Virtual Reality-Based Simulation of Age-Related Visual Deficiencies: Implementation and Evaluation in the Design Process

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Abstract. Age-related changes significantly affect elderly users' interaction with specific products and services. Nevertheless, the challenges experienced by elderly users are difficult to be perceived and understood, especially by younger people. Inspired by the concept of aging suits, we propose a Virtual Reality-based approach, where age-related visual impairments are simulated in virtual environments. The aim is to provide an approximation of the experience of viewing and interacting with a product, from the perspective of elderly persons with specific age-related visual problems. The effectiveness of the proposed approach is examined through an experiment involving package design evaluation. The experimental results demonstrate that Virtual Reality can play an important role on understanding the challenges that elderly users face, thus support the design of elderly-friendly products.

Keywords: Virtual reality · Simulation · Elderly-friendly design

1 Introduction

Age-related changes introduce increased levels of difficulty, but not necessarily incompetence, despite the general perception that elderly people are weak and cannot be self-dependent [1]. When it comes to products and services, difficulties faced by elderly people are often attributed to insufficient design [2], which fails to consider the characteristics of a large portion of end users and adequately address their needs.

Considering the United Nations' prospects for world population, in about 30 years, in almost all regions of our planet, one in four people will be over 60 years old [3]. Therefore, it becomes increasingly important to place more emphasis on elderly population in terms of product-service accessibility.

Inspired by the concept of aging suits, we propose a Virtual Reality (VR) based approach, where age-related visual impairments are simulated in virtual environments. The aim is to provide an approximation of the experience of viewing and interacting with products, from the perspective of elderly persons with specific age-related visual problems.

Albeit associated with an age group, the term "elderly" is relative and there is no precise age, over which someone is clearly considered an elderly person [4]. In the context of this research, we refer to "elderly" as people over 75 years old, as this age group is characterized by the greatest demand in medical and social care [5]. Since the process of aging is unique for different individuals [6] and depends on many factors apart from age, for the needs of this paper we refer to elderly people who experience age-related problems, but who can live an autonomous life.

2 Related Work

Various methods have been employed to facilitate and optimize the design of elderly-friendly products and services and various method classifications exist in the literature [7]. In the context of this research, the approaches to address elderly-users' needs in the design process are categorized into two types: the non-simulated and the simulated approaches.

With the term "non-simulated", we refer to analytical methods based mainly on data collection to record and understand the needs of the elderly users. Non-simulated approaches include, among others, Field Research, Participatory Design and User Personas. Concerning elderly users, the use of non-simulated methods raises difficulties, such as achieving targeted conversation and receiving specific feedback [2], partly due to the experiences of short-term memory loss encountered by the elderly [8]. Moreover, compared to the simulated, non-simulated methods do not provide a visualization of the problems faced by the elderly, thus the designers find it difficult to provide sufficient feedback during the evaluation stage of the design process [9].

The simulated approaches involve more applied methods in which the designers are using various accessories to simulate age-related changes and thus "take the role" of elderly users. There are several approaches for simulating age-related problems, including both physical [10] and VR-based aging simulators [9, 1, 3].

2.1 Physical Aging Simulation

Physical age simulators usually come in the form of "aging suits", such as the Age Gain Now Empathy System (AGNES), developed at the Massachusetts Institute of Technology (MIT) [10], which is used by students and professionals, to experience the difficulties that accompany old age.

While physical aging suits are capable of simulating aging effects, there are some weaknesses related to their use. The inability to easily customize the intensity of the effects of aging and the amount of the time required for the users' preparation to wear the accessories, are two of the most considerable ones. Cost is yet another factor that should be considered, as aging suits are expensive and are dedicated for the sole purpose of the aging simulation.

2.2 VR-based Aging Simulation

Instead, VR technology is more affordable and has a multipurpose use, so the cost corresponding to the simulation part is lower.

There are several reports on the simulation of age-related problems and visual impairments using VR technologies [9, 11, 12, 13]. In [11], a VR headset along with a PlayStation camera were used to create an environment that simulated visual problems, through live streaming videos on which appropriate filters were applied. This work bears similarities with our approach, but in our case the experience is fully virtual. Similarly, but dedicated to architectural and space design, [12] implemented a VR environment to simulate specific visual disabilities and support the understanding of the difficulties that visually impaired people encounter.

3 Methodology

Aging is a multidimensional phenomenon, affecting many aspects of a person's life, from physical changes [13] to complex mental disorders [14]. In the context of this research, we focus on two common visual impairments associated with aging.

Cataract. Cataract is one of the most prevalent eye disorders associated primarily with age [15]. Over time, cataract causes an increase in lens density, hindering the clarity of vision. Cataract disease can be associated with a series of symptoms such as yellowing of the lens, blurry vision, fainted colors symptom, difficulty in differentiating colors [15] and need for extra lighting [13]. In the virtual environment, the clouding of the lens was achieved using the blur image effect with the intensity amounted to 30%. For the simulation of toneless vision, image contrast was reduced to 20%. Finally, for the reduction of the lighting reaching the retina to one-third [13], image brightness was proportionally reduced.

Macular Degeneration. Nearly one in three people aged over 75 years old suffers from macular degeneration [13]. Macular degeneration mainly affects central vision and is associated with symptoms such as dark spots in the center of the field of view. To simulate the symptoms of this eye disease in the virtual environment, overlay textures were applied in the center of the viewport (Fig. 1, right).

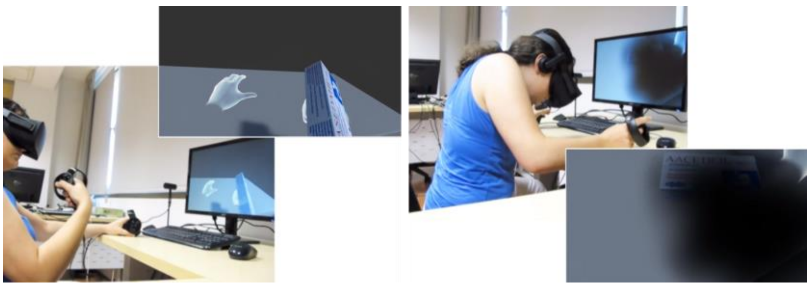

Fig. 1. Picture captured during the interaction with the non-aged VR environment *(left)* and the age-simulated VR environment *(right)*.

To test the efficacy of the proposed VR-based aging simulation, we carried out an experiment involving a pharmaceutical package design. The purpose was to investigate whether by using an age simulated VR environment, it is feasible to detect design faults on packages that could prevent the correct use of products by the elderly.

The experiment was conducted using the Oculus Rift CV1 VR headset along with the Oculus Touch controllers for the interaction in the virtual environment and the manipulation of the virtual pill box (see Fig. 1).

The virtual environment used in this experiment consisted of a three-dimensional object – the virtual representation of a real pill box, and a grey background with depth perception (see Fig. 1). For the modeling of the virtual box, scanned images of the six sides of the actual pill box were used. Using image editing software, two alternative virtual pill boxes were modelled using identical graphic elements to avoid the case where the participants remembered the information from the first trial.

The experiment was assessed by 23 young adults – 9 males and 14 females – aged between 18 and 34 years old. The participants were separated into two equal groups: the first group (group A) started the experiment using the aging simulated environment and then carried on with the non-aged virtual environment, while the second group (group B) performed the experiment in the opposite order. Thereby, previous knowledge and/or familiarity did not factor into the overall performance of the tasks and the results of the questionnaires.

During the experiment, the participants were requested to locate and read aloud: the name of the medicine (Q1), the expiry date (Q2), the amount of the active ingredient of each pill (Q3) and the indications about the medicine (Q3).

After the interaction with each of the two environments, participants were given a questionnaire (see Table 1) related to the ease of completion of the four requested tasks and were asked to provide answers on a 5-point Likert scale (1: the task was not easy at all, and 5: the task was extremely easy to perform). Moreover, they were asked to quote their perceived age in each of the two variations of the virtual environment.

4 Results

According to the experimental results, reading the information on the pill box was clearly more difficult in the age-simulated than in the non-aged virtual environment (Table 1). P-values were calculated with Fisher's exact test to compare the responses given after trying the non-aged and after trying the age-simulated virtual experience. There was a significant difference in all scores ($p<0.05$) concerning the reading part of the info. The results imply that the difficulty encountered could have been avoided if designers were able to visualize the packaging from the perspective of elderly people, effortlessly detect design defects and design a more elderly-friendly packaging.

Regarding the design elements that one would change in the package, while in the non-aged environment the answers were distributed, in the aging environment, most of the participants concluded that the main defect was the size of the fonts.

Given that virtual prototyping techniques are often used along with VR technology [16] to impart greater efficiency to the design process; the additional feature that the

VR-based aging simulation can provide, namely the visualization of age-related problems, could help in identifying design weaknesses related to elderly users.

Table 1. The questions regarding the easiness of the completion of the tasks along with the P values from the Fisher's exact test.

Questions	**Name (Q1)**		**Expiry date (Q2)**		**Quantity (Q3)**		**Indications (Q4)**	
Environment	**Non-aged**	**Aged**	**Non-aged**	**Aged**	**Non-aged**	**Aged**	**Non-Aged**	**Aged**
Median	5.00	4.00	4.00	3.00	5.00	4.00	4.00	1.00
Deviation	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00
P-value	0.01		0.00		0.00		0.00	

Regarding the perceived ages in the two variations of the virtual environment compared to participants' actual age, paired samples t-test was conducted between (1) the perceived age in the non-aged environment and participants' actual age (p=0.1056), (2) the perceived age in the aged environment and participants' actual age (p=3.201e-05) and (3) the perceived age in the non-aged environment and the perceived age in the aged environment (p=5.966e-05). The results indicated that participants realized that the experiment concerned age-related effects, even without having prior information about the aim of the experiment.

5 Conclusion

An investigation into the development and an evaluation of VR-based simulation of age-related visual impairments in the product design process, were presented. The aim was to investigate whether by using an age simulated VR environment, it is feasible to detect design faults on pharmaceutical packages that could prevent the correct use of medicines by elderly people. The results indicated that VR-based simulation can highlight the difficulties that elderly people, suffering from age-associated problems face during a seemingly easy process, such as reading pill package's information and support the design of elderly-friendly products and services. Similar applications could be used by designers to take the role of elderly consumers to facilitate the accessibility of products. Compared with other methods used for aging simulation, VR can be easily applied to many scenarios under highly controlled settings.
In the future, the incorporation of additional age-related factors is planned. A configuration could be made to enable the adjustment of the intensity and type of simulated aging effects based on different variables such as age, sex and lifestyle allowing in that way the customization of virtual aging simulators at various circumstances.

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