ADE2: Towards a Method for Implementing Serious Games for Older People's Memory Training

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Abstract: Over the years, cognitive deterioration appears, which is even more evident as age increases; therefore, it requires attention and treatment. Among the older adults' primary needs are learning and entertainment. These needs promote older people, caregivers, and health personnel to seek technological solutions that help during their free time while training the executive functions in the home or gerontological centers. Hence, serious games can teach without neglecting entertainment and fun. Thus, it is necessary to develop techniques, methods, tools, or standards for creating serious games by following a process that considers all the needs and specific characteristics of older adults. Hence, this paper presents a method named ADE2 that aims to facilitate the development of serious games for older adults aligned to usability standards, human-computer interaction (HCI) techniques, and healthcare and software engineering experts' considerations. Evaluating the feasibility of the method has been presented the construction of a serious game and a case study that evaluates the game's use perception. The evaluation was developed from the point of view of the psychological area and the end-user (older adult).

1 INTRODUCTION

The older adult population's growth has motivated researchers to look for ways to preserve these individuals' cognitive functions (e.g., attention, memory). Here, technological applications can provide positive support to reach that objective (Portugal et al., 2013); those applications can be applied at different treatment stages. Depending on the intervention's time and cognitive deterioration level, they can be classified as primary, secondary, and tertiary interventions, being the primary intervention when there are no manifestations of illness (Alves et al., 2009; Yanguas, 2007). These cognitive functions' training allows the older adult to have a greater degree of independence (Lustig et al., 2009).

This objective can be achieved through serious games, which are technological applications that entertain and are also used as tools that promote learning, cognitive-affective stimulation, among others, contributing to cognitive aspects, skills, and abilities, aspects socializers, and digital literacy (Ledo Rubio et al., 2016; Selzer et al., 2006).

Moreover, with serious games, the Human-Computer Interaction (HCI) accessibility criteria must be considered, consisting of appropriately detailed and documented activities to obtain a robust design. HCI allows the consideration of the player's characteristics, the interactions during the game, and the game's behavioral implications to include in the solutions. Therefore, better games can be designed and developed for society. Besides, the combination of serious games with HCI allows inquiring more deeply into the positive or negative impact of end-users with those solutions.

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To design serious games for older people, it is necessary to address the support of semantic and communicative components of knowledge to form effective tools to train the attention and memory of this population (Marchetti et al., 2015). Said information can be obtained, stored, retained, and later retrieved, which are aspects that older adults must maintain in constant training (McLeod, 2013).

Several primary studies address the creation of serious games for end-users in different domains and knowledge fields. In this sense, Bouchard et al. (2012) present a serious game focused on older adults with Alzheimer's, but at a tertiary intervention level, without considering the first stages of intervention. Although this contribution is interesting and presents a positive tool for people, it does not report any health experts' feedback. Lin et al. (2018) developed serious games to be used in a technological laboratory; these games focus on older people's attention and memory. These serious games are adjusted to physical abilities and cognitive functions, but whether older adults can use serious games is not considered. Although those solutions represent important tools for older people, they do not report the steps involved in their implementation; thus not considering the roles of each expert, the accessibility criteria (Pesántez et al., 2020), or a clear description of aspects that need to be considered to reach a target effective serious game. Consequently, it is necessary to have a method that allows the creation of serious games considering all needed aspects for their implementation.

This paper presents a method for creating serious games named ADE2. This method includes all aspects related to the accessibility and good practices to reach effective serious games for older people; those games are oriented to satisfy the training of specific cognitive functions (i.e., attention, memory). Therefore, the main contributions of this research are: i) An initial version of ADE2 method, its activities, guidelines, and artifacts involved ii) the implementation of a serious game which has been built considering each step of ADE2, iii) a case study that shows the use of the serious game oriented to train the attention and memory, which has been used by two older adults and two psychologists, their perceptions after they have tried and their feedback about the experience playing the game. This serious game was also evaluated in a controlled environment; due to the COVID-19 pandemic, the test with a higher number of participants is left as future work.

This article has the following structure: Section 2 presents related work. Section 3 presents the ADE2 method. Section 4 shows the viability of the method by creating a serious game step by step. Section 5 contains a case study where older people and health experts are involved. Furthermore, in Section VI, conclusions and future work are presented.

2 RELATED WORK

Studies that present serious games' methodologies and development to training attention and memory are analyzed in this section. The aim is to check if there are methods to build serious games focused on older adults, which provide training and evaluation of attention and memory.

Tost et al. (2014) and Tong & Chignell (2014) present serious games development using traditional software engineering methodologies such as agile methodology. Lin et al. (2018) present a serious game development to stimulate older adults' cognitive and physical functions without presenting the approach, methodology, or development technique that shows that it is necessary to apply accessibility criteria for older adults.

On the other hand, Bouchard et al. (2012) present a development approach where guidelines are addressed to design and implement serious games that adapt to older adults' needs using artificial intelligence techniques and difficulty adjustment. Likewise, Blasko et al. (2014) describe the development of a game (SPOT), which has the advantage of improving attention deficit disorder and cognitive problems in older adults. Savazzi et al. (2018) also describe a serious game for neurorehabilitation; physiotherapists validated this solution.

Rodriguez-Fortiz et al. (2016) present the development of serious games on a web platform that can improve accessibility from a computer or mobile device, where it is possible to develop serious games by focusing on the design of interfaces for the elderly population and its multiple needs.

Facing the psychological aspects, so far, it has been determined that older adults can significantly improve their cognitive skills through the constant use of a serious game. This is supported by the study of Chi et al. (2017), who present the design of a game package called "Smart Thinker," which is presented to improve the subject's basic cognitive skills.

Related to the presented solutions, it is possible to conclude that there is no methodology to create serious games where guidelines are applied for an effective design for older adults, which is able to fulfill the objective of training and evaluating cognitive functions and have it validated by software engineering and healthcare experts.

3 THE ADE2 METHOD

For the creation of a serious game to train and evaluate the cognitive functions of an older adult, a development method has been created, which integrates accessibility features and considered the participation of several professionals in different knowledge areas (e.g., psychologists, software engineers, project specialists, among others).

3.1 ADE2

The first phases to build serious games are based on two models: ADDIE (Bhushan & Bhushan, 2006), which is used for software development, and DODDEL (McMahon, 2007), which is used to create serious games. The ADDIE model was used to capture requirements, implementation of the application, and the evaluation of the solution; the DODDEL model was used to carry out the situation analysis document, the design of the solution because this model is oriented to the design of games, the evaluation of the application to elaborate documentation and the delivery. The ADE2 method is that it is a pipeline process, which provides the advantage of continuity with the domain expert throughout each artifact, especially in terms of cognitive functions.

The ADE2 method contains the following phases: i) analysis of the situation, ii) analysis of requirements, iii) design, development, iv) evaluation, and v) delivery; these phases are presented in Figure 1. Also, in each of the steps, verification and validation are carried out. Initial specifications are checked at verification, and validation consists of meeting the needs of all those involved (Sommerville, 2016). These phases are explained below:

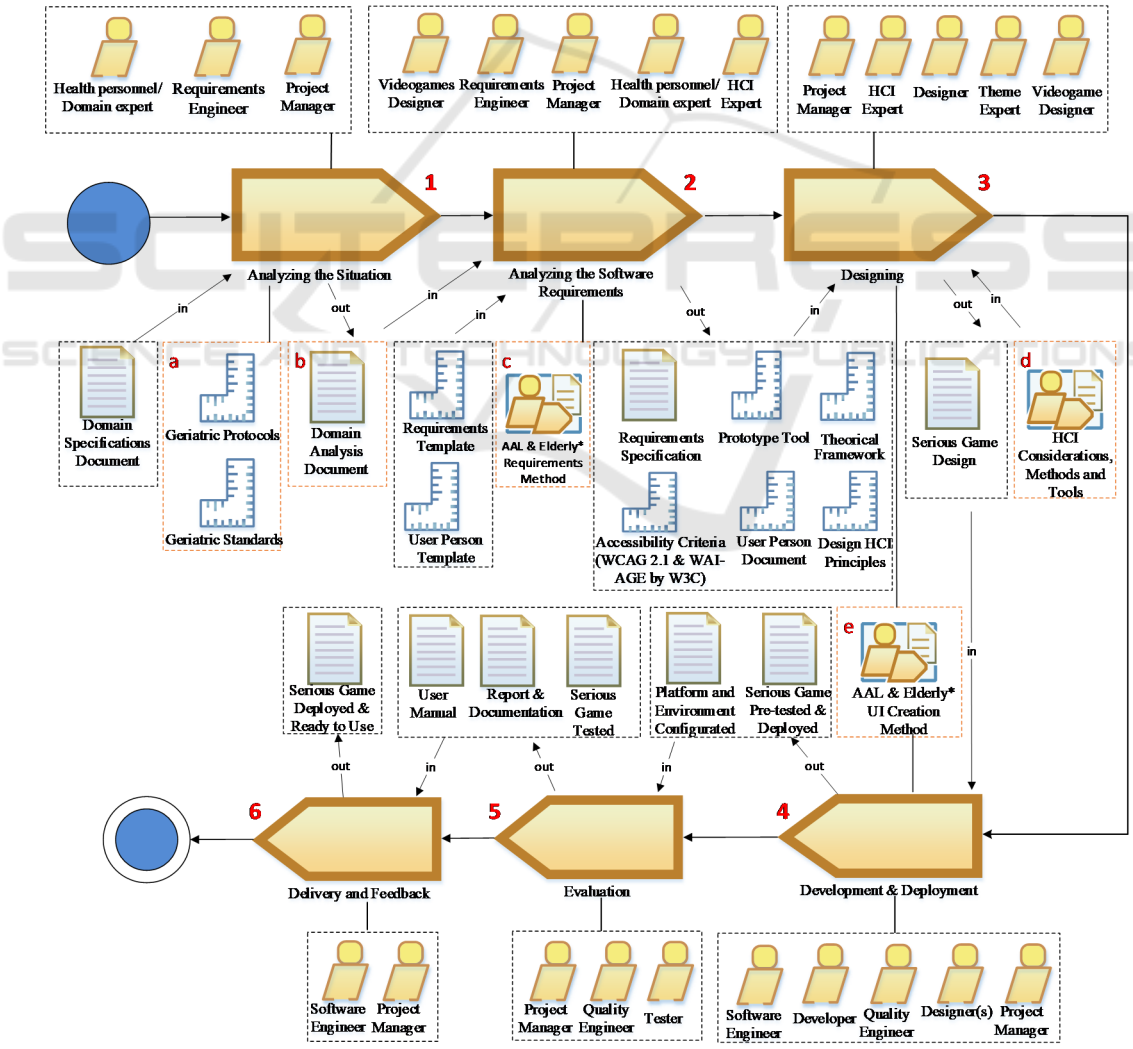

Figure 1: Main Method for building serious games for older people (ADE2).

3.1.1 Analyzing the Situation

This activity is shown in Figure 1(1), where the participants are the domain expert, the requirements engineer, and the project manager. The following guidelines are used based on the domain specification document: geriatric protocols and geriatric standards, as shown in Figure 1(a)(b) to obtain the artifact called domain analysis document. In this document, users will find detailed context, environment, and objectives to which the serious game will be destined (see Figure 1(c)).

3.1.2 Analyzing the Software Requirements

This activity is based on the domain analysis document (see Figure 1(2)). Here, the requirements engineer, the domain expert, and the project manager perform the requirements' formal specifications. The Ambient Assisted Living (AAL) & Elderly * Requirements Method guide can be used by actors such as the video game designer and the Human-Computer Interaction (HCI) expert who expands the specification of requirements. If the serious game is focused on the environment of assisted living, it may be more robust and useful for this type of environment.

3.1.3 Designing

This activity is shown in Figure 1(3); the HCI expert, and the videogame designer, carry out the game's prototyping through the use of a prototyping tool.

This prototype must consider the following guidelines: WCAG 2.1 & WAI-AGE by W3C accessibility criteria and HCI design principles. Using the guide called theoretical framework helps choose the most appropriate technologies to perform serious game development.

3.1.4 Development & Deployment

In the game's development and implementation, the software engineer and designer use the Ambient Assisted Living (AAL) & Elderly * UI Creation Method to implement user interfaces that are easy to understand and use for an older adult (see Figure 1(4)).Then, the quality engineer and the developer carry out the game's implementation. To move to the evaluation phase, the project manager must accept the final version of the game, which must not contain errors, and comply with the requirements raised in the initial step of the ADE2 method.

3.1.5 Evaluation

This activity is shown in Figure 1(5). Once the previous activity artifacts have been obtained, the tester and the quality engineer develop the user manual and perform the game's final tests. The final artifact will be achieved, a serious game; the project director will deliver it in the last step.

3.1.6 Delivery and Feedback

This activity is shown in Figure 1(6). As a final phase, the project director, and the software engineer, deliver the game for later use by an older adult.

3.2 Artifacts in the ADE2 Method

3.2.1 Domain Specifications Document

This document specifies the environment in which the user is located, what are the limitations of the environment, and other characteristics that the domain expert, in this case, the health area, considers necessary to describe. This document is made to have a clear idea of the environment and adapt the requirements to it. Also, geriatric protocols and standards should be incorporated because they belong to the technical-administrative aspect that influences older people's quality of care.

3.2.2 Domain Analysis Document

Here, it is possible to obtain the most relevant information to document the situation's analysis in a more summarized way. This document describes the application's purpose, the limitations, the users, the main characteristics, and the experts' requirements.

3.2.3 Requirements Specification

For the requirements specification, aspects must be obtained related to environmental and contextual details in which the application will be made. The final application design restrictions should include the user-persona document (Institute of Electrical and Electronics Engineers, 2008). This document details the characteristics of the user who will use the application. It is convenient for designers when sketching the application.

3.2.4 Serious Game Design

The user-persona and requirements specification documents must be considered to develop the prototype. At this point, several aspects should be

addressed: if the solution is responsive, allows collaborations in real-time, the operating system in which it runs, and the type of approach. Also, accessibility criteria must be considered, which provide information on the typography, fonts, and multimedia necessary to develop applications for older adults.

The HCI principles are another necessary task in the design because, in these principles, there are activities that must be included in the design to make it more user-friendly, such as shortcuts and informative comments.

3.2.5 Framework

It is necessary to start by developing a theoretical framework document, in which it is specified which of the possible frameworks meets the requirements to carry out the application. Once a framework has been chosen, all the advantages, disadvantages, and characteristics must be included in the theoretical document.

3.2.6 Serious Game Pre-tested & Deployment

Once the game has been developed in the chosen framework, it could finally be deployed. This activity provides the first test run of the application and the documentation with its results, errors, and solutions. In the ADE2 method, this is considered one of the most important deliverables, because it is the first version of the application developed. It is important to add that you can return to this stage as many times as necessary until the game works correctly.

3.2.7 Platform and Environment Configuration

This activity should include the components that will allow for the application to be tested. Among these components are the operating system and the application parameters for later use by end-users. The application must follow the detailed specifications within the requirements analysis document and comply with the accessibility criteria and HCI principles.

3.2.8 Serious Game Tested

Once the application has successfully passed the tests according to the inputs and all corrections and recommendations have been resolved, the application will finally be ready for deployment.

3.2.9 Report & Documentation

This document should include all the failures of the tests and the expert's recommendations in the domain. It must match the requirements specification.

3.2.10 User Manual

This document must specify the functionalities available in the application, the buttons and their action, and everything about installing the application if required.

3.2.11 Serious Game Deployed & Ready to Use

Once all the documents have been developed and the application is ready, it is necessary to install it on the platform or environment specified in the requirements document for final use.

3.3 Guidelines in the ADE2 Method

3.3.1 Geriatric Protocols & Standards

Including Geriatric Protocols and Standards is one of the advantages of ADE2. These are the contents that the domain expert provides to the project manager to have a clear idea about approaching the end-users. There are specifications in these protocols and standards according to the environment and the older adults' needs.

3.3.2 Requirements Template

To make a correct specification of requirements, it is essential to follow the IEEE 830 standard (Institute of Electrical and Electronics Engineers, 2008). In this standard, the purpose, the scope of the system, definitions, an overview, perspectives, functions of the system, product, specific requirements, and others can be specified.

3.3.3 User Persona Template

ADE2 recommends the use of the personal data template. This template must be filled with end-user’s information. The information about the motivations, frustrations, hobbies, and other activities and attitudes of the end-user are found. Figure 2 provides an example of the user persona template.

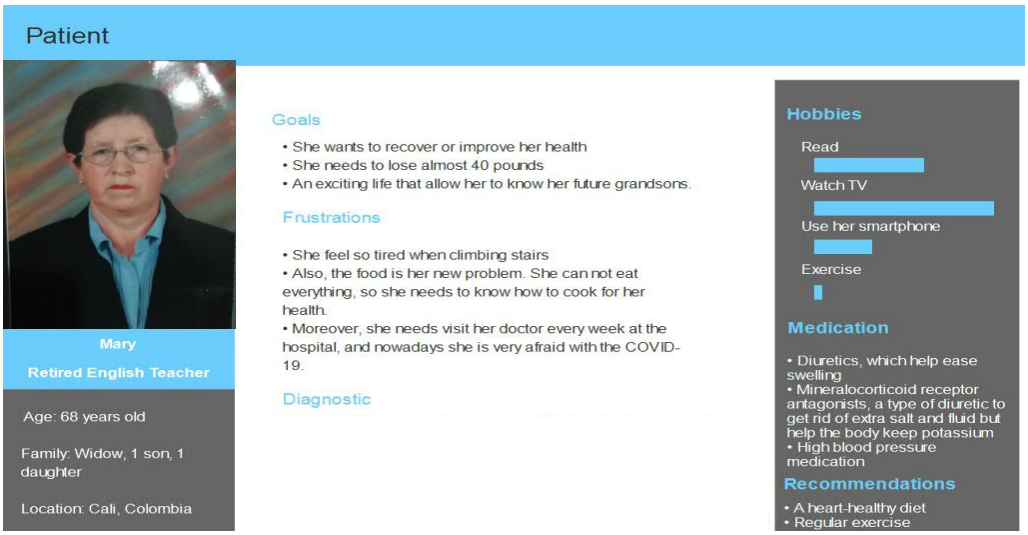

Figure 2: Example of a user-persona template.

3.3.4 Accessibility Criteria

Another advantage of ADE2 is the accessibility criteria because, in this, the interface development process is found, but focused on a particular end-user (Arch, 2008). This document will present the size and style of the text, the contrast, color, multimedia, and others that need to be adapted to the design for better user acceptance (see Table 1).

3.3.5 Prototype Tool

The prototyping tool must be the one that meets the requirements and best adapts to the accessibility criteria and the user persona template.

Table 1: Accessibility Criteria.

Type	Description
Text size	Most of the older adults have visual problems; therefore, they need the text size to be of considerable size for later use.
Text type and style	The text type or style can be easily or difficultly viewed by the older adult, it depends on visual problems.
Contrast and color	It is used to distinguish the visual elements within the game.
Multimedia	These resources guide users to carry out the tasks easily.
Text to speech	This parameter can be used by users who have a large percentage of vision loss; thus, they can overcome these types of obstacles through their voice, such as, for example, filling in the space of their name if required.

It is important to note that various prototyping tools should be considered and, their respective advantages and disadvantages should be listed. This will guide the choice of a tool that meets the specifications required for the prototype.

3.3.6 Theoretical Framework

This document provides information on the type of candidate technologies used for the back-end and front-end, their advantages and disadvantages to facilitate the actors' implementation and design process.

3.3.7 Design HCI Principles

Table 1 presents the HCI design principles; it is a guide that helps the designer to create an application that meets the requirements that are necessary to create a cleaner and more user-friendly application (Sosa-Tzec & Siegel, 2014).

HCI design principles have their guidelines for any operating system. It features activities such as using shortcuts, reporting task findings, offering simple error handling, and more.

4 DEVELOPMENT SERIOUS GAME USING ADE2

In this section, the six activities involved in the ADE2 method have been applied to create a puzzle game. Each of these activities is described at a high level and is detailed in Figure 3. The serious game's goal is to

reinforce an older adult's memory; it is based on self-recognition through the use of their photographs. This serious game represents an essential resource for the patient's training and cognitive rehabilitation at home and in a health center. Therefore, there is a current trend for procedures to design and apply intervention programs to promote patient motivation and minimize the total treatment time.

In Figure 4, the interface of the puzzle game is shown. This game is available at the following URL: https://puzzlegame-8ab23.web.app/home.

To access the game, the user must be registered in the system through a personal ID number. Then the user selects the desired image to start the assembly of the puzzle.

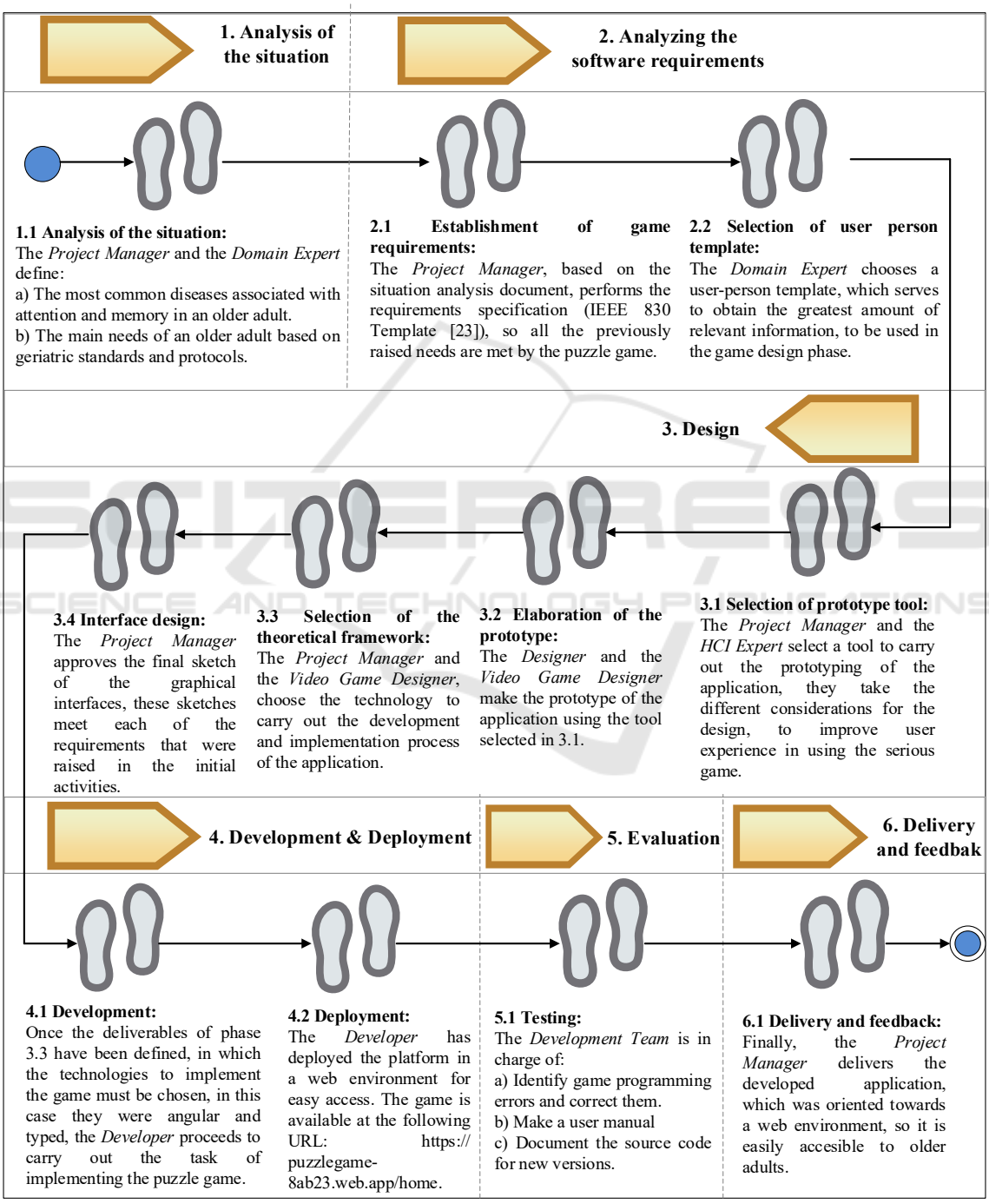

Figure 3: Steps to create the serious game using the ADE2 method.

5 CASE STUDY

A game built following the ADE2 method was evaluated through a case study. It follows the methodology proposed by Runeson et al. (2012). The activities to be followed during the execution of the case study are i) design, ii) ethical considerations, iii) preparation for data collection: procedures and protocols for data collection are defined, iv) collecting evidence: execution with data collection on the studied case, v) analysis of collected data and reporting, and vi) threats of validity analysis.

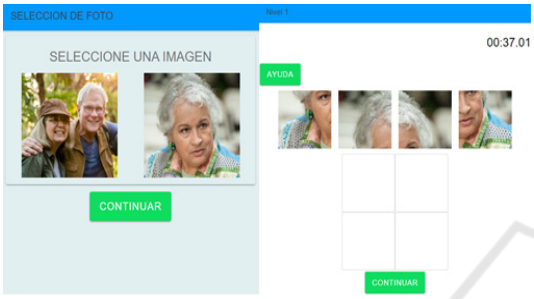

Figure 4: Puzzle game and units of analysis.

5.1 Design

Here, the main objective is to know the perceptions of health personnel and end-users regarding serious games created for cognitive training. In this context, the research questions are i) How does the psychologist perceive the technological solution's clinical utility? And ii) How does the end-user perceive the usefulness of the technological solution? The case study method is holistic-multiple, and the units of analysis are presented in Figure 5. The case study method is embedded-unique, and the units of analysis are presented in Figure 5. In this case, it corresponds to an embedded-unique case study. Due to within a case, multiple units of analysis are studied. It is considered unique because two particular phenomena are explored in a single context (Runeson & Höst, 2009).

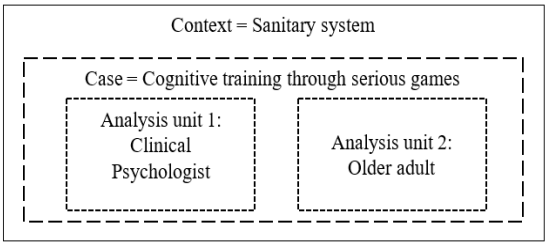

Figure 5: Embedded unique method.

5.2 Ethical Considerations

Although a research study is primarily based on trust between the investigator and the case (Amschler & Pradhan, 2001), some explicit prevention measures have been considered to prevent future problems. The main ethical factors included in this case study's: i) informed consent, ii) review of board approval, iii) confidentiality, and iv) feedback.

5.3 Preparation for Data Collection

Two surveys have been designed based on the Technology Acceptance Model (TAM) proposed by Davis (1985). This model consists of evaluating the Perceived Ease Of Use (PEOU), the Perceived Usefulness (PU), and the Intention To Use (ITU) in the future. The designed surveys were focused on the elderly and the health expert. This questionnaire, as it is shown in Appendix 1, uses a 5-point Likert scale.

5.4 Collecting Evidence

The game was presented to two older adults with the support of two different experts in cognitive health (Psychologist) (see Figure 6). Participants have been selected by convenience of therapeutic groups. Then, the professional and the end-user answered the survey questions.

Figure 6: Case study with older adults and an expert in the area of healthcare.

5.5 Data Analysis and Results Reporting

The average of the responses obtained for each construct of TAM was calculated (see Figure 7). With this, it was concluded that both health experts and older adults mention that the puzzle steps are easy to understand; besides, this technological input can reduce cognitive training time and effort. They also rescue that it is a useful input since it allows the

patient's cognitive training; for this reason, it could be used in the future.

5.6 Threats of Validity

The four threats that can put the case study at risk have been analysed, these are presented by Cook & Campell (1979) and are detailed below:

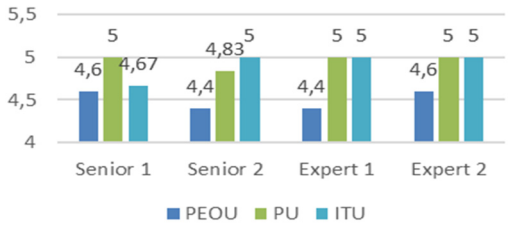

Figure 7: Results of the case study: user perceptions.

5.6.1 Construct Validity

Construct validity focus on the relation between the theory behind the case of study and the observation. To analyse whether the operative measures studied represented what the researchers had planned to investigate and what they investigated.

For this step, validated questionnaires were used, which have an ideal Cronbach's alpha; thus, the interview questions' constructs will be interpreted in the same way by the researcher and the people interviewed.

5.6.2 Internal Validity

Depending on how the subjects in a group are selected, the selection effects may vary. In this study, the age, educational level, profession, and any previous experience that the participants have with technology could influence the ease of use when using the proposed solution.

5.6.3 External Validity

The selection of the sample of individuals who participated was made at convenience. Due to the COVID-19 pandemic, access to the elderly population is restricted.

5.6.4 Reliability

From the interviews to the analysis, the evidence chain was carried out respecting the data's literality. Moreover, the qualitative responses were quantified using a Likert scale to avoid introducing interpretation bias.

6 CONCLUSIONS AND FUTURE WORK

The ADE2 method considers design aspects for older adults based on standards and protocols in creating serious games to train and evaluate cognitive functions, creating the prototypes following the domain analysis document and the individual user allows for a clearer design that goes hand in hand with the end-user and the recommendations of the health expert.

This method is designed to be applied in the engineering of serious game development for older adults in a scalable or iterative way. To test the viability of the method, a serious game consisting of a puzzle has been built. It has been presented to two psychologists (health care personnel) for evaluation and two older adults to use the serious game who is the direct manager to consider the interest and usability that will be provided in the application. The results show that the game is perceived as easy to use and as useful. Finally, in future work, each task of the ADE2 method will be studied in depth to expand and specialize each activity, role, and guide that intervenes in each phase; it is also expected to evaluate the method with experts in software engineering through controlled experiments and evaluate the game with more populations to present a discussion complete of the results obtained.

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APPENDIX 1

These questions have been applied to psychologist and older adults

1. I found the puzzle complex and difficult to follow

Totally agree 1 2 3 4 5 Strongly disagree

2. I believe that the puzzle could reduce the time and effort required for cognitive training

Strongly disagree 1 2 3 4 5 Totally agree

3. In general, the puzzle is difficult to understand

Totally agree 1 2 3 4 5 Strongly disagree

4. The steps to solve the puzzle are clear and easy to understand

Strongly disagree 1 2 3 4 5 Totally agree

5. In general, I consider the puzzle to be useful

Strongly disagree 1 2 3 4 5 Totally agree

6. The puzzle is difficult to learn

Totally agree 1 2 3 4 5 Strongly disagree

7. I consider that the puzzle is useful to improve the cognitive training process, specifically to improve the ability to remember events of daily life

Strongly disagree 1 2 3 4 5 Totally agree

8. If I need to use a tool for cognitive training, I would consider this puzzle in the future

Strongly disagree 1 2 3 4 5 Totally agree

9. I think the puzzle is NOT expressive enough to define how it is solved

Totally agree 1 2 3 4 5 Strongly disagree

10. The use of this puzzle could improve the patient's cognitive performance

Strongly disagree 1 2 3 4 5 Totally agree

11. I believe that patients can easily master the puzzle

Strongly disagree 1 2 3 4 5 Totally agree

12. In general, I think that the puzzle CANNOT be used as an aid to improve performance in remembering certain objects and events

Totally agree 1 2 3 4 5 Strongly disagree

13. If necessary, I would use this puzzle in the future

Strongly disagree 1 2 3 4 5 Totally agree

14. I would not recommend the use of the puzzle

Totally agree 1 2 3 4 5 Strongly disagree

15. Do you have any suggestions on how to make this game easier to use?

16. Why you do or do not intend to use this game in the future?