A Visuospatial Memory Game for the Elderly Using Gestural Interface

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Abstract. This work presents a visuospatial game designed for the elderly that uses gesture based interaction. The game is a computer version of the Simon Memory Game (known in Brazil as "Genius"), which was quite popular in the 80s. All the development phases are presented, since the requirements elicitation to the tests with potential users. The elderly population characteristics were taken into account for the game development. Details on the usability tests results with 10 users are given and also the analysis of this data.

Keywords: Usability · Games · Serious games · Gestual interface · Kinect

1 Introduction

According to the World Population Aging Report of the United Nations (UN), the number of people considered elderly, aged over 60 years, is growing faster than any other age group. As a result, the share of elderly in the population is increasing virtually everywhere. In the year of 2050, it is expected that this population will reach 2.1 billion people [1]. Factors related to medical and technological advances, sanitation improvements, prevention, control and cure of diseases that once were considered fatal are crucial to reducing mortality and increasing life expectancy, even in countries under development, which led to an increase in the elderly population rate.

On the other hand, several areas of Medicine have been faced problems arising from the loss or decrease of memory, due to the aging process [2]. In fact, according to Souza and Chaves [3], a considerable part of the elderly population complains about the difficulty of storing and rescuing information, such as forgetting to take medicines, locating objects and naming known people, affecting your well-being.

The literature suggests that, in healthy aging, there is the possibility of (at least partial) compensation of cognitive deficits [4–6]. Research on cognitive and memory training indicates that the healthy elderly are able to approximate their current performance to their maximum possible performance, revealing cognitive plasticity [7]. In fact, the studies conducted by [3, 8, 9] point out that the exercise of memory stimulation in healthy elderly considerably improves this cognitive aspect.

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In addition, according to Boot et al. [10], research shows that playing video games, even for a relatively short period of time, improves the performance of a series of tasks that measure visual and attention skills. These studies prove that playing, even for only 10 h, can improve performance in laboratory tasks differently from those who did not play.

Gestures have been used in human-computer interfaces to create more natural interfaces in new three-dimensional computing environments, leveraging the user experience as the basic movements of the domain, for example, raising a hand, walking or shaking his/her head [11]. The use of natural interfaces can reduce the degree of learning of the devices, especially important for the elderly population.

Although non-conventional devices, such as Microsoft Kinect [12], offer a good opportunity to motivate the physical and memory characteristics of the elderly by using gesture-based interfaces, the games available on the market may eventually cause danger, especially for the elderly population [13]. Therefore, it is necessary to develop these games taking into consideration usability issues, such as effort management and design concerning the age and simple configuration routines [14].

This paper aims to present the development of a computer memory game for the elderly, called Genius, using Kinect. Guidelines for the development of games for the elderly with natural interfaces are presented, such as the use of appropriate frequency sounds for the user class, the use of more vibrant cores, and the application to be run more slowly.

The current work is organized as follows: in Sect. 2, we present a series of Guidelines for the development of applications for the elderly; the Sect. 3 introduces a brief explanation on the types of memory and how ageing affects them; related works are presented in Sect. 4; in the Sect. 5 the development aspects are presented; in Sects. 6 and 7 we present the evaluation methodology used as well as the results obtained; and, finally, in Sect. 8 the discussion and future work.

2 Guidelines Addressed to Develop Serious Game for Elderly

The development of games for the elderly should take into account intrinsic requirements that this class of users has, such as physical limitations, memory, speed of movement, among others. As pointed out by [15, 16], to design an application taking into account the physical and mental limitations for the elderly, one must look at four sets:

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

- Mitigating the memory decline:
  - games must avoid the use of prior information, such as RPG games;
  - games must use simple interactions;
  - quick and complex interactions as well as quick and parallel actions must be avoided;
  - learning time should be greater;
  - games should embed familiar metaphors;
  - during the period of the game, additional and more detailed information should be provided;
  - complex screen must be avoided;
  - redundant information through multiple modalities should be provided;
  - load on memory and cognitive processing should be kept to a minimum;
  - avoid contradictions and inconsistencies of information arrangement, because they may confuse the users;
  - in gestural interfaces, it is advisable to use a set of few and easy movements.
- Preserving the senses:
  - use appropriate size of objects and source text, as well as higher contrast;
  - avoid synthetic speech, because it may be hard to be understood by older people;
  - 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;
  - avoid small targets and moving interface elements, and use appropriated colors;
  - use appropriate illumination and try creating intuitiveness.
- Working with impairments in motor skills:
  - create slower response times;
  - avoid continuous and flexible movements;
  - avoid a great variability in movement;
  - take into account motor disabilities;
  - try including Health stuff.

To summarize, the group of guidelines specific for designing applications for older adults addresses all the disabilities related, and is intended to provide hints to game developers to build more suitable interfaces this audience.

3 Types of Memory

In the Human-Computer Interface area, studies attempt to guide software designers in the construction of interfaces adapted to the characteristics of human memory, eliminating the need of memorization skills beyond the necessary and feasible from the typical user of certain systems.

Shneiderman [17] addresses three types of memory (Fig. 1) and the process of entry of information, as well as the search for this information:

1. Quick or Short-Term Memory: receives the input information captured by the sight, hearing, smell, taste and touch and passes them to the cognitive system. It is also where the output information are deposited, i.e. the information that is expressed by speech, movements and actions. The storage in this memory is of the order of 10 s

and its capacity is also quite limited. According to Miller [20], the amount of information stored is 7 ± 2, that is, by capturing a certain number of information by one of the perception senses, the short term memory is capable of storing an average of 7 of this information, with an average variation of 2, that is, between 5 and 9.

2. Work or Temporary Memory: where the information coming from the short-term memory is worked, concatenated, and then sent to the permanent memory. It is therefore a temporary memory, and the information contained therein can be retained for a much longer time than the short-term memory, but not permanently.
3. Permanent or Long-Term Memory: has large storage capacity in a long time. For example, events that occurred long ago and that a senior is able to count on many details.

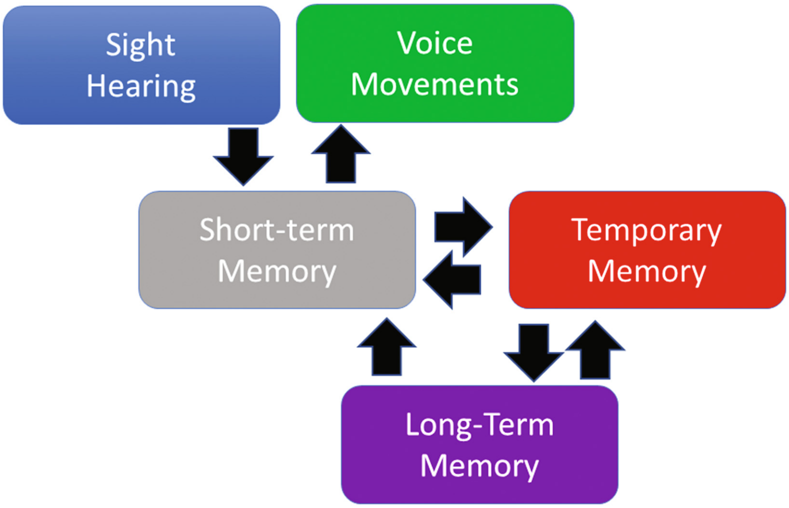

Fig. 1. Memory scheme [17]

Access to information is done not only by the working memory, but exceptionally directly by the fast memory. This information that "take shortcuts" does not need any mechanism for its recovery. For example, if we ask a person his/her name, address, telephone number, etc., this information comes immediately, since many of them are already brought up since one learns to speak, to understand, at a young age. However, when changing the phone number, or the car license plate, it will initially be necessary to use the working memory, using some mechanism to remember.

Often an elderly person has permanent memory intact, but forgets about recent events that would be in the short and medium term memory.

In this work, the short-term memory, which is capable of storing and reproducing visual and auditory stimuli specific to Genius, will be investigated.

4 Related Works

Several works have been carried out aiming the to develop applications to stimulate and enhance the elderly wellbeing. This section introduces a short survey on applications to the elderly audience and their intrinsic characteristics.

First, in [18], serious games for the older citizens are classified according to their specific goal and key design elements for improving the physical health of the target audience. This work shows that projects tend to take into consideration elder user needs in gaming design for health purposes, but little effort has been made to take into account the limitations of the aged cohort along the entire design process. It also points out that testing phases and usability evaluation are needed, and, finally, it claims that the use of modern input devices has allowed specialists to determine the patient performance in terms of motor functions. Nevertheless, the potential of use these capabilities to accurately perform medical assessment as a tool to guarantee effectiveness is not yet being totally exploited.

In [19], the challenges and opportunities of a new approach in motion-based game design for older adults are discussed. The importance of identifying core challenges and involve both users and experts in the design process can help game developers create safe, accessible and enjoyable motion-based games for older adults. As a conclusion, the authors argue that this approach could also contribute to the development of games for other user groups that consist of members with heterogeneous abilities and needs, fostering the creation of enjoyable games for vulnerable audiences.

The limitations of current design philosophies, and opportunities to facilitate the creation of accessible motion-controlled video games are highlighted in [14]. The work presents seven guidelines for the design of full-body interaction in games for older adults. The guidelines are designed to foster safe physical activity among older adults, thereby increasing their quality of life.

Some of the challenges to increase the quality of game designs and to improve game design processes, along with possible approaches, aiming to fuel intensified exchange about methodological experiences among researchers in the field are reported and classified in [20]. The authors suggest that, in order to obtain reliable results when evaluating exergames, it is necessary to provide methods which reduce the cognitive load of participants instead of overwhelming them by presenting too many new challenges at the same time. Small adjustments to the evaluation environment, accomplished with providing simple, specifically designed questionnaires, reading them out as structured interviews and keeping the session duration as short as possible helped reduce the cognitive load of participants experiencing age-related changes. It is also said that it is crucial to gain insights into long-term effects and detailed physical effects, which requires research methods that go far beyond those designed to examine exergames usability and accessibility.

In [21], an overview of common age-related changes, followed by a summary of game design considerations for senior audiences are presented. The impact of age on game design is discussed based on an analysis of the most important structural elements of games. The analysis shows that age-related changes in the cognitive and physical user abilities affect the use of games on multiple levels, making the complexity of games and interrelations between different game mechanics a crucial factor when designing for older adults.

5 Game Development

For the development of this game, a psychologist specialized in memory issues was consulted at the Neuroscience Laboratory of one of the Universities involved. The professional already uses some tests, such as the Corsi Block-Tapping Test [22] to analyze the amount of stored information dealing with visuospatial memory. The evaluation of the professional considered the game Genius based on the same principles of the Corsi Test and, thus, this game can be used with the same intention.

The interface of the electronic version of Genius is presented in Fig. 2a, and consists basically of four colored 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.

During an interview with the psychologist in the elicitation phase of the requirements for the virtual game, some functional and non-functional requirements were established. The functional requirements are presented below: (1) the electronic version must faithfully simulate the physical game; (2) one of the four buttons must be randomly selected incrementally; (3) in case of error, the user must be warned, by means of a characteristic sound accompanied by the finalization of the game; (4) the complete sequence of correct buttons should be recorded so that it can be analyzed by the psychologist.

In addition, it was defined that the non-functional requirements of this application would be: (1) the user must use the right or left hand to select an object (button); (2) each button has a distinctive sound; (3) the system should remain inactive for as long as the user does not press a button; (4) the game shall be single-player; (5) the user must use one hand at a time.

Developers followed the guidelines for game development for seniors presented in Sect. 3 of this article. Thus, it was taken into account that: (1) the game should allow slower movements than the original; (2) the test applicator shall provide explanations and demonstrations of how to use the game, considering that the majority of the public is not accustomed to using electronic games; (3) the buttons for the interaction should be large and with contrasting colors; (4) Depending on the person, an interview may replace or complement a post-test questionnaire; (4) the button, when selected, should provide visual feedback, such as resizing, brighter or changing color; (5) the game interface should adopt colors and sounds at appropriate frequencies.

There are several technologies available for the development of applications for the Kinect platforms different from the XBox 360 - OpenNI, OpenKinect, Microsoft SDK [12, 23, 24]. The game was implemented with the Microsoft Kinect SDK, which is Microsoft's solution for creating applications for the Windows operating system. The Microsoft Kinect SDK supports the C#, C++, and Visual Basic programming languages and requires Windows 7 (or higher). It allows you to use various features, for

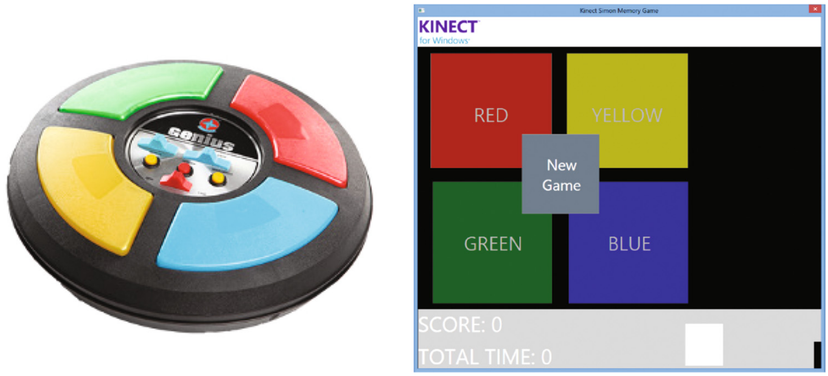

Fig. 2. (a) Genius by Estrela (Estrela [25]) (b) Genius Application Interface using Kinect

example, face tracking, voice commands, skeleton tracking, and others. The application interface is shown in Fig. 2b.

6 Evaluation Methodology

A preliminary usability evaluation of Genius game was carried out with 10 people from both genders, between 60 and 75 years old. Figure 3(a) and (b) show people using the game.

The physical environments used for the tests had no controlled conditions. The tests took place in two locations: a university room and also the home of some users.

Evaluations were performed through questionnaires and also interviews. Three questionnaires were designed: Profile, Expectations and Post-Test (Tables 1, 2 and 3). The Profile questionnaire contained multiple choice questions addressing gender, age, use of computer games, physical activities and knowledge in using Kinect; This questionnaire was based on and adapted from Mitchell [26].

The Expectation questionnaire used the 5-point Likert scale [27] and requested information related to the user's impression of the game to be interesting, easy, motivating and if the user liked to try out new technologies (based and adapted from [28]). The Post-Test questionnaire used the 5-point Likert scale and was based on and adapted from [29] and the Web Usability Questionnaire [30].

The Post-Test questionnaire addressed, through 20 questions, usability issues, pointed out by Nielsen [31], like feedback and cognitive load; as well as satisfaction, efficiency and effectiveness identified by the ISO 9241-11 [32], and the guidelines proposed by Gerling [13, 14].

The materials used in the evaluation (camera, questionnaires, computer with the game and Microsoft Kinect installed) were tested. Pilot tests indicated that an average of 30 min would be required for each test: 3 min for explanation/demonstration on the test; 3 min for filling in the profile and expectations questionnaires, 15 min for novice users to use the game for the first time and to adapt to the interaction form, 6 min for the test itself and finally 3 min for filling the Post-Test questionnaire.

Table 1. Pre-Test questionnaire (Profile)

1.Gender: () Female () Male 2.Workplace: () Company/homeoffice () University () home (housewife) () retired () undergraduate/graduate student () unemployed 3.Do you practice any physical activity (running, gym, water aerobics, sports) regularly? () Yes () No If yes, how many times per week () once a week () 3 times/week () everyday 4.Have you ever used Kinect? () Yes () No	5.Age Group: () under 45 () between 45 and 54 () between 55 and 65 () between 65 and 74 () 74 or more 6.How often do you use the computer in the week? () everyday () 3 times/week () once a week () never/almost never 7.How often do you use computer games to have fun?? () everyday () every week () every month () rarely/do not use

Table 2. Expectation questionnaire

Questions	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
I believe this game will be very interesting					
I believe it will be easy to use this game					
I feel quite motivated to play					
I really like new technologies					

Table 3. Post-Test questionnaire

Questions	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1. Whenever I pointed the hand to the application, I was able to "click"					
2. The application warned me when I committed an error					

(*continued*)

Table 3. (*continued*)

Questions	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
3. The application did not cause any muscular fatigue					
4. The application is quite enjoyable to use					
5. The Kinect movements are more precise than using a mouse					
6. My movements are faster using the Kinect than the mouse					
7. Kinect located my position and my hand easily					
8. I feel efficient while I'm playing the application					
9. I quickly understood the interaction mechanism of the game					
10. The application is very intuitive and easy to understand					
11. I would definitely use the application again					
12. Even at the first time, it can be assumed that this application is easy to use					
13. I did not feel stressed by this game in any situation					
14. It is quite easy to remember how to use this application					
15. My time was very well spent using the application					
16. Everything in the application is easy to understand					
17. The size of the buttons were suitable for playing. They did not hinder me.					
18. I could play for a long time, even standing					
19. The position I assume when I play is not uncomfortable and does not force me to stop					
20. The colors of the buttoms are easily identified when selected					

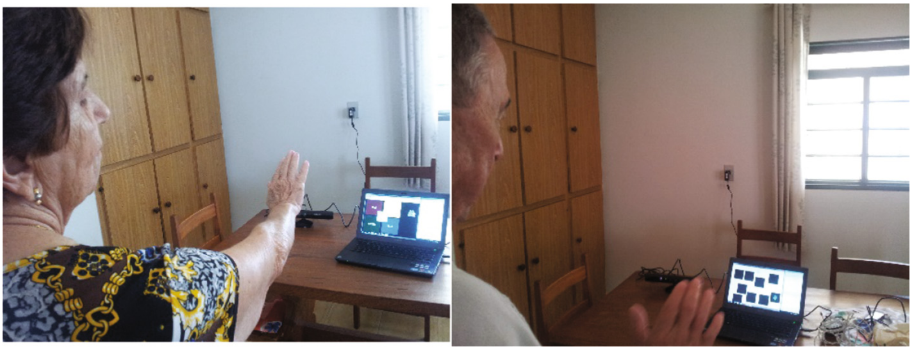

Fig. 3. Tests with people using the game

7 Results

From the answers obtained in the profile questionnaire, it was verified that, of the total users participating in the evaluation, 4 were female and 6 were male; no one had been in contact with Kinect; 7 people never or almost never use games to have fun, 1 uses weekly while 2 of them use monthly. Regarding the daily practice of physical exercises, 4 people never practice physical exercises.

In the responses to the expectations questionnaire, 2 participants fully agreed that the game would be very interesting, while the other 8 only agreed. Regarding the ease of use, the expectation was that it would be very easy (only 1 person indicated “totally agree”), 2 agreed and 7 disagreed. Regarding the motivational aspect of the game, 3 people totally agreed, 3 agreed, 3 became undecided and 1 disagreed. 5 evaluators agreed totally on the issue of very liking new technologies, 1 was undecided, 2 disagreed and 2 disagreed totally (Fig. 4).

The following charts 1 and 2 show the results from the compilation of responses from 10 users on the post-test questionnaire (Fig. 5).

The observation of the graphs allows to conclude, for this sample:

- Questions 1, 5, 6, 12 and 13 make it clear that the target audience finds it more difficult to use Kinect than using a mouse, nevertheless, they consider the use of the game to be safe (question 4);
- Users consider the feedback appropriate when they made a mistake in the game (question 2);
- the game was considered easy to understand and to learn and easy to memorize (questions 9, 10 and 14);
- not being able to use Kinect deftly on their first use caused a lot of frustration (question 8);
- Regarding physical limitations, the game did not cause muscle fatigue (question 3), but 40% of users were undecided or disagree as to whether they could play for a reasonable time because they would have to play standing (question 18). 40% were undecided if their position to play made them uncomfortable, while 10% said they were annoyed (question 19);

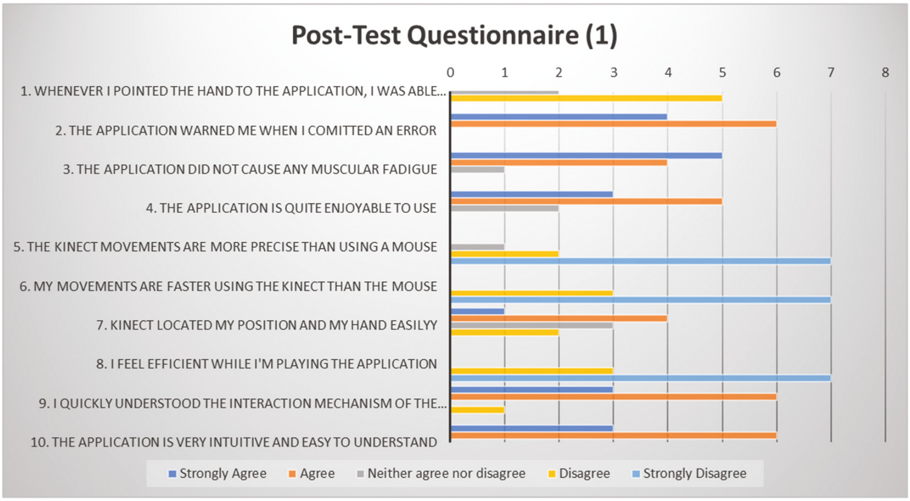

Fig. 4. Post-Questionnaire results – Part 1

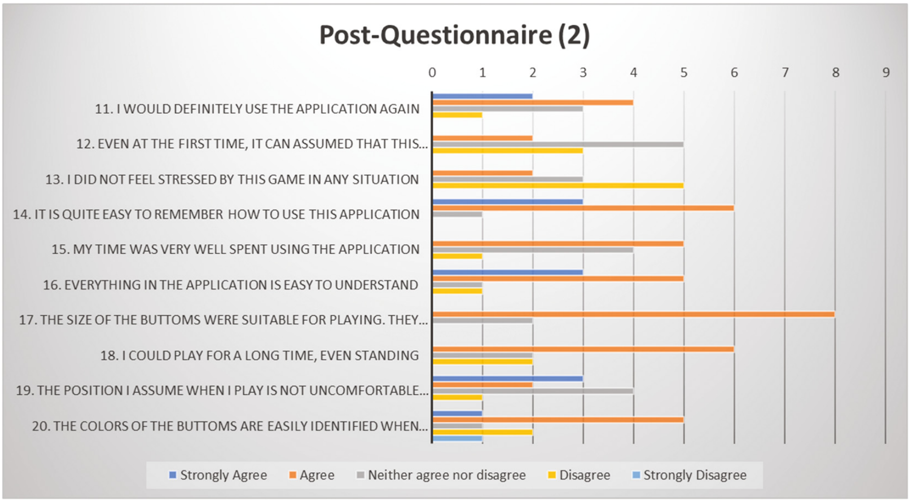

Fig. 5. Post-Questionnaire results – Part 2

- Questions 17 and 20, referring to the interface part, show that although most did not consider the size of the buttons a problem (question 17), the perception that the button was selected (change in brightness) was not as evident to the target public (question 20).

Through the interviews, it was noticed that the biggest complaint from the target audience was not having full control over the click movement and navigation, using the hands instead of the mouse. Several times, a hand icon (representing the mouse) disappeared, causing distress. Some people thought that the problem would be with them for not knowing how to use the device.

8 Conclusions

This paper presents the development of a memory computer game for the elderly using Kinect. The main focus is on the usability assessment, since not many papers are found in the literature addressing this topic, which was detailed enough in this article.

In order to develop applications for this target audience, it should be noted that directives, as pointed out by [13, 14], must be followed in order not to cause inconvenience or danger and still have a good usability for This population. It is also necessary to point out that in order to build computational applications for the elderly, it is necessary to have a multidisciplinary team, which certainly involves a health professional with the skills to do so. These professionals are able to guide the development and focus of the games, as well as can provide real testing environments and conditions with this target audience.

It was possible to verify, through the results of the evaluation questionnaires, that those users who do not have much frequency in the use of games nor of Kinect felt an initial difficulty in the handling of the equipment, but considered its use challenging. The data from this analysis will serve as feedback to the development team so that improvements can be incorporated into the game.

As future works, there is the possibility of performing visuospatial memory tests in the Neuroscience laboratory of the University (in a properly controlled environment); To verify if the use of this game, for training, can actually improve the storage capacity of the visuospatial memory of the elderly; And also, after improvements and interface adjustments required, provide a version of the game for free download.

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