



*Research article*

# A methodology for the development of serious games for the cognitive stimulation of elderly people with mild cognitive impairment

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## ABSTRACT

Mild cognitive impairment affects many older adults and can lead to severe dementia. Early detection and intervention are key to slowing its progression. Serious games offer a promising way to stimulate cognitive function. However, there is a lack of clear methodologies for developing effective serious games for cognitive stimulation. In this paper, we introduce a methodology for developing serious games to help people with mild cognitive impairment. We also include a case study of this methodology through the development of a serious game that underwent usability testing with older adults. The obtained results provide evidence that, by following the proposed methodology, it is possible to develop serious games that are well received by the target population.

**Keywords:** serious games, cognitive impairment, cognitive stimulation

## 1. Introduction

Mild Cognitive Impairment (also denoted as MCI) is characterized by a cognitive impairment that causes minimal impact on instrumental activities of daily living (e.g., language, visuospatial skills, executive functions, etc.) [1]. Its early identification could serve to initiate treatment and take into account the appropriate measures to avoid its further progression [2]. Rehabilitation or cognitive stimulation can help improve the cognitive abilities of people with this condition [3]. Nowadays, there are several proposals for performing appropriate cognitive stimulation; among the most outstanding are those related to the use of technology [4]. Within digi-

tal cognitive stimulation and rehabilitation, there is evidence that the use of Serious Games (SG) <sup>1</sup> allow the development of the brain's executive functioning and, in turn, help to improve cognitive skills with the potential to reduce problems caused by cognitive impairment [6]. Serious games are considered a promising solution that provides non-drug-based rehabilitation and treatment, aiming to satisfy, maintain, and even restore the patient's cognitive status through cognitive stimulation [7]. However, despite the importance of using serious games in the field of cognitive stimulation, there is a lack of a methodology that establishes in detail the steps to follow for the development of a SG oriented towards

<sup>1</sup>A serious game allows for the implementation of activities based on real-life scenarios; are intended to teach, as well as to transmit skills and information [5].

cognitive stimulation [6].

According to Garcia-Martinez et al. [3], the development of serious games that meet the requirements of having a medical perspective, usability, and user-based experience remains an unsolved problem. Attempting to solve this problem, they developed the COMFeeDY framework (Concepts, Objects, Mechanics, Feedback, and Dynamics). Having in mind to gain a better understanding of the relationship between older adults and the various technologies that can be used for cognitive stimulation, Palumbo [4] presented a survey to identify which are the most commonly used interactive devices for serious games, which are the cognitive functions that have been addressed by serious games supported by interactive technologies as well as the improvements on them after using these kinds of games. Lau & Agius [6] propose MCI-GaTE (MCI-Game Therapy Experience), which can be used for the implementation of SG that function as a tool capable of implementing physical and cognitive rehabilitation. This framework consists of four sectors which serve as a guide for the design and development of games: a) A player profile, b) Main elements that support recreational activities, c) Therapeutic components that support cognitive and physical rehabilitation through the implementation of tasks and scenarios that are tailored to the player's abilities, and d) Motivational components. MCI-GaTE was assessed by therapists who indicated that the framework has great potential for the design and implementation of therapeutic experiences. However, some aspects were highlighted as missing, such as the lack of times between game sessions, or that it is focused primarily on memory rehabilitation in people with cognitive problems, leaving aside all other conditions involved with MCI.

Attempting to contribute to solve this problem, we propose a methodology for designing serious games for cognitive stimulation in elderly people with cognitive problems. Our proposal includes aspects that have not been taken into account in the existing literature that are important to have a clear and comprehensive methodology. In addition, we also present a serious game denoted *Adventures in the corral, heroes of the flock*, which was designed and developed following the proposed methodology. For evaluation purposes, we asked a group of elderly people to interact with the serious game and report the results of a usability evaluation based on the player's experiences.

This paper is organized as follows. Section 2 introduces the methodology for the development of serious games for cognitive stimulation of the elderly with mild cognitive impairment. Section 3 describes the development of the case study based on the proposed methodology. Section 4 presents the results obtained from the usability study. Finally, Section 5 summarizes the conclusions and future work.

## 2. Proposed methodology

This section explains in detail each step of the proposed methodology to design serious games that can help to

cognitively stimulate elderly people with mild cognitive impairment.

### 2.1 Identification of conditions related to mild cognitive impairment

The type of cognitive impairment to be addressed must be defined: *Mild Cognitive Impairment*, *Medium Cognitive Impairment or Mild Dementia*, *Medium Cognitive Impairment (or Prolonged Dementia)*, or *Severe Cognitive Impairment (or Severe Dementia)* [8]. Afterwards, the type of condition that is sought to be stimulated must be identified. Some of the conditions that are caused by MCI are *concentration, perception, communication, orientation, motor coordination, conceptualization, language, judgment, calculation, and memory* [9, 10, 11, 12].

### 2.2 Identification of cognitive stimulation activities for people with mild cognitive impairment

The activities to be developed in the SG must be identified. These activities will be part of the participants' cognitive stimulation. With this in mind, Table 1 shows some examples of activities that can be implemented within the SG and that can help stimulate specific conditions.

### 2.3 Identification of the type of participants

Participants must be chosen taking into account the classification of cognitive impairment and the condition(s) to be addressed. However, if it is unknown whether or not a participant has cognitive impairment, as a first point, some tests must be applied to determine his or her condition. For this, there are several tests to identify cognitive impairment such as: Mini Mental State Examination, Montreal Cognitive Assessment, Clock Drawing Test, Mini Cognitive Examination, and Five Words Test, among others.

### 2.4 Identification of inclusive design approaches

It is important to define the interaction techniques in terms of navigation and selection. Navigation and selection allow the participant to interact with the User Interface(UI) elements of the virtual environment of the SG through the use of hardware; these must be easy to use and learn in order to reduce the amount of effort, taking into account the limitations of older adults with mild cognitive impairment. Some examples of hardware used for interaction are: mouse, keyboard, touch screens, joystick, Kinect, and Wii [21]. Equally important at this stage, is the definition of the UI elements of the virtual environment of the SG, including: i) **Text content** should be clear, precise, and engaging. Besides, it should be written in a large font, preferably black, and avoid abbreviations. Technical and scientific language should also be avoided. ii) **Basic elements**

**Table 1.** Activities that can be implemented for stimulating specific conditions.

Condition	Activities
Concentration	Finding identical figures, maze, word search, numbers or symbols, reading with simple activities, among others [13].
Perception	Identifying identical objects, word and number searches, relate objects, describe images, etc. [14].
Orientation	Locating oneself in time and space, identifying the current season, relating objects, writing personal information, etc. [15].
Motor coordination	Mazes, completing drawings, puzzles, associating objects with their functions, etc. [13].
Conceptualization	Identifying objects, giving meaning to an image, identifying geometric shapes, completing images, etc. [16].
Language and speech	Forming and completing words, completing sentences, ordering phrases, etc. [17].
Judgment	Associating objects, numerical and object series, joining related words, identifying patterns of different images, etc. [18].
Calculation	Addition, chain operations, mental calculation, etc. [19].
Memory	Memorizing details or images, making life books, etc. [20].

such as buttons, prompts, objects, etc., should be visible, large, and prominent. iii) **Images** they must be relevant to the context of the game being implemented and must also make sense. iv) **Color palette**, it is recommended to use a high-contrast color palette, as this can help improve visibility. Furthermore, it is also recommended not to include distractions in the virtual environment.

## 2.5 Design of competencies for cognitive stimulation

It is necessary to define how the activities selected (Section 2.2) will be implemented. Competencies must be defined so that the implementation of cognitive stimulation activity yields favorable results in the treatment of cognitive impairment.

## 2.6 Conceptualization of the type of game

The design characteristics of the game must be defined, as well as some other general aspects such as classification (pure progressive games, pure emergent games, etc.), genre (adventure, horror, fear, platforms, etc.), type of technology, mechanics, expected results, values, player effort, attachment to the result, negotiable consequences, and area of application. Some questions that can help identify such features are: *What is this game about?*, *How do I play?*, *What is the main idea or concept of the game?*, *Who are the characters that are going to appear in the story?*, *What are going to be the mechanics of the game*, and similar [22, 23, 24]. In addition, the type of approach to the game needs to be determined. Among the approaches to be considered, there are some focused on a specific theme, on the me-

chanics, dynamics, and emotional responses, or those that do not have limitations [25].

## 2.7 Narrative structuring

The narrative must have a structured process. To achieve this structure, it is necessary to define each of the chapters (levels) with their respective scenes. Once the story is defined, the dialogues or actions that will make it possible must be developed. After this, and as a final step, the relationship between the chapters, scenes, stories, dialogues, or actions with the cognitive stimulation activities proposed in phase two of the methodology must be defined. A narrative line can follow one of the types of stories: *linear stories*, *branching stories*, *open-ended stories*, *thematic settings*, among others [25].

Another aspect to keep in mind when creating a story is including and developing plots. There are three different types of plots: *i) Classic* based on the story of the main character versus the villain; *ii) Relationships* where there is a kind of relation (friendship, romantic, hatred, etc.) between the characters; and *Transformation* which narrates the internal development of characters through the need to overcome their goals. Afterwards, the script describing the structure of how the events will be developed must be defined. For doing this, some types of structure can be considered:

- **Classical**, composed by four elements: a) *Introduction* (describing the context of the world in which the story takes place, the game dynamics, and the rules must be provided), b) *Plot point* when something occurs and changes the course of how the main story is presented), c) *Knot* (it is the main part of the story, where the goal is

to escalate the problem to return to the initial or future calm point), d) *Climax* (which seeks to confront each of the problems presented).

- **Modern**, seeks to explore the character's internal conflicts, whether their hidden desires, fears, insecurities, dilemmas, or some type of psychological or emotional conflict. Its main objective is to develop the story by focusing on the protagonist's internal journey, self-discovery, or the resolution of internal conflicts.

Once the script is finished, the dialogues must be defined, which are all those arguments that will be said by the characters within the game or are all those texts that will be shown during the game [26]. Besides, the characters in the game need to be described; there are four kinds of characters: *protagonist*, *antagonist*, *secondary characters*, and *non-playable character*<sup>2</sup>, which are those within the game that are controlled by artificial intelligence, rather than by a player.

At this stage, it is necessary to design the chapters that comprise the process by which environments, challenges, and experiences are structured and developed, which players must experience as they progress through the game [27]. It is also required to define the position of the game elements and the mobility of objects.

#### 2.7.1 Labeling and evaluation of cognitive activities.

As a final step in developing this stage, the story situations in which the cognitive activities chosen in point II of the methodology will be developed must be defined, and the method of implementation must also be specified. In this final part, the moments, characters, objects, dialogues, etc., that will be involved in order to include the cognitive activities within the story, chapters, and scenes must be specified.

### 2.8 Adaptive structuring and personalization design

The user profile must be defined, including the patient's personal data (social and morbid data [12, 28]), and a record of all the activities performed, as well as their times and scores. In addition, it is important that the user profile allows the inclusion of personalized characteristics based on their abilities, needs, preferences, and condition, ensuring an accessible and effective interaction [29]. Finally, the user profile can also record patient preferences so that the game elements are tailored to these needs. In this sense, elements, decorations, objects, animals, etc., can be added or removed, text can be enlarged, audio elements can be increased in volume, audio can be slowed down, etc.

#### 2.8.1 Labeling and identifying inclusive design approaches

The inclusive aspects of gameplay, narrative, and game mechanics must be defined, but this time taking into ac-

count the final game structure. This means that if it is decided to use a gripper for game interaction, it must be specified which movements or actions can be performed with it. Finally, it is necessary to define how adaptability will be implemented within the game. Adaptability within the context of rehabilitation or stimulation ensures that the best decisions are made to guarantee intelligent rehabilitation, and this is achieved through the control of auditory, haptic, visual, and other aspects.

#### 2.8.2 Inclusion of artificial intelligence

Artificial intelligence provides certain tools that help within the mechanics, narratives, sounds, history, scenarios, etc. [30]. Some of these tools are the following [31]: movement techniques, complex movements, decision-making, and adaptation to the user.

### 2.9 Design of orientation and motivation strategies

The strategies that will be used to guide the players through the first steps of the SG's gameplay need to be defined. Also, the points and rewards system that will be implemented within the SG's gameplay must be explained, taking into account the narrative and mechanics of the SG. It is highly recommended to design a **Tutorial** to help the player become familiar with the game mechanics. Tutorials are the levels prior to the main game and the basis of it, where the player is expected to become familiar with the gameplay of the SG through the interaction with objects using the main commands. These should be presented naturally and simply, in addition to not being immersive, in order not to affect the gameplay of the main game and not to ruin the player's motivation [25]. Concerning the motivation strategies, it is important to specify how the rewards will be granted following the narrative and mechanics of the game. As players develop a greater attachment to the outcome or reward, the more interested and enthusiastic they become about the game. Similarly, the greater the commitment and effort that a player makes to complete a challenge, the greater the emotional burden related to the result and the rewards [23].

## 3. Evaluation of the proposed methodology

To validate the proposed methodology, a case study was conducted. In particular, it was used for the design and implementation of a serious game named as *Adventures in the corral, heroes of the flock*. Next, we describe the different stages of the methodology applied to this case.

1. **Identification of conditions related to mild cognitive impairment:** The primary focus will be on single-domain non-amnesic mild cognitive impairment. Particularly, the goal is to stimulate only the area of **concentration**.

<sup>2</sup><https://dictionary.cambridge.org/es/diccionario/ingles/npc>



## 2. Identification of cognitive stimulation activities for people with mild cognitive impairment: Identification of identical objects.

## 3. Identification of the type of participants:

Inclusion criteria:

- No tests will be performed to determine whether or not the patient suffers from any type of Mild Cognitive Impairment.
- Age range: People over 60 years old.
- Sex : Indistinct.
- Level of education: Not an important factor.

Exclusion criteria:

- Participants with Parkinson's disease will be excluded, as this condition can interfere with game results due to the relationship between control and the participant's spontaneous movements. Participants with depression will also be excluded, due to the fact that according to [32] this kind of rehabilitation has less positive impact on them.

## 4. Identification of inclusive design approaches:

- **Navigation and selection:** Two different hardware components were used for navigation and selection: a video game controller and a Bluetooth VR remote controller. In both cases, the corresponding joystick can move the elements in four directions: up, down, left, and right. Further, when using the video game remote controller for selection, it is required to use the button located at the bottom of the set of buttons positioned on the right side of the device; and when using the VR Bluetooth remote controller, the "C" key is the one used for selecting an element. Figure 1 shows both devices and their respective parts used for navigation (in green) and for selection (in red).
- **Textual content.** The SG includes instructions that are short, clear, and concise, using informal language; in addition, text will be written in large fonts.
- **Basic elements within the game.** All the visual elements of the game are placed at a considerable size, so that they are visible at all times.
- **Visual elements and images.** Visual elements or images used within the game (animals, objects, characters) are represented as close to reality as possible.

- **Use of colors.** The colors used are as close to real-life elements as possible. For elements such as the menu, dark background colors and light text colors are used.

## 5. Design of competencies for cognitive stimulation.

The main objective of this SG is to provide stimulation in the area of concentration for people with MCI who have concentration problems; however, it can also help stimulate *perception* and *memorization*. Regarding the design of the skills, the goal is for the person to be able to stimulate the area of concentration by carrying out an activity of identifying identical objects. The main theme of the game is for the player to be able, in the first instance, to identify the animal corresponding to the instruction provided and, subsequently, to identify the correct corral thanks to this same activity. Likewise, as mentioned above, this game can also stimulate the area of memorization and perception, which is carried out through the presence of short and clear instructions that will be said only once by voice and that will indicate to the player the order in which the animals must be taken to the corral; in this way, the player must read an instruction, identify the animal that the player wants to herd, identify the corral to which it belongs, and take it there.

## 6. Development of the conceptualization of the game type.

This SG is going to be a pure progressive game; it will have an adventure genre, and it will have an "A" rating (this means that its content will be suitable for all audiences). It is about a farmer who seeks to return all the animals that have escaped to their respective barnyard; to do this, the player must herd each one of them until none are left free. To correctly implement the game play within *Adventures in the corral, heroes of the flock*, the following rules and results must be followed:

- (a) **Rule:** The animals must be herded in the order indicated in the instructions that will be displayed on the screen.  
**Result:** If the player herds the animals following the instructions, they can move on to the next step, which is to attempt to lasso the animal. Otherwise, they will not be able to lasso the animal because it will not be active.
- (b) **Rule:** To herd an animal, the player must approach it and throw a lasso by pressing the corresponding key.  
**Result:** For the player to activate the lasso function, the player must be close enough to the animal. Otherwise, even if the animal matches the order of the instructions, the lasso will not be able to be thrown.



**Figure 1.** Devices used for in-game interaction. The parts used for navigation (green) and selection (red) are highlighted.

- (c) *Rule:* Once the animal is connected with the lasso, the player must walk to the animal's correct pen.

*Result:* If the player successfully moves the animal close to its pen, the player will be able to move on to the next step, which is to put it in the pen. Otherwise, the player will not be able to put the animal in the pen, as the gameplay of the SG does not allow animals to be placed in incorrect pens.

- (d) *Rule:* Once the player is close enough to the corresponding corral, the player must press a key to release the animal and have it go into its corral.

*Result:* If the player is positioned close enough to the pen of the linked animal, the player must press the correct key to allow the animal to enter the pen. Otherwise, the player will not be able to leave the animal inside its pen.

- (e) *Rule:* The game will have a total of 5 levels, each one with a different time limit in seconds ranging from 300 up to 540. All animals must be properly housed in their pens within the established time limit.

*Result:* If all the animals are placed in their pens within the allotted time, the game is won; otherwise, the game is lost.

There are two ways in which a game can finish:

- (a) *Option 1:* The game ends when the player has completed all five levels of the game.  
*Result:* The player wins the game.
- (b) *Option 2:* When the player does not finish putting the animals in their respective pens in time and once the game-end screen appears, click on "Exit" the game ends.  
*Result:* The player loses the game and can choose to play again or exit the game.

Figure 2 presents a graphical representation of

the elements implemented within the rules and the corresponding results.

#### Player efforts.

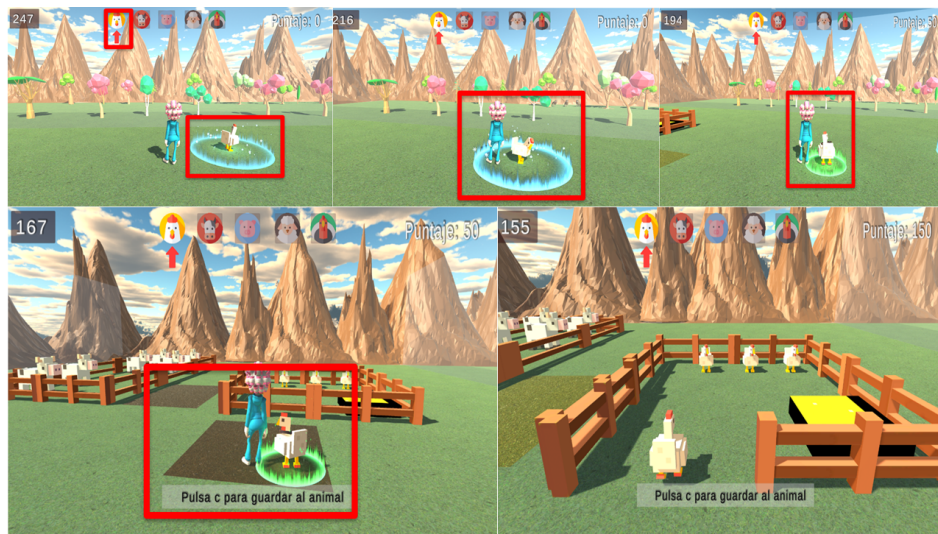
- The game has five levels, which the player will progress through automatically; that is, each time they complete a level, they will move on to the next. The difficulty of the gameplay increases with each level.
- Each time the player links an animal, the player will receive 50 points.
- Each time the player places the animal in its corral, the player will receive 100 points.
- In each level, the player can receive a maximum of points: 750 for levels one and two, 1050 for the third one, and 1200 and 1500 for levels fourth and fifth, respectively.

#### Negotiation consequences.

- Points will be used as in-game rewards, which will increase as the player follows the instructions.
- Celebratory sounds will be used as a reward each time the player follows the instructions within the game.

### 7. Narrative structuring.

- **Story.** The story is linear, and the SG starts with the following description: "One day, a farmer was putting all the animals on her farm in their respective pens; however, due to her carelessness, where the player didn't lock the pens, most of the animals managed to escape. Now the farmer must put all the escaped animals in their respective pens, and the player must do it quickly, because if night falls and the animals are not kept safe, they can be devoured by predators. This is because every night, wolves come



**Figure 2.** From top left, clockwise. First box: The instructions indicate grabbing the chickens, so it is necessary to get close to them. Second box: To grab the chicken, the player must get close enough to it; in this case, the player must be within the circle surrounding it. Third box: Once the player is close enough and presses the correct key, the circle surrounding the chicken turns green. Fourth box: Once the chicken is grabbed, it must be taken to its pen and a key pressed to enter it. Fifth box: Since the chicken was taken to the correct pen and the correct key was pressed, the chicken was successfully saved, and a reward was received.

*down from the hills in search of food and destroy everything in their path, whether animals or people.”<sup>3</sup>*

- **Character design.** There are three types of characters in the SG. The **Farmer** is the main character in the story and interacts with the animals to herd them into their corrals. The **animals** (cows, pigs, sheep, chickens, turkeys) are about to escape from their respective holding place. And finally, the **wolves**, which are predatory animals that will appear to eat the farm animals if the farmer doesn't manage to get them back into the corral in time.
- **Chapters design.** The game has five different chapters. In each of the chapters, the gameplay will be the same; the only difference within the chapters is the kind and number of animals that will appear: *Level 1*: Chickens and wolves; *Level 2*: Chickens, cows, and wolves; *Level 3*: Chickens, cows, pigs, and wolves; *Level 4*: Chickens, cows, pigs, sheep, and wolves; and *Level 5*: Chickens, cows, pigs, sheep, turkeys, and wolves.
- **Labeling and evaluation of cognitive activities.** As mentioned previously, the activity selected for cognitive stimulation of

concentration is the identification of identical objects. This activity is carried out within the game when the farmer identifies which corral the animal the player must herd belongs to and puts it there.

## 8. Adaptive structuring and personalization design.

- *User profile development.* No user profile was developed for this game.
- *Labeling and identifying inclusive design approaches*
  - (a) Both the video game controller stick and the VR Bluetooth remote controller stick will be used for the farmer's mobility (i.e., navigation) as well as to link the animal and place it inside the pen (i.e., selection).
  - (b) As for UI elements, each of them is implemented with a considerable size.
  - (c) Large fonts will be used to provide instructions within the SG.
  - (d) The colors used in the game will be as similar as possible to reality, to not confuse players within the SG.

<sup>3</sup>A video with an example of the serious game is available at [https://drive.google.com/drive/folders/11\\_XUmGXqgs2Poey2gtzR4VQayDy1aU4E?usp=sharing](https://drive.google.com/drive/folders/11_XUmGXqgs2Poey2gtzR4VQayDy1aU4E?usp=sharing)

- *Inclusion of artificial intelligence.* For this game, artificial intelligence was not included.

## 9. Design of orientation and motivation strategies.

- *Tutorial design.* For the development of this SG, a video tutorial was created in which the functionalities of the remote control are explained. This video explains in detail and through examples how to interact with each of the objects within the game.
- *Points and rewards system.* The reward system within this SG will be simple, with points awarded only for specific actions.

## 4. Assessing Adventures in the Corral, Heroes of the Flock

In order to assess the SG developed following the aforementioned methodology and also to determine whether it meets the objective of providing cognitive stimulation for elderly people with mild cognitive impairment, we carried out a usability study<sup>4</sup> as played by a group of 21 people in a community center located in the suburbs of Puebla, Mexico. We asked permission from the respective authorities, explaining the objectives of our research. All participants signed an informed consent before participating in this evaluation. The evaluation was conducted in two phases. In the first phase, a total of 12 people participated, all female, with ages ranging from 61 to 83 years old, where only 16.66% of the population had ever used video games in their lives. In the second phase, 9 people participated, all female, with ages ranging from 67 to 79 years old, with no previous experience in the use of video games.

In both phases, participants were asked to sit at a table in front of a computer. In the first phase, the players used a video game remote control for playing. In the second phase, people had the opportunity to choose a device for playing, either a video game remote control or a VR Bluetooth remote control. Only two people decided to use the former, and the remaining decided to use the latter. Once the interaction began, participants were informed that they could end the test at any time if they felt uncomfortable. Afterwards, they were asked to complete a short tutorial and start the game evaluation. In case people had any doubts about the interaction within the game, the researchers who conducted the test were allowed to interact. Likewise, every time a good action was performed, people were praised as an attempt to boost their confidence. Finally, every time the players ran out of time or finished a level, they were given the option to continue playing or end the game, to make them feel comfortable and not to feel pressure to continue playing, avoiding having a bad experience while using the SG.

<sup>4</sup>No clinical trials were conducted in this study, as it is an initial phase of evaluation. Rigorous clinical evaluations are planned for future phases.

We designed a 17-item Likert-scale (rated from 1 to 5) questionnaire, including aspects regarding usability, usefulness, and intention of use, to get some insights into the users' experience after using the SG. In particular, the questionnaire designed to assess usability was divided into the following sections: aesthetics, learning, operability, challenge, satisfaction, design, attention, and relevance. Overall, the results of the participants' perception suggest a *general acceptance* of the SG, with an average greater than or equal to 4.44 for most items, as shown in Table 2. The lowest value with regards to the *relevance* aspect, which suggests that participants may prefer other forms of exercise since, for most of them, this was the first time interacting with a video game.

From the results presented above, we may conclude that in general, the structure of the game was perceived as correct, which indirectly serves to evaluate the proposed methodology. No negative comments were expressed by the participants; instead, scores greater than 4 were obtained for most aspects. Furthermore, a possible explanation for the *relevance* aspect lower than the 4 score is the lack of previous experience of the participants in video games.

Despite the positive results obtained, there is room for improvement for the SG (which also applies to the methodology) according to the feedback provided by the participants in the evaluation. This is summarized in the following recommendations:

- **Paying attention to the duration of the game.** When designing activities, consider that participants with mild cognitive impairment may perform less well than healthy participants. An ideal scenario is that real patients evaluate the game, but when this is not possible, it is suggested to measure the time it takes a healthy subject to perform the activity and then multiply it by 3 times, trying to ensure that they have time enough to perform the activity.
- **Settings of the device for interacting with the game.** The movement speed for the characters must be lower than in a regular video game, since this can cause the elements to move very quickly, confusing the users.
- **Using levels.** When the SG includes levels, instead of continuously implementing them, adjust them within a main menu or within the user profile to make browsing easier.
- **Size of the landscape.** When the SG map is large, it is important to ensure that the player sees all the elements s/he will be interacting with from the start, in order to facilitate interaction with the game.



**Table 2.** Results of the usability study for phase 1 (E1) and phase 2 (E2).

Aspect	E1	E2	Related questions
Aesthetics	$n \geq 4.58$ $SD \leq 0.62$	$n \geq 4.44$ $SD = 0.5$	<i>“The elements that appear are pleasant and similar to reality.”</i> <i>“The letters, their size and the colors seemed adequate to me.”</i>
Learning	$n = 4.58$ $SD = 0.49$	$n = 4.44$ $SD = 0.63$	<i>“It was easy for me to learn to play.”</i>
Operability	$n \geq 4.58$ $SD \leq 0.5$	$n \geq 4.44$ $SD \leq 0.68$	<i>“The rules of the game were clear and concise.”</i> <i>“The tutorial kept me from making mistakes.”</i>
Challenge	$n \geq 4.25$ $SD \leq 0.60$	$n = 4.44$ $SD = 0.5$	<i>“The game’s difficulty was appropriate.”</i> <i>“The pace of the missions varied appropriately.”</i>
Satisfaction	$n \geq 4.58$ $SD \leq 0.49$	$n \geq 4.44$ $SD \leq 0.5$	<i>“I managed to overcome the obstacles and advance in the game.”</i> <i>“I feel satisfied with the exercise I completed.”</i>
Design	$n = 4.25$ $SD = 0.60$	$n = 4.44$ $SD = 0.5$	<i>“Some elements of the game made me laugh.”</i>
Attention	$n \geq 4.17$ $SD \leq 1.28$	$n \geq 4.00$ $SD \leq 1.29$	<i>“I was so focused on the game that I lost track of time. ”</i> <i>“I forgot about my surroundings while playing.”</i>
Relevance	$n = 3.50$ $SD = 1.32$	$n = 3.67$ $SD = 1.49$	<i>“I prefer to exercise with this game than with other forms”</i>

## 5. Conclusions

This paper presents a methodology for the design of serious games for cognitive stimulation of elderly people with mild cognitive impairment. Despite the growing interest in the use of computers for rehabilitation purposes, there is a lack of standard methodologies guiding the process of developing serious games for this purpose. We propose a set of steps that can help people involved in such a process to consider different aspects, ranging from stylistic design to the activities to be performed by patients. In addition, we developed a serious game following the proposed methodology. This game was evaluated by a group of elderly people, who interacted with it and then answered a usability questionnaire regarding their satisfaction with the game. The results obtained in usability evaluation show good levels of satisfaction, which gives evidence that the methodological approach presented helps in the development of effective and motivating serious games for this specific target population. As future work, we are interested in evaluating the usefulness of the proposed methodology from the perspective of software developers.

## Ethics statement

According to the guidelines of the Instituto Nacional de Astrofísica, Óptica y Electrónica Ethics Committee, this study was exempt from full ethical review. Nevertheless, all participants were informed about the study and provided voluntary consent prior to their involvement.

## CRedit authorship contribution statement

**Luisa Andrea Morales-García:** Conceptualization, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization and Writing – original draft. **Luis Enrique Su-car:** Conceptualization, Formal analysis, Investigation, Project administration, Resources, Supervision, Visualization and Writing – review & editing. **Delia Irazú Hernández-Farías:** Conceptualization, Formal analysis, Investigation, Project administration, Resources, Supervision, Visualization and Writing – review & editing. **Alberto L. Morán:** Conceptualization, Formal analysis, Investigation, Project administration, Resources, Supervision, Visualization and Writing – review & editing.

## Declaration of Generative AI and AI-assisted technologies in the writing process

The authors utilized Grammarly and ChatGPT to refine sentence structure and enhance readability. No content was generated by AI; all scientific insights and original ideas are the authors’ own.

## Declaration of competing interest

The authors declare no competing interests.

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