Ergonomic Evaluation of Manual Force Levels of the Elderly in the Handling of Products: An Analysis Using Virtual Reality

Rafaela Q. Barros[1], Marcelo Márico Soares[1], and Maria Goretti Fernandes[2]

[1] Program of Post-graduation in Design, Federal University of Pernambuco, Recife, Brasil, Av Academico Helio Ramos, S/No. Cidade Universitaria, 50.670-420, Recife, PE, Brazil
[2] Departament of Physiotherapy, Federal University of Sergipe, Aracaju, Brasil
{Rafaela Q.Barros,lotus100}@outlook.com

Abstract. Data from the World Health Organization - WHO [1] estimated that from 2000 to 2050, there will be a threefold increase in the population over 60-year-old population, which will rise to nearly 2 billion. It is important to designer understand the aging process and its peculiarities, such as those issues that affect cognitive issues and physical skills, thus enabling the understanding of products targeted on elderly people. The Virtual Reality via using haptic gloves to simulate everyday activities (EDAs) in a virtual environment. Thus, it is intended that this technology will enable the study of the measurement of forces applied in performing tasks. Data on measuring the levels of manual strength in the virtual environment were not found in the literature. Based on the data obtained in this review of the literature, the intention is to simulate elderly people´s manual activities with a view to quantifying levels of force.

Keywords: Virtual Reality, Manual strength and ergonomics.

1 Introduction

Data from the World Health Organization - WHO [1] estimated that from 2000 to 2050, there will be a threefold increase in the world population aged over 60, which will thus rise from 600 to nearly 2 billion people.

According to this source, the bulk of this growth is occurring in developing countries, like Brazil, where the number of elderly will grow from 400 million to 1.7 billion.

The World Health Organization (WHO) defines an elderly person being someone in the First World who is aged 65 and over, and 60 or over how old a limit of 65 or over the age of individuals in developed countries, and aged 60 or over for those from developing countries.

It is important to understand the aging process and its peculiarities, as those which affect cognitive and physical skills, thus enabling an understanding of products that will be targeted on the elderly.

A. Marcus (Ed.): DUXU 2014, Part IV, LNCS 8520, pp. 124–132, 2014.

Chaumon and Ciobanu [2] distinguish the aging process as being: normal (classic aging with degradation, certain human functions being maintained); pathological (various accidents or diseases increase or exacerbate the consequences of aging); optimal (identical or superior performance to that of younger people); and successful (when psychologically they adapt to change and/or accept their situation).

They report that the elderly may have different types of (permanent or temporary) deficiencies, namely those of: perception (hearing or vision); use (due to limitations in moving lower and/or upper limbs); psychological (greater psychological vulnerability), and so forth.

According to Paschoarelli et al. [3], the decline in levels of habitual physical activity for the elderly contributes to reducing functional fitness and to the manifestation of various diseases as a result of loss of functional capacity and decreasing motor performance in performing Every Day Activities (EDAs). Such problems may be related to inadequate demands on strength in packaging, particularly for vacuum-sealed products or which have child-proof safety seals.

Some tools, involving new technologies present themselves as suitable for handling everyday products. Among them Virtual Reality using haptic gloves stands out as this enables EDAs to be simulated in a virtual environment. Therefore, it is intended that this technology will enable the measurement of forces applied in performing tasks to be studied. Data on how to measure levels of manual strength in the virtual environment were not found in the literature.

2 Aging and Difficulties in Handling Products

The aging of the population is one of humanity's greatest triumphs and one of major challenges in terms of considering their abilities, needs and limitations when designing products and jobs.

As we enter the 21st century, global aging will cause an increase in social and economic demands worldwide. This demand is expressed on considering that this population will occupy jobs and use consumer products in their day-to-day lives. However, people of the Third Age are, in general, ignored with respect to their physical and cognitive demands being regarded as productive and active elements in our society.

It is important to understand the aging process and its peculiarities as those that affect cognitive issues and physical skills, thus enabling products targeted on the elderly to be understood.

According to Parente et al. [4], human aging, as well as other stages of life (development) is a transformation process of the organism that is reflected in its physical structures, in manifestations of cognition as well as in the subjective perception of these transformations.

Besides the problems of human beings' aging process, common complaints from the elderly are about the problems of inadequate demands when handling consumer products in relation to the sufficiency of the strength used when using for example, vacuum sealed packages. This type of situation is extremely important, taking into account the growth of the elderly population and increase in life expectancy [5].

Thus, according to Iida [6], the loss of the sense of touch is another important problem attributed to osteomuscular difficulties when handling objects. This is due to the difficulty in picking up or handling objects, while pointing out that the elderly´s notion of size or space stars to seem to be confused, thereby producing erroneous information about the strength and the environment to be used when performing tasks.

Both the strongest users, as well as the weakest ones, may perform actions that lead to accidents because they overload their ostemuscular systems when active, thus subjecting themselves to the risk of injury or simply of not managing to do the activity [7, 8].

Santos and Sala [9] point to the growth in the number of the elderly in relation to national population rates and medical advances, which prolong the current life expectancy of society. However, it would be useless to increase the satisfaction of these people if the limitations and progression of the quality of life were not taken into account.

The authors report that, over the years, the human body undergoes a natural aging process that induces functional and structural changes that impede the performance of daily activities independently. Although not fatal, these conditions generally tend to have a significant adverse effect on the quality of life of the elderly.

According to Smith [10], when a person gets older some changes may occur. Some characteristics and abilities of the elderly population differ considerably from those of younger people. It is extremely important that such changes are considered in the process of designing, planning and developing products that will be used by members of the elderly population.

Also according to Smith, the changes that occur with aging can be physical, such as changes in the size and shape of the body; or maximum strength decreasing; changes in the performance of the sensory functions such as vision and hearing; or they may be psychological, such as changes in cognitive or psychomotor functions.

Data from Brazil [11] and Duarte et al. [12] show that the life expectancy of the elderly population has been growing substantially due to improvements in their quality of life. Nevertheless, the aging process shows there is concern related to disabling events caused by problems about needing to maintain the functionalities of physical skills.

Duarte et al. [12], in their study, reveals that functionality can be interpreted as the individual's ability to perform activities or functions by making use of his/her abilities to engage on social interactions in leisure activities and in other conduct asked for in their everyday lives.

As a major part of the functionality considers the need to manipulate objects, the manipulation of objects is common in most ADLs, in which the hands, through the movement associated with the application of grip muscle strength action, perform the mechanical action. Incorrect sizing of the power demand of a product / activity can generate constraints on tasks.

The reduction in the strength to manipulate objects is one of the characteristics of aging. Thus, the purpose of this research study is to measure different levels of manual force of the physical demands on an elderly population manipulating everyday objects by means of Virtual Reality.

3 Ergonomics, Usability of Products

According to Campos et al [13], the intention of ergonomic design is to reduce the problems in the human-technology interface, and is based on the methods of usability analysis, which are applied in the production process of a product.

Falcao and Soares [14] consider usability as an important relationship for the individual that influences the choice of a particular product. Therefore, usability sets out to improve the user´s relationship with a product by making the interface clear, thereby making a good, effective and efficient interaction possible that might allow full control of the environment without problems appearing during the relationship.

In the studies of Voorbij and Steenbekkers [16], their analysis found that it is common for sizing strength in consumer products to be a problem especially in vacuum-sealed products or those that have child-proof safety seals. The reason for the difficulties was insufficient strength to use the packaging.

Exemplifying this context, Paschoarelli et al. [3] present studies reporting that in the UK in 1994, 550 accidents to the elderly occurred when glass bottles were opened and 610 accidents when the elderly opened plastic bottles. According to these authors, these episodes are related to the elderly using sharp instruments to assist in opening hard tops and complicated seals which are then manually removed.

According to Voorbij et al. [17], one study reports that nine packages available on the market were analyzed, six of which demanded strength higher than the capacity of the elderly and two made demands greater than the capacity of even young adults. Another study, presented by the same authors, found that 20% of subjects had difficulties in opening glass packaging.

Therefore, it is deemed necessary to understand the importance of the ability to use the hand as a clamp or claw, this position being called prehension or grip [18].

The study of the manipulative abilities of the hand began by analyzing holds and the forces involved. Hand grip positions are usually classified as prehensile or non-prehensile [19].

Most biomechanical research reports a range of manual force related to the age of the individual, there being increase in strength in young adulthood and a consecutive deficit until the onset of aging [15], [16].

Yoxall [20] says that certain types of packaging request the use of a certain force to open them and obtain access to the product, thereby determining that the consumer is able to exercise this strength, since packaging produced in the last 10 years has become more complex to open.

So it is important to stress the need for extreme efforts to open conserved food jars, since many users are unable to open them because they lack the appropriate strength. These packages were based on some studies covering an analysis of forces and torque related to gender and age. These are the key points for the proper use (or constraints) in opening a product [20].

Therefore, the biomechanical aspects of the human upper limbs are of utmost importance to the ergonomic design of hand tools so the following biomechanical and task factors must be taken into account: postures with flexions of the wrist; extreme postures and limitation the area which are disadvantageous to using strength. Regarding the design of grips and manipulations of objects that require greater effort, it is best to choose palm grips, flexion-extension movements to those of pronation-supination because they generate higher forces [21].

As to the object, according to Yoxall, account should be taken of size as this can significantly change the manual force needed. In product design and tasks, the grip position is favoured when done near shoulder height and force is applied in the horizontal direction.

Due to the reduction in manipulation strength, a characteristic of the elderly, performing tasks such as opening, closing, pulling and manipulating packaging becomes a challenge for these users. This research will identify limits of forces by simulating manual activities in virtual environments.

4 Virtual Reality and Simulation of Activities

In general terms, according to Rebelo et al. [22], virtual reality is a way to transport a person to a reality in which he/she is not physically present but it seems that he/she is there.

According to these authors, Virtual Reality (VR) is "the use of computer modeling and simulation that allows a person to interact with a three-dimensional (3-D) artificial environment that is visualized or in which there is other sensory involvement. In immersive VR situations, the user is located in an environment in which reality is simulated by using interactive devices. These send and receive information and can be used as goggles, headsets, gloves or body suits. In a typical VR environment, the user who wears a helmet with a stereoscopic screen sees animated images of a simulated environment".

Burdea and Coiffet (2003) divided VR technology into input devices (e.g., trackers, navigation and gesture interfaces) and output devices (e.g., graphics, sound and touch screens).

Rebelo et al. [22] present a description of VR applied to consumer products. The text below is mainly based on the analysis of these authors.

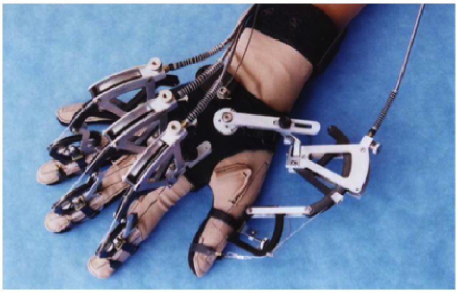
According to these authors, from the human point of view, input devices are activated by a user action (e.g., head movement, body movement and voice) and output devices activate the human senses (e.g., visual, auditory, tactile, proprioceptive). Therefore, an increase in inputs and outputs makes the system more immersive.

Immersion is also defined by its width (for example, several sensory modalities are stimulated) and depth (for example, with regard to the visual resolution). The greater the width and depth, the more immersive VR is.

Non- immersive VR, computers and an LCD monitor are often used. Sometimes, users can also wear 3-D glasses to enhance visual depth and create stereoscopic effects. Any input devices may be used, such as a joystick, a trackball, or a haptic glove.

Some tools that involve new technologies are suitable for identifying the strength limits when the elderly handle objects. Among these, Virtual Reality is suitable for simulating activities in digital and virtual environments. Most EDAs are performed by manual intervention and interaction with real world objects. Therefore, haptic gloves were designed to recognize the user's finger movements and transfer them to virtual environments. In general, a Haptics glove comprises an exoskeleton that enables information to be captured by flexing the fingers and the real location of the hand.

Force-feedback is implemented through a network of tendons that are directed towards the fingers. By using this equipment, what is offered is the sensation of the size and shape of an object that is being manipulated in a virtual reality environment. The processing system of the Instrumentation unit, a CyberGlove ®, communicates with the data of the CyberGrasp Force Control Unit (FCU). Figure 1 shows the haptic glove designed by the Immersion Corporation, and is called CyberGraspTM [24,25].



.

Fig. 1. CyberGrasp ™ haptic glove designed by Immersion Corporation

The CyberGrasp ™ may be used in conjunction with the CyberGlove ®, called CyberGrasp ™. The CyberGrasp ™ is a lightweight exoskeleton (16 oz) that fits under the CyberGlove ® device and can provide tactile feedback to the fingers. This is supplied to the fingers by means of a 24-"tendon" system or cables that run along the back of the hand and are attached to the tip of each finger. The CyberGrasp ™ can deliver a maximum of 12 newtons of force continuously to each finger [24].

In tactile feedback, tactile sensations such as the texture of a given surface are offered to the user. In feedback on strength, the device counterpoints itself to a given force applied by the user, thereby offering resistance and representing physical variables such as weight. Finally, thermal feedback seeks to represent the sensations of hot and cold [25].

According to Burdea and Coiffet [23] (2003), the user´s tactile perception is brought about by the concepts of touch and kinesthesia. Regarding touch, the user may feel different types of sensation such as temperature, pressure, vibration or pain and this will depend on the sensitivity of his/her kin. This sensitivity may vary according to the selected region where contact will be made. Kinesthesia, for its part, is related to the perception of the tensions exerted on muscles and joints. This perception is also called proprioception or force-feedback and is able to recognize the rigidity of objects.

While gloves are being used, the user may play, point to, manipulate and feel the object in the virtual environment. The gloves perform the behavior of a virtual hand within the environment, allowing the individual to undertake activities that the system will respond to [26].

The exoskeleton CyberGrasp ™, worn over a CyberGlove ® was originally created for the U.S. Navy for use in telerobotic applications. CyberGrasp ™ can be used apart from virtual reality simulation for handling hazardous materials and when using computer-aided design (CAD). In the experiment, the CyberGrasp ™ was used to aid the movement of the fingers of a 25-year-old person who suffered a stroke and whose ability to open a hand was diminished [24, 25].

In the study cited above, the individual studied had spasticity levels ranging from mild to moderate. However, on using the CyberGrasp ™, the flexion movement of the affected hand was improved and was worked in synchrony with the other hand during bilateral manual training. The results say that without this robotic assistance, hand tool has been improved and worked in sync with the other hand during bilateral training manual. The results describe that without robotic assistance, the subject would not have been able to develop simultaneous and bilateral movement adequately.

Thus, by using haptic systems it becomes possible to move or deform a virtual object - depending on the material that it is made of – by feeling its texture, weight, or the force resulting from this movement .To do so, the program must precisely calculate the force properties that the device should return to the user. If the force applied is excessive, the user will tire quickly and if it is very weak, the feelings will not seem true ones. The programmer must find a way to calibrate and balance these forces thus making the interface the most realistic one possible.

5 Conclusion

Based on this review of the literature, the intention is to formulate theoretical bases so as to apply Virtual Reality as an instrument for simulating manual activities of a population of elderly people that will enable the levels of forces used in manual activities to be quantified.

References

1. WHO – WORLD HEALTH ORGANIZATION. Questions and Answers. What are the public health implications of global ageing? (2011), http://www.nia.nih.gov/sites/default/files/nia-who_report_booklet_oct-2011_a4__112-12_5.pdf
2. Chaumon, M.E.B., Ciobanu, R.O.: Les Nouvelles Technologies au Service des PersonnesAgées: Entre Promesseset Interrogations – Une Revue de Questions. Psychologiefrançaise 54, 271–285 (2009)
3. Razza, B.M., Paschoarelli, M.C.: Avaliação de forças de preensão digital: parâmetrospara o design ergonômico de produtos. In: Pachoarelli, L.C., Menezes, M.S. (eds.) Design e Ergonomia: Aspectos Tecnológicos, p. 279. Editora UNESP. Cultura Acadêmica, São Paulo (2009) ISBN 978-85-7983-001-3
4. Parente, M.A.M.P.: Cognição e envelhecimento. Artmed, Porto Alegre (2006)
5. Voorbij, A.I.M., Steenbekkers, L.P.A.: The twisting force of aged consumers when opening a jar. Applied Ergonomics, 105–109 (2002)
6. Iida, I.: Ergonomia: Projeto e produção. E. Blucher, São Paulo (2005)
7. Pheasant, S.: Bodyspace: Anthropometry, ergonomics and the design of work, 3rd edn. Taylor & Francis, London (2005)
8. Mital, A., Kumar, S.: Human muscle strength definitions, measurement, and usage: Part I – Guidelines for the practitioner. International Journal of Industrial Ergonomics 22, 101–121 (1998); Human Muscle Strength Definitions, Measurement, and Usage: Part II – The Scientific Basis (Knowledge Base) for the Guide
9. Santos, F.A.N.V., Sala, S.F.: Ergonomia e terceira idade: aspectos relevantes para o projeto de produtos para pessoas idosas. In: Abergo 2010 –Ulaergo2010/ XVI Congresso Brasileiro de Ergonomia e III Congresso Latino de Ergonomia. Rio de Janeiro. Anais do Abergo 2010 –Ulaergo2010 / XVI Congresso Brasileiro de Ergonomia e III Congresso Latino de Ergonomia (2010)
10. Smith, S., Norris, B., Peebles, L.: OlderAdultdata: The Handbook of Measurements and Capabilities of the Older Adult. Nottingham. p. 4-9 (1998)
11. Brasil. Ministério da Saúde, Secretaria de Atenção à Saúde, Departamento de Atenção Básica. Envelhecimento e saúde da pessoa idosa. Brasília (2006)
12. Duarte, Y.A.O., Andrade, C.L., Lebrão, M.L.O.: Índex de Katz na avaliação da funcionalidade dos idosos. Revista Escola Enfermagem. 41(2), 317–325 (2007)
13. Campos, L.F.A., Paschoarelli, L.C., Silva, D.C., Muniz, F.J., Lanutti, J.N.L., Silva, J.C.P.: Análise física da força manual de torque: Contribuições para para o design de ferramentas manuais. In: XVI Congresso Brasileiro de Ergonomia, 2 a 6 de Agosto de 2010, ABERGO, Rio de Janeiro (2010)
14. Falcão, C.S., Soares, M.M.: Usability of Consumer Products: an analyses of concepts methods and applications. Estudos em Design (online). Rio de Janeiro 21(2), 1–26 (2013)
15. Mathiowetz, V., Rennells, C., Donahoc, L.: Effect of elbow position on grip and key pinch strength. The Journal of Hand Surgery, 694–697 (1985)
16. Voorbij, A.I.M., Steenbekkers, L.P.A.: The twisting force of aged consumers when opening a jar. Applied Ergonomics, 105–109 (2002)
17. Voorbij, A.I.M., Steenbekkers, L.P.A., Ramos, I.R., Toniolo, J., Cendoroglo, M., Garcia, J., Paola, C., Santos, F.: Two-year follow-up study of elderly residents in S. Methodology and preliminary. Revista de SaúdePública 32(63), 397–407 (1998)
18. Konin, J.: Cinesiologiaprática para fisioterapeutas, 1st edn. Guanabara Koogan, Rio de Janeiro (2006)

19. Cushman, W.H., Rosenberg, D.J.: Human factors in product design. Elsevier, New York (1991)
20. Yoxall, A.R., Janson, S.R., Bradubury, J., Langley, J., Wearn; Hayes, S.: Openability: Products design limits for consumer packaging Technology and Science. In: Khalid, H., Hedge, A., Tareq, Z. (eds.) Advances in Ergonomics Modeling and Usability Evaluation. Advances in Human Factors and Ergonomics Series, pp. 219–225. CRC Press, Boca Raton (2012)
21. Razza, B.M., Paschoarelli, L.C.: Hand strength and the product design: A review. Revista Tecnológica 18, 37–52 (2009)
22. Rebelo, F., Duarte, E., Noriega, P., Soares, M.: Virtual reality in consume products design: Methods and applications. In: Karwowski, W., Soares, M., Stanton, N. (eds.) Human Factors and Ergonomics in Consumer Product Design: Methods and Techniques, pp. 381–404. CRC Press, Boca Raton (2011)
23. Burdea, G., Coiffet, P.: Virtual Reality Technology, 2nd edn. Wiley-IEEE Press, New Brunswick (2003)
24. CyberGlove® Reference Manual v. 1, Virtual Technologies, Inc., Palo Alto (1991-1998)
25. CyberGrasp™ User's Guide v1.2, Immersion Corporation, San Jose C.A (2000-2003)
26. Rodello, I.A., Sanches, S.R.R., Sementille, A.C., Brega, J.R.F.: Realidade Misturada: Conceitos, Ferramentas e Aplicações. Revista Brasileira de Computação Aplicada 2(2), 2–16 (2010)