Guidelines for the Development of Gestural Interface Games for the Older Adults

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***Abstract*—Several factors such as medical and technological advances, improvements on basic sanitation, reduction of the mortality rate and increase in the life expectancy have contributed to augment the average age of the world population. Besides its clear advantages, this fact also introduces a new target audience for computational applications, with specific needs and restrictions: the elderly. The present work presents a set of guidelines for the development of gesture-based applications for older adults. These guidelines are the result of a comprehensive survey on projects which define issues and propose solutions for gestural interfaces as well as for the elderly audience. To evaluate the impact of using the guidelines on the usability of applications, a case study is presented.**

I. Introduction

According to the United Nations Report on Economic and Social Affairs [1], the population ageing, a process whereby the proportion of older people in the population increases and that of younger people declines, is the primary demographic consequence of fertility decline, especially if combined with increases in life expectancy. By the year of 2011, 11.2% of the world population was aged 60 years or over, and this proportion is expected to reach 22% in 2050.

Besides the issues concerning social security and public health, ageing may introduce negative physical, cognitive, and social consequences to individuals. There are losses in the average visual and auditory acuity, as well as in the average strength and speed of response [2].

Research has shown that playing games can have positive effects on the emotional and physical well-being of elderly people, and can motivate them to maintain a basic level of physical and memory activity [3], [4]. Using non-conventional devices, such as the Microsoft Kinect [5], may offer a good opportunity to create games able to motivate the physical and memory features of the eldery. However, the games available in the market can provide real danger to these people [6]. Thus, it is necessary to take into consideration usability criteria, such as exertion management, age-inclusive design and simple setup routines [7].

This work presents a set of guidelines for the development of applications for the elderly audience. These guidelines were conceived taking into account several age-related disabilities, and they are supposed to fulfill the needs of senior citizens in the sense of providing entertainment associated to benefits in the memory, motor and social skills. This work is organized as follows: in Section 2, a literature review of several works on guidelines for the design of applications for older adults is presented; Section 3 presents the types of memory and the how aging effects the memory of the people; Section 4 introduces a list of age-related disabilities that must be addressed in order to promote more suitable interfaces; the set of guidelines derived from the literature review is given in Section 5; Section 6 and Section 7 provides, respectively, a Case Study to investigate how adherent these guidelines are to the issues, as well as the results from a usability inspection carried out with the target audience; finally, the final considerations and future work are enrolled in Section 8.

II. Related Work

Several works aiming to provide guidelines for the development of applications for the elderly can be found. The scope of these works range from interfaces for mobile applications [8], serious games [6], [9], [10] to websites [11], [12] and complex interaction applications.

According to Gerling et al.[7], game design for elderly people has focused mainly on design guidelines and case studies. Gesture-based input for games has only explored the context of younger players.

First, in [8], a literature survey of the usage of touchscreen devices among older adults is carried out to distill and consolidate a set of design recommendations and guidelines classified into three dimensions, namely: Look and Feel, Functionality and Interaction. The purpose of these recommendations is to serve as an information base for touch-based interfaces for elderly people.

Seven guidelines, designed to foster safe physical activity among older adults in full-body interaction games are presented in Gerling et al[7]. This work also highlights the limitations of current design philosophies, and opportunities to facilitate the creation of accessible motion-controlled games.

Important changes in structural elements of games, due to age-related changes in cognitive and physical user abilities are discussed in [13]. The authors also discuss how important are the complexity of games and the interrelations between different game mechanics when designing for older adults.

A review and analysis of guidelines and articles relating to the needs of senior citizens with Web accessibility needs due to ageing is provided in Arch [11]. The main purpose of this work is to inform the development of educational materials which can better promote the needs of people who have accessibility needs due to ageing, and potential development of profiles and/or extensions on WAI - Web Accessibility Initiative- guidelines. Besides, the work provides an overview on the needs of older adults with functional impairments who access the Web, and is intend to compare how well is the coverage of these requirements by the WAI guidelines.

Still regarding the design and use of websites, according to [12], the users aged 65 and older are 43% slower than users aged 21–55. Thus, designs must change to better accommodate ageing users. This report also investigate questions, such as recommendations for making websites easier and more engaging for seniors; content and formatting techniques that help older people process information; styles that accommodate diminished eyesight; and how to conduct usability studies with seniors.

The present work introduces a comprehensive set of guidelines, suitable for the development of gesture-based interfaces for older adults. These guidelines are based, adapted, but not limited to the guidelines found in the related works, and address the issues and age-related disabilities.

III. Types of Memory and Aging Effects

Shneiderman [2] describes three types of memory, as well as the proccess of information input and retrieval: Short-Term Memory; Temporary Memory and Long-Term Memory.

Short-Term Memory receives input information captured by the sight, hearing, smell, taste and touch and passes it to the cognitive system. This type of memory is also where the output information is placed, that is, information expressed by speaking, gesture and actions. Storing in this memory takes about 10 seconds, and its capacity is quite limited. According to Miller [14], the total amount of information is 7 ± 2. In other words, when capting a certain number of information, the Short-Term Memory is able to hold an average of 7 information, with average variation of 2, i.e. between 5 and 9 information.

Temporary Memory (or Working Memory) is where the information that comes from the Short-Term Memory is handled and concatenated, before being sent to the Long-Term Memory. Thus, the information is kept for longer periods of time than the Short-Term Memory, but not in a permanent way.

Finally, Long-Term Memory is able to store a large amount of information for long periods of time. For instance, facts that occurred a long time ago and that a person is able describe in detail.

The access to information is not limited to the Working Memory. Short-Term Memory can, exceptionally, act as a way of access. The information that takes this ”shortcut” does not require any retrieval mechanism - for instance names, addresses, and phone numbers. These information is learned by people learn very early in life and can be recalled automatically. However, when the phone number or the car license plate number is changed, it will be necessary, in the beginning, to be associated to some retrieval mechanism of the Working Memory in order be retrieved.

According to Souza and Chaves [15], a substantial portion of the elderly population complains on the difficulty of storing and retrieving information, for instance for taking medicine, locating objects, and naming known people. In cognitive aspects, older adults often experience cognitive impairments, which affect problem solving skills, information processing and result in a reduced attention span when working on complex tasks [4].

Aiming to investigate how to reduce the memory loss in the elderly by means of stimuli, several studies in the Medicine area have been carried out [16], [17]. In its turn, studies in the Human-Computer Interaction area aim to stablish guidelines for building interfaces able to adapt themselves to the human memory characteristics, which do not require over the necessary and feasible memory skills. In the Games Development area, it is possible to couple these interests, that is, to build games and interfaces adaptable to the memory characteristics and that can inhibit memory loss in the eldery, in a ludic way. Computer games are also attractive for older adults, because they stimulate social interaction, provide practice in sensorimotor skilIs such as eye-hand coordination, enhance dexterity, and improve reaction time.

IV. Age-Related Disabilities

During the life span, the human body and the human mind are continuously subject to changes in practically all aspects of perceptual, cognitive, and motor functioning. This section presents some possible reasons why seniors do not use or dislike using computer devices.

A. Hesitation and Discouragement

According to a study conducted by the Nielsen Norman Group [12], 45% of older adults showed behaviors that indicated they were uncomfortable trying new things or hesitant to explore new technologies.

B. Age-related Changes in Cognition

According to Bouwhuis [18], there are two developmental trends on the cognitive level, namely the ”crystallised intelligence” and the ”fluid intelligence”, related to types of task and function.

The crystallised intelligence is supposely associated to the acquisition of new knowledge, improvement of skills, and extending the vocabulary. Even at a high age, people are quite able to use this store of knowledge, and may score higher than younger people on tasks requiring vast stores of information and establishing relations between pieces of information. The fluid intelligence, in its turn, is used in tasks where speed of processing is necessary. Although younger people are both faster and more accurate than older ones, when given more processing time, older people can attain the same level of

accuracy. Thus, the speed of processing seems to be the crucial difference between older and younger people, which lends credence to the idea that the perceptual world is also typified by its own temporal course of events.

Still according to Bouwhuis [18], loss of memory in seniors is essentially related to the same timing problem. While primary memory is hardly affected in old age, it involves retaining a few items with minimal processing. As soon as more processing is needed and the number of items to be remembered increases, memory performance decreases rapidly. Apparently, the more encoding time is available, the more the memory performance improves. It seems that older people tend to spend a longer time on encoding, but estimate that this period of time is sufficient for successful recall, which actually it is not. Yet, the encoding time taken corresponds to the time they took in earlier phases of life, which has largely become automated and is hard to change.

C. Declines in Auditory and Visual Acuity

According to Phiriyapokanon [19], issues related to the vision loss of seniors start to become more obvious around 60 years old. The visual field reduce, which makes it become more suitable to adjust the focusing point of the information devices to be stronger and closer to the center of the visual field. Older people have less sensitivity to color contrast than the younger people, especially in the blue-green range. Additionally, seniors have the capability decreased in tone detection in different frequencies. Hearing is also affected, being difficult to them hearing high pitched sounds with peaks over 2500 Hz [19].

D. Declines in Motor Skills

Physical decline is one of the general problems for the elders. It is generally accepted that performance of seniors is slower in terms of interaction tasks. For instance, they have problems concerning the mouse double-click. In general, seniors are slower in movement and response time, they consider harder to find a small target and are less accurate in their movements than younger people. That is, it can be implied that seniors may have difficulties to deal with general computer interactions, which are not designed for them [19].

E. Declines in Perception Skills

According to Bouwhuis [18], all the sensory modalities perceptual acuity start to continuously diminish at the mid-twenties age, and this process assumes a more progressive character after the sixty years-old, on average, but with a large variability, both in time of onset and in extent. This is valid more complex functions like speech comprehension, demonstrating a developmental nature of the changes. Such slow and mostly imperceptible changes over such a long time unavoidably lead to a different perception of the environment, creating a ”perceptual world” inherent to the person.

F. Computer Anxiety and Lack of Motivation for Initial and Expert Users

Despite a larger number of older adults is becoming involved in usability studies, there is a lack of information on their motivation. Tentatively, it has been assumed that people become more patient as they get older. Conversely, older people seem to act more impatiently. The reason for this may be an increasing awareness of impending limitations, or even death. Thus, they seem to prefer a small reward immediately than a larger one later, when it could become out of reach. Though frailty and health limitations could play an important role here, it appeared that the age effect was stronger than the health effect. Still it has to be borne in mind that health is strongly negatively correlated with age [18].

V. Guidelines Gestural Interfaces for Older Adults

According to the age-related issues found in the literature, a set of guidelines specific for designing applications for older adults was obtained. This set addresses all the disabilities related, and is intended to provide hints to the system developers build more suitable interfaces. The next subsections describe the guidelines more precisely.

A. Guidelines Addressed to Hesitation and Discouragement

In order to address the issue concerning the Hesitation and Discouragement of older adults to play digital games, Gerling and Smeddinck [9] propose a few guidelines to stimulate them to engage and play:

- the game must be playful, in other words, people should enjoy spending the time playing it;
- if possible, the game must involve another gamers. The reason is that playing with others tend to be more attractive than playing alone; this also explains the next guideline,
- the players shall be encouraged to use collaboration and competition;
- since men and women may have different topics of interest, the games shall be developed according to the gender of the players.

B. Guidelines Addressed to Age-related Changes in Cognition

The major concern of the research projects found in the literature is related to cognition issues. Several works investigating how the memory decline can be mitigated by stimulation through games provide a list of guidelines:

- the games must avoid the use of prior information, such as RPG games [9], [19], [20];
- games must use simple interactions [20], [19], [8], therefore quick and complex interactions [9], [20], [19], as well as quick and parallel actions must be avoided;
- the learning time should be greater [9];
- games should embed familiar metaphors [9], [19];
- during the duration of the game, additional and more detailed information should be provided [9];

- complex screen must be avoided [20], [19], [21], [8], [22], [12];
- redundant information through multiple modalities should be provided [8], [19], [20], [23], [18];
- the load on memory and cognitive processing should be kept to a minimum [20], [19];
- avoid contradictions and inconsistencies of information arrangement [19], because they may confuse the users;
- in gestural interfaces, it is advisable to use a set of few and easy movements [13].

C. Guidelines Addressed to Declines in Auditory and Visual Acuity

As people age, the senses become less sharp. Information received from your environment, in the form of sound, light, smells, tastes, and touch is converted to nerve signals and carried to the brain, where it is turned into a meaningful sensation. In games, vision and audition are the most stimulated senses. Therefore, the guidelines to preserve the sensation games are designed to provide are:

- use appropriate size of objects and source text, as well as higher contrast [9], [20], [19], [21], [8], [22], [12];
- avoid synthethic speech, because it may be hard to be understood by older people [20], [19];
- for non-speech audio signals, prefer lower frequency tones (in the 500-1000 Hz range), which are easier for elderly users to hear than higher pitched sounds [18], [20];
- avoid using small targets and moving interface elements [20];
- use appropriate illumination and try creating intuitiveness [20].

D. Guidelines Addressed to Changes in Motor Skills

Aging is accompanied by impairments in motor skills. When people age, they perform complex tasks more slowly and, in some cases, less accurately. To deal with it, literature review suggests the following guidelines:

- create slower response times [9], [20], [11];
- avoid continuous and flexible movements [20];
- void a great variability in movement [20];
- take into account motor disabilities [9], [20], [19];
- try including Health stuff [24], [20].

E. Guidelines Addressed to Declines in Perception Abilities

Adressing the declines in perception abilities, two suggestions are provided: using multimodal feedback for important information [20], [19], [22]; and providing appropriate affordances [20], that is, visual hints to the function of objects.

F. Guidelines Addressed to Computer Anxiety and Lack of Motivation for Initial and Expert Users

To deal with the possible lack of motivation, in strategy games, it is suggested to provide positive feedback for initial users [20]; also, the interface should be adaptable [13], [18], [21], [11], allowing both initial and expert users to adjust it according to their specific needs.

G. General Guidelines

Some guidelines are addresssed to more than one specific disability, or are related to general issues. These guidelines were named as ”General Guidelines”, and are composed by:

- the interface should clearly express where the user is in the dialogue, and which “tasks” are active [8]. This addresses declines in perception abilities, changes in cognition, and even may be useful to avoid the lack of motivation for Initial and Expert Users;
- the structure of the task must be clear, with a starting point and steps easily recognized and understood [19];
- applications should continuously provide easily recognized feedbacks of success or failure of every action [19];
- output messages should be as short as possible [25];
- choices should be as few as possible, whereas confirmatory statements should be as much as possible [25].

VI. Case Study - Simon Game

To evaluate the Guidelines suitability, an usability test, with a game designed for the elderly audience, was carried out. The game was developed to use the Microsoft Kinect as interface device. Prior to the development of the game, a psychologist specialized in memory issues was referred.

The game developed is an electronic version of the Simon memory game. The game interface consists basically of four coloured buttons: red, green, yellow and blue, associated to four different sounds. The player must memorize and reproduce sequences of sounds-colors in the same order they are presented. The first sequence has only one sound, and its size is increased by one every round. Advanced levels may reach 34-color sequences. The Fig. 1 shows the original game. According to the psychologist, the game can be used to evaluate the amount of information stored in the short-term visuospatial memory. The game was implemented using the Microsoft SDK, which is the Microsoft solution to the creation of Windows Operating System applications. The interface of the game is presented in Fig. 2.

An interview with the psychologist revelead both functional and non-functional requirements. Some of the requirements are listed as follows:

- the electronic version must accurately simulate the game;
- the ordering of the buttons must be random;
- a sound must signalize the end of the game - when a wrong sequence is entered by the user;
- the sequence of the buttons entered by the user must be recorded in a file, to be analyzed by the psychologist after the game ends;
- either only the right or the left hand is used to select the buttons;
- the interface must provide a feedback, such as changing in the size, color or brightness level, indicating the selection of the button;
- the interface must be inactive while the user does not select a button;
- the system allows one player at a time.

Fig. 1. Simon Game

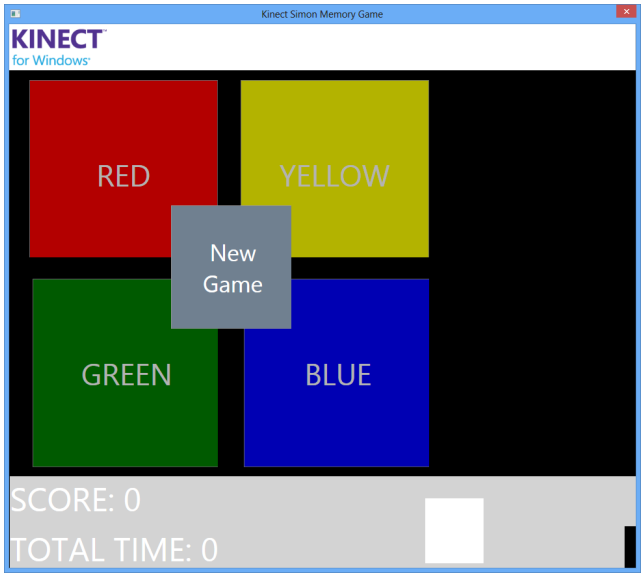

Fig. 2. Game Interface

Besides, during the application development, the guidelines presented in Section 3 were took into account. Some features were introduced into the game due to the observation of the guidelines, and wherever the game characteristcs allowed.

Regarding the guidelines addressed to hesitation and discouragement of the players, the interaction mechanism itself, which involves body movements, allied to the cognitive aspect, provided a playful game. The involvement of other players was not possible, since the game is played by only one user at a time; and the collaboration and competition aspect was not attended, but the developers are considering to introduce a ranking system to fullfill this guideline. The game is suitable for both genders, without adaptation.

The observation of the guidelines addressed to age-related changes in cognition lead to the following features:

- the player is exempted to use prior information;
- the game uses simple interactions, that is, the player must only select the correct block sequence; it is not necessary to navigate through the environment, because the interface does not uses a scroll bar, neither several pages of information;
- the interactions do not need to be performed quickly, because the correct sequence of colors is considered, no matter the time it is spent to introduce the sequence;
- the game does not requires parallel interactions, has incremental level of difficulty, and does not develop complex screen;
- redundant information is provided through multiple modalities - each button has a different color, plays a different sound, and is labeled with the name of the color associated to it;
- the load on memory and cognitive processing is kept to the minimum, in the sense that the only memorization needed is the sequence of buttons to be push;
- the movements necessary to the game are very few and easy to be performed, and embed familiar metaphors - pushing a button is performed by the movement of pushing with the hand in the air;
- the interface is slower, if compared to the original game.

As regards to the guidelines addressed to the declines in auditory and visual acuity, the size of objects and text fonts were considered adequate by the developers, the clickable objects do not move; the game does not use synthetic speech, and the audio signals use lower frequency tones (in the 500-1000Hz range). The tones adopted are actually lower than the recommended by the guidelines provided, varying from 209Hz to 415Hz, but these are the sounds used in the original game.

Concerning guidelines addressed to changes in motor skills, the game uses slower response times; it does not requires continuous and flexible movements, neither a great variation in movements; and its designed for providing better health to the users. However, the game does not take into accound motor disabilities, due to its interaction model, which requires body movement to be performed.

The declines in perception abilities were considered by using multimodal feedback for important information - sound and color changes to signalize button interactions, as well as errors, which were signalized by a ”razz sound”. Visual affordances were not used, due to the simplicity of the interface.

Finally, to address the computer anxiety and lack of motivation for initial and expert users, the game is not adaptable according to the level of expertise, in other words, there are no differences either in the interface or in the level of difficulty for more expert users, due to the characteristics of the original game.

Due to the initial requirements to strictly reproduce the original game, it is possible to notice that not all the guidelines were able to be considered. Some guidelines were not suitable and conflicted with the game characteristics.

VII. Usability Evaluation

The Usability Test was carried out with a group of 10 people, with ages varying from 60 to 75 years old. According to [26], a number of 5 users is enough to the majority of the usability tests, specially those aimed to detect usability errors. In spite of it, the target audience is quite heterogeneous, and, aiming to provide an effective usability test able to verify issues beyond interface errors, a larger sample of users would be necessary. The test took place in two different places: a room in the University and the house of the users. None of the environments had its light conditions controlled. The Fig. 3 shows users interacting with the game.

The evaluation was performed through three questionnaires and interviews. The first questionnaire was based and adapted from Mitchell [27], and it was formed by multiple-choice questions on gender, age, frequency on the use of computer games, physical activities and knowledge about the Microsoft Kinect. The second questionnaire, adapted from Hartikainen et al. [28], in its turn, used the 5-point Likert scale [29] to investigate the user impressions on the level of interest of the game, ease of use, level of motivation, and whether the user was willing to try new technologies or not. Finally, the post-test questionnaire also used the 5-point Likert scale and was adapted from Martins et al. [30] and from the Web Usability Questionnaire [31].

The Profile Questionnaire results were: 4 users were women, whereas 6 were men; none of the users had previous contact with the Microsoft Kinect; 7 users stated that rarely, or never play computer games for entertainment, 1 user plays weekly, and 2 users play on a month basis. Regarding the regular practice of physical exercises, from the total of 10 people, 4 declared never to practice.

The Expectation Questionnaire had two users declaring that they totally agreed that the game would be very interesting, while 8 users declared they only agree with that statement. The question ”I think the game will be very easy to use” had one user who totally agree, 2 users agree, whereas 7 disagree. The motivational aspect of the game was considered totally motivational by 3 users, 3 only agree, 3 were undecided, and 1 user disagree. 5 users agree that they are willing the try new technologies, 1 of them was undecided, 2 disagree and 2 of them totally disagree.

The Post Questionnaire results are shown in Fig. 4 and Fig. 5 allow to conclude that this sample of users considered:

- using a mouse is preferable than using the Kinect (according to the answers to the questions 1, 5, 6, 12, and 13), but that does not affect the question 4, which investigated how pleasant was using the game;
- the feedback provided when they commited an error was appropriate (question 2);
- the game was easy to learn and easy to memorize (questions 9, 10, and 14);
- not being able to master the Kinect in the first use was a cause of lots of frustration (question 8);
- the game does not caused muscular fadigue (question 3), however 40% of the users declared to be undecided or disagree the fact they could play it for a long time, since they would have to play it standing (question 18). 40% of the users also were not sure whether the position to play was uncomfortable or not, whereas 10% declared to be uncomfortable (question 19);
- the buttons in the interface had appropriate size and were not considered and issue (question 17), the feedback to the selection, in its turn (changing the color of the button), was not clear to the target audience (question 20).

The interview process revealed that the biggest complain of the audience was not having total control on the click movement and navigation via gesture interface. Several times, the cursor was not visible and caused some distress. Some users declared to think they were causing the problem for not knowing how to correctly use the device.

VIII. Conclusion

This paper presented a set of guidelines for gestural intefaces for designing games for older adults. The development of applications designed for this specific target audience must observe these guidelines, in order to avoid discomfort, danger, and yet to have a good usability level. These guidelines are related to Hesitation and Discouragement, Age-related Changes in Cognition, Declines in Auditory and Visual Acuity, Declines in Motor Skills, Declines in Perception Skills and Computer Anxiety and Lack of Motivation for Initial and Expert Users, and seeks to guide developers to address these issues.

It is also interesting to point out that building computer applications for the older adults audicence requires a multi-disciplinar team which involves, certainly, health professionals with the appropriate skills. Such professionals are able to conduct the development and the focus of the applications, as well as to provide environments and real test conditions with the target audience. Considering the results of the usability evaluation, it can be assumed that following the set of guidelines can be useful to avoid basic interface errors, but this is not enough to provide an suitable interface for older adults. Usability Evaluation reamains still an important phase in the development process.

The usability evaluation results allowed to conclude that users who are not frequent in the use of games neither in the use of the Kinect felt some initial difficulty to perform the gestures, but they considered it as a challenge. The sounds used in the game were not in the appropriate range - according to the guidelines - and the interviews and observation lead to notice that the users really had some trouble to distinguish the sounds. This reinforced the belief in the acceptance of the sound-specific guidelines.

The interface were considered suitable and delivered playful and interesting applications. Despite the issues related to muscular fatigue and mastering the device, the developers believe that the proper practice and constant use can lead to benefits in the physical condition of the users. Besides, the results also indicate that the testing the application is very

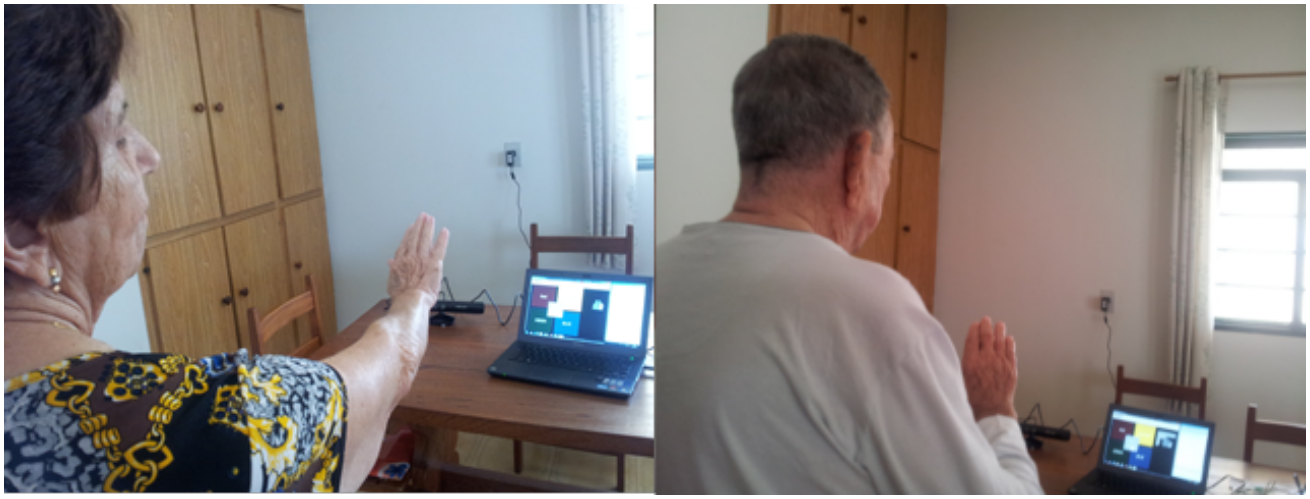

Fig. 3. Users Interacting With The Game

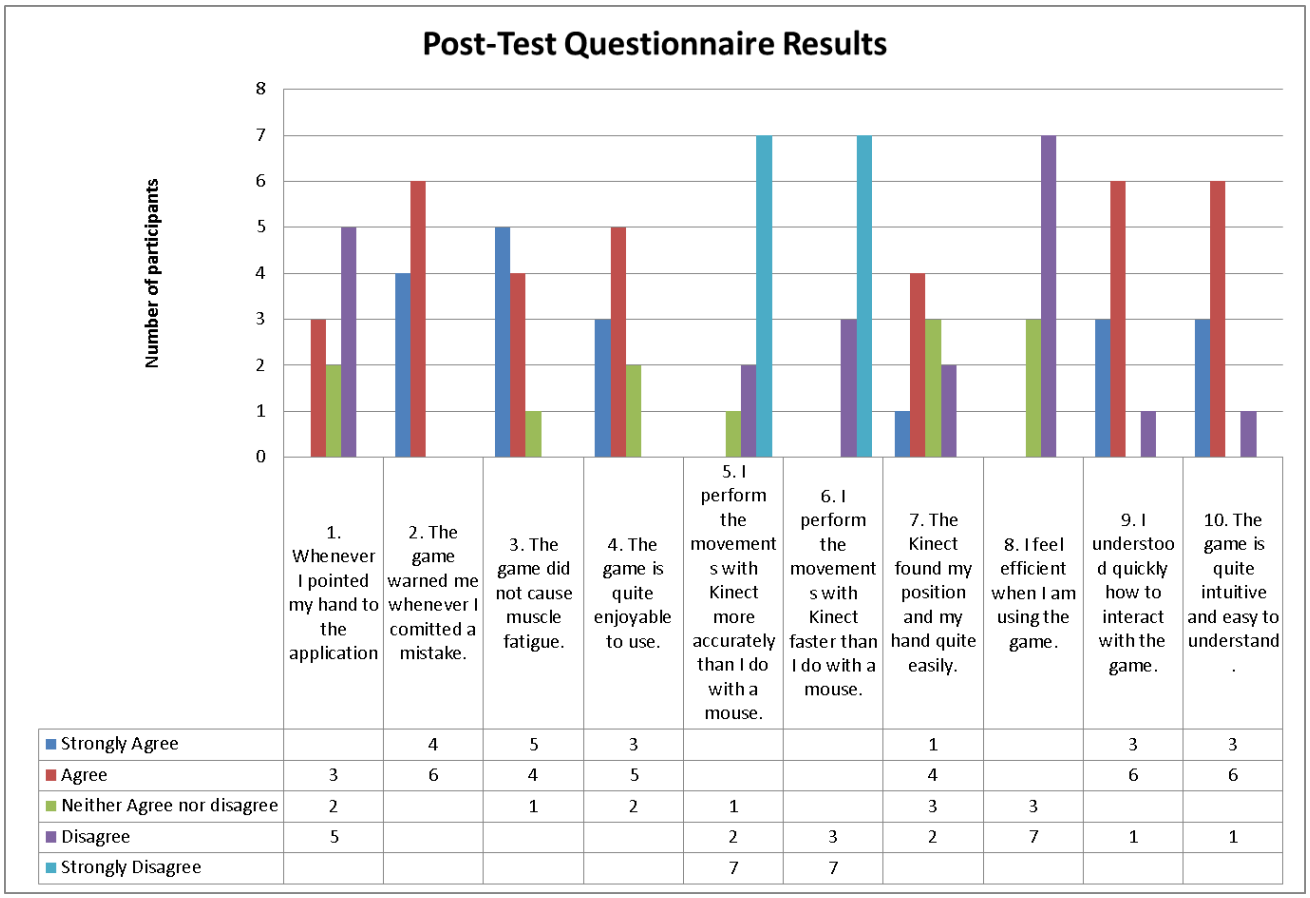

Fig. 4. Post-Test Questionnaire Results

important, due to the novelty of this type of interface and lack of familiarity of the users with the new devices that have been introduced. The analysis data will be used as feedback to the development team to incorporate improvements to the game.

The professional who provided the requirements for the application also expressed his expectations on it, in the sense that he would like to investigate whether the Kinect can also stimulate physical (spatial) aspects of the patient, leading to

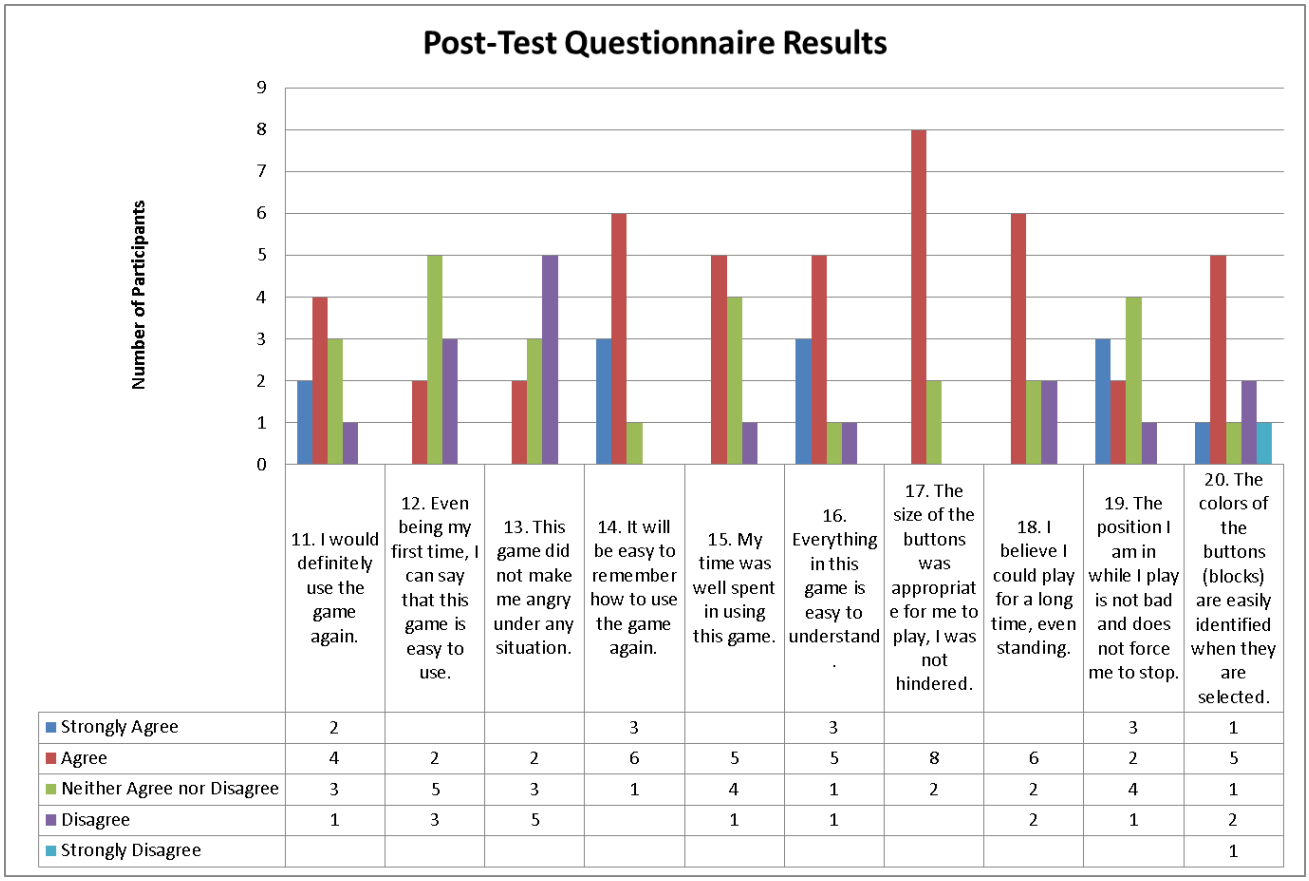

Fig. 5. Post-Test Questionnaire Results - part II

significant enhancements to the patient health, when using it as a training tool.

Future work includes the possibility of applying the game in visuospatial tests in the Neurosciences Laboratory of the University, in appropriately controlled environment, and checking if its use can really improve the short-term memory storage capacity in older adults. After incorporating the necessary enhancements and adjusts in the interface, a version of the game will be available for download.

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