WORKFORCE

The above discussion indicates that not only is the percentage of older people increasing in most parts of the world but that there will be a significant increase in the number of older people in the workforce. This workforce composition will not only affect the social and organizational culture, but will also be a major economic consideration for organizations and countries. Bureau of Labour Statistics [4] indicate that the proportion of the workforce over 55 is increasing whereas that of for 16-19 year olds is decreasing. The same is true for most of the developed countries which are also facing the challenge of an ageing workforce. This trend will affect organizations in a number of ways including a shortage of workers, loss of skills and knowledge and a highly competitive working environment for younger workers [5]. More precisely, the problem is not just the lack of workers but the drainage of skills, knowledge, experience and relationships through retirement and the economic cost of regaining them [6].

One way to manage the workforce shortage problem is to retain skilled and experienced workers for a longer time and increase their retirement age. However, retention of older workers demands several critical factors to be addressed, which are challenges for the managers, planners, designers, ergonomists etc. The next section briefly discusses several factors that must be addressed so that an older workforce might be effectively utilized.

4 UNDERSTANDING THE EFFECTS OF AGEING

Many changes occur with age and these changes may be physical, physiological, psychophysical, psychological, cognitive etc. Development of a proper understanding of all these changes is very important so that they can be accommodated so as to effectively utilize this skilful and experienced resource. There is a necessity to understand the effects of ageing in the context of work performance, so that the needs' of older workers might be addressed properly.

The musculoskeletal system plays an important role in the work performance of workers of all ages; however, it becomes a concern when products, processes, jobs and workplaces are

designed for an ageing workforce. Muscular strength is greatest between the ages of 25 and 30, after which there is a decline in strength such that the average strength of a 65 year old is about 70% of that of a 30 year old [7]. Other anthropometric characteristics like weight, body mass index, body height, fat weight and skeletal weight are also influenced by age. Young people (31-35 years) have the greatest stature and fat free body weight, whereas middle-aged people (51-55 years) have the greatest body weight, body mass index and fat weight [8]. Bone mass is also affected by the process of ageing, decreasing at a rate of 1% per annum from age 35 and resulting in fractures, disabilities and diseases such as osteoporosis. About 50% of women and 12% of men face osteoporosis problems after the age of 50 years [9]. Work occupation has a clear effect on physical capacity as shown by a study of groups of younger and older waste collectors with two age-matched control groups. The study revealed that the physical capacity of waste collectors for both age groups was greater than that of the control groups, possibly due to a training effect [10]. Good balance is a requirement of working in industrial environments and older people often face balance disorders which may cause falls and injuries. One in three persons aged over 65 fall at least once a year and about 15% of these falls cause serious injuries which have a high economic cost as well as the personal welfare concerns. These risks hinder older people performing tasks involving mobility and transfer [11]. Flexibility in body segment movement is crucial to many tasks including reaching, walking, materials handling etc. This mobility of joints decreases with age but the severity depends on several other factors such as gender and declines in balance and flexibility are considered as major causes for accidents and can be linked with decreased range of motion in the joints [12]. Joint movements either associated with small motor movements like gripping, grasping, twisting and turning or with large motor movements like sitting, standing, walking, bending, and stooping are significantly influenced by age. Working environments with activities like pulling, pushing, carrying, lowering, and lifting of moderate and heavy loads demand a tiring effort from older workers which can result in hazardous and unsafe work [13]. In common with many other responses, reaction time and speed of performing a task also decreases with ageing. It has been found that children are faster than adults on simple reaction time tasks and symbol digit tasks. However, older people were faster in a copying digits task [14]. Slow reaction times can have an impact on work performance and may possibly affect quality so the capacity of older people in this respect must be matched to any demands of a production system. Ageing contributes to visual impairment, so for example contrast sensitivity decreases from an age of about 40 or 50 [15] and older people require appropriate lighting [16]. More than half of the aged population suffers from some sort of hearing loss and this is most noticeable in men. The decline in capability begins in the 50s and becomes very noticeable in the 70s [17]. Heavy dynamic physical work is limited by the maximal cardio-respiratory capacity of the workers and this has been shown to have a strong gender dependency and a marked decrease with age [18]. The cardiovascular system supplies oxygen to the muscles and its functional capacity decreases with age. The maximum cardiovascular capacity occurs at 25 and about 15-20% is lost by 50 [18], affecting the work capacity of older workers. Physical or mental effort may cause a feeling of tiredness or fatigue resulting in reduced work capacity and possible health problems. Fatigue is difficult to quantify, but feelings of fatigue are more common in older people and may have psychological consequences such as depression [19]. Memory deteriorates with age but older

people have the ability to acquire knowledge and strategies that help in adapting to new situations. Careful and appropriate selection of cognitive abilities improvement strategy can improve performance and training provides benefits to young and old alike [20].

5 STRATEGIES FOR AN AGEING WORKFORCE

The foregoing discussion has centred on areas where the older worker has lesser capabilities than their younger counterpart. Gerontologists consider 75 to be a milestone beyond which the effects of ageing become very significant but the “younger” old from 50 to 75 have many advantages over younger workers. These advantages are predominantly cognitive and social and include sagacity, prudence, strategy, wisdom, decision-making, logical reasoning, critical thinking, experience, better product knowledge, loyalty, greater motivation, better engagement with work and more quality conscious [21]. Strategies for coping with or benefitting from an older workforce should therefore concentrate on utilising and enhancing these positive characteristics whilst providing support and assistance (for example through workplace design) to ameliorate the physical aspects of ageing. It should also be noted that the continuous migration of work from the physical to the cognitive is an extremely powerful reason for adopting this strategy. In this way the challenges of an ageing workforce can actually be seen as an opportunity to adopt strategies to take full benefit of the older workers’ capabilities.

6 INCLUSIVE DESIGN METHODS

Previous research had resulted in the creation of an inclusive design tool called HADRIAN [22] which is based on the SAMMIE digital human modelling (DHM) system to provide holistic information on people of a broad range of size, shape, and ability and a means of using this database to assess the inclusiveness of proposed designs. Earlier work has focussed on domestic and travel environments and recently attention has turned to industrial situations, particularly assembly. The HADRIAN database consists of physical and behavioural data on 100 individuals covering a broad range of ages and abilities and is not intended to be representative of the more general population as it was deliberately skewed towards the older and disabled. However, the sample spans from 1 to 9 on the office of population censuses and surveys (OPCS) severity scores [23], and there are over 20 recognised impairments represented in the database. A key feature of the database is how the data are presented (Figure 2) as a catalogue of individuals which we believe to be an essential component of a successful inclusive design tool. One aspect of this is that an individual’s dataset can be used as if they were a real member of a user trial and this is achieved by describing tasks (e.g. an assembly task) through a simple language that can then drive the integrated DHM system through an automatic evaluation of the proposed workplace to determine whether or not it is feasible (Figure 2). Using the complete database of individuals or a sub-part of interest can then determine the percentage accommodation.

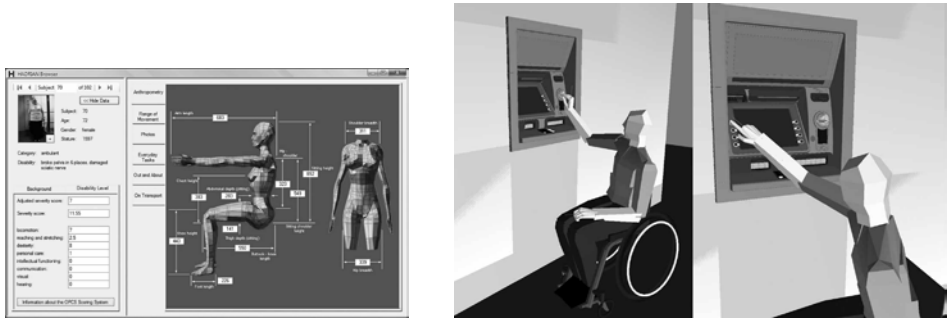


Figure 2. Screenshot of a part of the HADRIAN database (left) and task-driven evaluation of an ATM (right).

7 UK DISABILITY DATA

The severity scores used in the 1996/1997 disability follow-up survey, conducted by the Office of National Statistics (UK), for the assessment of level and severity of disability for different age groups in the whole United Kingdom population are very similar to those used in HADRIAN. In common with the disability survey, the data collected for the HADRIAN database presents severity scores against different functional capacities such as locomotion, reaching/stretching and vision so it has been possible to compare the two sets of data. The large-scale ONS survey extrapolated the information gathered to provide estimates of total levels of disability within the entire UK population. Assessment of the level of disability is a complex issue as it is influenced by a number of factors like age, race, culture, social and economic background, but the alignment of the HADRIAN data with the large national survey provides a valuable assessment tool. HADRIAN, with its small set of data representing 100 or so individuals, can give indications of the consequences of design decisions for millions of people with similar levels of ability/disability. In particular, the functional capacities of reaching, stretching, locomotion and vision are the primary requirements of any working environment and directly affect the output and welfare of a worker. The older workforce comes across many problems where the main cause is a mismatch between job demands and these functional capacities, and so, this database can be proactively used for design assessments to provide design suggestions for the better accommodation of older workers.

8 MOBILITY DATA

The reduction in joint range of motion (ROM) is thought to be a major contributor to reductions in mobility suffered by older people which in turn leads to reduced capability at common industrial tasks such as assembly. Data previously collected [24] for the HADRIAN system was re-analysed to investigate this proposition. A total of 66 people participated in the study. 42 of the participants were fully able-bodied and 24 had some disabilities (8 were wheelchair users and 16 arthritis patients). The able-bodied subjects were further divided into three age groups, i.e. 20-40, 40-60, and 60-81 years consisting of 10, 13 and 19 subjects

respectively. Two approaches were used for data collection, (1) a traditional approach where manual measuring devices were used and (2) an electronic motion capturing system (CODA) and average values were used for this study. A total 18 joint ranges of motion values were measured, with each value measured for both the dominant and non-dominant side of the body [24]. An ANOVA test was employed to demonstrate the influence of different factors such as age, gender and disability on joint ROM. Results clearly indicate that joint ROM significantly decreases ($p < 0.05$) with increased age and disability, especially for arm abduction, arm medial and lateral rotation, elbow flexion, wrist flexion and wrist adduction. Moreover, disabilities like wheelchair users and arthritis patients also show a considerable decrease in arm flexion, elbow supination and wrist extension. However, no significant differences were observed for gender or dominant/non-dominant sides of the body.

9 CONCLUSIONS

Demographic changes and the consequent economic considerations will result in an older workforce. Whilst this provides some positive opportunities in terms of utilizing the older worker's often improved cognitive and social characteristics, it also provides some challenges in accommodating reduced physical capabilities. The methods of Inclusive Design, which have previously been used in domestic and travel situations to improve the inclusion of older and disabled people in society can also be considered for addressing the problems of workplace design for the older worker. The HADRIAN methodology has been proposed for this and glimpses have been given as to how it relates to large-scale national surveys on disability and how the underlying mobility (range of joint motion) data can be related to the specific characteristics of the older worker. Future research will be concerned with task analysis so that assembly-based task elements can be included within the HADRIAN design system.

REFERENCES

- [1] U.N.O. *United Nations programme on ageing*, <http://www.un.org/esa/socdev/ageing/popageing.html> (accessed 14th March 2011).
- [2] O.N.S.UK (Published on 24 June, 2010). Office of national statistics, UK. <http://www.statistics.gov.uk/cci/nugget.asp?ID=949> (accessed 14th March 2011).
- [3] World Bank, <http://data.worldbank.org/>. (accessed 14th March 2011).
- [4] United States Department of Labor, Bureau of Labor Statistics, <http://www.bls.gov/> (accessed 14th March 2011).
- [5] R.J. Burke and E.S.W. Ng, The changing nature of work and organizations: Implications for human resource management. *Human Resource Management Review*, 16(2), pp. 86-94, 2006
- [6] K. Dychtwald, T. Erickson and B. Morison, It's time to retire retirement, *Harvard Business Review*, 82(3), pp. 48-57, 2004.
- [7] S.G. Wanger, A. Pfeifer, T.L. Cranfield and R.L. Craik, (1994). The effects of ageing on muscle strength and function: A review of the literature. *Physiotherapy Theory and Practice*, 10(1), pp. 9-16, 1994.

- [8] J.T. Viitasalo, P. Era, A.L. Leskinen and E. Heikkinen, Muscular strength profiles and anthropometry in random samples of men aged 31 - 35, 51 - 55 and 71 - 75 years, *Applied Ergonomics* 18(1), pp. 78-78, 1987.
- [9] W.D.K. McArdle and V.L. Katch. *Exercise physiology: energy, nutrition, and human performance (5th ed.)*, Lippincott Williams and Wilkins, Baltimore, MD, 2001.
- [10] B. Schibye, A.F. Hansen, K. Sogaard and H. Christensen, Aerobic power and muscle strength among young and elderly workers with and without physically demanding work tasks. *Applied Ergonomics*, 32(5), pp. 425-431, 2001.
- [11] D.L. Sturnieks, R. George, and S.R. Lord, Balance disorders in the elderly, *Neurophysiologie Clinique/Clinical Neurophysiology*, 38(6), pp. 467-478, 2008.
- [12] H. Chiacchiero, B. Dresely, U. Silva, R. De LosReyes and B. Vorik, The relationship between range of movement, flexibility, and balance in the elderly., *Topics in Geriatric Rehabilitation*, 26(2), pp. 148-155, 2010.
- [13] K.M. Kowalski-Trakofler, L.J. Steiner and D.J. Schwerha, Safety considerations for the aging workforce. *Safety Science*, 43(10), pp. 779-793, 2005.
- [14] L.F. Laux and D.M. Lane, Information processing components of substitution test performance, *Intelligence*, 9(2), pp. 111-136, 1985.
- [15] C. Owsley, E. Sekuler and D. Siemsen, Contrast sensitivity throughout adulthood, *Vision Research*, 23(7), pp. 689-699, 1983.
- [16] A. Mital, L. Ayer and J. Gorman, A lighting evaluation of a facility for elderly *In: Advances in industrial ergonomics and safety III*, W. Karwowski and J.W. Yates, (eds), Taylor & Francis, London, pp. 675-681, 1991.
- [17] M. Bergman, V. Blumenfeld, D. Cascardo, B. Dash, H. Levitt and M. Margulies, Age-related decrement in hearing for speech. Sampling and longitudinal studies, *Journal of Gerontology* 31(5), pp. 533-538, 1976.
- [18] J. Ilmarinen, and J. Rantanen, Occupationally induced stress, strain and peak loads as related to age, *Scand J Work Environ Health*, 6, pp. 274-282, 1980.
- [19] D.S.F. Yu, D.T.F. Lee and N.W. Man, Fatigue among older people: A review of the research literature, *International Journal of Nursing Studies*, 47(2), pp. 216-228, 2010.
- [20] F.I.M. Craik and T.A. Salthouse, *In: The handbook of aging and cognition, (2nd Ed)*, Lawrence Erlbaum Associates, Mahwah, NJ, pp. 775, 2000.
- [21] R.R. Feinsod and T.O. Davenport, The aging workforce: challenge or opportunity? *WorldatWork journal*, pp. 14-23, 2006.
- [22] R. Marshall, K. Case, J.M. Porter, S.J. Summerskill, D.E. Gyi, D. Davis and R.E. Sims, HADRIAN: a virtual approach to design for all, *Journal of Engineering Design*, Vol 21, Nos 2-3, pp. 253-273, April-June 2010.
- [23] J. Martin, H. Meltzer and D. Elliot, *OPCS surveys of disability in Great Britain: the prevalence of disability among adults*. HMSO, London, 1994.
- [24] D.E. Gyi, R.E. Sims, J.M. Porter, R. Marshall and K. Case, Representing Older and Disabled People in Virtual Users Trials: Data Collection Methods, *Applied Ergonomics*, 35, pp. 443-451, 2004.