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Juan Francisco Ortega Morán[1] ENG; J Blas Pagador[1] PhD; Vicente Gilete Preciado[2] PsyD; José Luis Moyano-Cuevas[1] ENG; Trinidad Rodríguez Domínguez[3] PhD; Marta Santurino Muñoz[3] BSN; Francisco M Sánchez Margallo[1] PhD

[1]Centro de Cirugía de Mínima Invasión Jesús Usón Cáceres ES
[2]Neuropsychologist Cáceres ES
[3]Universidad de Extremadura, FENTO, Robolab Cáceres ES

Corresponding Author:
Juan Francisco Ortega Morán ENG
Centro de Cirugía de Mínima Invasión Jesús Usón
Ctra. N-521, km. 41,8
Cáceres
ES

Abstract

Background: Cognitive stimulation of older people helps to prevent, and even treat, age-related diseases, such as Mild Cognitive Impairment. Playing games reduces the probability of suffering from this pathology related to the loss of the ability to carry out some instrumental activities of daily living.

Objective: This work describes the design and development of a serious game for the cognitive stimulation of the elderly with exercises related to the daily life task of shopping, presenting also a pilot study for its preliminary usability validation.

Methods: The designed serious game includes four exercises consisting of shopping in a hypermarket, ordering products, payments and organizing the purchase, dealing thus with the most frequent cognitive problems of elderly associated to episodic declarative memory, naming, calculation and organization, respectively.

Results: 19 older people participated in the pilot study for the usability validation of the serious game, indicating that they like the aesthetic and interesting topic of the game. It has a high level of entertainment and could be useful in daily life for mental stimulation. It is intuitive, but the ease of use and readability of the instructions could be improved.

Conclusions: This study suggests that the innovative serious game developed could be accepted by older people for their cognitive stimulation in order to prevent or treat Mild Cognitive Impairment, although a long-term intervention test should be performed. Its ecological validity design with everyday tasks, adaptable level of difficulty and motivational mechanisms include a differentiating factor compared to similar serious games.

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Keywords: Serious game; Mild Cognitive Impairment; cognitive stimulation; design; pilot study; older people

Introduction

The increase in life expectancy means that we can live with age-related pathologies, such as dementia. The prevalence of this pathology is clearly on the rise, and currently, there are approximately 46 million people affected worldwide [1], and 640,000 in Spain [2]. This acquired syndrome is characterized by a progressive deterioration of cognitive functions, which influences activities of daily living and decreases the level of independence of individuals. Dementia is classified into grades, where in its mild stages simple activities remain intact, but as impairment progresses, the severity of symptoms increases [2-4]. Mild Cognitive Impairment (MCI) is considered a precursor to mild dementia so that those with MCI are much more likely to progress to this type or level of dementia, especially in older cases [4]. Treatment usually includes drugs that aim to reduce or delay cognitive, psychological and behavioral symptoms [5], but non-pharmacological treatments are also very important. These include reality orientation, reminiscence and validation therapies, and cognitive stimulation [6].

Cognitive stimulation includes techniques that focus on treating cognitive aspects through activities that allow them to be worked on globally and simultaneously [6,7]. Cognitive and reminiscence activities, multisensory activities and also those that work on social aspects are used, with group activities that facilitate integration and social participation among users [8]. In fact, several studies confirm an improvement in different aspects of the cognitive sphere and in the quality of life of

people with dementia who have participated in this type of therapies [9,10]. We also found improvements in mood and Activities of Daily Living (ADL) maintenance [11].

Currently, Information and Communication Technologies (ICT) instruments and tools are incorporated to non-pharmacological treatments. These technological devices facilitate performance, which can lead to a greater sense of self-efficacy and improve one's own perception of functionality, as well as reduce the burden of caregivers. Some of the devices most commonly used with people with dementia are tele-assistance, devices to work on cognitive functions and robotics [12]. Among them, the most widely used are those that can be connected to the internet (tablets, mobiles, computers, video game consoles), a wide variety of resources that allow diversification of therapies and increase motivation and adherence to treatment [8,13]. The use of ICTs as therapeutic tools requires a previous study of the person's abilities and skills for their use and management, in order to avoid feelings of frustration that can lead to discouragement from therapy and/or rejection of the device [9]. It is therefore essential to gradually approach the device and its applications, looking for intuitive tasks that the user can easily carry out independently [9,13].

Serious Games are ICT games whose main objective is to give a therapeutic and evaluation value to the playful action of the games. They have been tested in different areas of intervention in pathologies with cognitive impairment [14,15], particularly dementia [16]. Through Serious Games we can work to delay deficits, increase autonomy and relationships with their social environment and improve the quality of life of people with dementia [17]. For the intervention, the occupational therapist may include in their individual intervention plans games to work on physical, cognitive and/or social aspects.

In this study, we describe the design and development process of a serious game developed for the cognitive stimulation of the elderly with exercises related to the daily life task of shopping. We also present results of a usability validation conducted on a pilot study with the game.

Methods

Game development process and design requirements

In the process of designing and developing this serious game, researchers, game designers and developers, healthcare professionals, and older adults have participated, since interdisciplinary collaboration plays an essential role [18].

Firstly, two focus groups were performed with 11 psychologists and 6 occupational therapists from Extremadura (Spain) to identify the needs, limitations and motivations of older people to use cognitive stimulation programs. Four thematic areas were identified: (1) the most frequent cognitive problems of the older people are mainly focused on memory loss, disorientation, difficulty in performing executive tasks or in concentrating; (2) motivation is the fundamental element for success of new training exercises; (3) technological barriers are mainly related to interface design problems and cultural level; and (4) the low degree of awareness of the elderly regarding the importance of leading an active life. This served as a basis for designing the new tool to promote the cognitive training.

In the implementation of this serious game for Android OS, Unity 3D (C#, Visual Studio 2017) has been used, following the design recommendations established in previous studies [19]. In this sense, the game interface has been designed taking into account that the target audience is elderly people and adapted to their needs, including the minimum necessary information in a clear and concise way, which allows the adult to understand the objective of the game. Regarding user interaction, the game

has been designed to be used on Tablet, as it is a more natural interaction than other methods such as using the keyboard and mouse, thus facilitating the acceptance of the elderly [20].

Two fundamental characteristics have been taken into account in the design of this serious game. Firstly, ecological validity, for which the game has been designed based on a day-to-day activity of the elderly, such as shopping. In this way, a greater interest and acceptance by the elderly is achieved, making them see that it is a useful tool in their daily lives. Secondly, the possibility of configuring the game so that the professional can adapt the difficulty to the needs of each elderly person.

Game description

First exercise: shopping in a hypermarket

Episodic declarative memory is the neurocognitive function that is affected earliest in Alzheimer's disease due to the initial involvement of the hippocampal formation in the medial temporal lobe, so stimulation of episodic declarative memory in people with MCI who are affected by mnesic impairment is of utmost importance.

This exercise is designed with the specific aim of stimulating verbal intentional episodic declarative memory at the level of the three mnesic processes of encoding or fixation, consolidation or storage and recall or retrieval of information, thus consisting of three phases:

1.1 Learning Phase: The user must learn a series of products from a shopping list in three sub-phases (Figure 1): a) Organization of the list by categorization, since structure the information facilitates its deep encoding; b) Identification of specific characteristics that differentiate the products, since better fixation of information with clues optimizes recall; and c) Intentional memorization of the list in a specific time.

1.2 Interference Phase: This task simulates the preparation of the wallet with the money to pay for the purchase. It activates the processes of attentional control at the level of selective attention to choose the correct banknotes/coins, working memory to sum the money and monitoring of the execution to avoid errors.

1.3 Recall Phase: The user is presented with a map of a hypermarket where the sections are marked out and has to fill a shopping basket with those products from the shopping list studied in the Learning Phase among distracting products. The aim is to stimulate the mnesic process of recalling short-term episodic declarative memory.

Second exercise: ordering products in a hypermarket

On the one hand, expressive language impairment manifests itself very frequently and early in the form of anomia, a naming deficit that consists of the difficulty to recall the name of objects. Due to the great frustration caused by this early expressive language difficulty for people with MCI, it is essential to include naming stimulation tasks within the global stimulation of expressive language in cognitive stimulation programmes.

On the other hand, complex visual gnosias, in which visual recognition and identification of objects is hindered by a modification of the characteristics of the objects' images, are one of the cognitive functions that are affected in the early stages of several primary cortical degenerative dementias, hence the importance of their stimulation.

This exercise is designed with the specific aim of stimulating language at the level of naming and complex visual gnosias in two phases:

2.1 Phase 1: Hypermarket product naming, where the user has to write the name of the image of those products that appears (Figure 2).

2.2 Phase 2: Visual recognition and identification of hypermarket products through their distorted images and subsequent naming of these products. The emphasis is placed on the stimulation of complex visual gnosias, making it difficult to recognize and identify the objects to be named.

Third exercise: payments

Executive attentional control processes are affected early in several types of primary and secondary dementias such as subcortical vascular dementia. Working memory, a key element of executive attentional control, is the ability to maintain and manipulate information in on-going cognitive activity, such as money management for shopping. It is therefore very important to place great emphasis on the stimulation of these cognitive processes in order to maintain the highest possible level of functional independence of each person.

This exercise consists of three phases and is designed with the specific aim of stimulating the working memory through calculation tasks by simulating purchase payments:
3.1 Phase 1: The user has to make with banknotes/coins the exact payment of the purchase (Figure 3).
3.2 Phase 2: The user must check whether the return received is correct, and if not, he/she must select the banknotes/coins necessary to make the return amount correct.
3.3 Phase 3: The user has to check the price charged for each product on the purchase receipt to verify whether corresponds to the price on offer for that product in the catalogue of offers, and in case of error, to mark on the receipt the products for which the amount on the receipt is erroneous.

Fourth exercise: organization of the purchase

Executive functions, such as planning and organization, reasoning, cognitive flexibility or monitoring when problem solving, are crucial functions for a good performance of any adult in Advanced and Instrumentals ADLs. In the context of cognitive treatments for MCI, the stimulation of executive functions is a compulsory subject given their close interdependence with the maintenance of a high level of functional independence and personal autonomy in ADL.

This exercise is designed with the specific objective of stimulating this executive function of organization, but also the abstract reasoning, the performance monitoring, visual gnosias, semantic memory and visuospatial function.

In this exercise, the user must arrange the products of a purchase in the rooms of a house whose floor plan appears on the screen and which consists of the following spaces: kitchen, terrace, bathroom, pantry, living room and bedroom (Figure 4). Within each of these rooms of the house there are several storage locations for the products.

Acceptance and usability study

Several validations of the serious game were carried out by 4 elderly people from the Association of Friends of the Minimal Invasion Surgery Centre in Cáceres (Spain), 5 people from senior centers in Castelo Branco (Portugal) and 10 participants who attended the FEHISPOR fair held in Badajoz (Spain). The inclusion criteria were elderly people between 60 and 80 years old, with MCI or without cognitive impairment.

Both ethical approval and written participants consent were waived for this study because they were not within the scope of Law 14/2007 of 3rd July on Biomedical Research, which indicates that human health-related research involving invasive procedures needs approval by the ethical committee and patient consent, but in this study the participants were not involved in invasive procedures. Only verbal informed consent was considered sufficient.

Participants tested the game until all exercises were completed and then filled in a questionnaire scoring questions with a 5-value Likert scale (1-lowest value, 5-highest value) about the usefulness and usability of the game. A descriptive analysis with average values of the answers provided by the participants was performed.

Results

The 19 people who participated in the study (Table 1) showed their opinions regarding serious game, which is shown in Figure 5.

Table 1. Demographics of participants.

Age	75,34 ± 1,40
Sex	Women: 16
	Male: 3
Level education	Secondary
Smartphone experience	Once a week

All items were highly valued with a score over 3.5 out of 5 (which is the threshold for an item to be considered as positively validated), and an average value of 4.28. On the one hand, the most valued aspects were that participants like the game (4.8), both from the aesthetics point of view (4.5) and the interesting topic (4.5) of the game. On the other hand, the items that had the lowest score were the ease of use of the system (3.9) and also the ease of reading instructions (4.0).

Discussion

Principal Results

From a cognitive point of view, the first effects of deterioration in the elderly are directly related to the loss of the ability to carry out some instrumental activities of daily living. However, there are multiple studies showing that people who read or play games are less likely to suffer from dementia or even Alzheimer's disease [21,22]. In particular, the use of serious games has proven its value as cognitive therapy for older people [23]. In the literature, different games have been designed and validated for cognitive stimulation [17], but it is not common for these games to use tasks focused on activities of daily living. The aim of this work has been to describe how a serious game has been designed and implemented for cognitive stimulation of the elderly by means of memory, naming, calculation and organization exercises, which are key in daily life tasks such as shopping. In this way, this serious game deals with the most frequent cognitive problems of older people indicated by health professionals.

The preliminary pilot study carried out to validate the usability of the serious game has showed that participants had a great opinion of this game, considering the theme interesting and useful for mental stimulation, so we can think a priori that the game could be well accepted among older people. Users find the serious game intuitive and aesthetically appealing, therefore it meets the principles of simplicity and intuitiveness for the design of user interfaces for the elderly to avoid extracognitive load for the user [24].

Taking into account preferences of older people, game themes should meet their interest because seniors have a predilection for games related to real life [25]. In this sense, ecological validity has been considered in the design of our serious game, since it is important for validation of cognitive skills that influence functional tasks in real-world contexts [26]. Moreover, the fact that the difficulty

of the game can be set by the professional in order to provide an achievable difficulty by each senior user is important to motivate them to play and also to avoid frustration, anxiety or negative emotions when playing [25].

The literature has described the benefits of using the Tablets for cognitive stimulation [27], but at the same time the rejection and barriers for older people in the use of these technologies have also been described [28]. In this regard, the results obtained in this study indicate that the game is easy to use and understand. However, these are preliminary findings as the study participants use Smartphones in their daily live, which greatly reduces the rejection of this type of technology. Anyway, as future work, it is necessary to improve the interaction and facilitate the use of the game to avoid the rejection of elderly, since results obtained from the questionnaires regarding the ease of use and instructions reading of the game were positive, but there was room for improvement.

A feature of this serious game is that it provides feedback to the user at the end of each stage of the game, indicating whether the task is correct or not, and the type of mistake that has been made. This agrees with Brox et al. [29] stating that feedback provided when older people achieve their goal should be immediate. Moreover, to avoid frustration, which is another key aspect of the game, the system also provides encouragement messages during the completion of the game so that the user can try again. This positive feedback for encouragement favors a successful experience of older user with the game [30], allowing them to achieve the goals of high motivation [25]. The use of narratives and the low complexity of the game are factors that motivate the elderly to play [31]. In this way, motivational mechanisms have been included in this serious game, which is the fundamental element for success of new training exercises.

This serious game presents an alternative format to traditional interventions for older people, so we suggest defining a protocol to assess the effects on the cognitive function of the elderly with a long-term intervention after a period of time in order to test the effectiveness of this serious game.

Limitations

The study has the limitation of the small sample size of the pilot study belonging to a limited geographical area, which may influence generalizability of results. Therefore, it is necessary to extend these presented results with a larger sample size, including people of different cultural levels, with different experiences in the use of tactile devices, as well as people with different levels of cognitive impairment, to test the robustness of our findings.

Comparison with Prior Work

Ecological validity has been taken into account in the design of the serious game of this work with tasks focused on activities of daily living, such as shopping. This is not common in the different games designed and validated for cognitive stimulation found in the literature. This innovative factor favors a greater interest and acceptance by the older people.

Conclusions

In this work, an innovative serious game for cognitive stimulation of older people has been designed and developed focused on the daily-life activity of shopping, incorporating motivational elements and allowing for difficulty adaptability. The set of exercises included in the serious game have been described, including the theoretical basis on which each exercise has been implemented, dealing with the most frequent cognitive problems of elderly associated to episodic declarative memory, naming, calculation and organization. This study could serve as a basis for future serious games for cognitive

stimulation of older people that may benefit from the knowledge obtained about the design strategies followed.

A pilot study carried out with older adults has shown that this serious game is intuitive, has a high level of entertainment and is useful for its application in daily life. In conclusion, according to the preliminary results obtained, we can think that the serious game could be widely accepted by the elderly and, therefore, become a tool to contribute to delaying their deterioration and increasing their independency. In this way, the serious game developed could contribute to increase the low degree of awareness of the elderly regarding the importance of leading an active life.

Acknowledgements

Conflicts of Interest

None declared.

Abbreviations

ADL: Activities of Daily Living
ICT: Information and Communication Technologies
MCI: Mild Cognitive Impairment

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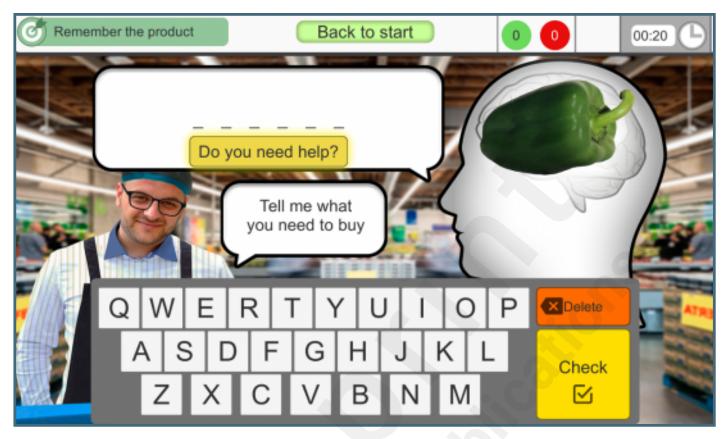
Supplementary Files

Figures

First exercise to work episodic declarative memory with three mnesic process: encoding, consolidation and recall.
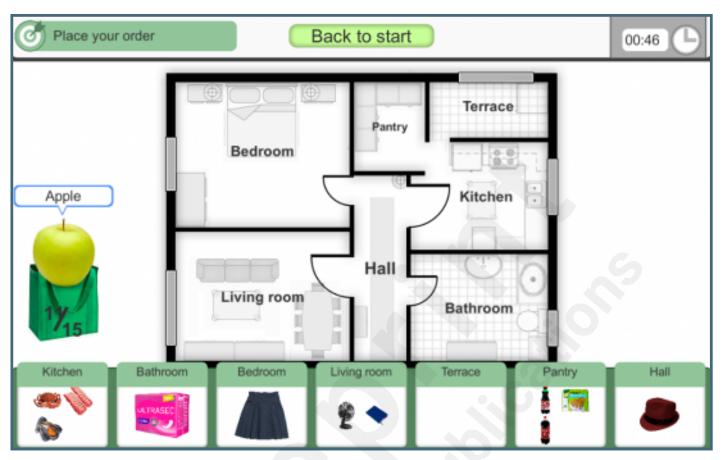
Second exercise to work expressive language and complex visual gnosias.

Third exercise to work executive attentional control.

Fourth exercise to work executive functions.

Average score of the elders who participated in the validation.