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AMELIA - Mobile Memory Training Interface for Older People

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Master in, Computer Science and Business Management

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TECNOLOGIAS
E ARQUITETURA

Department of Information Science and Technology

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Resumo

A população do planeta tem vindo a envelhecer a um ritmo acelerado e devido aos progressos na área da saúde e da medicina a esperança media da vida está a aumentar. Nestas condições, surgiu um novo desafio de envelhecer em casa, originando novas necessidades associadas à manutenção da qualidade de vida.

A vida sedentária na população idosa com pouca atividade na sociedade pode causar problemas de saúde mental incluindo declínio cognitivo ou a demência.

Foi, portanto, proposto a criação de uma aplicação mobile que consiga treinar a memoria do idoso através de exercícios baseados no conceito "Life Story Work", de forma a combater a deterioração das faculdades como a compreensão e o raciocínio.

O desenvolvimento desta app foi acompanhado por cinco profissionais da área da saúde e da tecnologia. A validação da aplicação realizou-se através de grupo de utilizadores representados por pessoas com idades avançadas.

A análise dos dados recolhidos permitiu concluir concluir que o desenvolvimento da APP Amelia foi muito relevante e apreciada entre os profissionais, cuidadores dos idosos e para os próprios idosos. Foi inclusivé descrita como uma abordagem mais agradável do que jogos sérios comuns, por utilizar o passado, o lado pessoal dos utilizadores, para criar exercicios semelhantes. Este teste permitiu comprovar o preenchimento de um gap de falta de aplicações no mercado que usem o trabalho de história de vida para realizar jogos sérios.

Palavras-Chave: App móvel, aplicação móvel, sistemas inteligentes, jogo sério, Computação Pervasiva, declínio cognitivo, deficiência cognitiva, treino de memória, estimulação cognitiva.

Abstract

The planet's population has been aging at a rapid pace and due to advances in health and medicine the average life expectancy is increasing. Under these conditions, a new challenge of aging at home has emerged, giving rise to new needs associated with maintaining quality of life.

A sedentary life in the elderly population with little activity in society can cause mental health problems including cognitive decline or dementia.

Therefore, it was proposed the creation of a mobile application that can train the memory of the elderly through exercises based on the concept "Life Story Work", in order to combat the deterioration of faculties such as comprehension and reasoning.

The development of this app was monitored by five health and technology professionals. The app was validated through a user group represented by elderly people.

The analysis of the data collected allowed us to conclude that the development of the Amelia APP was very relevant and appreciated among professionals, caregivers of the elderly and for the elderly themselves. It was even described as a more enjoyable approach than ordinary serious games, because it uses the users' past, personal side, to create similar exercises. This test proved to fill a gap of lack of applications on the market that use life history work to make serious games.

Index Terms: Mobile app, mobile application, intelligent systems,, serious game, Pervasive Computing, cognitive decline, cognitive Impairment, memory training, cognitive stimulation.

Contents

List of Tables

List of Figures

CHAPTER 1

Introduction

Currently, the world population is ageing rapidly and it is estimated that the number of people over 60 years old will increase by up to ten percent [**1**]. One of the characteristics of this new generation of elderly people is the concept of "Aging in Place" [**2**], which means, ageing at their home. With the improvement of living conditions, elderly people have been choosing to spend their final stage in the comfort of their homes.

As aged people, they may have numerous illnesses and disabilities. Using technological advances, optimal healthcare support can be provided. Given the scenario of aging at home, other problems may appear, such as loneliness and cognitive decline. These problems come not only from age, but also from lack of exercise and social isolation. Knowing that dementia is aggregated to the previously mentioned factors, there is an urgency to seek the necessary follow-up to avoid worsening the health status of the elderly [**1**]. People diagnosed with dementia, which is a non-curable disease, are helped through treatment that can ease the symptoms of dementia. Mild cognitive decline and mild cognitive impairment can be treated and in this way allow the individual to never reach dementia [**3**].

The quality of life of the elderly, in their housing, depends on maintaining their cognitive and motor skills, and therefore, the way to encourage them to remain autonomous and decrease institutionalization is by training their memory. This training should be adjusted in multiple factors (e.g. duration, quantity and difficulty) and also customized in order to better stimulate users and reduce monotony in the exercises [**4**].

Current technologies are increasingly developed and capable of fulfilling these requirements. Several studies prove that by providing solutions to cognitive decline through technological systems, we can contribute to a better quality of life for the elderly, highlighting mental sanity [**5**] [**1**] [**6**].

1.1. Objectives

The main objective was to develop a prototype mobile application capable of providing memory training in people with cognitive decline and motivating them in wanting to improve. The proposal was made by a team composed of professionals from ISCTE-IUL,BRU Research Center (ISCTE) and Instituto de Telecomunicacoes (IT-IUL).

This team will be responsible for monitoring and evaluating the app throughout the project, so it was considered relevant to create a demonstration table (Table 1) that proves their credibility. In this way, the veracity of the criticisms and suggestions made in Chapter 4 was supported.

TABLE 1. Associated Professionals' Data

Experience	Academic Degree	Total Citations (Scientific Articles)	Research Areas
over 20 years	PhD	6892	Intelligent Sensors for the Internet of Things Distributed Instrumentation Systems Wireless Sensor Networks Remote Sensing Smart Sensors for Biomedical Applications Applied Computational Intelligence for Sensors and Instrumentation Virtual Reality and Augmented Reality for Serious Games in Physiotherapy Intelligent devices for Physiotherapy Applied Thermography
over 25 years	PhD	1377	Data Science Machine Learning and Deep Learning Computational Finance and Economics Healthcare Analytics Nonlinear time series analysis and econometrics Dynamical systems
over 35 years	PhD	6107	Multivariate Statistics Marketing Research Surveys and Sampling Methods Segmentation statistical methods
over 10 years	PhD	287	Health Management Aging Quantitative Methods
over 25 years	PhD	55	Physiotherapy Neurology Aging Fragility in the Elderly Mental Health

The goal of this MSc project involves: 1) the development of a mobile application for Android that collects information associated with the concept "Life Story for Memory"; 2) an information system that allows to record personal data (the life story), store a set of questions for memory training and store the results of cognitive training.

The application will have built-in memory training related to the life story concept and tools for creating the user's story. This story will be built through a list of questions based on the life story work, which in turn will be stored in a remote database. Then memory training games customized for each user will be created based on each user's past. The application will use a scoring system to rate the player's performance in each of the games, in order to be able to analyze the results later.

The information system should have an application server and a database, both in the cloud, so that the application tests can be done in different network zones, i.e., without the devices and the server being connected to the same network. The database must be able to store all the information necessary for the proper functioning of the application. It should receive and send data, via PHP scripts, so that the Java code, in which the application will be built, can customize the user's questions and games.

1.2. Structure

This project is organized as follows: the first chapter covers the introduction and objectives of this dissertation. Then, the second chapter discusses the state of the art. It begins with a literature review, an analysis of similar applications in the market and ends with the theoretical concepts needed for the project. Then the development methodology is presented in the third chapter, and the fourth chapter reports on the entire development of the application as well as all the steps of the methodology. In the fifth chapter a pilot

test is done with real users and an analysis of the results obtained. Finally the last chapter includes the conclusions strength and drawbacks and the future work.

CHAPTER 2

State of the Art

This chapter was built with the purpose of analyzing and making known the relevant studies to the subject under study and the existing applications up to the time of the project's completion. In this sense, the importance of constant monitoring of the target audience and the construction and availability of tools that contribute to their cognitive development was also reinforced.

2.1. Related Work

This project approached 2 distinct areas, Technology and Psychology, it was considered more appropriate to conduct a literature review before starting the development of the proposed application. The review methodology used was a Systematic Literature Review (SLR) based on Kitchenham [**7**] guidelines and indications.

The purpose of a SLR is to allow a researcher or thesis student to do a detailed search, able to gather all the necessary information to answer the questions that are going to be studied. In order to detect as much relevant literature as possible, the SLR has 3 essential phases that were fulfilled in this phase of the project: 1) SLR Planning; 2)SLR Conducting; 3) SLR Reporting.

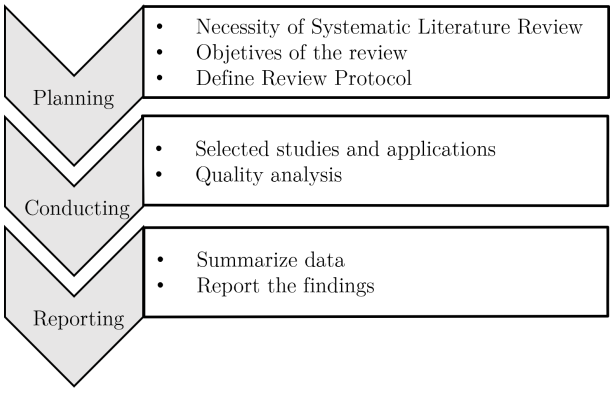

FIGURE 1. SLR phases

However, according to studies conducted, doing a Systematic Literature Review can also mean bringing issues to the quality of the research [**8**] [**9**]. In a study conducted by Krüger[**8**], the authors concluded that often simply using a search script in common databases may not be enough for a perfect study. The reason for this is that databases do not always work the same way when using the same strings, even if they are adapted. In addition, during the course of writing the thesis, the need may also arise to do additional research to clarify doubts and address previously unknown concepts [**10**]. Therefore, it

was considered more advisable to do the aforementioned SLR as well as a complementary research, using Google Scholar and the Snowballing method for the latter.

The hypothesis of considering this review as Multivocal Literature Review (MLR) was analyzed, which is an extension of the SLR with the right to use grey literature. However, grey literature is considered to be literature that is not published formally in journal articles or books (e.g. white papers, videos, websites, blogs) [**11**] [**12**] and in the case of this project all documents were taken from journals or conferences, even those from the complementary research.

2.1.1. SLR Planning

This project covered two very broad areas, Technology and Psychology, which triggered the need to conduct a systematic literature review to ensure that all articles and studies linking both fields are gathered.

The main objective of this review is to understand the different approaches to cognitive training, in the elderly, through technology and thus to ascertain the extent of studies where the life story is a major focus. It is also intended to analyze a sample of applications currently on the market to better understand what already exists and gather the best features for the development of the application in view.

The SLR research consisted in the elaboration of a string with keywords related to the subject in question, which was used in four scientific databases. For this, we resorted to reputable databases with a lot of information in the areas of computer science and health.

- **ACM:** https://dl.acm.org/.
- **IEEE:** https://ieeexplore.ieee.org/search/advanced
- **Scopus:** https://www.scopus.com/
- **EBSCO:** https://search.ebscohost.com/

To make the search as precise as possible, the extra functionality of the advanced search engine was used in all the databases mentioned. Other databases were initially used, but later removed because they did not interpret the string in the same way as the four chosen. According to Krüger (2020) this kind of problem brings imperfection to the literature review [**8**]. Although it may seem redundant to use similar keywords, it was considered appropriate to use similar words to cover as many articles as possible, since not all authors use the same terms. The string separated the similar terms by "OR" and divided the technology area from psychology by "AND".

The word "dementia" was not used in the keywords because, as mentioned in the Introduction Chapter, the objective of this work is to create tools that may help those who are in a transitional phase between perfect health and dementia. In this way, we tried to reduce the number of articles that addressed symptom relief techniques, thus increasing the number of results for approaches that effectively treat cognitive decline.

As for the complementary search, we tried to make associations of the word "Life Story Work" with both areas previously mentioned.

Keywords: "mobile app" OR "mobile application" OR "intelligent systems" OR "mobile application" OR "serious game" OR "Pervasive Computing") AND ("cognitive decline" OR "cognitive Impairment" OR "memory training" OR "memory training" OR "cognitive stimulation").

This string was used in each of the repositories without using any filter and then the number of articles found was reduced with the help of each of the filters present in Table 2.

TABLE 2. Inclusion/Extraction Criteria

ID	Inclusion	Exclusion
IE1	Keywords are present in the Abstract	Abstract does not have the keyword
IE2	Keywords are present in the Title	Title does not have the keyword
IE3	Documents in English or Portuguese	Documents not written English or Portuguese
IE4	Articles from Conferences and Newspapers	Articles or papers do not belong to conferences or newspapers
IE5	Unique article	Duplicate article
IE6	Articles addressing the topic in question	Articles address another theme than the one in question

2.1.2. SLR Conducting

Initially, the search was done on the full text, using only the keywords string mentioned, and in total 9756 articles were collected, and then each of the inclusion or exclusion criteria were used sequentially to reduce the sample.

2.1.2.1. Select Studies

IE1 was used to locate the key words in the abstracts of the articles. This ensured that the words were referenced in the summary of the paper rather than appearing by coincidence in the full text. However, too many articles were still covered, so we had to use IE2 to find documents whose main theme was the keywords themselves, since they belonged in the title.

IE3 was used to exclude articles with languages other than English and Portuguese, from which only six were removed. The IE4 filter was created to select only articles published in scientific journals or conferences, however, as it was used so close to the end, only three documents were eliminated.

After implementing these filters, only 69 articles remained, all of them in English and Portuguese, with the keywords in the title and published in relevant formats. With the help of the Mendeley tool it was possible to reduce this number to 21 articles after removing the duplicate articles (IE5) and those without any kind of character of interest to the subject being studied (IE6). The scheme in Table 3 better elucidates the whole filtering process that gave rise to the 21 articles in the SLR.

Regarding the complementary articles, seven documents were added that address the life story and relate it to technological approaches or cognitive training for people with mild cognitive impairment.

Table 3. SLR selected studies

DataBase	Full Text	IE1	IE2	IE3	IE4	IE5	IE6
ACM	277	7	1	1	1	1	1
IEEE	1618	368	15	15	12	12	10
SCOPUS	7549	224	46	41	14	14	6
EBSCO	402	124	18	12	10	10	4
						Total	21

It was also considered relevant to conduct a search for similar applications or applications with some degree of similarity in order to understand what existed on the market until then. In this search 9 memory training or life story applications were found.

- **CogniFit:** https://www.cognifit.com/pt.
- **LIFEBIO:** https://www.lifebio.org/.
- **RemArc:** https://www.bbc.co.uk/taster/pilots/remarc.
- **Alzminder:** alzminder.com.
- **Book of You:** https://www.bookofyou.co.uk/.
- **Dakim: https:**//www.dakim.com/.
- **Storii: https:**//www.storii.com/.
- **MindMate: https:**//www.mindmate-app.com/.
- **House of Memorys:** https://www.liverpoolmuseums.org.uk/house-of-memories/my-house-of-memories-app.

2.1.2.2. Quality Analysis

Initially it was considered important to verify the dates of the articles to understand the evolution of the studies on cognition and technology, since no filter was used for publication dates.

Through Figure 2 we can see that in the early 2000s technology and cognition were not a very recurrent subject. Only after 2017, with the evolution of technologies and the emergence of social concerns such as aging, did studies begin to increase in a linear way. It was found that fifty percent of the studies were conducted in the years 2014, 2020, and 2021. It can also be seen that more than half of these articles are journals, as shown in Figure 3.

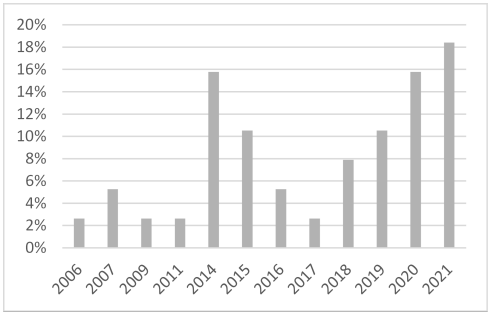

FIGURE 2. List of Questions

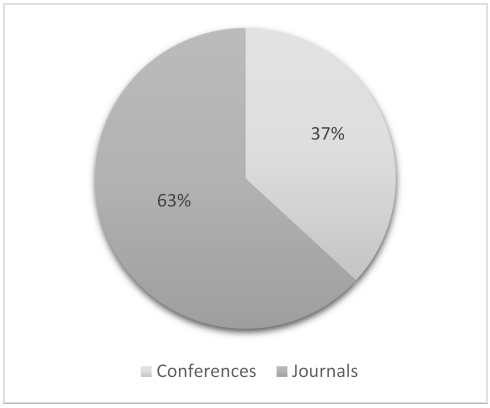

FIGURE 3. List of Answers

To qualify the journals we used the Scimago Journal & Country Ranks, which ranks the journals where the articles are published, through parameters such as number of citations and prestige of the journals that make these citations. Analyzing Figure 4 it is possible to see that half of the documents found belong to journals of maximized quality (Q1), while the other half is divided into journals with Q2 and Q3. Note that the journals not found or without evaluation were classified as NA.

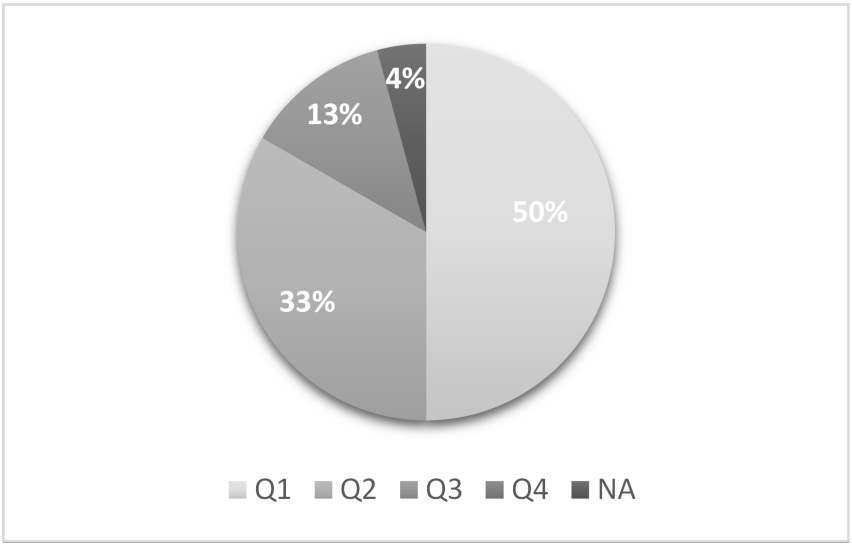

FIGURE 4. Ranked Newspapers

2.1.3. SLR Reporting

The objective of this review was to analyze the various technological approaches to cognitive training in order to determine the number of studies that involved the life story. TTable 4 was created to organize the studies by types of technological approaches. Six approaches were found and as can be seen in the table, only four articles used reminiscence as a form of cognitive stimulation. This proves the need for further study on this topic.

With this in mind, it was considered relevant to analyze each approach. Although not directly related to the focus of this work, they may help to better understand the receptivity of the elderly to technologies, as well as the best methods to stimulate cognition.

TABLE 4. Technological Approaches

References		Technological Approaches
SLR	Complementary	
[13]	[15]	Robots
[2]13][16][17][18][19][20][21][22][23][25]	-	Assessments Apps
[3][4][16][17][24][25][26]	-	Virtual Reality
1][2][4][5][6][13][16][17][18][19][20][21][24][27][28][34	-	Serious Games Apps
[5][6][14][16][29]	[15]	Assistive Apps
[33]	[30][31][32]	Life Story Apps

2.1.3.1. Robots

Robotics was one of the least documented approaches in this review, however, it was possible to understand that it already performs numerous functions in assisting people with cognitive impairment. Currently, humanoid robots are used to interact with groups of elderly people and help them with their daily tasks.

Their success in nursing homes is due to the fact that they are programmable and therefore allow simulating multiple elderly care scenarios (e.g. taking medication, reading books, acting as a companion) [**13**] [**14**]. It was also clear, that the results depended on the user's relationship with the robot, as they preferred to interact with robots with characteristics as human as possible [**15**]. On this topic, no other aspects taken from the literature proved to be relevant to the research at hand.

2.1.3.2. Assessments Apps

There are also Assessment Apps, i.e. mobile applications and web forms that are dedicated to the early detection of cognitive decline or disorder. Some studies choose to use simple exercises in the form of serious games [**16**] [**17**] [**18**] while others choose to use international tests (e.g. Mini Mental State Examination) [**19**] [**20**] [**21**]. It is important to identify, through these exercises, if a person has memory or reasoning problems, as it helps prevent them from heading towards a more serious stage such as dementia [**21**] [**22**].

It was also proven in a study by Charalambous (2020) that the overwhelming majority of the applications created do not use input from health professionals, thus proving the unreliability of their diagnoses[**22**]. This technological approach did not prove to be very relevant for the purpose of the study, since it only uses memory detection mechanisms and does not contribute to its training. On this topic, the use of recognized tests (MMSE) to characterize the capabilities of the elderly was considered important and was used in Chapter 5 to evaluate the users of the pilot test of the Amelia application.

2.1.3.3. Virtual Reality

Another of the approaches found, more promising and with better prospects for the future, was Virtual Reality [**23**]. This is due to the fact that it is possible to create personalized realities for the elderly . Health professionals are therefore given freedom to design all kinds of tests and experiments that otherwise would not be possible due to lack of resources [**17**] [**24**].

The studies and projects done in this field choose to train memory by performing simple tasks (e.g. watering plants, searching for objects, or cooking with recipes) [**25**]. Through the analysis of the documents on virtual reality it was possible to see that the adhesion of elderly users is very positive [**3**] [**25**] [**26**]. However, it is still necessary the constant monitoring by younger and more experienced people in technologies. One of the common aspects in most of these applications is the need to supervise these people during the exercises, which demonstrates the lack of effectiveness and the importance of making fully autonomous tools or interfaces.

2.1.3.4. Serious Games Apps

Naturally, Serious Games were the predominant approach in the collection of articles. This type of game has a different purpose than normal, as the word "Serious" indicates that the games are intended for educational purposes rather than entertainment [**27**]. This educational approach can be targeted at various areas (e.g. health, education, tourism, business) and in this case it addressed cognitive training.

Unlike other educational and training products, serious games stand out because they allow immersion of the user in performing exercises. People feel motivated by the outcome of their decisions and are captivated to play for long periods of time without losing interest [**27**]. If these games are built with cognitive stimulation techniques, it is possible to make cognitive training more dynamic, interactive and intensive for people with cognitive decline [**27**] [**6**] [**28**].

2.1.3.5. Assistive Apps

Assistive Tools Apps are applications that aim to remind the user or help him or her to perform important daily tasks for autonomy. These include 1) reminders to take medication, 2) instructions on how to turn on the television, and 3) tools to facilitate contact with a doctor or family member. However, this technology only helps people with impaired cognitive states and, like the assessments, does not contribute to cognitive training [**29**] [**5**]. Despite this, the literature consulted has shown that making mobile applications easier to use contributes to a better use of it [**16**] [**29**].

2.1.3.6. Life Story Apps

Finally, as can be seen in Table 4 , Life Story literature is scarce. Reminiscence studies show the importance of drawing on the past to stimulate cognition. This approach consists of collecting personal information about the user in order to build a complete repertory of his or her life [**30**] [**31**]. Since long-term memory is the last to be affected during deterioration of cognition [**32**] [**33**], the exercise of bringing past memories into the present helps to promote cognitive training. However, given that this is the most relevant approach of this project and that there is not much scientific support, a detailed analysis of 9 applications was made.

Finally, it is important to emphasize that no articles were found in which the two approaches that are the focus of this study (life story and serious games) were associated.

This in turn proves the significant relevance of conducting a project aimed at linking these two cognitive training tools.

2.1.3.7. Application Analysis

Appendix A was created to specify in more detail the characteristics of each of the nine applications found.

The type of platform for these applications is one of the first important points to consider. Only mobile and web applications were analyzed to prove that older people prefer the use of touch screens over mice and computers [**25**].

As the goal of this project is to develop an application that combines serious games with life stories to train memory, apps that perform these functions were selected. However, no apps that combine the two on the same system could be found, so separate research had to be done. In the table, Alzminder has both functions, but does not link them. It only performs separate exercises just like the other applications.

One important factor for the applications is their design and visual structure. Most of them (five out of nine) fail in this aspect. The design is supposed to be as user-friendly as possible, and since these users are elderly people with poor motor skills, it is important that the buttons, images and gestures are simple and large. The biggest problem encountered was the complexity of the tasks and the amount of extra information and functionality in the applications.

Cognitive reminiscence training needs huge amounts of personal information (videos, audio, phrases, images) while serious games training is much simpler and more interactive. The personal nature of the first, however, makes the exercises much more engaging and interesting since they are personalized and not as monotonous as the serious games.

There was also a high frequency of additional tools that complement these applications (e.g. suppport features, accessements, stimulation) and contribute to a better use of the app. The most common was the use of instructions or help in audio format, which allowed to assist the user without overlaoding information on the screen.

Only two of the apps had accesscments that were used to customize the user experience. The difficulty of the cognitive games was based on the results of cognitive tests, however, the tests were not very professional (no international recognition e.g. MMSE). It is concluded, therefore, that the user characterization is unreliable.

Finally, the use of stimuli in cognitive training was also verified. Only three of them used this type of resource, by using scores and metrics of progress and evolution. This way, they were able to better engage users and motivate them to obtain more ambitious scores in each use [**34**].

With this, despite the limited documentation of life story applications, it was possible to better understand the characteristics of these applications. In the end it became clear that for the development of a complete application it would be necessary:

- Build a simplistic design that avoids unnecessary content.
- Use larger buttons and images.

- Basic gestures (touch, swipe, scroll).
- Limit functionality to only the most relevant.
- Audio aids
- Provide clear instructions
- Use stimuli that motivate the user.
- Make it as autonomous as possible, to avoid the need for constant support.

2.2. Cognitive decline vs Mild cognitive impairment (MCI)

The aim of the study in question is primarily targeted at the older layer of society and is intended to train their cognition. Cognition has four stages of severity, the first being no cognitive loss .

The second one is normal cognitive decline, the name given to the loss of one or more cognitive abilities such as memory, awareness, comprehension, and reasoning. These losses come from natural aging. During old age, people tend to distance themselves socially, exercise less, and not keep abreast of society's changes, which leads to increased alienation, forgetfulness, and reasoning failures [**1**].

The third, mild cognitive impairment lies between the state of dementia and cognitive decline caused by aging. While decline at older ages is considered normal, cognitive impairment represents a threat to the health of the elderly, as it is considered the preceding phase of dementia [**17**]. The symptoms are slightly more severe than those of aging, however, they begin to affect the lives of the elderly more because they make it difficult to make decisions and to remember to take their pills [**17**] [**18**] [**26**].

The last and worst step is dementia, a term used to encompass a set of diseases, the most popular of which is Alzeimer's disease, that make it impossible to live an autonomous and normal life [**3**].Although information was collected based on articles that address dementia, this disease was not delved into because it is of a very distinctive character. Not only does memory training involve completely different specifications (e.g. alternatives to reading), but also extremely simplistic exercises have to be created due to the decrease in mental faculties.

2.3. Elderly and Technologies

The older stratum of society is famous for the stereotype of their aversion to new technology such as smartphones, computers and tablets. However, several studies have proven that the elderly have become increasingly receptive to technological innovation, with many of them participating and complying with positive results in many technological research (e.g. mobile applications, Virtual Reality) [**6**] [**1**].

This is due to the increase of cell phone ownership in the elderly as well as the concern to create more personalized and appropriate systems designed to support elderly population considering specific problems and disabilities [**1**].

2.4. Memory Training

One of the steps to prevent or help people with cognitive decline is to train their memory, through exercises that keep the brain in constant stimulation, so that it combats cognitive deterioration. The literature [**16**] [**28**] also served to understand that there are many methods for this purpose such as:

- Grammar exercises: word association exercises, crossword puzzles or word relationships.
- Reminiscence: doing mental exercises that help the person or patient remember events from their past such as names of family members or important events (e.g. marriages, birth of children). Although recent memory is affected, long-term memory was not, so it can be used to improve cognition [**1**].
- Puzzles: doing puzzles helps combat mental challenges and consequently improves reasoning
- Daily tasks: performing simple daily tasks (e.g. watering plants, cooking, cleaning, or looking for objects) allows seniors to exercise their memory. Although they are not very complicated tasks, their stagnation increases their difficulty in performing them.

2.5. Life Story Work

Life history work is a set of activities related to reminiscence (remembering the past). In this approach, a health professional goes through chronologically all the experiences of a patient in order to create a repertory of the patient's life. To do this he uses an extensive set of questions, which have been properly constructed to cover all kinds of stories and experiences of the elderly person. The repository created is usually a book or an album that is constructed from images, videos, texts or audios collected by the patient themselves or by family members [**30**] [**32**].

This type of work can be done on children or the elderly and is intended to help patients preserve their identity. Elderly people tend to lose their cognitive faculties, but their memory of past events is still in good condition, so this type of approach is possible[**31**]. It also helps professionals to better understand the patient's interests and inclinations for better treatment and assistance.

The applications found with embedded life stories have only computerized this kind of work, turning books into digital books. These have the potential to act as reminders of people's lives, resembling the assistive tools in section 2.1.3.5. Exemplifying the association made, just as these applications use reminders to recall the elderly to take pills, so Life Story applications help people remember the episodes and people in their lives. For example, the applications LIFEBIO and House of You, collect information about the user's past to be later consulted and remembered. The first one asks about 100 questions that are answered in audio format and then played back. The second, on the other hand,

allows a similar set of questions to be answered through text, and photos or videos can be added to support the content of the answer.

CHAPTER 3

Artifact Development and Evaluation

For the development of the application in question, the Design Science Research (DSR) methodology was used. Since this involved the actual creation of a physical artifact and not the elaboration of a theoretical study, it was necessary to follow the methodology idealized by Peffers (2007) [**35**].

As can be seen in image x, this methodology is composed of six stages. The first two stages have already been performed at the beginning of this study where the problem at hand was discussed as well as the objectives and the idealized solution.

Then, three phases follow, which together can be iterated multiple times in order to improve the application through the feedback received in the evaluation phase. The development and demonstration phases serve, respectively, to produce and present the features created in each iteration. Unlike a methodology like Waterfall, DSR is agile and allows for modification of requirements and adaptations during the development process.

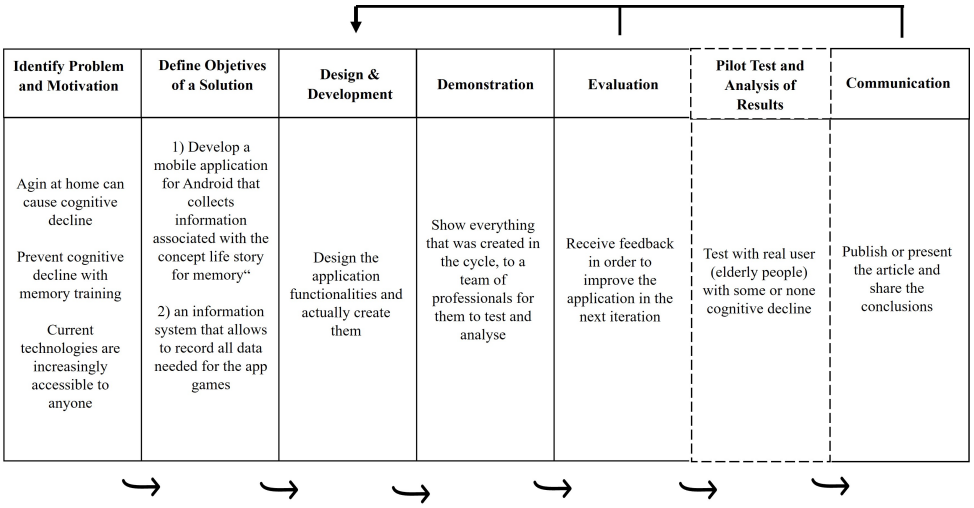

FIGURE 5. DSR methodology with extra phase

To the Peffers model was added a complementary phase considered important for the project, Pilot Test and Results Analysis (Chapter 4), which was not included in the iteration. In addition to the demonstrations for the professionals involved, it was decided to create this step to report the app's tests with a small sample of real users. The goal of this stage was to receive feedback, of a finished app, from the users of the application themselves, since they are the biggest beneficiaries of this project.

Finally, it is necessary to communicate the results of the study by publishing a scientific paper in a scientific journal or in proceedings of an international conference.

Before starting the development of the application it was necessary to create a list of requirements. Although changes can be made, it is important to have an updated task list to organize the work to be done throughout the project. Table 6 shows all the proposals made by the professionals connected to the project.

This team is composed of 5 professionals (described in Section 1.1) which made it complicated to frequently group all the people in meetings, without anyone missing. It was then decided to divide the team into two distinct parts for more flexibility:

Table 5. Areas supervised by each team

Team	Focus Topics
IT Team	Functionalities Architecture Good programming practices Database Server.
Social Team	Visual aspects Cognition training techniques Language Questions and Answers Life Story Work

3.1. DSR 1

After a literature review and an analysis of the applications found, it was necessary to build a list of requirements for this project. These requirements were proposed by both the author and the professionals associated with the project.Priority levels were used to ascertain the importance and urgency of meeting some of these requirements.

Table 6. Application Requirements

Requirements	Priority
User registration and authentication	1
Memory games	2
Remote database for storing users, questions, answers and scores.	1
Solutions to help illiterate seniors	3
Server to allow use of the application anywhere	2
Platform compatible with phones and tablets (adjustable to different sizes without damaging the design)	2
Simplistic design suitable for the elderly	3

3.1.1. Architecture

Although one of the project's proposals was to create an information system with a remote database, we chose, in a first phase, to use the development computer as a server. To do this, the WAMP software was installed which, in turn, automatically installed a collection of important software for this experiment.

WAMP has a package composed by Mysql Apache and PHP. These three pieces will be fundamental for the initial tests because, together, they allow local development without the need for an external server.

Php is a language used in the development of applications that act in the back-end, that is, unlike Javascript that is processed directly in the client or Browser, php needs to be interpreted in the server-side. This server is Apache and when it receives a PHP file, it forwards it to the PHP module so that the script can be interpreted and return an HTML response. This response, in turn, is sent back to the client by Apache.

However, since these tools do not allow you to save user or account data, Mysql is the complementary tool capable of doing so. In the php files it is possible to make calls and request data for the SQL database that after being processed will be returned in readable structure (HTML) to the client browser.

The architecture in Figure 6 was made to help create the relational database.

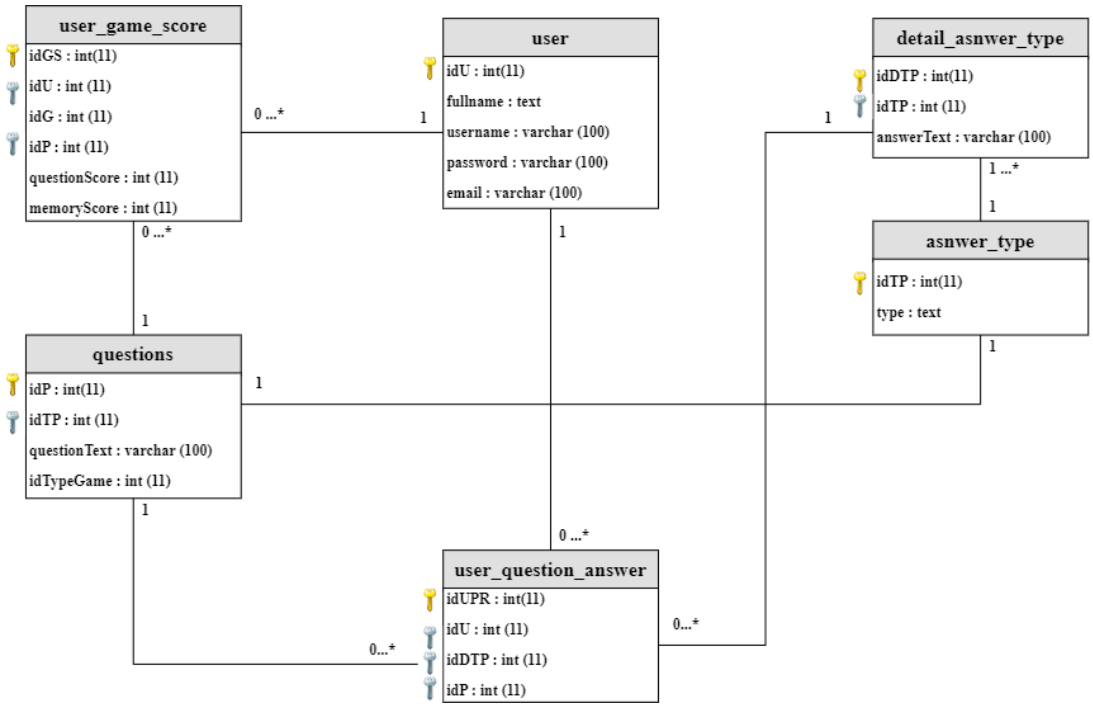

FIGURE 6. Database Architecture

The database was created in phpMyAdmin as it is one of the most common web application for managing MySQL databases. Unlike other applications (e.g. MySQL console), this tool allows you to run complex queries, create and delete databases and export the data in multiple formats in a very simple way. As it is a web browser-based interface, phpMyAdmin uses the Apache web server installed by Wamp.

As shown in the image, in the **users** table the person's data is registered. Of these data, only the password and username fields are relevant because it was through them that the player's authentication was done.

The **questions** table is responsible for storing the text of the questions and the idTypeGame code (explained in Section 4.3.1). This table also has as foreign key the id of the table "answer_type", because each answer is directly associated with an answer theme (e.g. ages, male names). Two questions can have the same theme.

The **answer_type** table on the other hand is only used to organize the answers in the table "detail_answer_type" and to specify the theme of the answers.

The **detail_answer_type** table was used to record the official answers to the questions. These answers are used in section 4.3.1 for most cognitive games.

The **user_question_answer** table is used to store the life story of each user. Each person can answer several questions (all different), however they can only have one answer for each.

Finally, the **user_game_score** table was responsible for storing all the scores obtained by the users. Each person can play multiple times and therefore will get multiple scores that will be recorded in this table. The possible scores were divided into points for normal questions and points for memory games.

3.1.2. Development

Next, research was done to find out the best programming languages and development environments. There are several possible languages such as Python, Java, Kotlin, C#, however, Java was chosen simply because of the author's own interest, since none of them overlap with the others. A hybrid development was not chosen, limiting this project to be tested only on Android devices and to be developed in Android Studio.

Throughout this project we created multiple php files that were called in the built in java code. These files performed one of two functions, GET or POST, and were intended to fetch or publish elements to the database, respectively. In this first iteration two interfaces were developed.

The first, corresponding to SigUp, allows the user to create his profile with a username, email and password through a file invoked in java with a POST command. This file was given the name signup.php and placed in the www folder of Wamp since it is responsible for generating dynamic content in the world wide web.

The second interface, corresponding to the Login, had a similar construction to the first, this time with its own php file, login.php, which is responsible for authenticating the user, previously created, through the username and password.

In this first phase only the table "users" was built, to test the registration of players inserted in sigup and authentication of the data entered in the login.

3.1.3. Demonstration

The demonstration phase was used to show the development created so far, which in this case is the Login and Signup page shown in Figure 7 and Figure 8, respectively.

On the signup page you can add your name, user name, email and password, and at the end you click on a button that takes you directly to the next page (developed in DSR 2). At the same time, this data is inserted into the users table of the database.

On the login page there are only two fields to be completed and that, in turn, will be analyzed by the php file to see if they match the data present in the DB.

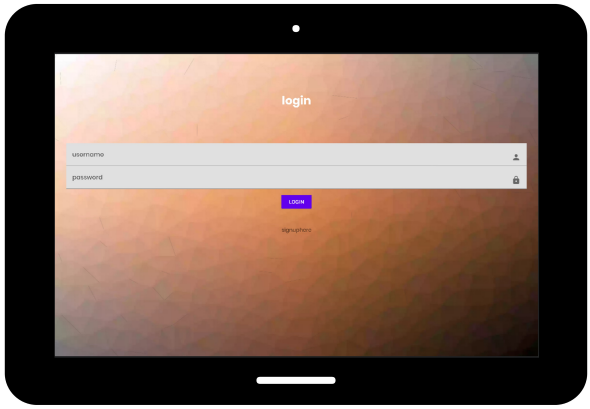

FIGURE 7. Amelia APP: Login Page

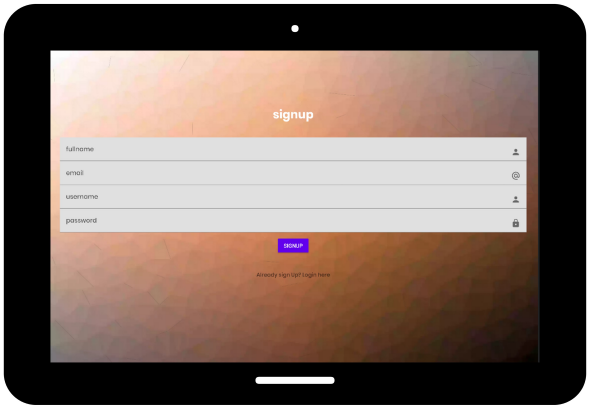

FIGURE 8. Amelia APP: SignUp Page

3.1.4. Evaluation

Since no progress had yet been made on the social part of the project, this phase was devoted entirely to getting feedback from the IT Team.

Although the registration and authentication components were well built, a criticism emerged regarding the login process. While most people are used to creating user accounts, logging in and remembering passwords, the target audience of this application is not. Given that this project aims to develop an application that is easily accessible, especially to the elderly, another approach to login is needed.

This approach should allow the user to be able to log in quickly and effectively without having to type a lot or remember complicated passwords.

Everything else received a positive evaluation and the care to be taken with the construction of the rest of the database was reinforced, since the results and the analysis of the success of the application depend on the organization of it.

3.2. DSR 2

3.2.1. Development

In the second iteration of the DSR we first started by analyzing the feedback obtained in the previous evaluation. It was concluded that one of the best ways to fix the log in problem was to create a new type of authentication.

Instead of entering the username and password, these two words were associated to a Qr Code and a java code was developed to interpret it. The log in page was therefore changed to a camera page, where the user only had to point the tablet at a code on a screen or paper in order to log in. This idea came up on the recommendation of the IT Team because it was a common practice in previous work with elderly people, in which they had participated.

Next, before creating the pages with questions and answers about the user's life it was necessary to create a list of appropriate questions. The social component team provided a very relevant document regarding the type of questionnaire used in the life story work.

However, it was concluded that there would have to be some restructuring of the questions. In the document, all the questions were open-ended, and this prevented the answers from being systematized and reused throughout the games. It was understood that the best way to collect the information and obtain answers was through closed-ended questions, and in this way the list of questions in Appendix B was created.

After the list was made, the pages "List of Questions" and "List of Answers" were created. Each one with its associated php file to go to the database to fetch or place the information.

The list pages have a similar design with scroll lists for better access to each question with a simple swipe. These two pages are the only ones in the application where access is supposed to be exclusive to caregivers or family members of the elderly, since this is the most important component of the application. This is because all the games and interactions of the application will be based on the life story of each user, more precisely on the answers entered on these pages. For these reasons, it was decided to make the pages as complete as possible instead of keeping them simplistic, because they are not meant to be used by elderly people.

The next step was to expand the database by creating the rest of the tables in Figure 6 (from DSR 1).

In the "questions" table the questions created were placed, in the "answer_type" table the possible answer themes were entered (for example: names, years, places) because several questions can have the same answer type. In the table "detail_answer_type" the multiple answers for each theme were put (e.g. for answer_type = name, the detail_answer_type would be André, João or Gustavo). Finally the last two tables, "user_question_answer" and "user_game_score", were created to record, respectively, all the answers of the questionnaire and all the scores of the games.

Finally, after building and organizing the necessary structure for the development of the serious games, the first interactive page for the users was created, entitled Quiz. In this exercise, each question in the quiz and 4 possible answers were taken from the database and everything was presented in a very simple way on the screen.

3.2.2. Demonstration

This demo served to show the Android User Interfaces created, as well as the changes made to the Login page.

The application starts on the new login page, which this time presents only a camera capable of reading QRcodes. After logging in, the user enters the questions page (Figure 9) which displays a scrollable list, where all the questions entered in the database have been placed. It shows up the Answers Page (Figure 10) where the helper should, with the elder's cooperation, click on one of the possible answers in order to create the user's life story. Whenever a question is answered, it is automatically added to the database in the "user_question_answer" table, and the screen returns to the questions page in order to continue answering.

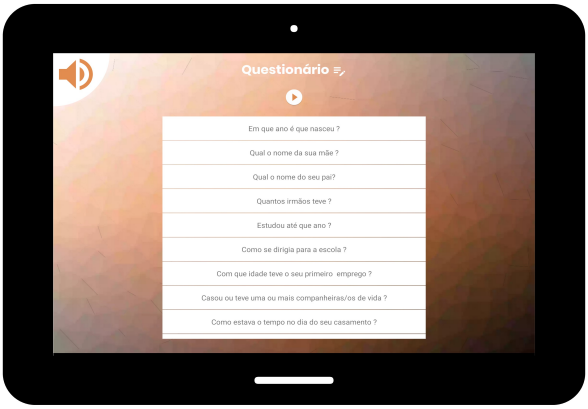

FIGURE 9. Amelia APP: List of Questions page

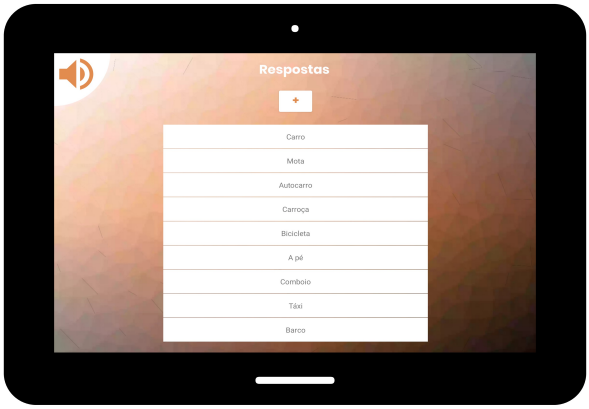

FIGURE 10. Amelia APP: List of Answers page

At the end of the quiz, the helper must click the play button to start the game. Next, an activity appears with 1 question and 4 answers (Figure 11), where 3 of them are randomly false and one is the true answer that corresponds to the one previously saved in the database. One of the features that was created for this game was an audio button that allows the user to hear all the text on the screen and thus help the elderly in case of difficulties or limitations in reading.

FIGURE 11. Amelia APP: Quiz page

3.2.3. Evaluation

In this evaluation, both teams participated as there was already social and technological content to be analyzed. Regarding the questions, the observations can be seen in Appendix B:

Regarding Quiz it was suggested that there were improvements at the visual level (become more appealing) however both teams praised the layout and size of the buttons, as it showed to be accessible for the type of target users.

They also consider well implemented the possibility of playing the question and answers via audio, as it is a good solution for users with low levels of literacy [**6**].

Regarding the application itself, the technology team praised the Qrcode solution but criticized some aspects related to the lists. The "List of Questions" did not allow the user to understand which of the questions had already been answered, and the user had to remember if he had already answered or not.

As for the "List of Answers", there was a missing option to add an answer that was not already present in the database, and there was also no possibility to edit the answer if it was wrongly answered!

These problems limited this interface because there were no solutions to change answers or correct mistakes. In this manner the usability of the application was compromised until a change was made by the developer.

3.3. DSR 3

This cycle was longer and equivalent to two cycles due to the impossibility of grouping the teams for evaluation phases and, therefore, the work developed was longer and more extensive.

3.3.1. Development

Again, at the beginning of the cycle, the new functionalities to be added or changed were analyzed according to the criticisms made in the previous phase.

Priority was given to improving the questions in the database and a new list of questions was built. As can be seen in Table 7, the number of questions was greatly reduced. The author and the Social Team came to the conclusion that it was preferable to decrease the size of the list in order to be able to better customize the games. One of the reasons that also led to this cut was the length of answers created for each one. Unlike what was done initially, each question now has a fairly large number of answers to try to cover as many life stories as possible.

Table 7. Updated List of Questions

ID	Question	Answers
1	In what year were you born?	Years
2	What is your mother's name ?	Female Names
3	What is your father's name?	Male Names
4	How many siblings did you have?	Numbers
5	Until what grade did you study ?	Years
6	How did you get to school ?	Transports
7	At what age did you have your first job ?	Age
8	Married or had one or more life partners …	Yes/No
9	What was the weather like on your wedding day ?	Weathers
10	Where was your wedding ?	Places
11	How many children did you have?	Numbers
12	What is your favorite animal ?	Animals

A feature has also been integrated that allows you to add new words to the database in the "List of Answers" activity. This feature allows to directly add answers to the database and therefore had to limit the insertion to only letters and characters in order to prevent incorrect words in the list of answers.

Regarding gameplay, it was decided to interweave Quiz with memory and comprehension games, where each one relates to the theme of the previous game. To demonstrate with a real example, in Quiz the question "Where was your wedding?" appears, and after it is answered, the next game will necessarily be about the theme "wedding sites", (e.g. a game where you would have to select pairs of possible wedding sites). Then it will be a Quiz question again, and then another memory game on the theme of this second question, and so on.

For this, several types of approaches observed in the literature review were investigated, from which 4 types of games emerged, explained later in the demonstration. However, a problem arose with how to distribute the four types of games across the quiz questions. Some of the questions had answers that were not very relevant to make the idealized games and, therefore, it was necessary to assign a specific code for each question (idTypeGame) in the "questions" table.

This code has a component that indicates whether or not the group of answers associated with its question is appropriate to make the games. If it is, the java code will automatically fetch all the answers to that question and use them for the games, if not, it will build a new and more appropriate list of words which in turn will be used to run the games.

In order to make the application more interactive and visually appealing, it was decided to associate the answers with corresponding images, so that it could interact with the user without always having to use words. The aforementioned code also participates in the choice of questions that allowed to have images associated with their answers.

Another important feature of this code, is the ability to bring randomness to the games played. In the code it is possible to indicate how many of the 4 games are associated with each question and the Java code randomizes these games every time the app is opened. In this way, during different uses of the app, for the same question, different types of games can appear, avoiding repetition of the experiences of the elderly.

Thanks to the positive reviews regarding the audio aid created, it was decided to expand the concept to the entire application. A button was created for all activities with audio instructions to help users and can be clicked infinite times. These instructions were also automated to start as soon as the user enters a new page.

Finally, the server was created, which is a fundamental piece of this project to perform tests anywhere and with any user. It was decided to use an Amazon Web Services (AWS) service, the Amazon Elastic Compute Cloud (EC2), to replicate what had already been created on the development computer.

The intention was to reproduce exactly what was created on the author's computer but on a Windows virtual machine, installing wamp, importing the SQL database and migrating the php files to the new www file. However, since the connections were no longer local, it was necessary to open a specific port to receive requests coming from the tablets used in the pilot test in Chapter 5. Otherwise, it would not be possible to get the data coming from or brought into the database.

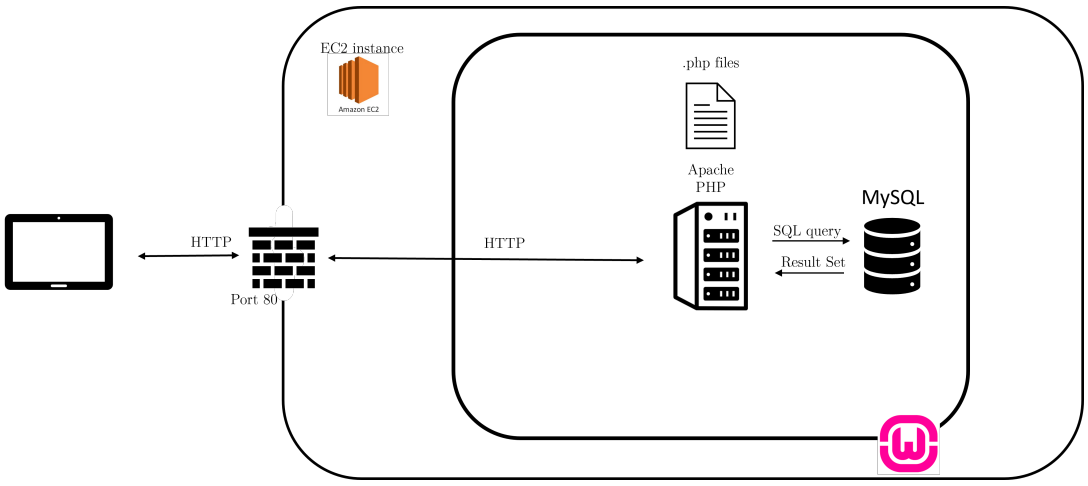

FIGURE 12. Information System

3.3.1.1. Security and Data Protection

Although the core of this project is not concerned with security and data protection, it was considered important to understand how these aspects work. The transport layer is responsible for transferring data between two machines, yet anyone can access this data if no security protocols are implemented. One of these is Transport Layer Security (TLS), the successor to Secure Sockets Layer (SSL). TLS is used to encrypt sensitive information that passes between applications (e.g. browser and the web server) and that we do not want to be caught by others. This encryption is done asymmetrically using

key pairs (private and public), and therefore it is only possible to access the information through a digital certificate. Therefore, it is advisable to use a secure version of HTTP to transport the information, i.e. HTTPS (HTTP encrypted by TLS certificate). Since this is an academic work, where the core is not security, it was chosen to make only HTTP connections, however, if there are intentions to bring the application to market it is advisable to protect the transport layer.

Apart from transport, it is also important to protect access to the data. To do this it is recommended to use Multi-factor authentication (MFA), which allows access only after two or more methods have been confirmed. These methods can be knowledge (e.g. password, PIN), possession (e.g. authentication app, USB) and something only the user is (e.g. picture of ID badge, fingerprint).

3.3.2. Demonstration

A page was created (Figure 13) where the player is allowed to choose between taking the quiz or starting the games. It was understood that after taking the first quiz it would never be necessary to take another one, and therefore the player could simply click on the play button to start the games.

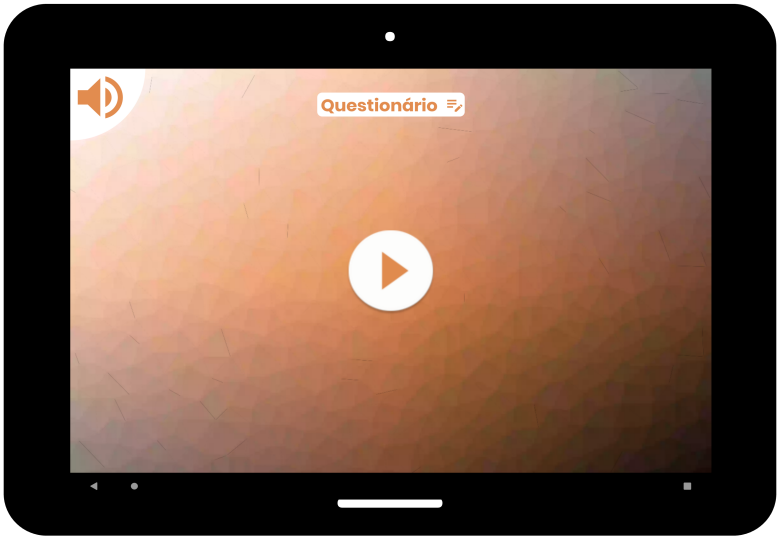

FIGURE 13. Amelia APP: Play or answer questionnaire page

The first game created was "Word Pairs". A page is presented with 12 cards face down with words on the other faces. The objective of the game is to find all 6 pairs of equals words. These words will always be chosen randomly from the list of answers associated with the previous Quiz question. First you click on one of the cards to see its contents, then you click on another to try to match it. If you don't make a match, the cards are flipped down so that you can play again.

The second game," Image Pairs", is similar to the first, but using images as the content of the cards. In both, whenever a pair is made an incentive system is activated that throws confetti in order to stimulate the user.

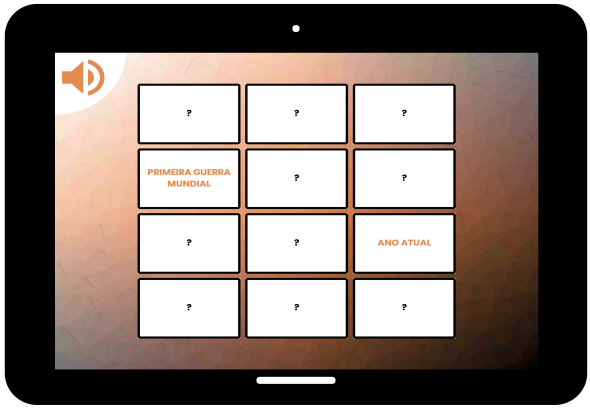

FIGURE 14. Amelia APP: Word Pairs page

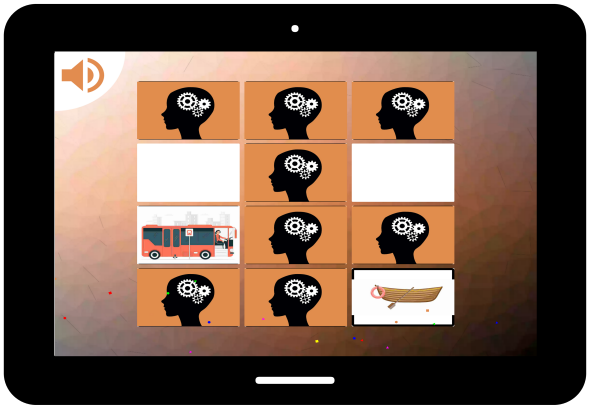

FIGURE 15. Amelia APP: Image Pairs page

The third game is the "Different Word" game. Using the same type of list of answers associated with the question, 16 words are presented on the screen, but one of them does not belong to the theme of all the others, and that is the one you have to discover. While the cognitive function of the first two games is memory training, this one tries to stimulate reasoning and comprehension.

Finally, the "Sequence" game, forces the user to memorize a set of 3 images when the "play" button is clicked, so that the user can discover the correct sequence of figures. In this game it is also allowed to repeat the picture slide show so that the user has another chance to memorize the pictures before answering. Again, the incentive mechanism is also present whenever you get the question right, because it is important to maintain the user's interest. This exercise trains both retention and attention in the elderly.

All games are started with specific instructions to help users understand the game. If further attempts are needed to understand what is required, the button with the megaphone symbol can always be clicked.

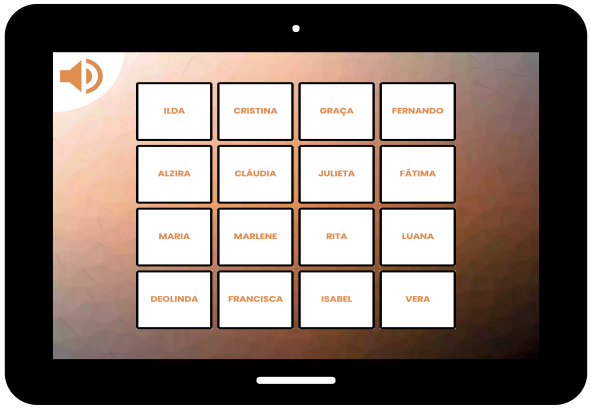

FIGURE 16. Amelia APP: Different Word page

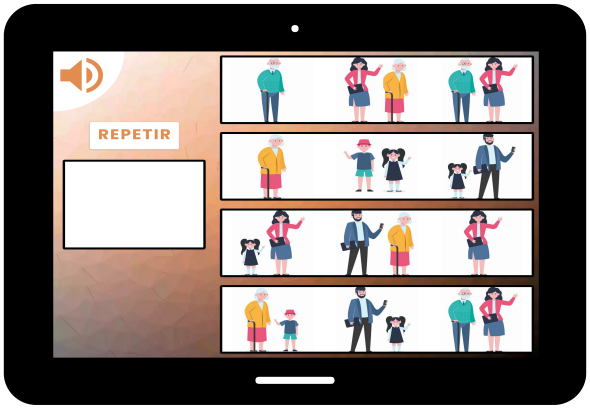

FIGURE 17. Amelia APP: Sequence page

3.3.3. Evaluation

In this evaluation the Social Team reviewed the questions and answers and approved them as final and possible to use in the project. They also praised the cognitive games and the interactive approach, pointing out only that the best way to test the games would be to use a sample of target users.

The audio component was also praised, because it further automated the help and better understand the exercises and allowed a decrease in the need for external support, making the app more autonomous.

Regarding the IT team, it was observed that the functionalities for editing the answers in the questionnaire section had not yet been implemented.

It was also noted that the audio continued to play even when leaving the page. It was also suggested to put colors on the visual simulations to make it more pleasant when the player gets it right.

CHAPTER 4

Pilot Testing - Results and Discussion

This chapter has no development or demonstration, despite having evaluation, and for these reasons was not considered as one of the iterations.

With the support of the Alcoitão school and ISCTE, it was possible to gather a small sample of volunteers to test the Amelia APP. This sample was composed of eight elderly people who, each accompanied by a student from the school, performed the exercises proposed in the application.

For the project, ISCTE provided 4 tablets. It was then decided to divide the volunteers into two equal groups and each one used the APP for 1 week (two weeks in total). The tests were performed once a day during those weeks..

4.1. User Analysis

Before collecting and analyzing the results it was necessary to classify the elderly in the sample, through 3 types of evaluation. An intensive questionnaire was made, present in the Appendix C , which was solved by each elderly with the help of the student in charge, to get to the results in the Appendix D. The 3 metrics used were Mini Mental State Examination(MMSE), Lawton Index and the Barthel Scale.

TABLE 8. Scales for MMSE, Lawton, Barthel

MMSE	
Education	Score
0 - 2 years	≤ 22
3 - 6 years	≤ 24
≥ 7 years	≤ 27

Lawton Index	
State	Score
Severe or total dependency	0 - 5 points
Moderate dependence	6 - 11 points
Mild dependence or independent	12 - 16 points

Barthel Scale	
State	Score
Totally independence	100 points
Mild dependence	99 - 16 points
Dependence	75 - 51 points
Severe dependence	50 - 26 points
Total dependence	≤ 25 points

The MSSE is an exam with a series of questions, which are usually asked by a doctor, to identify cognitive impairment such as problems in thinking, communicating, or reasoning. It is used in situations of brain injury and also to detect whether someone has cognition problems or dementia. The scale of the scores is shown in Table 8.

The Lawton Index is a test that aims to assess an elderly person's ability to perform instrumental activities of daily living (e.g. using the telephone, preparing meals, using medication). It aims to assess the patient's autonomy to perform the tasks of daily living and to understand if a follow-up plan is needed.

The Barthel Scale is similar to the second one because it measures an individual's ability to perform several activities of daily living and assigns scores to his or her degree of dependence. This scale can evaluate and show the ability of individuals with neurological problems. The scores taken into consideration are shown in Table 8.

It was considered important to analyze the data in Appendix D to better understand the characteristics of this sample and in this way be able to justify, later, some of the results of the application tests.

The sample is predominantly female and the average age is around 76. Through the Appendix D, it is possible to verify that the people with more years of studies (U1,U2,U5) perform more intellectual jobs while the other five users worked in less or not so mental stimulating areas of the primary sector (e.g. fishing, agriculture).

For these initial tests, it was decided to select a sample with lower or no cognitive severity, because the application of the prototype, is still in a very early stage.

A summary table (Table 9) of the previous table (Appendix D) was then created to better analyze the cognitive states of the people. It can be seen that only 2 of the people showed results of cognitive decline and only 1 of them showed a state of mild dependence. All the rest of the sample was positively evaluated without decline or dependence.

TABLE 9. Synthesis of the users' characterization

Users	MMSE	Lawton	Barthel
U1	Withou Cognitive Impairment	Independent	Totally Independent
U2	Withou Cognitive Impairment	Independent	Totally Independent
U3	Withou Cognitive Impairment	Independent	Totally Independent
U4	Withou Cognitive Impairment	Slightly Dependent	Totally Independent
U5	Withou Cognitive Impairment	Independent	Totally Independent
U6	With Cognitive Impairment	Independent	Totally Independent
U7	With Cognitive Impairment	Independent	Totally Independent
U8	Withou Cognitive Impairment	Independent	Totally Independent

4.2. Results

Next, 19 and 20 Figures were created, showing the daily scores obtained in the application's cognitive exercises. We separated the scores by Quiz points and Memory Game points. The criteria used for ranking the performance in each game were as shown in Table 10.

As for the Quiz scores it can be seen that the results do not vary much. Through the 18 and 19 figures it can be seen that most of the results were between 11 and 10, with the maximum daily score being equal to 11. Through these results we can prove, as in the studies of Cabrera [**1**] and McKeown [**31**], that for these individuals it was not complicated to perform reminiscence exercises, since long-term memory is the last to be affected. The individual exercise scores were also analyzed to try to justify the fact that U7's values were closer to 9 points. This elderly person had several days when he got the same question "You studied until what year?" wrong. The constant negative scores in

this exercise may indicate that: 1) the question was complicated by the need to do math; or 2) it may have been answered wrongly in the questionnaire done with the helper, and since then, the elderly answered several times "wrong" however right. As for the results of the Memory Games, as expected, the results fluctuated greatly between users. Visibly no very significant developments can be seen, possibly due to the fact that the duration of the testing was only one week. U7 and U8, had low scores compared to the other users, but more conclusions were only drawn after a table relating cognitive states to scores was drawn (Table 11).

TABLE 10. Quiz points scale

Game	Guidelines	Score
Quiz4	Right or wrong	0 or 1 point
Word Pairs	It's considered one attempt to turn over two cards	10 attempts - 5 points 13 attempts - 4 points 17 attempts - 3 points 20 attempts - 1 point
Images Pairs	It's considered one attempt to turn over two cards	10 attempts - 5 points 13 attempts - 4 points 17 attempts - 3 points 20 attempts - 1 point
Sequence	It's considered one attempt to click on a sequence	1 attempt - 5 points 2 attempts - 3 points 3 attempts - 1 point
Diferent Word	It's considered one attempt to click on a word	1 attempt - 5 points 2 attempts - 3 points 3 attempts - 1 point

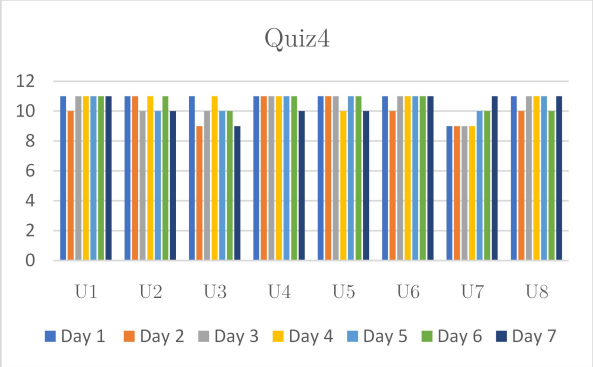

FIGURE 18. Quiz Scores per user and day

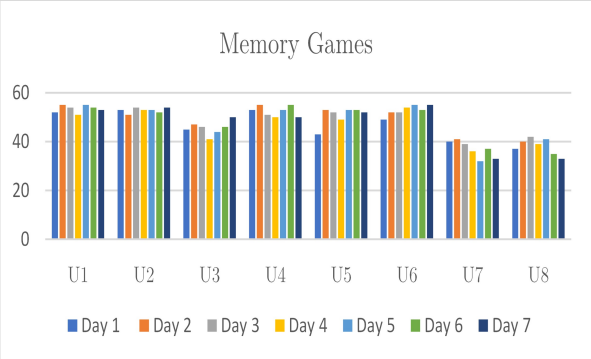

FIGURE 19. Memory Games Score per user and day

Looking at the data in Table 11 several findings can be made. Most users with better cognitive scores on the MMSE also had quite high scores on the memory games, as is the case for U1, U2 and U5 (53.42; 52.85;52.85). At the opposite end of the spectrum was also the case of user U7, who showed cognitive decline on the questionnaire exam and scored quite low on the application (36.85) as expected. However, not all results were as expected and the most critical were U6 and U8. Although U6 has a cognitive decline, his scores (52.85) were very high on the application, and the opposite was also true for

U8 (38.14). It was decided to further analyze the MMSE questionnaires taken by these two users to be able to justify these discrepancies in results. U6 made mistakes in two exercises, the orientation exercise and the evocation exercise (remembering a sequence of words spoken out loud). Thus, it was expected that he would get weaker scores in the sequence games, however, since these are random, it is not possible to find out if he got many of these. Given that a total of 42 questions with a chance of getting "Sequence" were practiced over the 7 days, the probability that U6 performed many sequences is high, and therefore more negative results should appear. It was then concluded that other factors may have affected the sample, such as: 1) the exercises being more accessible than the MMSE; 2) the scoring scheme being more beneficial than harmful; 3) the use of some external support. In U8's case, the exercises he got wrong on the Mini Mental State Examination are related to language and perceptibly. According to the feedback present in the evaluation in section 5.3, it is pertinent to note that the player may have had difficulties understanding the exercises and that this harmed his scores. Regarding the Quiz scores, everyone remained consistent and with maximum or almost maximum scores, which proves that the questions about the past are the easiest for these users. The pilot test obtained good analysis of the results, however it is important to consider the need for a test with a larger group of users in the future, so that a more accurate structure of the metrics of the application scores can be made. It will also allow the progress of the users to be analyzed, as in this sample the results did not fluctuate much.

TABLE 11. Comparison table between average points and International Cognitive Assessments

Users	Average Quiz4 Points	Average Memory Game Points	MMSE	LAWTON	BARTHEL
U1	10.86	53.43	Whithout Cognitive Decline	Independent	Totally Independent
U2	10.57	52.86	Whithout Cognitive Decline	Independent	Totally Independent
U3	10.00	45.57	Whithout Cognitive Decline	Independent	Totally Independent
U4	10.86	52.43	Whithout Cognitive Decline	Slighly Dependent	Totally Independent
U5	10.71	50.71	Whithout Cognitive Decline	Independent	Totally Independent
U6	10.86	52.86	With Cognitive Decline	Independent	Totally Independent
U7	9.57	36.86	With Cognitive Decline	Independent	Totally Independent
U8	10.71	38.14	Whithout Cognitive Decline	Independent	Totally Independent

4.3. Evaluation

In addition to conducting pilot tests, the user group was also asked to complete a feedback questionnaire. This last questionnaire aimed to receive criticism needed for future improvements of the app and to verify if the App had a positive impact on their lives.

The questions in the questionnaire, Appendix E, were made in order to better structure the criticism for a better understanding of the feedback. In Appendix F, we can see that there are some observations regarding the size of the buttons and letters and regarding the phrasing of the game instructions, particularly the "Sequence" "Different Words.

Several people also felt that the duration of the exercises was pleasant, with only one being negative, and the regularity with which they preferred to play rivaled a lot between "playing every day" and "only twice a week". As for autonomy, everyone found it easy to use the application by themselves, but only after some time of getting used to it. In relation to new or different features, the creation of more games and more stimulation tools was proposed, such as, for example, other stimuli like confetti or the presentation of performance at the end of the app.

As for the Amelia APP itself, the reviews were very positive where they reinforced the interest in continuing to use this app because they are not exclusively dedicated to memory training and have a personal life history component. However, in order to be even more personal they found it necessary to add more questions and images related to the users.

CHAPTER 5

Conclusions

The project aimed and created the Amelia mobile APP that provide memory training to the elderly, based on life story work, and also an informational system to support it.

There were 3 DSRs for the development, from which it was possible to obtain constructive feedback for the elaboration of a complete application, capable of stimulating cognition with a set of quizzes and serious games.

At the end of the project, an application for Android OS was created with tools adjusted for a greater autonomy of the elderly. This application has a system of questions to create the user's life story and a set of interactive games. The application allows users to play infinite times and records all the results in a cloud database.

Feedback regarding the functionality of the application, was obtained through multiple validations. All reviews and opinions were crucial in the construction of the application because it allowed to receive feedback. It was given from professionals related to health and technology , as well as from the users themselves who will use this app in the future. Through this evaluation it was possible to conclude that the development of the Amelia APP was very relevant and appreciated among professionals , caregivers of the elderly and for the elderly themselves. It has even been described as a more enjoyable approach than ordinary serious games, because it uses the users' past, personal side, to create similar exercises.

Some features were also praised, such as the audio instructions, as they allowed seniors with low or no literacy to interact with the application in the same way. In addition to reducing the need for external support, they also praised the ability to relive their experiences every time they played.

Despite some exceptions, the results of the pilot test were able to prove that the worst results were associated with people who scored worse on international exams (e.g. MMSE). Although the effectiveness of the memory games was not proven (due to lack of time), it could still confirm the similarity in the tests.

In summary, it was successfully create an application that tried to fulfilled an existing gap in cognitive training approaches and was used as a first experiment for the association of reminiscence with cognitive training through serious games.

5.1. Limitations

One of the main limitations of this project was the amount of users and the testing time. More time and more people were needed to draw better conclusions regarding the progress created by the application. However, since this was a pilot test to receive the

first real reviews regarding the application, very valid and important information was also collected.

Regarding the operating system, this application was developed for android which limits the number of devices on which it can be tested (e.g. noiphones, no computers). If this work is continued by someone else who has ambitions to improve the application, it will have to be transformed into a hybrid language.

5.2. Future Work

Regarding future work, it should be mentioned that there are some changes to be made in the architecture of the information system. If there is interest in bringing an improved version of this application to the market, it is necessary to pay attention to some issues related to security and data protection. In section 3.3.1.1 the necessary detail can be found to better understand the steps to be taken.

During the project it was decided to give the users a paper with the Qr Code for their login. However, as future work it is advised to create a system that builds a Qr Code and sends it to the email after the user's sign up.

According to the users' suggestions it is possible to suggest the creation of more interactive games and the collection of more personal content for the customization of these games (e.g. videos, audios, photos).

As for the system for assigning points for the application's games, it would be advisable to do a large-scale test to find out the most common values and thus assign an improved scale. This way, the results obtained can be more precise and the conclusions more viable.

This application can also be improved if an assessment is made and difficulty levels are created for the games, based on these assessments. This would help avoid the monotony of the exercises, which makes progress impossible.

5.3. Academic Contribution

To conclude the project it was also necessary to complete the last step described in Peffers' model. To this end, the results were communicated at EPE 2022, 12th International Conference and Exposition on Electrical and Power Engineering, under the title "Memory Training Interface for Elderly based on Mobile App". Supporting documents can be found in Appendix G, Appendix H, Appendix I and Appendix J .

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APPENDIX A

Applications description

App	Platform Type	CognitiveTraining	User Life Story	Design	Support Features	Acessment	Duration	Stimulation
CogniFit	Web App	Multiple Serious Games	No	Big buttons Simple moves Simple colors and clean design	Sound when user fails	Determines User's cognitive level with games	Very Long	Game Score Cognitive Evolution Chart
LIFEBIO	Mobile App	Reminiscence	Sim	Very Complex for helpers One big button for user but all others are very small Simple colors and clean design	Tutorial for helpers Speech Tool to capture stories with artificial intelligence	No	Very Short (can do one or multple)	No
RemArc	Web App	Reminiscence	No	Very Simplistic Big Buttons Images, Videos, Audio	None	No	Very Short (can do one or multple)	No
Alzminder	Mobile App	Serious Games	Sim	Big buttons Simplistic Design	Voice Reminders SOS Emergency Call Button	No	Short	No
Book of You	Web App or Book	Reminiscence	Sim	Big Buttons Big Letters Not Appealing	None	No	Medium	No
Dakim	Web App	Serious Games	No	Too much Information Big Buttons and Big images Simple Moves	Audio informing the user what to do	No, but when the user improves it increases difficulty	Long	Timer Comparisson Session Progress Last Session Score
Storii	Mobile App	Reminiscence	Sim	Small buttons Complex for elders to navigate	Ability to contact family members	No	Medium	No
MindMate	Mobile App	Serious Games Workout Fodd recipes	No	Very Complex Games are very easy to use but in order to start them it is very difficult for and elder Too much information	None	No	Short	Earning points in games Today´s activitys Weekly goals
House of memorys	Mobile App	Reminiscence	Sim	Complex for elders to navigate Forces Landscape Mode (everything gets bigger and wider)	Instructions and for every button the s	No	Short	No

APPENDIX B

First List of Questions and Answers & Feedback given by professionals

ID	Questions	Answers	Feedback	Keep/Delete
1	When were you born?	1941-1950 1951-1960 1961-1970	Do not use gaps. Use just numbers instead	Yes
2	What is your mother's name ?	Ana Raquel Maria Fernanda	Choose popular names of the time	Yes
3	What is your father's name ?	Jorge Paulo Miguel Pedro	Choose popular names of the time	Yes
4	What is your position in relation to your siblings ?	younger oldest intermediate did not have	Replace for "How many brother do you have"	Yes
5	How many siblings do you have/have ?	none 1-2 3-5 more than 5	Do not use gaps. Use just numbers instead	Yes
6	Until what age did you study ?	never Until 14 years old Between 15 and 18 years old more than 18 years old	Replace for "until what year did you study"	Yes
7	How did you get to school?	on foot by train by bicycle other vehicle	Ok	Yes

8	What was your favorite subject when you were a child?	Mathematics Science Languages History	-	No
9	What is the name of your best childhood friend ?	Andreia Cristina Afonso Paulo	This concept of childhood friend doesn't have much to do with this generation. Replace it with where you went to school	No
10	How old were you when you went to work for the first time?	0-10 years old 11-20 years old 21-30 years old 31-40 years old 41-50 years 51-60 years old	Do not use gaps. Use just numbers instead	Yes
11	What was the professional area of your first job?	Construction Transport Mining Professional Services Utilities Business and Repairs Telecommunications Health Entertainment Education Government Financial Services	Only jobs from that time	No
12	How many jobs have you had?	none 1 a 3 3 a 10 more than 10	-	No
13	In which professional area did you like to work the most ?	Construction Transport Mining Professional Services Utilities Business and Repairs Telecommunications Health Entertainment Education Government Financial Services	-	No
14	In which professional area have you worked the longest?	Construction Transportation Mining Professional Services Utilities Business and Repairs Telecommunications Health Entertainment Education Government Financial Services	-	No

15	Do you regret or would you make any changes in your career path	yes no	-	No
16	Who are the most important group of people in your life.	family friends co-workers partner	-	No
17	Have you married or had a life partner?	yes no	Possible to have had more than one	Yes
18	What was the weather like on your wedding day?	Sun Rain Cloudy Not Married	Ok	Yes
19	Where was your wedding ?	City Countryside Beach Not remarried	Select actual places	Yes
20	How many children did you have?	none 1 or 2 3 to 6 more than 6	Do not use gaps. Use just numbers instead	Yes
21	Which of these animals have you had?	Dogs Cats Birds others	None should be also na option	Yes
22	What would you like to do more in your free time?	Read books Go for a walk Playing sports Listening to music Socializing	Remove and ask a question related to what you like to wear most	No
23	What events have marked your life ?	War Travels Births Work Fortune	-	No
24	What do you consider most important in your appearance ?	Clothes Hair Body nothing	-	No
25	What kind of music do you prefer to listen to	Classical Opera Hip-Pop I don't like	Replace for "What is your favourite singer"	Yes
26	What style of television do you prefer ?	Drama Action Crime Romance	Replace for"What is your favourite show"	Yes
27	What are your interests and hobbies ?	Board Games Books Hiking Art Sports	Replace for "What you like to do most in your free time"	Yes
28	Which group of people is most important in your life	GrandChildre Children Siblings Parents	Not the best question to ask	No

APPENDIX C

MMSE & Lawton & Barthel Assessment

AMELIA (Age, MEmory, Loneliness and Intelligent Ambients)

Nome	
Idade	
Sexo	
Naturalidade	
Nacionalidade	
Local de Residência	
Qual foi /é a sua profissão principal?	(assinale com "X" de acordo com as seguintes hipóteses)
Quadro superior	
Profissão Intelectual e Científica	
Profissão Técnica Intermédia	
Empregado Administrativo	
Pessoal dos Serviços e vendedores	
Trabalhador qualificado da Agricultura e da Pesca	
Trabalhador da Produção Industrial e Artesão	
Operador de Instalações Industriais, Máquinas e Montagem	
Trab. não qualificado Agricultura, Indústria, Comércio, Serviços	
Doméstica/o	
Nunca teve atividade remunerada	
	NS ☐ NR ☐
Escolaridade	
Número de anos de escolaridade completos	
Sabe ler e escrever, mas sem escolaridade	
Estado Conjugal	(assinale com "X" de acordo com as seguintes hipóteses)
Solteiro	
Casado (a)	
Divorciado (a)	
Viúvo(a)	
Vive conjugalmente com alguém	
Com quem vive?	**(assinale com "X" de acordo com as seguintes hipóteses)**
Numa Instituição	
Sozinho	
Com cônjuge/companheiro/a	
Com cônjuge/companheiro/a e filho/a (s)	

Mini Exame Cognitivo

J. Morgado, C. S. Rocha, C. Maruta, M. Guerreiro e I. P. Martins (2006). Laboratório de Investigação da Linguagem, Faculdade de Medicina de Lisboa, Instituto de Medicina Molecular, Hospital de Santa Maria, Lisboa

J. Morgado, C. S. Rocha, C. Maruta, M. Guerreiro e I. P. Martins (2009). Cut-off scores in MMSE: a moving target? European Journal of Neurology. doi:10.1111/j.1468-1331.2009.02907.x

Idade: _____ anos

Escolaridade: _____

Data: __/__/____

1. ORIENTAÇÃO (1 ponto por cada resposta correcta)

Em que ano estamos?_____

Em que mês estamos?_____

Em que dia do mês estamos?_____

Em que dia da semana estamos?_____

Em que estação do ano estamos?_____

Em que país estamos?_____

Em que distrito vive?_____

Em que terra vive?_____

Em que casa estamos?_____

Em que andar estamos?_____

Nota:

2. RETENÇÃO (contar 1 ponto por cada palavra correctamente repetida).

"Vou dizer três palavras; queria que as repetisse, mas só depois de eu as dizer todas; procure ficar a sabê-las de cor"

Pêra _____

Gato_____

Bola_____

Nota:

3. ATENÇÃO E CÁLCULO (1 ponto por cada resposta correcta. Se der uma errada mas depois continuar a subtrair bem, consideram-se as seguintes como correctas. Parar ao fim de 5 respostas).

"Agora peço-lhe que me diga quantos são 30 menos 3 e depois ao número encontrado volta a tirar 3 e repete assim até eu lhe dizer para parar".

27_____24_____21____18____15_____

Nota:

4. EVOCAÇÃO (1 ponto por cada resposta correcta).

"Veja se consegue dizer as três palavras que pedi há pouco para decorar".

Pêra _____

Gato_____

Bola_____

Nota:

5. LINGUAGEM (1 ponto por cada resposta correcta).

a. "Como se chama isto? Mostrar os objectos:

Relógio_____

Lápis_____

Nota:

b. "Repita a frase que eu vou dizer: O RATO ROEU A ROLHA"

Nota:

c. "Quando eu lhe der esta folha de papel, pegue nela com a mão direita, dobre-a ao meio e ponha sobre a mesa" (ou "sobre a cama", se for o caso); dar a folha segurando com as duas mãos.

Pega com a mão direita_____

Dobra ao meio_____

Coloca onde deve_____

Nota:

d. "Leia o que está neste cartão e faça o que lá diz." Mostrar um cartão com a frase bem legível,

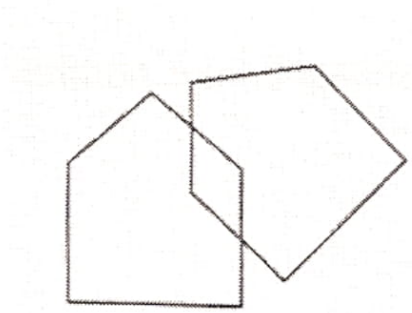
e. "Escreva uma frase inteira aqui". Deve ter sujeito e verbo e fazer sentido; os erros gramaticais não prejudicam a pontuação.

Nota:

6. HABILIADDE CONSTRUTIVA (1 ponto pela cópia correcta).

Deve copiar um desenho. Dois pentágonos parcialmente sobrepostos; cada um deve ficar com 5 lados, dois dos quais intersectados. Não valorizar tremor ou rotação.

DESENHO



CÓPIA

(Máximo 30 pontos)

TOTAL:

Considera-se com defeito cognitivo:

- ≤22 para escolaridade de 0 a 2 anos
- ≤24 para escolaridade de 3 a 6 anos
- ≤27 para escolaridade igual ou superior a 7 anos

Índice de Lawton (versão Azeredo & Matos, 2003)

	Índice de Lawton (versão Azeredo & Matos, 2003) - Avaliação das atividades instrumentais da vida diária	
	Classificar cada item de acordo com os seguintes critérios: Sem ou grave perda da autonomia = 0; Necessita de alguma ajuda = 1; Autónomo ou com ligeira perda de autonomia = 2	
1	Usar o telefone	
2	Ir às compras	
3	Preparação das refeições	
4	Cuidar da casa	
5	Lavagem da roupa	
6	Meio de transporte	
7	Responsabilidade sobre a medicação	
8	Capacidade para usar o dinheiro	
TOTAL	Valores de corte: 0-5 dependência grave ou total; 6-11 dependência moderada; 12-16 - ligeira dependência ou independente	

Escala de Barthel – Versão de 1989

1 - "Não pode"

2 - "Pode com ajuda máxima"

3 - "Pode com ajuda moderada"

4 - "Pode com ajuda mínima"

5 - "Pode por si próprio"

1. Higiene Pessoal:	0	1	3	4	5
2. Tomar Banho:	0	1	3	4	5
3. Alimentação:	0	2	5	8	10
4. Casa de Banho:	0	2	5	8	10
5. Escadas:	0	2	5	8	10
6. Vestir:	0	2	5	8	10
7. Intestinos/Defecação:	0	2	5	8	10
8. Bexiga/Urinar:	0	2	5	8	10
9. Transferências cadeira/cama:	0	3	8	12	15
10. Deambulação:	0	3	8	12	15
11. Manuseio da C.R: (*)	0	1	3	4	5

100 pontos – **totalmente independente**

99 a 76 pontos – **dependência leve**

75 a 51 pontos - **dependência**

50 a 26 pontos – **dependência severa**

25 e menos pontos – **dependência total**

Novas linhas gerais para as funções da Escala de Barthel

Higiene Pessoal

1. O paciente é incapaz de fazer a higiene pessoal e é dependente em todos os aspetos
2. Assistência é requerida em todos os passos da higiene pessoal
3. Alguma assistência é requerida em um ou mais passos da higiene pessoal
4. O paciente é capaz de efetuar a sua própria higiene pessoal, mas requer a mínima assistência antes c/ou após operação
5. O paciente pode lavar suas mãos e face, cabelo, lavar os dentes e barbear. Um paciente do sexo masculino pode usar qualquer tipo de gilete, mas deve inserir a lâmina, ou retirá-la da gilete sem ajuda, assim como retirá-la da gaveta ou armário. Um paciente do sexo feminino deve aplicar a sua própria maquilhagem, se utilizarmos não necessita de auxílio a pentear ou entrelaçar o cabelo

Tomar banho

1. Total dependência enqu7anto toma banho
2. Assistência é requerida enquanto toma banho
3. Assistência é requerida quer na transferência para o duche /banheira ou quer com o lavar e secar; incluindo incapacidade de completar a tarefa devido à sua condição ou doença etc.
4. Supervisão é requerida para a segurança, no ajustar da temperatura da água ou na transferência
5. O paciente pode usar uma banheira, um duche ou tomar um banho completo de esponja. O paciente deve ser capaz de fazer todos os passos seja qual for o método empregue sem que outra pessoa esteja presente

Alimentação

1. Dependente em todos os aspetos e necessidade para alimentar-se
2. Pode manipular um dispositivo de alimentação, usualmente uma colher, mas alguém deve providenciar assistência ativa durante a refeição
3. Capaz de se alimentar sem supervisão. Assistência é requerida em tarefas associadas como colocar leite/açúcar no chá, sal, pimenta, espalhar manteiga, voltar um prato ou qualquer outra atividade
4. Independência na alimentação com treino anterior, exceto no cortar da carne, abrir pacotes de leite, tapar jarro, etc. A presença de outra pessoa não é requerida
5. O paciente pode alimentar-se de uma mesa ou tabuleiro quando alguém coloca a comida ao seu alcance. O paciente deve pôr um dispositivo de assistência se necessário, cortar comida e se desejado usar sal ou pimenta, espalhar manteiga, etc.

4. Supervisão pode ser requerida para segurança na toalete normal. Uma pia pode ser utilizada á noite, mas assistência é requerida para esvaziar ou limpar
5. O paciente é capaz de sair ou entrada casa de banho, apertar e desapertar as roupas, prevenir o sujar das roupas e usar papel higiénico sem auxílio. Se necessário o paciente pode utilizar uma pia, uma tina ou urinol à noite, mas deve ser capaz de esvaziá-lo e limpá-lo

Escadas

1. O paciente é incapaz de utilizar as escadas
2. Assistência é requerida em todos os aspetos, durante a utilização das escadas, incluindo assistência com meios auxiliares
3. O paciente é capaz de subir/descer mas é incapaz de transportar auxiliares de marcha e necessita de supervisão e assistência
4. Geralmente nenhuma assistência é requerida. Em certos momentos supervisão é requerida para a segurança aliada à rigidez matinal, dificuldade na respiração, etc.
5. O paciente é capaz de subir/descer um lanço de escadas em segurança sem auxílio ou supervisão. O paciente é capaz de utilizar o corrimão, apoios ou canadianas quando necessário e é capaz de transportar esses auxiliares à medida que ele/ela/desce ou sobe

Vestir

1. O paciente é dependente em todos os aspetos do vestir e é incapaz de participar nesta atividade
2. O paciente é capaz de participar em alguns aspetos mas é dependente em todos os aspetos do vestir
3. Assistência é necessária em colocar e/ou remover alguma roupa
4. Apenas a mínima assistência é requerida com a roupa de apertar como botões, fechos, cintos, sapatos, etc.
5. O paciente é capaz de pôr, remover e apertar a roupa, dar laços nos atacadores dos sapatos, colocá-los, apertá-los, remover cintas, coletes, suspensórios como é pedido

Intestinos/Defecação

1. O paciente é incontinente
2. O paciente necessita de auxílio para assumir a posição apropriada e com técnicas de facilitação dos movimentos intestinais
3. O paciente pode assumir a posição apropriada mas não consegue utilizar técnicas de facilitação ou limpar-se sem auxílio e tem acidentes frequentes. Assistência é requerida com os auxiliares de incontinência como fraldas, etc.
4. O paciente pode requerer supervisão com o uso de supositórios ou clister e tem acidentes ocasionais
5. O paciente pode controlar os intestinos e não tem acidentes, pode usar supositórios ou utilizar clister quando necessário

Bexiga/Urinar

1. O paciente é dependente enquanto urina, é incontinente ou tem um cateter
2. O paciente é incontinente, mas é capaz de assistir com a aplicação de um dispositivo interno ou externo
3. O paciente está geralmente seco durante o dia, mas à noite necessita de alguma assistência com os dispositivos
4. O paciente está geralmente seco durante o dia, mas pode ter acidentes ocasionais ou necessita de mínima assistência com dispositivos internos ou externos
5. O paciente é capaz de controlar a bexiga durante dia e noite e/ou é independente com dispositivos

1. Incapaz de participar na transferência. Dois indivíduos auxiliares são requeridos para transferir o paciente com ou sem o dispositivo mecânico
2. Capaz de participar, mas com a máxima assistência de outra pessoa requerida em todos os aspetos da transferência
3. A transferência requer a assistência de outra pessoa. Assistência pode ser requerida em alguns aspetos da transferência
4. A presença de outra pessoa é requerida como uma medida preventiva
5. O paciente pode seguramente aproximar-se da cama numa cadeira de rodas, tirar os braços da cadeira de rodas, levantar os apoios dos pés, transferir-se com segurança para a cama, deitar-se, voltar à posição de sentado num dos lados da cama, alterar a posição da cadeira de rodas, voltar a transferir-se para a cadeira de rodas com segurança. O paciente deve ser independente em todas as fases da sua atividade

Deambulação

1. Dependente na deambulação
2. Presença constante de um ou mais assistentes é requerida durante a deambulação
3. Assistência é requerida com meios auxiliares c/ou a sua manipulação. Um individuo é requerido para oferecer assistência
4. O paciente é independente na deambulação mas incapaz de andar 50 metros sem auxílio, supervisão é requerida para a proteção ou segurança em situações difíceis
5. o paciente deve ser capaz de utilizar canadianas se necessário, colocar e retirar as canadianas, assumir a posição de pé, sentar-se e colocar estes auxiliares de marcha na posição correta para voltar a utilizar. O paciente deve ser capaz de usar canadianas, bengalas ou andarilhos e caminhar 50 metros sem auxílio ou supervisão

Manuseio da Cadeira de Rodas (alternativa/deambulação)

Só utilizar este item se o paciente for classificado para a deambulação com “0” e também só se o paciente tiver o treino adequado no manuseio da cadeira de rodas.

1. Dependente na condução da cadeira de rodas
2. O paciente pode andar pequenas distâncias numa superfície regularmente plana mas assistência é requerida para todos os outros passos na utilização da cadeira de rodas
3. Presença de um indivíduo é necessário e constante assistência é requerida para manipular a cadeira de rodas colocando-a ao pé de uma mesa, cama, etc.
4. O paciente pode conduzir sozinho a cadeira de rodas por duração razoável em terreno regular. Mínima assistência pode ser requerida em “curvas apertadas”
5. capaz de conduzir a cadeira de rodas independentemente, o paciente deve ser capaz de andar numa curva, manobras de voltar atrás, manobrar a cadeira até ficar perto de uma mesa, cama, casa de banho, etc. O paciente deve ser capaz de conduzir a cadeira de rodas até pelo menos 50 metros

APPENDIX D

Users Data

	U1	U2	U3	U4	U5	U6	U7	U8
Age	80	76	74	79	74	76	77	84
Gender	M	M	F	F	F	F	M	F
Place of birth	Angola	Lisbon	Lisbon	Lisbon	Lisbon	Portuguesa	Portuguesa	Portuguesa
Nationality	Portuguese	Portuguese	Portuguese	Portuguese	Portuguese	Portuguese	Portuguese	Portuguese
Place of Residence	Lisboa	S.João do Estoril	S.João do Estoril	Carcavelos	Benfica	Mem-Martins	Mem-Martins	Linda-a-Velha
What was / is your main occupation?								
Senior Management					x			
Intellectual and Scientific Profession	x	x						
Intermediate Technical Profession								
Administrative Employee								
Service workers and salespeople								
Skilled agricultural and fishing workers								
Industrial Production Worker and Craftsman								
Industrial plant, machine and assembly worker								
Unskilled worker Agriculture, industry, trade, services			x				x	
Domestic Worker						x		
Never had a paid activity				x				x
Doesn't know								
No answer								
Education								
Number of years of schooling completed	16	10	4	4	17	9	9	3
Can read and write, but no schooling								
Marital Status								
Single		x	x	x				
Married						x	x	
Divorced					x			
Widowed	x		x	x				x
Living conjugally with someone								
With whom do you live?								
In an institution								
Alone								x
With spouse/partner		x				x	x	
With spouse/partner and child(ren)								
With child	x				x			
With other family members								
Hired Staff								
MMSE	30	30	27	26	30	25	25	27
Lawton Index	16	16	14	12	16	15	14	14
Barthel Scale	100	100	100	100	100	100	100	100

APPENDIX E

Feedback Questionnaire

QUESTIONÁRIO

Responda da forma mais completa possível às seguintes questões. Sempre que possível, pode também fazer sugestões.

- 1) O que achou da componente visual (tamanho dos botões, cores, organização, imagens, tamanho do texto, etc)
- A componente visual estava boa, bom tamanho de letras e botões.

- 2) Em relação às instruções áudio, sentiu que estavam boas/médias/más? Justifique com exemplos de situações especificas (um jogo em específico, uma palavra confusa, etc)
- O audio estava bom e era perceptível. No jogo da palavra intrusa, não deu para perceber bem, era melhor que no audio desse um exemplo prático, assim á mais fácil de compreensão.

- 3) O que achou da duração dos exercícios?
- A duração foi a suficiente.

- 4) Qual o número de vezes máximo que gostaria de utilizar a app numa semana?
- 2 vezes por semana.

- 5) Como se sentiu a usar a aplicação? Gostou de usar a aplicação? Se não, porquê?
- Gostou, os jogos eram divertidos e as perguntas estavam bem construídas.

- 6) Conseguiu usar a aplicação de forma totalmente autónoma/parcialmente autónoma/nada autónoma?
- Parcialmente autónoma, para ligar a aplicação, porque os jogos fazia autonomamente.

- 7) (Para a pessoa auxiliar) Que funcionalidades(features) recomendaria adicionar à aplicação para torná-la melhor?
- A meu ver, todos os jogos deviam ter indicações escritas.

- 8) (Para a pessoa auxiliar) Adicione nesta questão feedback que não tenha sido abordado nas questões anteriores, mas que acha relevante expressar.
- Numa forma geral a aplicação estava boa, acho que podia haver mais jogos como sopa de letras, e mais perguntas do questionário inicial como: com quantos anos deixou de estudar, em vez de em que ano deixou de estudar, também podia ter mais perguntas em relação nomes dos filhos, idade dos filhos, ano em que casou, nome dos irmãos…

Obrigado pela colaboração

APPENDIX F

Users Feedback

Question Number	Feedback 1	Feedback 2	Feedback 3	Feedback 4	Feedback 5	Feedback 6	Feedback 7	Feedback 8
1	Slight delay in response to touch	All good	All great	Too small and letters that remain blank get confused with those not found	Bigger and bolder letters, and darker colors	Good font size and buttons	All good	Very Good
2	**Good** diction and good speech	**Average**, difficulty in understanding the game of the "sequence" and the "Different Word" (only be able to go next activty after audio stops)	**Average**, confusion in understanding the game of the sequence and the "Diferent Word"	**Good**	**Good**, but the "Difefferent Word" is barely understandable, should give a pratical example to understand it better	**Good**, but the intrusive word game is barely understandable, should give a pratical example to understand it better	Helped and **good**, but after a while they become very repetitive and boring	**Good**, audio keeps going when answer fast
3	Normal, no problems	Good duration	Good	Very long	Fast and fairly easy	Sufficient	Sufficient	Took longer at first but got better after adaptation
4	Once a day, however should have a hardship function to follow up with the patient if he is doing well	Every day	Every other day	Once a day	Twice a week	Twice a week	Twice a week	Once or twice a week, however he did not mind playing avery day
5	Interesting to pass the time Wants to continue the training	Liked it but wanted more game variety	Liked it but wanted more game variety of games	Didn't like it, for people who don't use technology and are impatient like me it gets complicated (wants fewer questions)	Liked, felt good but found the exercises a bit repetitive Enjoyed the personal side of the application	Liked, the games were fun and the questions were weel constructed	Liked, the games were fun nad good to pass the time	Really enjoyed playing
6	Totallu autonomous	Fully autonomous	Partially autonomous	Not at all autonomous, needed help several times Granddaughter read all of the questions	Liked, felt good but found the exercises a bit repetitive	Partially autonomous, needed help to start, but then played autonomous with few needs f help	Partially autonomous, needed help to start, but then played autonomous	Not at first, but by the middle of the week was already fully autonomous
7	Progress bar	Some final feedback regarding your score and if it improved form the previous time	Games should be locked until audio ends	Less memory games	Confetti should come from the middle In "Different Word" the word candle (in portuguse) gets confusing because it also means "sail"(portguese)	Games shloud have written instructions	boxes that are left blank get confusing and they click anyway should put "how many years did you study" in the question about the year you studied	More animations like confetti because they see that they get it right and feel stimulated and happy when they get it right
8	none	Was able to be autonomous, had a lot of interest during the week but found the game a bit repetitive	Easy to use	The question "until what year did you study" implies doing year counts instead of saying you studied until fourth grade	Nothing else to add	Should be more word games and more questions in the initial questionnaire, such as how long you studied, names of siblings, age of children	Don't put so many stick figures, because the old people compare themselves to it and it makes them fell old	none

APPENDIX G

EPE 2022 Certificate of Participation

CERTIFICATE OF ATTENDANCE

This is to certify that:

Andre Baptista, Octavian Postolache, Diana Mendes, Elisabeth Reis, Dalia Nogueira

have presented a scientific contribution at

the 12th INTERNATIONAL CONFERENCE AND EXPOSITION ON

ELECTRICAL AND POWER ENGINEERING - **EPE 2022**

held in IASI, ROMANIA, October 20 - 22, 2022.

Conference chair,
Prof. Marinel Temneanu
Dean of Electrical Engineering Faculty

APPENDIX H

Paper Submitted for Publication for EPE 2022 : 12th International Conference and Exposition on Electrical and Power Engineering (EPE2022)

Memory Training Interface for Elderly based on Mobile APP

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***Abstract*—Currently, the world population is aging rapidly and one of the characteristics that will accompany this new generation of elderly people is the concept of "aging in place", which means aging at home. The quality of life of the elderly in their home depends on the maintenance of their cognitive and motor skills and, therefore, the way to encourage them to remain autonomous and reduce institutionalization is by training their memory. To help on solving problems like cognitive decline in elderly population it was developed a memory training mobile application based on life story work. The APP has the contribution of many professionals and was validated with a small group of elderly users. Analysis of the collected data is presented in the work to underline the effectiveness of developed APP on cognitive training.**

***Keywords*—mobile app, mobile application, intelligent systems, serious game, Pervasive Computing, cognitive decline, cognitive memory training**

I. Introduction

Currently, the world population is aging rapidly, and it is estimated that the number of people over 60 will increase by up to 10 percent [1]. One of the characteristics that will accompany this new generation of elderly people is the concept of "aging in place" [2], which means aging at home. This is because with the emergence of better living conditions and well-being in their homes, the elderly will choose to spend their last stage of life at home.

With aging, people begin to face numerous diseases and disabilities, however, with technological advances, many of them can be softened. Given the aging scenario at home, possibly other problems will appear, such as loneliness and cognitive decline. These problems not only come from age, but also from lack of physical exercise and social isolation. Knowing that dementia is associated with the previously mentioned factors, there is an urgent need to seek the necessary follow-up to avoid worsening the health status of the elderly [1] [3] [4].

The quality of life of the elderly in their home depends on the maintenance of their cognitive and motor skills and, therefore, the way to encourage them to remain autonomous and reduce institutionalization is by training their memory.

Current technologies are increasingly accessible to anyone, facilitating interpersonal contact. In this way, by providing solutions for cognitive decline through technological systems [5], we can contribute to a better quality of life for the elderly, especially mental health [6] [1]). To help solve these problems, it was proposed to develop a memory training application based on life story work.

This type of work consists of carrying out questions and questionnaires based on the life of an elderly person, in order to better understand their past [7] [8]. The personal information collected is then used by healthcare professionals to help their patients reflect on their identity, give them comfort by remembering their family or simply to follow their preferences and needs. Unfortunately, this work is very dependent on the doctor-patient interaction, and this project aims to automate this work and associate it with the performance of cognitive exercises.

II. Methodology

For the development of the application in question, the Design Science Research (DSR) methodology was used. As it is about the creation of a physical artifact and not the elaboration of a theoretical study, it is necessary to follow the methodology idealized by Peffers (2007).

In image x, this methodology is composed of six phases. The first two steps were already carried out at the beginning of this study, where the problem in question was discussed, as well as the objectives and the idealized solution. Then followed three phases that together can be iterated multiple times in order to improve the application through the feedback received in the evaluation phase. Unlike a methodology like Waterfall, DSR is agile and flexible and allows for requirements modification and adaptations during the development processes.

Another phase considered relevant in this work was added to the Peffers model [9], "Pilot Test and Results Analysis". In addition to the demonstrations made to the professionals involved, it was decided to create a special stage for a last test with a small sample of users. The objective of this stage was to receive feedback from the users of the application, as they were the biggest beneficiaries of this project.

III. Artifact Development and Evaluation

The Before starting the development of the application, it was necessary to create a list of requirements by professionals linked to the project. This team was made up of 5 people and the team was divided into two distinct parts for greater

flexibility: IT Team (features, architecture, programming, database, server), Social Team (visual aspects, cognition training, language, Life Story Work).

The development process involved 3 iterations and in the evaluation phases both teams gave their opinion on their area in order to make the feedback as constructive and relevant as possible. The main requirements are following presented:

1. User registration and authentication;
2. Memory games;
3. Remote Database to save users, questions, answers and scores;
4. Solutions to help illiterate seniors;
5. Server that allows you to use the application anywhere;
6. Platform compatible with phones and tablets (adjustable to different sizes without affecting the design);
7. Simplistic design suitable for the elderly;
8. Tablet must allow multiple accounts;
9. Save each user's life story.

A. DSR Cycle 1

1) Development: It was decided to develop the application in Java in Android Studio.

Although one of the project's proposals involves the creation of a remote database and a server, it was decided at first to use the development computer as a server. For this, the WAMP software was installed, which function is to automatically install a collection of important software for this experiment. Throughout the project multiple php files were created which were invoked in the built java code. These files per- formed one of two functions, GET or POST, and aimed to fetch or publish elements in the database, respectively. In this first iteration, two interfaces were developed.

The first, corresponding to "WSign Up", allows the user to create his profile with a username, email and password through a file invoked in java with a POST command. This was given the name signup.php and placed in the WWW folder of Wamp as it is responsible for generating dynamic content on the "World Wide Web".

The second interface, corresponding to" Login", had a similar construction to the first one, also with its own php file, login.php, which deals with user authentication, previously created, through username and password.

A database was also created in PHPMyadmin with only one table, named Users, which was used to register the users inserted in the "Sign Up" and to authenticate the data inserted in the "Login".

2) Demonstration: The demonstration phase served to show the development created so far.

On the registration page it is possible to add the name, username, email and password and at the end click on a button that takes you directly to the next page (carried out in DSR Cycle 2). On the "Login" page there are only two fields to be completed and which, in turn, will be analyzed by the php file to see if they match the data present in the DB. As for the database, the Users table was organized with all the fields of the "Sign Up" and, if necessary, other fields could be added.

3) Evaluation: As there was still no progress in relation to the social part of the project, this phase was entirely dedicated to obtaining feedback from the IT team. Despite the well-constructed registration and authentication components, there was a criticism regarding the login process. Although most people usually are able to create user accounts, logging in and remembering passwords, the target audience presents specific difficulties. Bearing in mind this the application was designed to have an easy to use interface.

That it is necessary to have another approach to login. This approach should allow the user to be able to login quickly and efficiently without having to type or remember complicated passwords. Everything else had a positive evaluation and the care to be taken with the construction of the rest of the database was reinforced, since the results and the analysis of the success of the application depend on the organization of the same login.

This approach should allow the user to be able to login quickly and efficiently without having to type too much or remember complicated passwords. Everything else had a positive evaluation and the care to be taken with the construction of the rest of the database was reinforced, since the results and the analysis depends by the success of the application.

B. DSR Cycle 2

1) Development: In the second iteration of the DSR, we started by first analyzing the feedback obtained in the previous evaluation and came to the conclusion that one of the best ways to correct the problem for the "LogIn" was to create a new type of authentication. Instead of typing the username and password, these two words were associated with a QR Code and a java code capable of interpreting it was developed. It was therefore changed to a page with a camera, in which the user only had to point the tablet at the QR Code present on a phone screen or paper to connect.

Then, before creating the pages with questions and answers about the user's life, it was necessary to create a list of suitable questions. The Social Team provided a very relevant document regarding the type of questionnaire carried out in the life story work; however, it was concluded that there would have to be some restructuring in the questions. In the document, all questions were open-ended, and this prevented the answers from being systematized and reused throughout the games. It was understood that the best way to gather information and obtain answers was through closed-ended questions.

The "List of Questions" and "List of Answers" are presented in Fig. 1 and Fig. 2 as part of implemented APP. The APP pages are the only ones in the application where access is supposed to be exclusive to accompanying persons or family members of the elderly. This is because all the games and interactions of the application will be based on the life story of each user, more precisely the answers entered. For these reasons, it was decided to make the pages as complete as possible instead of keeping them simplistic, as they are not dedicated to the elderly.

In order to be able to store all the information, the database had to be expanded by creating 4 more tables: one to store the answers, one to store the questions, one to store the answers given by each user and another to store the scores of each player.

Finally, after having built and organized the necessary structure for the development of serious games, the first interactive page for users, "Quiz 4" (Fig. 3), was also created. In this exercise, each question of the questionnaire and 4

possible answers were retrieved from the database and everything was presented on the screen in a very simple way.

2) Demonstration: This demo served to show the android pages created, as well as the changes made to the "Login" page.

The application starts on this page, which now presents only one camera capable of reading QR codes. After authentication, the "List of Questions" page is accessed, in which is presented a scrollable list of all the questions present in the database.

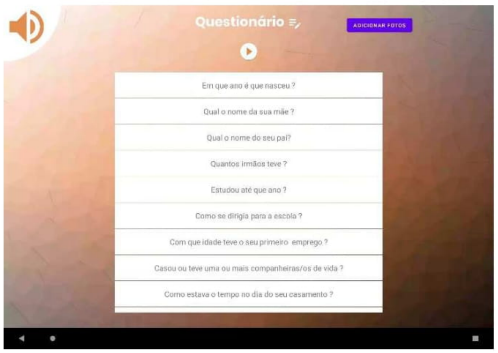

Fig. 1. List of Questions.

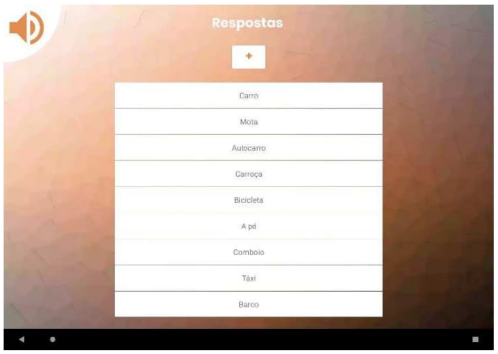

Fig. 2. List of Answers.

Fig. 3. Quiz 4.

The user must click on each question in order to display the corresponding answers screen. It shows up the "List of Answers" page, where the helper must, with the cooperation of the elderly person, click on one of the possible answers in order to create the user's life story. Whenever a question is answered, it is automatically added to the database and the screen returns to "List of Questions" in order to continue answering. At the end of the quiz, the user can finally start playing "Quiz 4", a page with 1 question and 4 answers, in which 3 of them are randomly false and the other one is the true answer corresponding to the previously stored one. One of the features created for this game was an audio button that allows the user to hear all the text on the screen and thus help the elderly person in case of reading difficulties or limitations.

3) Evaluation: In this evaluation, both teams participated as there was already social and technological content to be analyzed. Regarding the questions, the Social Team criticized the language used and the type of answers, e.g. one of the questions said "What is your position in relation to your brothers" with answers "the youngest, the oldest, the middle one" and in this example it was suggested that the question was changed to "How many siblings do you have".

As far as "Quiz 4" is concerned, it was suggested that there were visual improvements to make it more appealing, however both teams praised the layout and size of the buttons as it proved to be accessible to the target users.

They also consider the possibility of reproducing the question and answers via audio well implemented, as it was a good solution for users with low literacy levels. One of the observations made by the Social Team was the need to add memory games. This is because the first memory to be lost is the most recent one and, therefore, in order to train users' cognition, it was also important to perform cognitive training exercises in addition to life story questions.

Regarding the application itself, the technology team praised the QR Code solution but criticized 3 aspects related to the lists' activities. The "List of Questions" did not allow to see which of the questions had already been answered, and the user had to remember if he had already answered. As for the "List of Answers", there was no option to add an answer that was not present in the database and there was also no possibility to edit if it had been incorrectly answered.

C. DSR Cycle 3

1) Development: Again, at the beginning of the cycle, the new functionalities to be added or changed were analyzed, according to the criticisms made in the previous phase. It started by prioritizing the improvement of the database questions where a new list of questions was built.

A feature was also integrated in the "Response List" that allows adding new answers to the database. Regarding the gameplay, as suggested, it was decided to alternate "Quiz 4" with memory and comprehension games, where each one relates directly to the theme of the previous game. Demonstrating with a real example, in "Quiz 4" appears the question "Where was your wedding?" and after answering, the next game is necessarily about this same theme "wedding places", e.g. a cognitive game to find pairs of possible places for marriages. The Quiz 4 final questions are:

- What year were you born?
- What is your mother's name?
- What is your father's name?

- How many brothers did you have?
- Until what year did you study?
- How did you go to school?
- At what age did you have your first job?
- Married or had one or more life partners
- How was the weather on your wedding day?
- Where was your wedding?
- How many children did you have?
- What is your favorite animal?

Several types of approaches were investigated from which 4 types of games emerged, explained later in the demonstration, and all of them will be based on the answers to the previous, "Quiz 4", question. In order to make the application more interactive and visually appealing, we decided to associate these answers with corresponding images, so that we could interact with the user without always using words.

Thanks to the positive reviews regarding the audio help, it was decided to expand the concept to the entire application. A button was created in all activities with audio instructions to help users. These instructions have also been automated to start as soon as the user enters a new page and the button allows you to listen again as many times as you want.

Finally, a fundamental part of this project to carry out tests anywhere and with any user was created, the server. We chose to generate a virtual machine on the Amazon Elastic Compute Cloud (EC2) that was created with similar characteristics to the development computer.

The intention was to reproduce what was created on the author's computer but in a Windows virtual machine by installing Wamp and importing the SQL database into the same www file. However, taking into account that the connections were no longer local, it was necessary to open port 80 to receive requests from the tablets used in the pilot test of Chapter 4. Otherwise, it was not possible to obtain the data coming from or brought to the database. As this is an academic work, where security was not the core, we chose to make only Http connections (port 80). However, in the Conclusions chapter, more precisely in the subsection of future work, it was clarified how to proceed in relation to security issues or overcrowding of users for a possible entry into the applications market.

2) Demonstration: The first game created was "Word Pairs" (Fig. 4). A page with 12 face down cards with words on the other faces is displayed. The objective of the game is to find 6 pairs of identical words. These will always be chosen randomly from the list of answers associated with the previous "Quiz4" question. First you click on one of the cards and its contents appear and then you click on another one face down allowing to play again. The second game, "Image Pairs" (Fig. 5), similar to the first, but uses images instead of words. Whenever a pair is made, an incentive system is activated that throws confetti in order to stimulate the user.

The third game is "Different Word" (Fig. 6). Using the same type of list of answers associated with the question, 16 words are displayed on the screen, however one of them does not belong to the theme of the others and that is what you have to discover. This exercise, unlike the first one that trains memory, serves to stimulate reasoning and understanding.

Finally, the game "Sequence" (Fig. 7), forces the user to memorize a set of 3 images, when clicking the "Play" button, and then he has to discover the correct sequence of figures.

In this game it is also allowed to repeat the slide show so that the user has a new opportunity to remember them before answering. Once again, the same incentive mechanism is also present whenever the question is correct, because it is important to maintain the user's interest.

All games start with specific instructions to help users understand the game. If more attempts are needed to understand them, you can always click on the button with the megaphone symbol.

3) Evaluation: In this evaluation, the Social Team analyzed the questions and answers and approved them as final and possible to use in the project.

The audio component was also praised, as it further automated the help and understanding of the exercises and allowed for a reduction in the need for external support, making the app more autonomous.

Regarding the IT team, it was noticed that the features for editing the answers in the questionnaire section and the lack, of a scoring scheme attributed to the games had not yet been implemented.

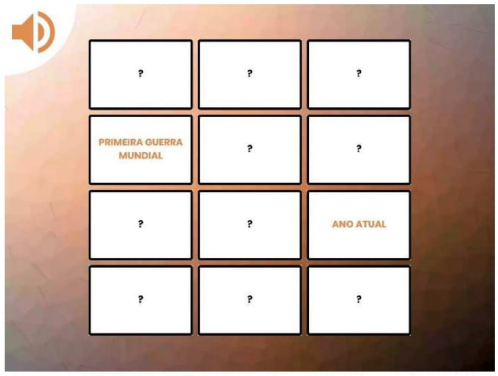

Fig. 4. Word Pairs.

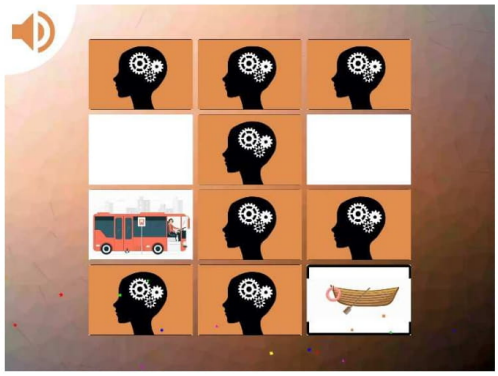

Fig. 5. Image Pairs.

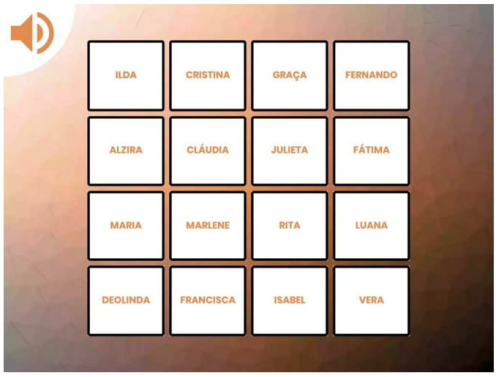

Fig. 6. Different Word.

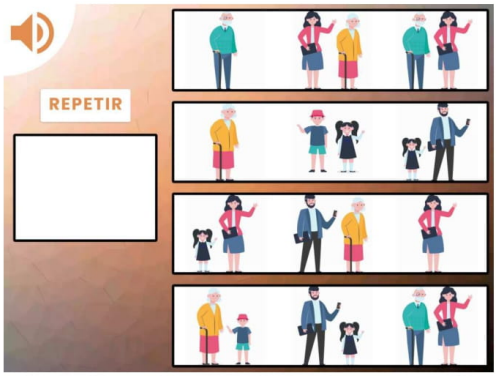

Fig. 7. Sequence.

IV. Results and Discussions

The system validation was carried out based on the collaboration between Health School of Alcoitão and ISCTE research units.

A. User Analysis

Using a number of students volunteers the developed APP was previous tested. The test with final users involved 8 elderly people who, accompanied by these students, performed the memory training based on AMELIA application. The training was performed once a day for a week. Having only access to 5 tablets, the tests took 2 weeks with 4 users each.

Before collecting and analyzing the results, it was necessary to classify the elderly volunteers in groups through 3 types of evaluation. An intensive questionnaire was carried out, which was solved by each elderly person with the help of the student in charge, and the results in Table I were obtained. The 3 metrics used were Mini Mental State Examination (MMSE), Lawton Index and Barthel Scale.

The MSSE is a test with a series of questions, which are usually asked by a doctor, to identify cognitive impairment, e.g. problems with thinking, communicating or reasoning. It is used in situations of brain damage and to detect if someone has cognition problems or dementia.

TABLE I. User Evaluation Scores

Users	MMSE	Lawton	Barthel
U1	Without Cognitive Impairment	Independent	Totally Independent
U2	Without Cognitive Impairment	Independent	Totally Independent
U3	Without Cognitive Impairment	Independent	Totally Independent
U4	Without Cognitive Impairment	Slightly Dependent	Totally Independent
U5	Without Cognitive Impairment	Independent	Totally Independent
U6	With Cognitive Impairment	Independent	Totally Independent
U7	With Cognitive Impairment	Independent	Totally Independent
U8	Without Cognitive Impairment	Independent	Totally Independent

The Lawton Index is a test that aims to assess the conditions of an elderly person when performing instrumental activities of their daily lives, e.g., using the telephone, preparing meals, taking medication. It aims to assess the patient's autonomy to perform daily routine tasks and see if a follow-up plan is needed.

The Barthel scale is similar to the second because it measures an individual's ability to perform various activities of their daily lives and assigns scores to their degree of dependence. The Barthel index can assess and show the ability of individuals with neurological problems.

Table I results were obtained considering the scores that allows us to draw some conclusions. Thus, from eight participants, only two showed cognitive decline in the MMSE test and all of them, with the exception of U4, showed independence results in the other 2 tests.

B. Analysis of Application Scores

Then, Table II was created based on the scores obtained daily in the application exercises.

As you can see the results of the games are distributed by average of and are separated by "Quiz 4" score and "Memory Games" score for a better analysis of the data. Observing the data collected by the application, several observations can be made. Most users with better cognitive scores on the MMSE also had very high scores on memory games, like U1, U2 and U5 (53,52,85,50,71). At the opposite end, it was also found, as is the case of user U7, who showed cognitive decline and obtained very low scores in the application (36.85). However, not all results were as expected and the most critical were the U6 and U8. Although U6 has a cognitive defect, its scores (52.85) were very high in the application, and the opposite happened with U8 (38.14). It was decided to further analyze the MMSE questionnaires carried out by these two users in order to try to justify these discrepancies in the results.

The U6 made mistakes in two exercises, the orientation, and the evocation (remember the sequence of words said aloud). In this way, it was expected that you would get weaker scores in the games, however, as these are random, it is not possible to find out if U6 got too many "Sequences", for example. However, considering that 7 games were played and each one with 6 questions, where there is the possibility of sequences appearing, the probability that U6 has performed enough sequences is quite high and, therefore, more negative results should appear. It is then concluded that other factors may have affected the sample, e.g. the exercises being more

accessible than the MMSE, the scoring scheme being more beneficial than detrimental or even the use of some external support. In the case of U8, the exercises he got wrong in the Mini Mental State Examination are related to language and perceptibly. According to the feedback present in the evaluation of the following section, it is relevant to note that this may have been the factor that led to the low scores in the application, due to difficulties in understanding the exercises.

Regarding the "Quiz 4" scores, all remained constant and with maximum or almost maximum scores, which proves that the questions about the past are the easiest for these users.

TABLE II. USER EVALUATION SCORES

Users	Average Quiz 4 Points (MAX = 11)	Average Memory Points (MAX = 55)
U1	10.50	54.00
U2	10.57	52.85
U3	10.34	45.57
U4	10.00	50.10
U5	10.71	50.71
U6	0.85	52.85
U7	9.57	36.85
U8	10.71	38.14

1) Evaluation: In addition to carrying out the pilot tests, the user group was also asked to complete a feedback questionnaire. This was aimed to receive the necessary criticism to improve the application and verify if the App had a positive impact on their lives.

The questions were asked in order to better structure the criticisms for a better understanding of the feedback. There were some observations in relation to the size of the buttons and words and in relation to the formulation of the instructions of the games, namely the "Sequence" and "Different Word".

The duration of the exercises was pleasing to most, with no negative observations, and the regularity with which they preferred to play rivaled a lot between "playing every day" and "only twice a week". As for autonomy, everyone felt it was easy to use the application alone, however only after getting used to it for some time. Regarding additional features, it was proposed to create more games and more stimulation tools [10], such as other types of confetti or the presentation of performance at the end of training. As for the app itself, the reviews were very positive and reinforced the interest in continuing to use this app. The most commented aspect was the fact that it is not exclusively dedicated to memory training and has a personal life story taste. However, they would like it to be even more personal with the addition of more questions and images related to their lives.

V. CONCLUSIONS

This study aimed to create a memory training mobile application AMELIA based on the Life Story model and to verify the receptivity of this new approach as well as its results in elderly volunteers. For the development, three DSRs were carried out, which contributed a lot to create a more complete final APP. The analysis of the data collected showed that the application pleased most of the users. The APP represent an effective tool that can be used with good results on cognitive training. The relevance of associating the life story with memory exercises was also proven, as they helped to stimulate the elderly' training and their interest.

Finally, as future work, it is proposed to carried out tests for an extended period of time with more users and to better understand the impact of the developed application. Additionally, a development of an appropriate architecture for market entry, such as the use of reverse proxies and elastic cloud platforms are also considered.

ACKNOWLEDGMENTS

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APPENDIX I

Technical Program EPE 2022, page 19

	Fe2O3 magnetic nanoparticles via physical vapour deposition (PVD)		Patrascu, Georgiana ; Schreiner, Cristina
97	Composites with Nano Conductive Channels Architecture Uniformly Distributed Through the Thickness of the Material and Oriented in the Magnetic Field (WIEPMDA)	**(WIEPMD)**	Aradoaei, Mihaela*, Lucaci Andreea Maria, Aradoaei Sebastian, Schreiner Cristina Mihaela, Nastasache Maria
129	Compression Of Acquired Data In Order To Make Transmission And Processing More Efficient	**(WIEPMD)**	Pintilei Madalina Ancuta, Ursu Ileana, Aradoaei Sebastian, Schreiner Cristina Mihaela, Aradoaei Mihaela, Olteanu Alin
137	Continuous Improvement in Education Based on Deming Model in Worldwide Context	**(WIEPMD)**	Scarlatache, Vlad-Andrei A*; Aradoaei, Sebastian T; Olariu, Marius Andrei; Filip, Tudor Alexandru; Scarlatache, Florina
96	Obtaining nanocomposite films with predefined thermal conductivity, with controlled anisotropy	**(WIEPMD)**	Aradoaei Mihaela*, Lucaci Andreea Maria, Aradoaei Sebastian, Schreiner Cristina, Ciobanu Romeo Cristian
160	Piezoelectric Nanofibrous Composite Materials for Energy and Electronic Applications	**(WIEPMD)**	Fabiani Davide*, Ciobanu Romeo Cristian, Aradoaei Mihaela

7th International Workshop on Electromagnetic Compatibility and Engineering in Medicine and Biology (ECEMB)

10.15 -11.45 Amphitheater E2

Chairmen: Paul Bechet, Eduard Lunca

65	SNR measurement of ionospheric channels for availability evaluation under NVIS propagation	**(ECEMB)**	Sorecau, Emil*; Sorecau, Mirela; Craiu, Neculai ; Sarbu, Annamaria; Bechet, Paul
115	Low frequency magnetic field survey in different areas of a hospital's environment	**(ECEMB)**	Pavel, Ionel*; David, Valeriu; Roman, Marina-Georgiana; Bordas, Alexandru-Marian
161	Gait Rehabilitation in Virtual Reality Serious Game Interactive Scenarios	**(ECEMB)**	Beatriz dos Santos Gonçalves, Octavian Postolache, José Miguel Dias Pereira
169	Memory Training Interface for Elderly based on Mobile APP	**(ECEMB)**	Andre Baptista, Octavian Postolache, Diana Mendes, Elisabeth Reis Dalia Nogueira
173	Assessment of Extremely Low-Frequency Magnetic Field from Multiple High-Voltage Overhead Power Lines in Parallel Configuration	**(ECEMB)**	Vornicu, Silviu; Lunca, Eduard; Neagu, Bogdan Constantin; Baiceanu, Florin Constantin

APPENDIX J

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By Eduard Lunca

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Memory Training Interface for Elderly based on Mobile APP

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***Abstract*—Currently, the world population is aging rapidly and one of the characteristics that will accompany this new generation of elderly people is the concept of "aging in place", which means aging at home. The quality of life of the elderly in their home depends on the maintenance of their cognitive and motor skills and, therefore, the way to encourage them to remain autonomous and reduce institutionalization is by training their memory. To help on solving problems like cognitive decline in elderly population it was developed a memory training mobile application based on life story work. The APP has the contribution of many professionals and was validated with a small group of elderly users. Analysis of the collected data is presented in the work to underline the effectiveness of developed APP on cognitive training.**

***Keywords*—mobile app, mobile application, intelligent systems, serious game, Pervasive Computing, cognitive decline, cognitive memory training**

I. Introduction

Currently, the world population is aging rapidly, and it is estimated that the number of people over 60 will increase by up to 10 percent [1]. One of the characteristics that will accompany this new generation of elderly people is the concept of "aging in place" [2], which means aging at home. This is because with the emergence of better living conditions and well-being in their homes, the elderly will choose to spend their last stage of life at home.

With aging, people begin to face numerous diseases and disabilities, however, with technological advances, many of them can be softened. Given the aging scenario at home, possibly other problems will appear, such as loneliness and cognitive decline. These problems not only come from age, but also from lack of physical exercise and social isolation. Knowing that dementia is associated with the previously mentioned factors, there is an urgent need to seek the necessary follow-up to avoid worsening the health status of the elderly [1] [3] [4].

The quality of life of the elderly in their home depends on the maintenance of their cognitive and motor skills and, therefore, the way to encourage them to remain autonomous and reduce institutionalization is by training their memory.

Current technologies are increasingly accessible to anyone, facilitating interpersonal contact. In this way, by providing solutions for cognitive decline through technological systems [5], we can contribute to a better quality of life for the elderly, especially mental health [6] [1]). To help solve these problems, it was proposed to develop a memory training application based on life story work.

This type of work consists of carrying out questions and questionnaires based on the life of an elderly person, in order to better understand their past [7] [8]. The personal information collected is then used by healthcare professionals to help their patients reflect on their identity, give them comfort by remembering their family or simply to follow their preferences and needs. Unfortunately, this work is very dependent on the doctor-patient interaction, and this project aims to automate this work and associate it with the performance of cognitive exercises.

II. Methodology

For the development of the application in question, the Design Science Research (DSR) methodology was used. As it is about the creation of a physical artifact and not the elaboration of a theoretical study, it is necessary to follow the methodology idealized by Peffers (2007).

In image x, this methodology is composed of six phases. The first two steps were already carried out at the beginning of this study, where the problem in question was discussed, as well as the objectives and the idealized solution. Then followed three phases that together can be iterated multiple times in order to improve the application through the feedback received in the evaluation phase. Unlike a methodology like Waterfall, DSR is agile and flexible and allows for requirements modification and adaptations during the development processes.

Another phase considered relevant in this work was added to the Peffers model [9], "Pilot Test and Results Analysis". In addition to the demonstrations made to the professionals involved, it was decided to create a special stage for a last test with a small sample of users. The objective of this stage was to receive feedback from the users of the application, as they were the biggest beneficiaries of this project.

III. Artifact Development and Evaluation

The Before starting the development of the application, it was necessary to create a list of requirements by professionals linked to the project. This team was made up of 5 people and the team was divided into two distinct parts for greater

flexibility: IT Team (features, architecture, programming, database, server), Social Team (visual aspects, cognition training, language, Life Story Work).

The development process involved 3 iterations and in the evaluation phases both teams gave their opinion on their area in order to make the feedback as constructive and relevant as possible. The main requirements are following presented:

1. User registration and authentication;
2. Memory games;
3. Remote Database to save users, questions, answers and scores;
4. Solutions to help illiterate seniors;
5. Server that allows you to use the application anywhere;
6. Platform compatible with phones and tablets (adjustable to different sizes without affecting the design);
7. Simplistic design suitable for the elderly;
8. Tablet must allow multiple accounts;
9. Save each user's life story.

A. DSR Cycle 1

1) Development: It was decided to develop the application in Java in Android Studio.

Although one of the project's proposals involves the creation of a remote database and a server, it was decided at first to use the development computer as a server. For this, the WAMP software was installed, which function is to automatically install a collection of important software for this experiment. Throughout the project multiple php files were created which were invoked in the built java code. These files per- formed one of two functions, GET or POST, and aimed to fetch or publish elements in the database, respectively. In this first iteration, two interfaces were developed.

The first, corresponding to "WSign Up", allows the user to create his profile with a username, email and password through a file invoked in java with a POST command. This was given the name signup.php and placed in the WWW folder of Wamp as it is responsible for generating dynamic content on the "World Wide Web".

The second interface, corresponding to" Login", had a similar construction to the first one, also with its own php file, login.php, which deals with user authentication, previously created, through username and password.

A database was also created in PHPMyadmin with only one table, named Users, which was used to register the users inserted in the "Sign Up" and to authenticate the data inserted in the "Login".

2) Demonstration: The demonstration phase served to show the development created so far.

On the registration page it is possible to add the name, username, email and password and at the end click on a button that takes you directly to the next page (carried out in DSR Cycle 2). On the "Login" page there are only two fields to be completed and which, in turn, will be analyzed by the php file to see if they match the data present in the DB. As for the database, the Users table was organized with all the fields of the "Sign Up" and, if necessary, other fields could be added.

3) Evaluation: As there was still no progress in relation to the social part of the project, this phase was entirely dedicated to obtaining feedback from the IT team. Despite the well-constructed registration and authentication components, there was a criticism regarding the login process. Although most people usually are able to create user accounts, logging in and remembering passwords, the target audience presents specific difficulties. Bearing in mind this the application was designed to have an easy to use interface.

That it is necessary to have another approach to login. This approach should allow the user to be able to login quickly and efficiently without having to type or remember complicated passwords. Everything else had a positive evaluation and the care to be taken with the construction of the rest of the database was reinforced, since the results and the analysis of the success of the application depend on the organization of the same login.

This approach should allow the user to be able to login quickly and efficiently without having to type too much or remember complicated passwords. Everything else had a positive evaluation and the care to be taken with the construction of the rest of the database was reinforced, since the results and the analysis depends by the success of the application.

B. DSR Cycle 2

1) Development: In the second iteration of the DSR, we started by first analyzing the feedback obtained in the previous evaluation and came to the conclusion that one of the best ways to correct the problem for the "LogIn" was to create a new type of authentication. Instead of typing the username and password, these two words were associated with a QR Code and a java code capable of interpreting it was developed. It was therefore changed to a page with a camera, in which the user only had to point the tablet at the QR Code present on a phone screen or paper to connect.

Then, before creating the pages with questions and answers about the user's life, it was necessary to create a list of suitable questions. The Social Team provided a very relevant document regarding the type of questionnaire carried out in the life story work; however, it was concluded that there would have to be some restructuring in the questions. In the document, all questions were open-ended, and this prevented the answers from being systematized and reused throughout the games. It was understood that the best way to gather information and obtain answers was through closed-ended questions.

The "List of Questions" and "List of Answers" are presented in Fig. 1 and Fig. 2 as part of implemented APP. The APP pages are the only ones in the application where access is supposed to be exclusive to accompanying persons or family members of the elderly. This is because all the games and interactions of the application will be based on the life story of each user, more precisely the answers entered. For these reasons, it was decided to make the pages as complete as possible instead of keeping them simplistic, as they are not dedicated to the elderly.

In order to be able to store all the information, the database had to be expanded by creating 4 more tables: one to store the answers, one to store the questions, one to store the answers given by each user and another to store the scores of each player.

Finally, after having built and organized the necessary structure for the development of serious games, the first interactive page for users, "Quiz 4" (Fig. 3), was also created. In this exercise, each question of the questionnaire and 4

possible answers were retrieved from the database and everything was presented on the screen in a very simple way.

2) Demonstration: This demo served to show the android pages created, as well as the changes made to the "Login" page.

The application starts on this page, which now presents only one camera capable of reading QR codes. After authentication, the "List of Questions" page is accessed, in which is presented a scrollable list of all the questions present in the database.

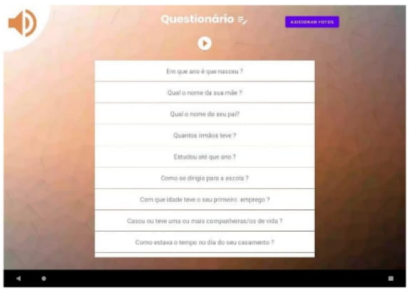

Fig. 1. List of Questions.

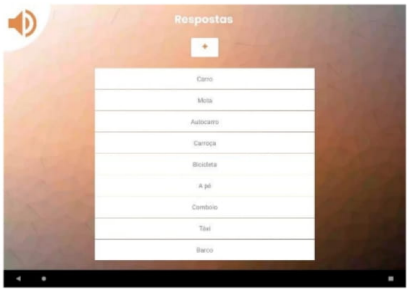

Fig. 2. List of Answers.

Fig. 3. Quiz 4.

The user must click on each question in order to display the corresponding answers screen. It shows up the "List of Answers" page, where the helper must, with the cooperation of the elderly person, click on one of the possible answers in order to create the user's life story. Whenever a question is answered, it is automatically added to the database and the screen returns to "List of Questions" in order to continue answering. At the end of the quiz, the user can finally start playing "Quiz 4", a page with 1 question and 4 answers, in which 3 of them are randomly false and the other one is the true answer corresponding to the previously stored one. One of the features created for this game was an audio button that allows the user to hear all the text on the screen and thus help the elderly person in case of reading difficulties or limitations.

3) Evaluation: In this evaluation, both teams participated as there was already social and technological content to be analyzed. Regarding the questions, the Social Team criticized the language used and the type of answers, e.g. one of the questions said "What is your position in relation to your brothers" with answers "the youngest, the oldest, the middle one" and in this example it was suggested that the question was changed to "How many siblings do you have".

As far as "Quiz 4" is concerned, it was suggested that there were visual improvements to make it more appealing, however both teams praised the layout and size of the buttons as it proved to be accessible to the target users.

They also consider the possibility of reproducing the question and answers via audio well implemented, as it was a good solution for users with low literacy levels. One of the observations made by the Social Team was the need to add memory games. This is because the first memory to be lost is the most recent one and, therefore, in order to train users' cognition, it was also important to perform cognitive training exercises in addition to life story questions.

Regarding the application itself, the technology team praised the QR Code solution but criticized 3 aspects related to the lists' activities. The "List of Questions" did not allow to see which of the questions had already been answered, and the user had to remember if he had already answered. As for the "List of Answers", there was no option to add an answer that was not present in the database and there was also no possibility to edit if it had been incorrectly answered.

C. DSR Cycle 3

1) Development: Again, at the beginning of the cycle, the new functionalities to be added or changed were analyzed, according to the criticisms made in the previous phase. It started by prioritizing the improvement of the database questions where a new list of questions was built.

A feature was also integrated in the "Response List" that allows adding new answers to the database. Regarding the gameplay, as suggested, it was decided to alternate "Quiz 4" with memory and comprehension games, where each one relates directly to the theme of the previous game. Demonstrating with a real example, in "Quiz 4" appears the question "Where was your wedding?" and after answering, the next game is necessarily about this same theme "wedding places", e.g. a cognitive game to find pairs of possible places for marriages. The Quiz 4 final questions are:

- What year were you born?
- What is your mother's name?
- What is your father's name?

- How many brothers did you have?
- Until what year did you study?
- How did you go to school?
- At what age did you have your first job?
- Married or had one or more life partners
- How was the weather on your wedding day?
- Where was your wedding?
- How many children did you have?
- What is your favorite animal?

Several types of approaches were investigated from which 4 types of games emerged, explained later in the demonstration, and all of them will be based on the answers to the previous, "Quiz 4", question. In order to make the application more interactive and visually appealing, we decided to associate these answers with corresponding images, so that we could interact with the user without always using words.

Thanks to the positive reviews regarding the audio help, it was decided to expand the concept to the entire application. A button was created in all activities with audio instructions to help users. These instructions have also been automated to start as soon as the user enters a new page and the button allows you to listen again as many times as you want.

Finally, a fundamental part of this project to carry out tests anywhere and with any user was created, the server. We chose to generate a virtual machine on the Amazon Elastic Compute Cloud (EC2) that was created with similar characteristics to the development computer.

The intention was to reproduce what was created on the author's computer but in a Windows virtual machine by installing Wamp and importing the SQL database into the same www file. However, taking into account that the connections were no longer local, it was necessary to open port 80 to receive requests from the tablets used in the pilot test of Chapter 4. Otherwise, it was not possible to obtain the data coming from or brought to the database. As this is an academic work, where security was not the core, we chose to make only Http connections (port 80). However, in the Conclusions chapter, more precisely in the subsection of future work, it was clarified how to proceed in relation to security issues or overcrowding of users for a possible entry into the applications market.

2) Demonstration: The first game created was "Word Pairs" (Fig. 4). A page with 12 face down cards with words on the other faces is displayed. The objective of the game is to find 6 pairs of identical words. These will always be chosen randomly from the list of answers associated with the previous "Quiz4" question. First you click on one of the cards and its contents appear and then you click on another one face down allowing to play again. The second game, "Image Pairs" (Fig. 5), similar to the first, but uses images instead of words. Whenever a pair is made, an incentive system is activated that throws confetti in order to stimulate the user.

The third game is "Different Word" (Fig. 6). Using the same type of list of answers associated with the question, 16 words are displayed on the screen, however one of them does not belong to the theme of the others and that is what you have to discover. This exercise, unlike the first one that trains memory, serves to stimulate reasoning and understanding.

Finally, the game "Sequence" (Fig. 7), forces the user to memorize a set of 3 images, when clicking the "Play" button, and then he has to discover the correct sequence of figures.

In this game it is also allowed to repeat the slide show so that the user has a new opportunity to remember them before answering. Once again, the same incentive mechanism is also present whenever the question is correct, because it is important to maintain the user's interest.

All games start with specific instructions to help users understand the game. If more attempts are needed to understand them, you can always click on the button with the megaphone symbol.

3) Evaluation: In this evaluation, the Social Team analyzed the questions and answers and approved them as final and possible to use in the project.

The audio component was also praised, as it further automated the help and understanding of the exercises and allowed for a reduction in the need for external support, making the app more autonomous.

Regarding the IT team, it was noticed that the features for editing the answers in the questionnaire section and the lack, of a scoring scheme attributed to the games had not yet been implemented.

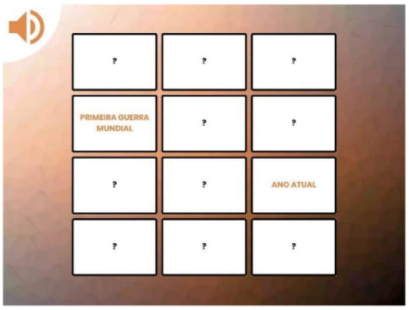

Fig. 4. Word Pairs.

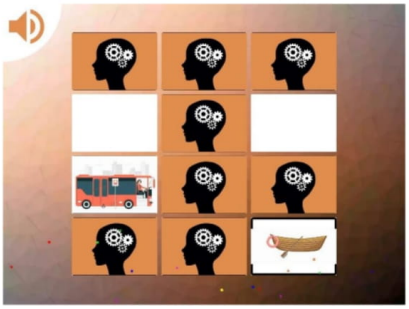

Fig. 5. Image Pairs.

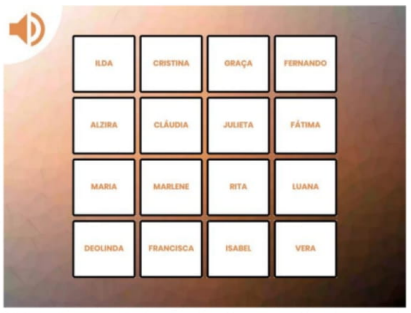

Fig. 6. Different Word.

Fig. 7. Sequence.

IV. Results and Discussions

The system validation was carried out based on the collaboration between Health School of Alcoitão and ISCTE research units.

A. User Analysis

Using a number of students volunteers the developed APP was previous tested. The test with final users involved 8 elderly people who, accompanied by these students, performed the memory training based on AMELIA application. The training was performed once a day for a week. Having only access to 5 tablets, the tests took 2 weeks with 4 users each.

Before collecting and analyzing the results, it was necessary to classify the elderly volunteers in groups through 3 types of evaluation. An intensive questionnaire was carried out, which was solved by each elderly person with the help of the student in charge, and the results in Table I were obtained. The 3 metrics used were Mini Mental State Examination (MMSE), Lawton Index and Barthel Scale.

The MSSE is a test with a series of questions, which are usually asked by a doctor, to identify cognitive impairment, e.g. problems with thinking, communicating or reasoning. It is used in situations of brain damage and to detect if someone has cognition problems or dementia.

TABLE I. User Evaluation Scores

Users	MMSE	Lawton	Barthel
U1	Without Cognitive Impairment	Independent	Totally Independent
U2	Without Cognitive Impairment	Independent	Totally Independent
U3	Without Cognitive Impairment	Independent	Totally Independent
U4	Without Cognitive Impairment	Slightly Dependent	Totally Independent
U5	Without Cognitive Impairment	Independent	Totally Independent
U6	With Cognitive Impairment	Independent	Totally Independent
U7	With Cognitive Impairment	Independent	Totally Independent
U8	Without Cognitive Impairment	Independent	Totally Independent

The Lawton Index is a test that aims to assess the conditions of an elderly person when performing instrumental activities of their daily lives, e.g., using the telephone, preparing meals, taking medication. It aims to assess the patient's autonomy to perform daily routine tasks and see if a follow-up plan is needed.

The Barthel scale is similar to the second because it measures an individual's ability to perform various activities of their daily lives and assigns scores to their degree of dependence. The Barthel index can assess and show the ability of individuals with neurological problems.

Table I results were obtained considering the scores that allows us to draw some conclusions. Thus, from eight participants, only two showed cognitive decline in the MMSE test and all of them, with the exception of U4, showed independence results in the other 2 tests.

B. Analysis of Application Scores

Then, Table II was created based on the scores obtained daily in the application exercises.

As you can see the results of the games are distributed by average of and are separated by "Quiz 4" score and "Memory Games" score for a better analysis of the data. Observing the data collected by the application, several observations can be made. Most users with better cognitive scores on the MMSE also had very high scores on memory games, like U1, U2 and U5 (53,52,85,50,71). At the opposite end, it was also found, as is the case of user U7, who showed cognitive decline and obtained very low scores in the application (36.85). However, not all results were as expected and the most critical were the U6 and U8. Although U6 has a cognitive defect, its scores (52.85) were very high in the application, and the opposite happened with U8 (38.14). It was decided to further analyze the MMSE questionnaires carried out by these two users in order to try to justify these discrepancies in the results.

The U6 made mistakes in two exercises, the orientation, and the evocation (remember the sequence of words said aloud). In this way, it was expected that you would get weaker scores in the games, however, as these are random, it is not possible to find out if U6 got too many "Sequences", for example. However, considering that 7 games were played and each one with 6 questions, where there is the possibility of sequences appearing, the probability that U6 has performed enough sequences is quite high and, therefore, more negative results should appear. It is then concluded that other factors may have affected the sample, e.g. the exercises being more

accessible than the MMSE, the scoring scheme being more beneficial than detrimental or even the use of some external support. In the case of U8, the exercises he got wrong in the Mini Mental State Examination are related to language and perceptibly. According to the feedback present in the evaluation of the following section, it is relevant to note that this may have been the factor that led to the low scores in the application, due to difficulties in understanding the exercises.

Regarding the "Quiz 4" scores, all remained constant and with maximum or almost maximum scores, which proves that the questions about the past are the easiest for these users.

TABLE II. USER EVALUATION SCORES

Users	Average Quiz 4 Points (MAX = 11)	Average Memory Points (MAX = 55)
U1	10.50	54.00
U2	10.57	52.85
U3	10.34	45.57
U4	10.00	50.10
U5	10.71	50.71
U6	0.85	52.85
U7	9.57	36.85
U8	10.71	38.14

1) Evaluation: In addition to carrying out the pilot tests, the user group was also asked to complete a feedback questionnaire. This was aimed to receive the necessary criticism to improve the application and verify if the App had a positive impact on their lives.

The questions were asked in order to better structure the criticisms for a better understanding of the feedback. There were some observations in relation to the size of the buttons and words and in relation to the formulation of the instructions of the games, namely the "Sequence" and "Different Word".

The duration of the exercises was pleasing to most, with no negative observations, and the regularity with which they preferred to play rivaled a lot between "playing every day" and "only twice a week". As for autonomy, everyone felt it was easy to use the application alone, however only after getting used to it for some time. Regarding additional features, it was proposed to create more games and more stimulation tools [10], such as other types of confetti or the presentation of performance at the end of training. As for the app itself, the reviews were very positive and reinforced the interest in continuing to use this app. The most commented aspect was the fact that it is not exclusively dedicated to memory training and has a personal life story taste. However, they would like it to be even more personal with the addition of more questions and images related to their lives.

V. CONCLUSIONS

This study aimed to create a memory training mobile application AMELIA based on the Life Story model and to verify the receptivity of this new approach as well as its results in elderly volunteers. For the development, three DSRs were carried out, which contributed a lot to create a more complete final APP. The analysis of the data collected showed that the application pleased most of the users. The APP represent an effective tool that can be used with good results on cognitive training. The relevance of associating the life story with memory exercises was also proven, as they helped to stimulate the elderly' training and their interest.

Finally, as future work, it is proposed to carried out tests for an extended period of time with more users and to better understand the impact of the developed application. Additionally, a development of an appropriate architecture for market entry, such as the use of reverse proxies and elastic cloud platforms are also considered.

ACKNOWLEDGMENTS

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