FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

User-Driven Design, Development and Evaluation of a Tablet-Based Cognitive Gaming Platform for Seniors

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Master in Informatics and Computing Engineering

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Abstract

Population ageing is becoming more of a reality as time goes by. The percentage of seniors in the overall population is growing each year and it is only believed to grow even more in the next years. Associated with ageing are several age-related changes that can affect seniors both physically as well as cognitively which, if ignored, can impose serious threats in their quality of life and self-esteem.

Digital games are believed to hold the potential to stimulate the brain and help reduce and even stop the natural decline of cognitive abilities. However, the way that technology is designed and implemented does not favours the needs and goals of the senior population. As such, their receptivity towards computers, and consequently digital games is very low, as they have difficulties understanding the benefits that such systems can bring. However, in the last few years, new types of devices possessing more intuitive ways of interaction such as tablets and smartphones have emerged, which can be a new opportunity to change the way seniors perceive technology.

The primary goal of this project is to design, develop and evaluate a tablet-based gaming platform with its target audience being the senior population. The games provided by the gaming platform have the objective of stimulating various areas of the cognitive domain in order to help maintain, or even increase, the mental capabilities of the senior players contributing to an improved overall well-being. In addition, the game platform also aims at promoting social interaction between seniors by means of group play activities and game results sharing using a ranking mechanism.

To achieve these goals, we start by performing a study of the specific characteristics of the senior user as well as what makes a game appealing to the player, and why the tablet proves to be an advantageous device to our target audience. With the results of our research we develop a solution that incorporates cognitive and social mechanisms into its games, while performing iterative evaluations together with the final user by adopting a user-centered design methodology. In each design phase a pre-selected group of senior participants experiments with the game platform and provides feedback to improve its features and usability. Through a series of short-term and long-term evaluations the game platform proves to be appealing to its intended users providing good usability and an enjoyable gaming experience.

Resumo

O envelhecimento da população está cada vez mais a tornar-se uma realidade à medida que o tempo passa. A percentagem de idosos na população geral está a crescer a cada ano e é previsto que continue a crescer ainda mais nos próximos anos. Associado com o envelhecimento estão diversas mudanças físicas e cognitivas que, se ignoradas, podem impor ameaças graves na sua qualidade de vida e auto-confiança.

Acredita-se que os jogos digitais tenham o potencial de estimular o cérebro e ajudar a reduzir ou até mesmo parar o declínio natural das capacidades cognitivas. No entanto, a forma como a tecnologia é desenhada e implementada não favorece as necessidades e objectivos da população sénior. Como tal, a sua receptividade para com os computadores é muito baixa, pois sentem dificuldade em compreender os benefícios que esses sistemas podem trazer. No entanto, nos últimos anos, novos tipos de dispositivos com métodos de interação mais intuitivos como *tablets* e *smartphones* têm emergido, o que pode significar uma nova oportunidade para mudar a forma como os séniores vêm a tecnologia.

O objectivo principal deste projecto é o de desenhar, desenvolver e avaliar uma plataforma de jogos para *tablets* sendo o seu público alvo a população sénior. Os jogos oferecidos pela plataforma de jogos têm o objectivo de estimular as várias áreas do domínio cognitivo de forma a ajudar a manter, ou até mesmo aumentar, as capacidades mentais do jogadores séniores contribuindo para uma melhoria geral do seu bem-estar. Mais, a plataforma de jogos também visa promover a interacção social entre séniores por meio de actividades em grupo e partilha de resultados de jogo via um mecanismo de classificações.

Para atingir estes objectivos, começamos por efectuar um estudo das características específicas do utilizador sénior assim como perceber o que torna um jogo atraente para o jogador, e porque é que o *tablet* prova ser um dispositivo vantajoso para o nosso público alvo. Com os resultados da nossa investigação desenvolvemos uma solução que incorpora mecanismos cognitivos e sociais nos seus jogos, ao mesmo tempo que são efectuadas avaliações iterativas com o utilizador final por meio de uma metodologia de desenho centrada no utilizador. Em cada fase de desenho um grupo pré-selecionado de participantes sénior experimenta a plataforma de jogos e fornece *feedback* para melhorar as suas funcionalidades e usabilidade. Através de um conjunto de testes de curto e longo prazo a plataforma de jogos prova ser atraente para os seus utilizados oferecendo uma boa usabilidade e uma agradável experiência de jogo.

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João Marques

"I haven't failed. I've just found 10,000 ways that won't work."

Thomas A. Edison, on the invention of the lightbulb.

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Abbreviations

FUSAMI	Fraunhofer Usage Mining
HCI	Human-Computer Interaction
ICT	Information and Communications Technology
iOS	iPhone Operating System
LCD	Liquid Crystal Display
OS	Operating System
PC	Personal Computer
PD	Participatory Design
PIN	Personal Identification Number
UCD	User-Centered Design

Chapter 1

Introduction

Population ageing is growing at a surprising rate. There are approximately 810 million persons aged 60 years or over in the world and this number is projected to grow to more than 2000 million by 2050 [oED13]. As people age, their self-esteem tends to lower and their ability to independently perform regular daily tasks decreases as well, much due to the natural age-related changes that affect the human body and mind [Zim09].

One commonly held belief is that seniors are more likely to resist change and are unwilling to engage in new technology however, many studies that examined the attitude of seniors towards computers found that they are indeed, receptive to their use [CL09]. The use of technology has the potential to improve the quality of life for the senior population [CL09], and as such, this is a concern that researchers worldwide are taking increasing notice. One of the most noted reasons for lack of motivation of seniors to use computers is the lack of perceived benefit [WHH10]. Seniors tend to believe that they have no use for such device and there is no gain to them, either because the computer does not satisfy their needs or they do not understand the technology well enough to perceive their benefits.

In recent years, new devices have been revealed that possess the potential to change the way seniors perceive technology. Devices such as tablets and smartphones are incorporated with touch-screens that provide a more natural and intuitive method of interaction, which lowers the skill requirements that usually come attached with other type of peripherals such as the keyboard and mouse [WWR+05].

As such, this project proposes a solution in the form of a game platform designed particularly with seniors players in mind, exploiting cognitive stimulation games that could help seniors maintain their mental capabilities, thus improving their overall quality of life. The game platform would take advantage of a tablet device which presents a more natural and intuitive interaction paradigm that could potentially help seniors perceive the advantages that technology can bring to their lives. Additionally, the game platform would serve as a community environment providing

a diverse range of social mechanisms, such as group play and game results sharing which would hopefully help promote healthy social interactions.

Ultimately, it is strongly believed that this project could help seniors realize all the collateral benefits that new technology can deliver in their everyday lives to improve their overall well-being.

1.1 Background

The project of creating a game platform specifically for seniors was promoted by *Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions* (Fraunhofer AICOS[1]) located in Porto, Portugal. Fraunhofer AICOS mission is to *enhance people's living standards by offering them intuitive and useful technology solutions that can facilitate their access to Information and Communication Technologies*.

This project acts as a component for another project at Fraunhofer AICOS named *Ambient Assisted Living for All* (AAL4ALL), which consists in defining specific standards for Ambient Assisted Living solutions for the Public Primary Health Care sector, addressing aspects of medical and social interaction with elderly persons.

Lastly, the initial research behind the development of a gaming platform for seniors began with the work of two colleagues from Fraunhofer AICOS in 2011, serving as the foundation for this thesis. Their research proved to be a valuable asset directly influencing the outcome of this project.

1.2 Goals and Contribution

The main goal of this thesis is to design, develop and evaluate a tablet-based gaming platform that provides mental stimulation through a series of games targeting several different areas of the cognitive domain, its primary audience being the senior population. Alongside the primary objective, the game platform also works as a social environment where senior players can interact with each other, sharing gaming experiences and game results through several social mechanisms found inside the application.

To achieve this goal, an analysis of our target audience and its specific features, needs and wants was performed, in combination with the realization of what makes games appealing to the players and the reasons behind the tablet device success in this new era.

In order to guarantee a favourable outcome for the gaming platform, the design process adopted an user-centered design methodology where a group of senior participants evaluated the developed prototypes iteratively to ensure that the project remained consistent, appealing and above all with efficient usability.

Throughout all stages of development a great amount of valuable knowledge was acquired regarding working with this particular audience, improving the design of an application in an

[1] http://www.fraunhofer.pt

iterative and incremental manner, as well as make the most of new interaction paradigms provided by recent devices such as the tablet device.

The authors believe that this thesis has the potential of becoming a worthy contribution to the Human-Computer Interaction community, hopefully improving the outcome of future projects and research in the area.

1.3 Thesis Outline

This thesis is organized in seven chapters:

This chapter (1) introduces the context of this research, as well as its background, goals and contribution, and this section outlining the structure of the thesis.

Chapter two (2) provides the literature work that acts as the foundation for this project. It begins with a study of our target audience, the senior user, and its specific characteristics and age-related changes, including its relationship with modern technology. Following with an explanation of what constitutes a game with a primary focus in learning and its required mechanisms, as well as a review of the tablet's advantages over other devices, the chapter will close with a breakdown of previous projects that experimented with cognitive training in seniors through games.

Chapter three (3) details the methodology to be adopted for this project and why it is believed to be indicated towards our target audience. It continues with the process behind the recruitment of the seniors that participated in the evaluation tests of the game platform, concluding with the techniques used in every stage of designing, developing and evaluating the project.

The gaming solution proposed to achieve the goals of this project is detailed in chapter four (4). This chapter encompasses all the steps taken during every phase of the project, from the early designs of the game platform to its final form implemented in the tablet device.

In chapter five (5) the results supplied from long-term evaluation tools are presented and explained on how they can contribute to improving usability for seniors.

Chapter six (6), building upon everything that was performed during the preceding chapters, draws some lessons learned throughout the project that could prove to be helpful in future research with working with an older audience.

Finally, chapter seven (7) manifests the contribution that the project was able to provide and identifies a series of possible improvements to the game platform.

Chapter 2

Understanding the Potential of Mobile Games for Seniors

Ageing brings forward a great number of changes to the mind to the senior population, cognitive and psychosocial likewise. These changes create profound effects in how seniors perceive themselves and their limitations, such perceptions being justified or self-imposed. Independent of the reasons, the consequences of these age-related changes can be serious, and limit the extent to which seniors are able to perform certain activities and interact with newer technologies.

This chapter first begins by examining some of the most critical age-related changes that influence the senior population and their perception towards new technologies. Continuing in line with the purpose of this project, an overview of what constitutes a game with a particular focus in learning is presented, alongside their mechanisms requirements and engagement techniques when appealing to players. Following with a review of the main characteristics and uses of tablet devices and their advantages, this chapter concludes with a synopsis of several successful experiments in cognitive stimulation and training using games.

2.1 The Senior User

As people age they change in a myriad of different ways. While some of those changes may be for the better, others are not. There are many myths surrounding ageing, as it is common with stereotypes, but those myths are often inaccurate. It is a common belief that older adults tend to become more difficult to deal with and inflexible as they age, but it turns out that most people's personalities remain roughly the same throughout their lifespan [Ass98]. Succumbing to depression and being unable to cope with the inevitable declines associated with ageing are also believed to be usual patterns. However community dwelling older adults are found to have lower rates of diagnosable depression compared with younger adults and that most older people successfully adjust to the challenges of ageing and live happy and productive lives [Ass98]. An

explanation for this fact is that as people age they seem to devote extra time and attention in managing their affective states and avoiding sadness or anxiety [Mcg06].

Notwithstanding, most older adults do experience normal, age-related changes that may affect their lifestyle. Such changes are often divided into three categories: cognitive, perceptual and psychosocial, with the focus of this work being on the cognitive kind.

In order to successfully stimulate the cognitive side of the mind through technology-based methods, the user must feel at ease with the technology, and be willing and motivated in accepting new concepts and learning new skills, meaning that a fundamental knowledge of the needs and wants of the senior population is of paramount importance.

2.1.1 Cognitive Age-Related Changes

As people grow older, they experience physiological changes that can cause defects in ordinary functions of the brain that previously did not occur.

The two basic cognitive functions most affected by the ageing process are attention and memory [Gli07]. Some form of attention is used in virtually all other cognitive domains except when tasks have become automatic. Therefore, declines in attention can have several implications on a senior's ability to function adequately in everyday life. Seniors are more challenged by tasks that require a division of attention than younger adults, particularly when the attentional demands of such tasks is high [Tsa98]. Similarly, seniors' performance is slower than younger adults when attention must be switched between several tasks [VC02], albeit such difficulty is often due to a general slowing of information processing rather than being prone to distractions, which is found to not have a relevant impact on senior's task performance [MS00].

Memory can be divided into working or short-term memory and long-term memory. Working memory is hypothesized as one of the main sources of age-related problems in a multitude of cognitive tasks, such as long-term memory, language, problem solving and decision making. Working memory is essentially a limited capacity system that involves the manipulation of information that is, at the present moment, being analysed [CNP04]. In a sense, working memory is really a divided attention task and as such, it is not surprising that seniors have problems in working memory. Unlike short-term and working memory, long-term memory requires the retrieval of information that is no longer present of being maintained in an active state, having been acquired a few minutes ago or many years before. In general long-term memory in seniors is largely preserved, and some sections, such as semantic memory, which relates to one's storage of general knowledge of the world, often exceeds that of younger people [Gli07]. On the other hand, long-term memory sections such as episodic or prospective memory, tend to more easily become affected by normal ageing. These involve the correct encoding, storage or retrieval of information, and although seniors may be able to focus on salient information they fail at perceiving peripheral details or integrating contextual aspects of an experience [GRD01].

Age-related changes in cognitive function may vary considerably across individuals and cognitive domains, with some cognitive functions having a more prominent decline over others as a

result of normal ageing. Attention and memory seem to be the two areas where much of the research has been done, and in fact many of the cognitive deficits associated with ageing have been found to be related with these two components.

2.1.2 Perceptual and Psychosocial Age-Related Changes

As ageing takes place, seniors senses may become less accurate due to normal ageing processes. The most dramatic sensory changes associated with ageing are vision and hearing, but all senses can be equally affected.

Vision impairment is the most common sensory problem of seniors and begins to take effect by the age of 40. Around 95% of individuals age 65 and older wear glasses or report having the need to use them in order to improve their vision [USC04]. Some of the most affected visual capacities are peripheral vision and susceptibility to light. Peripheral vision allows a person to perceive movement in the limits of their vision field and it may require seniors an extra effort to acknowledge everything that is happening around them. Also, as the flexibility of the eye decreases, it takes seniors more time to accommodate to changes in light, as in the case of moving from a bright room into a poorly lit one.

Hearing is also altered with age. Many seniors suffer from *Presbycusis*, which reduces their ability to hear high-frequency sounds, preventing them from correctly understand speech [IS09]. This kind of impairment can often prevent seniors from actively engaging in social interactions out of fear of saying something wrong or misunderstanding what other people said. When designing applications that rely primarily on sounds, it is then often advised to complement with visual cues in order to leverage this disadvantage.

Motor skills changes with ageing also associated with decreases in response times, coordination and flexibility of movement [CL09]. The haptic processes, which denotes the use of touch to retrieve information about a certain object, can also suffer changes, namely with the loss of sensitivity in hands [MR10]. This type of impairment may therefore impact how seniors value interactions using touch and gesture-based applications, as the system must allow enough time for the user to slowly and clearly understand what has to be done and in what manner.

Although physical age-related changes are easier to perceive due to their visible nature, psychosocial changes are equally important in understanding seniors' lives.

Seniors gradually experience a loss of independence, often requiring aid from family members or friends to complete tasks in which they were previously completely self-sufficient. These situations can lead to a feeling of helplessness and loss of self-esteem [Zim09]. However, seniors seem to be more aware of their capabilities and limitations compared to the younger generation, likely due to their greater life experience. This allows them to better assess themselves and more easily adapt to the natural changes of the body and mind, ultimately helping seniors accept their new reality [HK01].

Even though seniors generally display very high interest in interacting with friends and close family members, preference usually lies in cultivating their existing relationships rather that creating new ones [Mcg06]. However, seniors that experience feelings of abandonment may be more open-minded to a system that allows them to foster social interactions and feel closer to others.

2.1.3 Seniors Interaction with Technology

The elderly people among us continue to remain on the edge of the technology world. While there has been progress in shrinking this gap, a lot still remains to be done. Curiously, usage of computers and the Internet by seniors is one of the fastest growing consumer segments of society [HCH08]. Furthermore, this group could significantly benefit from this high-tech products, as concerns such as social interaction, healthcare and education could potentially be enhanced through increased usage of computers.

For the most part, computers and their associated peripheral devices, both hardware and software components, are not designed with seniors in mind. Hardware-wise, we have very small buttons and plug-in devices (e.g., printers, speakers, external drives, etc.) that are difficult to see and manipulate by seniors. Likewise, software applications usually demand a steep learning curve and what can be easy or obvious for a younger person is not necessarily so for the elderly.

In one study, Gregor and Dickinson [GD06] noted that there are 250 possible operations on the first page of Microsoft Outlook, a popular and commonly used e-mail client program. Such overwhelming array of choices poses natural complications in the usage of the program, even for advanced users. In their study, 50% of a group of beginner seniors failed to complete basic e-mail tasks. This level of complexity can impose cognitive difficulties that block access to technology, both to seniors and younger people alike.

There are a number of reasons as to why seniors are not so keen on using computers or the Internet, and some of the following stand as the most relevant [WHH10]:

1. **Perceived lack of benefit:** Often seniors believe they have no need for computers and there is nothing they can benefit from them, either because the technology does not meet their needs, or they do not understand the technology sufficiently to appreciate the benefits. This is believed to be the most significant reason why seniors tend to distance themselves from computers.

2. **Lack of interest or motivation:** As it is to be expected, because seniors do not fully understand the value of the technology, a lack of interest or willingness to learn is bound to settle.

3. **Lack of knowledge:** Sometimes a misperceived lack of knowledge to learn and use the technology is a concern for seniors. Due to the young nature of technology, seniors believe they do not have the necessary skills to operate the devices and understand the applications. Language distinctions between the application and the user can also negatively impact the experience.

4. **Costs and fear of quickly outdated hardware:** Hardware and software costs are also variables in the acceptance of technology by seniors, and the fear of acquiring quickly outdated hardware further aggravates this question.

5. **Perceived barriers due to physical limitations:** Impairments on vision, hearing or hand movements can also influence as to why seniors feel they are not adequate for the usage of technology.

Seniors' attitude towards technology greatly influences their perception on its usefulness and their motivation in learning new skills [CS98]. In addition, age-related changes in cognition may have an negative impact on access and use of technology. Declines in working memory may make it difficult for seniors to understand new concepts or recall complex procedures. Declines in attention may also complicate tasks where a constant change in focus between several displays of information is needed.

Still, available studies indicate that seniors are in fact receptive to using computers and, as they become more experienced, their attitude and motivation also rises [CS98], however, the nature of their experiences, available training and support, as well as ease of access are determinant factors for their receptivity.

2.2 Gaming in Serious Contexts

Games have existed for as long as human kind has, from humble beginnings using simple materials such as wood or stone, to the latest achievements in the digital realm. For a very long time, people saw games simply as a form of entertainment. Alternative purposes for games, however, have been tested focusing on learning new concepts through playing. Those games that focus on acquiring new skills are named *Serious Games* [Abt70].

Employing games as an approach to teach players new skills and competences is an effective method [ZC11] due to the ability to recreate real-world situations without risk, as well as achievement and competition-driven environments, putting players to the test against themselves and each other. When designing an engaging and stimulating game it is important to cater for all kinds of players, whether they play for 5 minutes or 5 hours, so they feel compelled to maintain the habit of playing regularly, which otherwise would not have a serious impact on learning. The right game mechanisms have therefore a very important role in the success of the game and consequently in its ability to imbue players with new knowledge.

2.2.1 Serious Games and Edutainment

In its pure essence, a serious game is a game designed for a primary purpose other than pure entertainment [MC06]. Although serious games can be entertaining, one of their main purposes is to solve a problem. Sometimes a game will deliberately sacrifice fun and entertainment in order to achieve a desired progress by the player. The term *serious game* was actually used long before

the introduction of computer and electronic devices into entertainment. Clark Abt discussed the idea and used the term in his 1970 book *Serious Games* [Abt70] and his references were primarily to the use of board and card games.

Although there was an early attempt in the early 1980s to use video games for teaching, *Edutainment*, as it came to be called, never caught on [DeM07], and most of the emphasis in the first thirty years of the video game era was on entertainment alone. However, in the past few years, a growing group of game designers, businesspeople, military leaders, health professionals, religious groups and political experts have come to realize that video game principles can be applied to a diverse range of subjects and purposes. In 2002, the Woodrow Wilson International Center for Scholars in Washington D.C. launched the *Serious Games Initiative* [1] which main goal is to help introduce in a new series of policy education, exploration, and management tools utilizing state of the art computer game designs, technologies, and development skills. Later in 2004, other focused sub-groups began to appear including *Games for Change* [2] which focuses on social issues and social change, and *Games for Health* [3] which addresses health, healing and medical training.

One of the primary consumer and producer of serious games is the United States Military, which needs to prepare their personnel for a variety of environments, cultures, and situations. They need to understand their surroundings, be able to communicate, use new technologies and quickly make decisions [Klo08]. One of their most popular games is *America's Army* [4], originally intended as a recruitment tool. This game, which is available for free, uses state-of-the-art technology and graphics to simulate training and military operations in a realistic setting. After their basic training, players perform tasks and missions together with other players online. They are rewarded by a scoring system not for committing random acts of violence, but for accomplishing missions and working as a team. Players are taught to think before they act, and for those who commit wrongful acts, they are sent to a virtual prison where they are given a ten-minute time-out with nothing to do. *America's Army* is an example that shows that people can learn within a game context.

One must be careful as not to confuse serious games with training software or even entertainment games. Training software guides the user through a series of pre-defined steps from point A to point B using almost always the same predetermined way. An entertainment game just seeks the experience of playing itself. Meanwhile, a serious game has a challenge or an objective, consisting on generating knowledge from the user experiences, or in other words, in a serious game, the user must lead its own process. All in all, a serious game possesses both entertainment game and training software characteristics [NPMn11]. Table 2.1 presents a structured comparison between these three types of applications.

Video games can be regarded as providing authentic, meaningful and powerful contexts for learning. Games provide players, in the role of learners, with real challenges that require the development of skills and employment of strategies in order to achieve the game objectives. Understanding games in this manner opens the possibility for games to move beyond their primary

[1] http://www.seriousgames.org/
[2] http://www.gamesforchange.org/
[3] http://www.gamesforhealth.org/
[4] http://www.americasarmy.com/

Table 2.1: Comparison between entertainment games, training software, and serious games [NPMn11]

	Entertainment Game	**Training Software**	**Serious Game**
Goal	Nothing further the pleasure, fun and entertainment	Learning, skills and knowledge acquisitions	Player training
User requirements	Venturing and skills	Knowledge and capabilities	Knowledge, capabilities, venturing and skills
Interactivity	High (could be difficult): more challenging implies a better experience	Low: more easy is better	High level of player interactivity
Visualization requirements	Efficient management of content, development and an attractive interface	Friendly interface	Efficient management of content and development of an attractive and friendly interface
Software requirements	Fast processing of dynamic data and images	Evaluation from comparisons with real data	Precision: comparisons with real data simulation. High data and images processing capability
Methodology	Surprise and interest	Clear and predictable	Surprise, interest and clarity

focus within entertainment and explore new contexts and markets. Higher education, the health sector, the military, and non-government organizations are all potential clients of game-based solutions. The key is combining purpose with play.

2.2.2 Social Interaction in Games

Social interaction is becoming an increasingly important theme in gaming. The success of the Wii console [Gau07], and its focus on casual multiplayer games, has highlighted how important playing with friends is to reaching wider audiences and creating successful game experiences.

When creating a game, it is therefore important to be able to understand the types of social interaction that exist, and measure them during the development of the game. One of the most popular models to define player types is the *Bartle Types* [Bar13]. Bartle divides players into four types:

- **Killers (Clubs)** - Killers are interested in competition with other human players, as opposed with interaction with non-player characters.

- **Achievers (Diamonds)** - Achievers are most interested in gaining points or alternative in-game measurements of success. These players will often stray from the main objective of the game to gain items that have no in-game benefit besides prestige, such as Achievements or Trophies.

- **Explorers (Spades)** - These players are interested in discovering everything about the game, and will explore new areas or take non-optimal routes to explore. They do not enjoy time limits, since this limits the potential to explore options.

- **Socializers (Hearts)** - These players are interested in the social aspect of the game play, rather than the game itself. They enjoy interacting with other players, and use the game primarily as a means of communication.

Each player type has its own motivations and needs, therefore it is important to appeal to every type when designing a game that focus on social interaction. Players of the Killer type would feel more motivated to play if their dedication was awarded with some kind of advantage in a subsequent round of the game, such as accumulated extra points or a head start in a time trial game. A game can be tailored towards encouraging interaction from Achievers by offering the opportunity to visibly display success, from badges, trophies and achievements to leader boards. When targeting games towards Explorers, it is important to display a wide variety in content, both in the game mechanics and graphically. Mini-game collections, like *Mario Party* [5] and *Wii Party* [6], are good examples of games that encourage social interaction from Explorers. Socializers will benefit from emphasis in communication between players, even in typically competitive gameplay, ensuring that they remain engaged in the game.

Every game benefits from attracting each of these types of players, for together they are able to intensify the overall experience of the game and push the boundaries even further, not only for the developers to improve their games, but also for players, as it simulates as close as possible the real world with people with different kind of intentions, interests, motivations and goals.

2.2.3 Mechanisms for Cognitive Stimulation and Training

Several studies have focused on the effect of cognitive stimulation games on seniors [DES+92] [Tor08][JMA+10], even if most of the research done in this area was based on games that were not specifically designed with the needs of elderly people in mind. However, even with regular games, results show that seniors who played games increased their performance on tests of visual fluency and visual perception ability [JMA+10], obtained faster reaction times [DES+92], improved their overall cognitive skills and maintained the self-concept and quality of life [Tor08]. It has been reported even, that those benefits lasted for several weeks and could be transferred to common everyday tasks [All13].

Cognitive stimulation mechanisms have already been implemented successfully in mainstream games such as the *Brain Age Series*[7] developed by the video game company Nintendo, in collaboration with Dr. Kawashima – famous Japanese neuroscientist from Tohoku University (Tokyo, Japan) – for the Nintendo DS mobile console platform. These games claim that, through simple

[5] http://www.marioparty.com/
[6] http://wiiparty.nintendo.com/
[7] http://brainage.com

math-related activities and literatures passages to read aloud, when performed on a regular basis, one could potentially increase blood flow in the brain, and stimulate both hemispheres.

The *Brain Age Series* for the Nintendo DS and other similar cognitive training games for recent consoles that innovate in terms of the control mechanisms, prove to be good choices for elderly people [Tok13]. The Nintendo DS provides a touch-screen instead of more complex controls such as joysticks or several buttons. Other example is the Nintendo Wii console that promotes motion-based controls. These alternative styles of gaming provide user-friendly interfaces for seniors, allowing for more natural and intuitive interactions.

2.3 The Tablet Device

Until some time ago, communications between humans and machine was made primarily through what is called *indirect input devices*, which include peripherals commonly used such as the keyboard and the mouse. These devices are mainly associated with the WIMP - Windows, Icons, Menus and Pointers - interaction paradigm, widely used in desktop and laptop computers.

However, such devices pose difficulties in the way humans interact with computers, and recently, more intuitive and natural input devices have arisen. Known as *direct input devices*, they enable a more Direct Manipulation interaction paradigm which is characterized by a focus on the visibility of objects of interest, quicker feedback to the user and the replacement of complex commands with actions which manipulate directly with the visible options [DFAB03]. Users can simply touch the item that they want to manipulate directly on the screen and interact with it in a similar fashion as they would do it in the real world.

Such a natural way to connect people with computers aids immensely in motivating new users, especially seniors who never had many opportunities to experiment with new technology, to realize the benefits that it can bring to their lives.

2.3.1 Origins and Social Boom

The tablet device and its associated special operating software takes it origin from a technology named pen computing – a computer user-interface based on using a pen (or stylus) and a graphics tablet, rather than devices such as a keyboard, mouse or joysticks – and thus the development of tablets as a whole has very deep historical roots [Huu03].

Following many years of research, mainly in academic environments, several companies began to design their own commercial products in the 1980s. Apple (formerly known as Apple Computer) started its tablet project in 1987, eventually releasing the Apple Newton in 1993, with a 6-inches display screen and weighting 800 grams [Hor13].

In 1999, Microsoft attempted to re-institute the tablet concept and in 2000 coined the term Microsoft Tablet PC, built on Microsoft's own specifications and running a licensed specific tablet enhanced version of its Windows Operating System (OS) [Cen13]. Microsoft Tablet PCs were targeted to address business needs mainly for note-taking purposes, and as data capture devices

for the health sector, such as retrieving feedback on the patient experience at the bedside [Ola13]. However, due to unresolved problems Tablet PCs failed to gain popularity. The devices were too heavy to use for extended periods, the specific features design to support the usage of tablets (for instance finger and virtual keyboard support) were not present in all contexts and there were very few applications specific to the platform [Bri13].

The tablet market was reinvigorated by Apple through the introduction of the iPad in 2010 [Eat13]. While the iPad placed restrictions on the user to install software, it shined in its attention to detail for the touch interface, which is considered a milestone in the history of the tablet device [Bri13] and provided several multimedia applications such as web browsing, email, photos and videos, as well as word processing, spreadsheet and presentation software.

Not wanting to lose ground to competition, several other companies began announcing their own versions of the tablet device, with as many as 80 new tablets being presented at the Consumer Electronics Show in January 2011, including the Motorola Xoom tablet, Samsung Galaxy Tab, Toshiba Thrive and the Blackberry Playbook, with several designed to run Android 3.0 Honeycomb, Google's mobile operating system for tablets. Still, by the time other companies entered the tablet market, Apple had already released their second generation iPad2. Despite the large number of competing tablets released in 2011, Apple still continues to dominate the market, with 54.7% of media tablet sales in the last quarter of 2011. Nevertheless, it is expected that Android tablets overtake the iPad in worldwide marketshare by 2015, greatly due to the large amount of vendors with low-priced devices [Byf13].

2.3.2 Characteristics and Uses

However large the tablet market may have become, three fundamental characteristics constantly apply [Hus13]:

- **Capability** - Tablets are able to run a myriad of rich applications that can even compete with their desktop and laptop counterparts. Applications range from word processing, spreadsheet and presentation software to music and video editing, photos or videos visualization, web browsing and even games.

- **Mobility** - Tablets can conveniently be transported from one place to another due to their small size and weight. Furthermore, they can be attached to a docking station at a desk, allowing access to peripherals such as a keyboard, mouse, monitor or network connection, therefore combining greater mobility with the access to the capabilities of a desktop computer.

- **Natural Interaction** - Touch-screens provide the user with a more intuitive interaction with the technology, incorporating the use of natural gestures such as touching or dragging unto applications. Speech recognition is also becoming more of an integral part of tablets, allowing users to dictate content or control applications using their voice.

In the last few years, the tablet market has expanded to attend to a large number of different users with different needs. Sizes range from 7 to 11-inches and battery life can go from 5 up to 10 hours, depending on the intensity of use (videos and games can deplete the battery faster) [Shi13]. Storage space also provide a wide range of options, from 16, 32 or 64 gigabytes of internal storage, up to the 250 gigabytes hard drive provided by the Windows 7-based CTL tablet [Rid13]. Tablet devices use touch screens as primary input and come integrated with an accelerometer – an acceleration sensor – and some provide Bluetooth connectivity and a camera (sometimes two) to take pictures and record video. Tablets can run several different operating systems such as the Android OS, the iPhone OS (iOS) or even Windows 7 and each provides native and exclusive applications, as well as multi-platform applications through the online market center [Shi13].

A survey conducted by Google's mobile advertising network AdMob in March 2011 [AdM13] offered some insights into what people where using their tablets for, where, and for how long. The statistics indicated that tablet owners were shifting their time away from television and PCs to consume more content from these slate devices. Their survey, which polled 1430 people in the U.S. found that 84% of tablet owners played games on their tablets, 78% searched for information, 74% used it for email, and 61% read the news. The two least popular activities, according to the survey were shopping and e-book reading, with only 42% and 46% of users, respectively, saying they used their tablets for these purposes.

Business owners can also take advantage of tablets, being lightweight and compact, to get tasks done seamlessly anywhere, create presentations for meetings or update websites and blogs. Business people may need to travel extensively as part of their jobs to meet clients and participate in projects, and tablets allow them to get work done on the road, to productively use travel time. A business that stays up-to-date with technology improves its image to the general public and shows an understanding of customers' needs and interests, especially companies operating in the technological industry [Mur13].

2.3.3 Direct and Indirect Input Devices

When interacting with computer systems, one of the many factors that influences the user experience is the used input method. Two types of input devices can be distinguished according to their input method: Indirect Input Devices and Direct Input Devices [RFMP05].

Indirect Input Devices include peripherals like the mouse or the keyboard and are characterized by requiring a transformation between the action performed by the user and the resultant action executed on the device. As an example, when using the mouse, the system translates the movement of the mouse from one point to another, and when the user double clicks an application, the system transforms the double click into an action inside the system to open the chosen application. This kind of events are associated with the WIMP – Windows, Icons, Menus and Pointers – interaction paradigm that are still today widely used in desktop and laptop computers.

Direct Input Devices – touch screens and gestural interfaces – although not necessarily new, provide more intuitive and natural input methods that enable a more Direct Manipulated interaction paradigm [DFAB03]. Contrary to indirect input devices, users can directly touch the screen

using their fingers to manipulate the various items that are presented to them at the moment, and interact with them in a way that resembles the real world method of interaction. This kind of familiar relationship between the user and the device makes it easy for an inexperienced user to quickly become proficient in using applications that take advantage of this type of input devices [WWR+05].

To better understand the advantages and disadvantages of each input device, a comparison between both types is presented in Table 2.2.

Table 2.2: Comparison between direct and indirect input devices [DFAB03]

Device	**Advantages**	**Disadvantages**
Direct Devices Examples: touch screen, light pen, voice recognition	- Direct hand-eye coordination - No need to memorize commands - Minimal training - High user acceptance - Requires less space - Long, ballistic movements accomplished quickly - Better for pointing tasks	- Arm fatigue - Limited resolution - Difficulty with precision - Slow entry - Finger or arm may obscure screen - Inadvertent activation - No inherent feedback
Indirect Devices Examples: rotary encoder mouse, joystick, trackball	- Can adjust control-display ratio - More precise - Gives tactile feedback - Experienced users prefer it for long periods of use	- Requires translation between rotary and linear movement - Requires translation between hand and screen - Requires learning time - Movement time between controls is lengthy

As can be observed, Indirect Input Devices are more precise and are generally favoured by users with more experience, however, they require extra learning time and a comfortable amount of hand-eye coordination which can be a problem for seniors with disabilities such as Arthritis or Parkinson [Hol09]. Direct Input Devices have lower cognitive and coordination demands, making them more appealing to novice users or users with trouble memorizing complex controls or perfectly controlling their movements [WWR+05].

2.3.4 Tablet as the Chosen Device for the Project

The tablet was the device chosen for the project at hand by virtue of the inherent characteristics that empower this device, essentially its capabilities, mobility, and (natural) touch and gesture-based interaction.

The tablet possesses computing power rivalling that of laptops and is able to run a vast selection of rich applications, therefore not limiting creativity or imposing profound problematic restrictions on available resources, allowing the development of attractive and stimulating applications.

Mobility was also a determinant factor in the selection of the tablet device. Due to its relatively small dimensions, a tablet can be transported virtually everywhere and used in virtually any

situation. This is clearly an advantage considering our target audience of the senior population. The reduced weight and dimensions, compared to most other devices, make it easier for seniors to travel with a tablet and have it available to use more frequently, aiding in the objective of routinely playing cognitive stimulation games.

Probably, one of the most interesting aspects of the table device lies in the touch-screen and its Direct Manipulation interaction paradigm. This inherently natural and intuitive user interface contributes for a softer learning curve which may help new users feel motivated and more confident in using new applications and in seeking new experiences.

2.4 Successful Uses of Games for Seniors

Several projects have already proven their success in stimulating the human brain through games, either by using a more commercial approach targeting a massive audience, or by implementing customized platforms towards the senior population while considering their own requirements.

The mainstream side of cognitive training games, due to their wider audience, implement mechanisms that consider people of all ages and backgrounds. Often, these games provide social interaction features, such as results sharing and comparison, which are important components for engaging players into the game.

Cognitive training and learning through games has been a popular topic in the last years and has spanned several studies [JPW+06][JPMP04][ONI+11] that supported the creation of customized game platforms focusing on an older audience, with the goal of slowing down the natural decline of cognitive abilities as a result of ageing.

2.4.1 Brain Age Series

Brain Age [3] is a series of entertainment video games that employs puzzles as its the main method of mental stimulation. It was developed by video gaming company Nintendo for the Nintendo DS hand-held video game console. Inspired by the work of Japanese neuroscientist Dr. Ryuta Kawashima – author of the book *Train Your Brain: 60 Days to a Better Brain* which sold over 2.5 million copies globally –, the game features various activities designed to stimulate the brain routinely such as simple calculations, picture drawing and word rearrangement.

Brain age is designed to be played a few minutes every day and is entirely touch and voice-controlled, having the player either writing the answer to the puzzle directly on the touch screen or saying it into the microphone.

The game includes four modes: Brain Age Check, Training, Quick Play, and Sudoku. The Brain Age Check gives the player three puzzles to complete, and depending on performance, reports a theoretical assessment of the age of the player's brain, with an increase in brain age as performance decreases. Training mode allows the player to try a variety of puzzles and, if the

[3] http://brainage.com

player succeeds in completing those puzzles, it is awarded with new puzzles, difficulty modes, or additional features.

Brain Age also features a multiplayer mode where up to 16 players can compete in speed calculation games and exchange scores with each other.

2.4.2 Big Brain Academy Series

Big Brain Academy [4] is another series of puzzle video games developed by Nintendo. One of its games, Big Brain Academy: Wii Degree, was released for the Wii console in 2007, and makes use of the Wii Remote, allowing players to point and click on-screen.

In Big Brain Academy, tests are performed to measure a brain's mass. The heavier the brain, the smarter the brain is or has a better reaction time. The game features three modes of play: Test mode, Practice mode, and Versus mode. Test mode consists of a test using five puzzles, with one puzzle taken at random from each of the five categories (Think, Analyse, Compute, Identify, and Memorize). After the test, the player is given a letter grade and information on what areas it should improve. Practice mode allows the player to select specific activities to improve, features three difficulty modes and awards either a bronze, silver, gold medal or platinum depending on player's performance. Finally, in Versus mode, up to 8 players can compete to determine who has the best score.

2.4.3 Embedded Cognitive Assessment Algorithms

One study in 2006 titled *Embedded Assessment of Cognitive Performance with Elders' Use of Computer Games in a Residential Environment* [JPW+06] presented a method for embedding cognitive assessment algorithms within a suite of computers games that seniors found enjoyable to play on a routine basis. Also, the cognitive assessment algorithms served as input to tailored hints and help functions for users of diverse cognitive abilities. Frequent assessments were made to allow the detection of relevant changes in various aspects of performance, in order to adapt the user interface in real time and provide a mechanism of early detection of cognitive problems.

The experiment attempted to incorporate conventional metrics of verbal fluency, short-term and working memory, planning abilities, and divided attention into computer games that seniors felt motivated to play with. This benefited from multiple nearly continuous measures to filter and average, and in addition, to analyse within subject trends. The ability to compare an individual's current performance to their own baseline substantially reduced confounding effects as result of education, language abilities, and culture. In addition, this method was able to characterize variability in performance over time, which remarks for a strong indicator of cognitive function.

To select the games to use in the experiment, the authors observed which features were most enjoyable and easily understood by seniors and also did a cognitive task analysis on each of the games to characterize its appropriateness for providing information on one of the cognitive dimensions.

[4] http://bigbrainacademy.com

In one of the games, in order to obtain a more direct measure of short term and working memory, the authors adapted the standard Concentration card game where users needed to remember the location of various cards they selected and then match pairs. Game difficulty was adapted based on number of cards and the cognitive difficulty of the matches, which ranged from simple shape and color matches to significantly more complex matches, such as matching a digital clock time with the equivalent analogue picture.

Most of the experience and testing resulted from a customized implementation of the Solitaire game of FreeCell, ensuring a win rate of between 50% and 80%. This game was found to be the most popular among seniors that participated in the experiment and in addition, the game required a significant degree of planning to finish successfully. In this customized version of FreeCell, user performance was compared with a computer solver which calculated the minimal number of moves required to complete the game given an initial layout of cards. Both solutions were compared in a two dimensional plot and the slope of the subjects performance was used as a measure of efficiency of play. Using only data from the performance in this game, the authors were able to distinguish cognitively healthy subjects from those with mild cognitively impairment.

2.4.4 ElderGames

ElderGames [1] is a project funded by the European Commission within the Society Technology Area, to develop games using advances visualization and interaction interfaces with a high preventive, therapeutic and entertainment situations, while improving their cognitive, functional and social skills. The Consortium is formed by universities, industries, elderly leisure/care centres and technology centres/associations from Spain, Norway, United Kingdom, Finland, Austria and Italy. The project relies on the assumption that playing a game may have several benefits for elderly people, and that technologies may increase these benefits by providing specific integrated solutions to other aspects of elderly people's everyday lives. The main goals target to:

1. Promote the e-inclusion of elderly people by means of play activity.
2. Contribute to an overall improvement of the abilities impacting quality of life through play, with particular emphasis on cognitive skills.
3. Support communication between elderly citizens and their families across Europe by means of play proposals which will allow them to share their experiences by means of an alternative-augmentative communication system capable of overcoming linguistic barriers.
4. Provide experts specialising in elderly care and supervision with an innovative play application to be used in their daily professional work, able to monitor variables related to quality of life, specially cognitive skills.

The project created a pre-commercial version of an interactive-play board (named ElderGames) that gave them the opportunity to scientifically explore how emerging advances in Information and

[1] http://www.eldergames.eu/

Communications Technology (ICT) could be adapted, applied and combined with play activities to obtain a preventive therapeutic tool for improving cognitive skills and quality of life (affective, physiological and social) in old age.

ElderGames is also the first play platform able to monitor cognitive health and welfare, allowing an early detection of cognitive diseases or social unease, and as such, implement the advisable response to them. The ElderGames interactive board also integrates an alternative communication system for overcoming the linguistic barriers which could exist between different native languages, allowing online games between users from different European countries.

The assessment of user requirements involved both experts in ageing and seniors participating in the project, and in order for applications to have the highest preventive value, the Consortium studied and selected the key variables which impact the quality of life for the elderly user placing particular emphasis on cognitive skills. Ergonomic tests were also carried out by the University of Padova in Italy to help ensure the development of a comfortable play table with appropriate content for software development.

The hardware uses gaming technology such as mixed reality – the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time – displayed on a large Liquid Crystal Display (LCD) screen. The system consists of five main components: a computer, one plasma or LCD TV, four cameras, a wooden table on which to mount the game and four pointers. Three identical prototypes were developed and installed in the test centres participating in the project. Both experts as well as users, were informed and trained in the use of the ElderGames applications.

Results from real play sessions provided information regarding the level of acceptance of the technology by means of motivational studies, the perception of the play therapy proposal and the connection of the monitoring system as regards to other traditional methods of cognitive assessment.

2.4.5 SOCIABLE

SOCIABLE [2] introduces an approach for ICT assisted cognitive training and social interaction for a wide range of senior citizens including those with intact cognition, others with Mild Cognitive Impairment, as well as patients suffering from mild Alzheimer's Disease. The project relies on the deployment of a set of applications over a surface computing platform supporting personalized cognitive training interventions designed according to medically principles covering all cognitive skills.

The applications support an approach combining the conventional human care factor with an ICT surface computing platform, enabling:

[2] http://www.cognitivetraining.eu/

- Medical experts and other health professionals to manage seniors' medical records in a fully electronic manner. Computer-based access to the medical records, facilitates information management and reporting at various control points within a given cognitive training programme.
- Medical experts and institutions to design and customize cognitive training and social interaction activities to the individual needs of their patients.
- Seniors to undertake cognitive training exercises and social interaction activities, in the scope of a motivating play environment empowered by the surface computing platform.

Main SOCIABLE results up to date include:

- An ICT based model for cognitive training and social interaction of seniors.
- The SOCIABLE platform software running over both surface tables and tablet PCs.
- 25 cognitive training games.
- The Book of Life application – a virtual personal diary, containing life experiences, memories and thoughts, create by the senior user – implemented over both surface tables and tablet PCs.
- Tools for medical experts and health professionals supervising SOCIABLE sessions.

A first experiment comprising 117 senior subjects that participated in SOCIABLE programmes was performed. The evaluation involved the comparison of the assessment scores of an experimental (composed of seniors participating in the SOCIABLE pilot operations) and a control group (composed of elderly people that did not participate in the pilot operations with the SOCIABLE platform). The evaluation revealed that the treatment had a positive effect on the cognitive and functional abilities of the elderly people that participated in SOCIABLE. Specifically, improvements to the Mini Mental State Examination and the Clinical Dementia Rating scores were observed, demonstrating benefits in terms of attention, verbal memory and language.

2.5 Summary

In this chapter, we reviewed the specific characteristics of the target audience for this project and how they were able to relate so far to the currently available technology. We attested that, although games with the main purpose of learning is a fairly new concept, or has not yet found its way to a more mainstream market, it shows great potencial in improving people's lives, and new technology will only serve as a catalyst to that purpose, as it has been proven from the several projects reviewed in the previous sections.

In the next chapter, the methodology adopted for this project will be reviewed and all the necessary steps to successfully implement will be explained in detail.

Chapter 3

Designing for the User

As technology is evolving and becoming more reliable, it is also growing in complexity resulting in products which are "unusable by most human beings" [Vic04]. Even user experience experts may have the tendency of assuming they know how interfaces should be designed, producing results that would work perfectly for them, but are unlikely to work for other users [Ore07].

It is important to understand that "design should begin by identifying a human or societal need, and then fulfil that need by tailoring the technology to the specific, relevant human factors" [Vic04]. Software development needs a more user-centered approach; it is not enough that products have an abundant amount of functionality or that users want to use it. It is also fundamental that users will be able to effectively use them.

Human-Computer Interaction (HCI) is the "discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" [CV96]. By applying the principles of this discipline, we aim at developing a product that considers seniors' characteristics and provides them with the benefits that technology can bring to their lives.

In this chapter, we perform an analysis of the most appropriate methodology to use in this project and detail the design phases that will enable the implementation of a suited product for our target audience, the senior population.

3.1 User-Centered Design Methodologies

Among the several HCI methodologies that exist, User-Centered Design (UCD) and Participatory Design (PD) put together a process in which the needs of the end user of a product are focused throughout all development stages. This helps developers gain a better understanding of the user's needs and goals, which will lead to a more appropriate product [RSP12]. The main difference from other product design philosophies is that user-centered design attempts to optimize the product

around how users can, want or need to use the product, rather than forcing the users to change their behaviour to accommodate it.

Back in the late 60's, early 70's, when PD was making its first appearances, users were rarely considered throughout the process of design and development of a computer system. Workers of Scandinavian companies were dissatisfied with the way computers were introduced to them, and felt a lack of motivation due to the inadequacy of designers in understanding the workers needs [Kyn91]. The problem was that designers had little information about what the requirements and goals of workers were, resulting in a sub-par product. The need for better cooperation between designers and users led to the elaboration of a "cooperative design to emphasize the importance of bringing together the competence of designers and users", where the process of mutual learning "implied that designers learn about the application and users learn about new technical possibilities" [Kyn91]. This became the concept of PD – embracing the users in the process of development.

Although cooperation between designers and end-users is crucial in implementing an appropriate and accurate product, this form of collaborative work can be challenging to perform. Teaming persons with different backgrounds can impose difficulties with the specification process of a system, due to their cultural differences [RSP12]. In the case of seniors, the differences may be even more serious, as the amount of technical information that encompasses the process of designing a computer system could lead to reluctance in participating in the development process.

The main difference between the UCD methodology and the PD methodology is the degree in which the user is involved in the process. In UCD, the product is developed considering the user, however they are not a constituent part of the team. Essentially, User-Centered Design is based on three basic principles [Cos00]:

1. Analyse users and tasks;
2. Design and implement the system iteratively through prototypes of increasing complexity;
3. Evaluate design choices and prototype with users.

Theses fundamental steps imply the understanding of users since the initial phase, focusing on deeply understanding the users' characteristics, needs, goals, and context to deliver a solution that meets their requirements. For these reasons, the methodology adopted in the development of the game platform for seniors will be based on a UCD approach. The following sections describe the necessary steps to sustain this methodology.

3.2 Design Phases

Fundamental activities were devised (Figure 3.1) to be carried throughout the development life cycle in an iterative fashion. The cycle is to be repeated until the design solutions meet the defined user requirements and for each phase of the process there are several techniques that can be used

to achieve the desired outcome. The conception and results of each design phase are presented next.

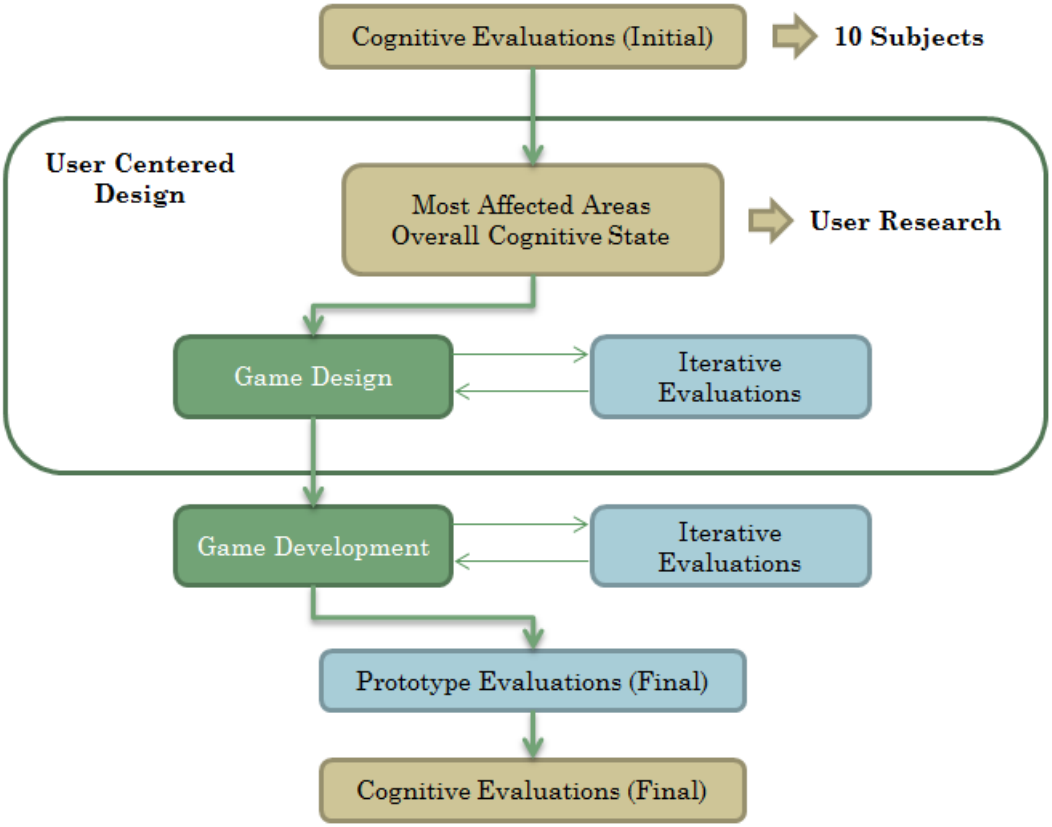

Figure 3.1: Methodology Phases

3.2.1 Recruitment and Interviews

The first phase was to get in contact with seniors who lived nearby so that they could participate in the usability tests several times during the required test phase period. Fraunhofer AICOS has an available contact network of recreation and health centers where seniors spend their time with other seniors, alongside the supervision of professional caregivers who are well versed in taking care of older people. Within those centers, we selected seniors who, through participation in previous projects, had proven to possess the willingness and resiliense to confortably perform in these kind of usability tests and could give constructive feedback on the application's strengths and weaknesses.

During the course of approximately two weeks, we welcomed several senior participants at Fraunhofer AICOS to allow them to become familiarized with the project and understand what their past experiences with computers have been like, if they were at ease or had any hardships. During this period, we had the opportunity of working with a specialized psychologist who performed several cognitive assessment exercises to each senior to evaluate their current mental state

and understand which cognitive areas of the brain should be focused on the games to be designed in the next phases. While one senior was performing exercises with the psychologist, we would be making informal conversation with the other seniors, learning about their experiences with technology and even showed them the tablet device for them to experiment with natural interaction mechanisms and feel more comfortable with the tool.

After all examinations were completed, we composed a group of 10 senior participants – 7 women and 3 men, with ages ranging from 63 to 80 years old – who had achieved good scores in the cognitive assessment exercises. This was necessary so that we could correctly evaluate the efficiency of the game platform and its games, as seniors who had serious struggles in mental ability due to illness or depression could bias the results.

These 10 senior participants were part of one recreational center who met every day to socialize with other seniors, and another group who met once a week alongside a nurse practitioner to perform social activities and play games to maintain their cognitive abilities.

3.2.2 Iterative and Incremental Prototyping

The design and development phases, in line with a UCD methodology, should follow an iterative approach. This iterative nature implies a need for the evaluation of each iteration in order to improve the developed solutions, generally by making use of prototypes. Prototypes are important resources that have the goal of communicating to the user the intended idea of the developers and overcome misunderstandings in the design, in much greater detail that simple descriptions would be able to [RSP12]. The most commonly used types of prototypes fall in one of two categories: low-fidelity or high-fidelity prototypes.

Low-fidelity prototyping – also known as paper prototyping (Figure 3.2) – is a technique that started becoming a common practice in software development since the mid-1990's, and is now widely used at many companies. Their main purpose is to bring fast results early in development, when the cost of making significant changes is still relatively inexpensive, and allows the developers to try many more ideas than with high-fidelity prototypes. Besides all the benefits that low-fidelity prototypes can bring to the development team, they also bear advantages for the end-users. They pose less of a threat to novice users who have little or no experience with computers, and helps focusing on the concepts and functionality instead of the visual appeal [Sny03]. Especially in the case of seniors, these are great advantages as they may provide us with better feedback on to better improve the game platform.

On the final steps of the prototyping phase, high-fidelity prototypes running on the computer system, in our case on the tablet device, were developed and presented again to our senior participants (Figure 3.3). These high-fidelity prototypes were fully functional and had the intended look and feel of the final product. These highly detailed prototypes have the disadvantage of being very difficulty to perform significant changes, and if the application crashes due to a programming bug, further tests with the user would have to be postponed. For these reasons, it is best for high-fidelity prototypes to be developed at latter stages in the development process, after a great amount of feedback has already been gathered from the user.

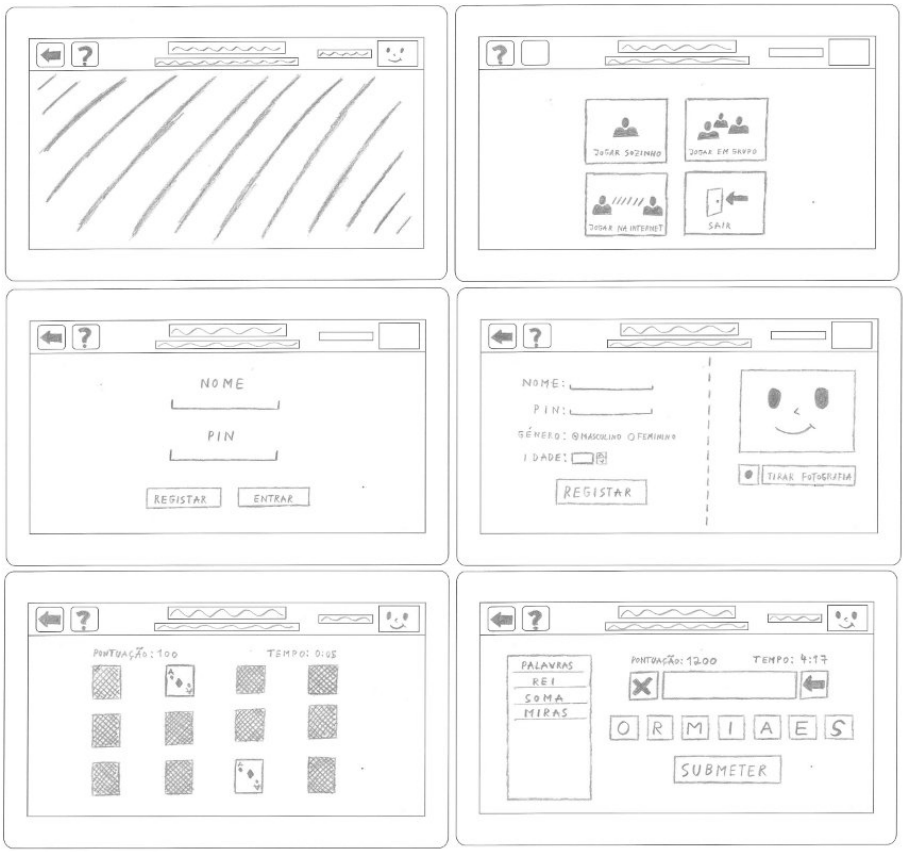

Figure 3.2: Low-Fidelity Prototypes Overview

3.2.3 Evaluation Techniques

After each development iteration, there is a need to evaluate the designed solution. There are two main forms of evaluation: formative and summative evaluation. Formative evaluation is "intended to improve designs" [DFAB03], whereas summative evaluation is a test for the final product, used as a last confirmation that the product has achieved its intended goals [Cos00].

The evaluations tests for this project took the form of usability tests and were performed in collaboration with seniors from two distinct recreational centers for older people. There were two particular techniques adopted to perform evaluations on the designed prototypes, from which we customized their protocols to better adapt to our intended goals, namely: empirical studies and wizard-of-oz.

Empirical studies aim at gathering information through observation and experimentation with users [DFAB03]. In our usability tests, we created a group of tasks to be performed which were described in the testing protocol followed during the tests. Several options were given to the user to allow him to choose whichever he though best conveyed the intended outcome of the task. We would question the user as to why one option was chosen over the other, and found interesting that some of our "apparently obvious" choices were not so appealing as we initially believed. During all steps of the evaluation protocol, we made sure to take notes on every aspect of the test, not

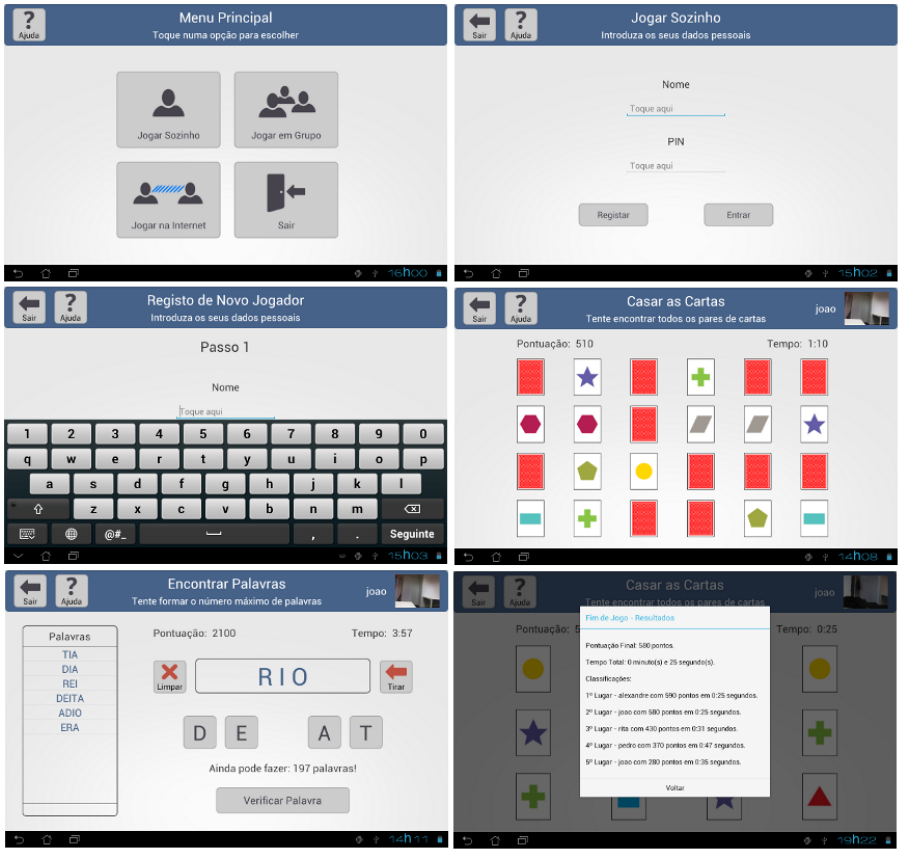

Figure 3.3: High-Fidelity Prototypes Overview

only from direct feedback from the senior, but also from indirect feedback – facial expressions and body language – that sometimes contradicted what the senior verbally responded. This may be due to the fact that some seniors always wanted to please us and not make any mistakes, so as not to feel undermined by his colleagues' performances.

The second evaluation technique used is called wizard-of-oz. This technique was first used by John Kelley [Kel84] to test a natural language interface application. He performed an experimental simulation where users were given the impression of interacting which a computer system that was capable of understanding English the same as a human being, when in fact the experimenter was supplying the answers himself behind the scenes. This technique has evolved and is now widely used in testing and iterative design. For our project, an wizard-of-oz simulation was performed to resemble an online game environment in which seniors could play against their friends without the need to stand in the same physical space.

3.3 Summary

The main purpose of the cognitive game platform is to, ultimately, help improve or at least maintain seniors' cognitive abilities so that they can enjoy a more fulfilling lifestyle. However, the time

allocated for the development of this project was not lengthy enough to perform long-term evaluation tests and apply the final cognitive assessment exercises meant to analyse a possible change in the cognitive ability of our senior participants. Nevertheless, we believe that the methodology and techniques applied for that purpose are correctly implemented shall the opportunity arise.

In the next chapter, the core implementation of the game platform is explained in detail, from the technical specifications of the tablet device and the game platform itself, to the iterative design of the low and high-fidelity prototypes.

Chapter 4

Developing a Tablet-Based Cognitive Gaming Platform for Seniors

Following the literature review and the definition of the methodology, this next phase begins by overviewing the core fundamentals of the game platform and the Android framework from which it was built. The next section details which are the main requirements to adhere by when designing the application, detailing the necessary functionalities and database structure. The final section encompasses the focus of the project, where the analysis, design and evaluation of all components of the game platform, including the cognitive games, are reviewed in detail, from the initial low-fidelity prototypes to the final polished high-fidelity prototypes.

4.1 Platform Overview

The main goal was to design and develop a game platform targeting the senior population that would provide cognitive training through the regular practice of a range of games, each focusing on a specific area of the cognitive domain. Equally important was to provide mechanisms that would promote social interaction among seniors and help them realize the benefits that modern technology can bring to their lives. Last, but not least, was to automatically extract data from user interaction with the application, such as patterns of actions, and game-related data such as gameplay time, scores, number of repeated or unnecessary actions, among others.

The games were designed to be, first of all, simple to understand and quick to learn. Using concepts familiar to seniors, such as playing cards and word-building games proved to be an effective approach as they became more at ease and cooperative during the tests. Game elements needed to be carefully selected and efficiently positioned on the screen to make sure not to confuse the player and help them quickly identify which elements should be interacted with to progress in the game.

A registration module was developed to ensure that each player could progress accurately through his or her training, without interference from other players. Players were able to log on to the system via a username and a set of digits, similar to a Personal Identification Number (PIN) commonly used in mobile phones and other devices. Besides a more controlled training environment, the registration system also provided the chance for players to preserve their game scores through a leaderboard ranking feature developed for the purpose of further engaging the players by promoting social interaction through healthy competition.

Also, a proof of concept was conducted to verify if seniors were able to the understand the concept of an online environment, where games could be played with other friends in different locations. For this purpose, seniors were exposed to a simulated online environment requiring no Internet connection, as the elderly recreation centers where the usability tests were performed did not have one at their disposal.

Data extraction mechanisms were integrated within the application, regarding interactions with each widget on the screen. This allowed a detailed analysis of some of the most common actions performed while navigating through the application, resulting in a more well thought planning of each iteration in the development, which consequently led to fewer bugs and greater user satisfaction. Gameplay statistics, such total duration, score, correct and incorrect moves among others, were recorded as well to help further understand player's habits and routines.

As stated previously (in section 2.3.4) the game platform was developed with the tablet device in mind, mainly because of its mobility, large screen size and extended duration of battery lifetime. For this project, an Android based tablet, using Android OS 4.0.3 firmware version. A 10.1 inches display was chosen, providing a large area of visibility for seniors but also more space to efficiently organize all information during the design phases.

The ultimate goal would be that one day all seniors could afford a tablet device and use it in their homes, so that they could at any time and in any place use this game platform to not only entertain, but also improve their lives, cognitively and sociably. This time, however, all usability tests were conducted at elderly recreation centers, using a pre-selected group of senior participants, using constant feedback to further improve the game platform.

One final note about the platform: since all the usability tests were performed with seniors which native language was the Portuguese language, all screenshots presented in this chapter will be in Portuguese. However, translations in English will be given as the platform is described.

4.2 The Android Operating System

Android is a Linux-based operating system for mobile devices such as smartphones and tablets developed by the Open Handset Alliance, a consortium of 84 firms led by Google, aiming at developing open standards for mobile devices [Pro13]. Android has a large community of contributors that develop applications that extend the functionality of the devices. Developers write Android applications primarily in a customised version of the programming language Java [Sha13] and those applications can be downloaded via third-party sites or through online markets such

as Google Play, Google's proprietary application store. As of June 2012, there were more that 600,000 applications available for Android and the estimated number of applications downloaded from Google Play exceeded 20,000 million [Smi13]. The operating system itself is installed on over 300 million devices including 12 million tablets [Pat13].

Android has many reasons that support its strong position in the mobile market, from which the following are highlighted:

- **Open-Source Framework** - Android provides developers with the free open source Linux OS. This means that source code is transparent and available to any developer who wants to modify it or understand how it works. The results are a higher degree of efficiency on system resources and knowledge sharing between developers in the community. In addition, it allows for lower budget needs in companies or even single persons who want to develop for Android.

- **Leading Market Share** - As of the first quarter of 2012, Android leads the United States smartphone market with 61% market share, compared with Apple's iOS 29% market share [Whi13]. Such immense market penetration anticipates that applications developed in Android will inevitably reach a higher number of audience, which consequently leads to an increased success rate.

- **Popular Game Platform** - Mobile gaming in smartphones and tablet devices is now a fierce competitor to consoles and PCs alike. A recent survey [Res13] has discovered that over 125 million people play mobile games in the United States and United Kingdom. Phones and computers were found to be the most common game devices (33% and 32%, respectively), whereas dedicated consoles were only at 18%. One explanation for this fact may be due to the easiness of use that touch-screen interfaces provide and the fact that mobile devices offer other functionalities besides gaming that balance the purchasing cost.

For these reasons, the Android platform proves to be a good choice for the development of this project, as the transparency offered by the framework and its support from the community will aid in addressing future problems that may be encountered. Android's position in the market as the top leader will help broadcast this project even further, reaching more people and hopefully increasing its acceptance rate. Also, the daily growing audience of mobile gaming is an indicator that tablets and the Android platform will take an even stronger position in the entertainment market in the following years.

Android Activity Lifecycle

As the user navigates through an application, the Activity instances in the application transition between different states in their lifecycle. When the activity starts for the first time, it comes to the foreground of the system and receives user focus. During this process, the Android system calls a series of lifecycle methods on the activity in which the user interface and other components are set

up. If the user performs an action that starts another activity or switches to a different application, the system calls another set of lifecycle methods on the first activity as it moves to the background.

During the life of an activity, the system calls a core set of lifecycle methods in a sequence similar to a step pyramid which can be seen in Figure 4.1. Each stage of the activity lifecycle is a separate step on the pyramid. The top of the pyramid is the point at which the activity is running in the foreground and the user can interact with it.

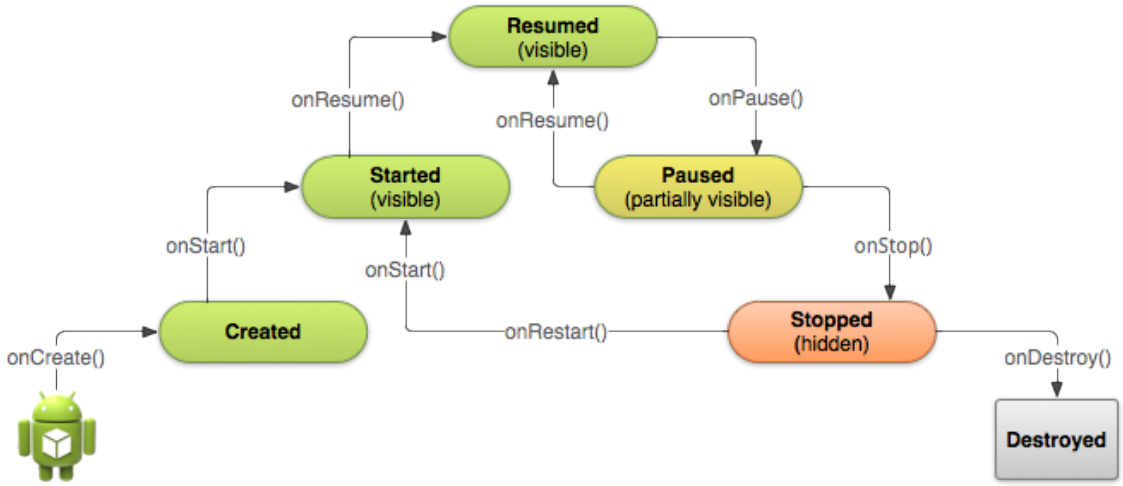

Figure 4.1: Android Activity Lifecycle [And13]

As perceivable from the above figure, activities remain most of their lifecycle in one of the following three states:

Resumed The activity is in the foreground and the user can interact with it. This state is also sometimes referred to as the running state.

Paused The activity is partially obscured by another activity. The activity in the foreground is semi-transparent or does not cover the entire screen. The paused activity does not receive user input and cannot execute any operation.

Stopped The activity is completely hidden and not visible to the user. While stopped, the activity instance and all its state information such as variables is retained, but as in the Paused state, it cannot execute any operation.

Implementing the activity lifecycle methods properly ensures that the application behaves well in several ways, including that it:

- Does not crash if the user switches to another application.
- Does not consume valuable system resources when the user is not actively using it.
- Does not lose the user's progress if they leave the application and return to it at a later time.

This is a very important step in the implementation of any application, but especially important in the development of a game platform designed for seniors. As per observation of the seniors in our test group, we noticed that they tend to often press areas other than the main screen, such as the Android status bar on the bottom of the screen, either accidentally or intentionally out of curiosity. Therefore, it is very important that the game platform is able to preserve its data, and restore it, at any given time that the application is switched for another.

4.3 Specification

In order to design an efficient game platform for the senior population, one that will attract and maintain the attention of its players for preferably a extended period of time, it is essential to understand what they want and need in a application of this kind. Seniors have different requisites from the younger population, and what would work for one age group, may not work for others. Nevertheless, there exist a few common guidelines that apply to all users, regardless of age. Next are the top five requirements that were adopted during the design of the game platform:

Usability Seeing as the game platform was designed and developed specifically for an older audience, usability is one of the most important requirements of the platform. The interface should be as simple as possible, with only the absolute necessary information presented at one time. Interface elements should be positioned consistently throughout all screens and be clearly visible, using buttons of large dimensions and text with big font sizes. Descriptive images should also be used in addition to text to better express the information that is trying to be conveyed.

Engageability One of the main purposes in developing the game platform is to settle into players the habit of playing the games for at least a few minutes each day, in order to stimulate their cognitive in a consistent way to achieve the best results. For this reason, it is of paramount importance to engage players into the game and its social capabilities by creating fun games who appeal to the senior population, and arouse an urge for competition (and cooperation) between themselves.

Performance The game platform should run fast and without delays. When an operation is known to take a considerable amount of time to finish, the application should warn the user. Also, lengthy operations should be few and far between. Otherwise, the player may become impatient and stop playing. To prevent such situations, operations must be optimized so as to perform quickly, using only the indispensable resources, and not wasting battery lifetime.

Robustness The system must be robust and not stop abruptly. This is particularly important in the case of seniors where they may quickly lose interest in the platform if they see that it does not work properly, or worse, if they believe that the application failed as a result of misuse on their part and fear that the situation could worsen should they continue trying to interact with it.

Extensibility The platform should be easily extensible and adding new games should not be burdensome. The system should provide simple abstract methods to facilitate the retrieval and storage of information, with the only responsibility remaining being that of the game logic. The more easily approachable the game platform is to development, the more interest it will instill to developers, and help it grow with more games and functionalities.

4.3.1 Functionality

The game platform, although beneficial to everyone, was primarily designed with a focus on the senior population. For this reason, the games embody characteristics similar to those of the genre of casual games, which are basically designed to be played for a short period at a time everyday.

There are three playing modes: solo play, group play and online play. Solo play, as the name indicates, was created to be played by a single person. Since one the games' main purposes was to cognitively stimulate the player, there was an implicit need to isolate him from other players. Otherwise, the player might receive help from others and not use his capabilities to its maximum potential, which is essential when trying to develop one's mind power. Another reason for playing by oneself is to be able to register the final score (and time) of a game session, and compete with other players. In group play, several players can join a single game and help each other in finishing it. It features the same games and mechanisms as in solo play mode, however, it does not require a previous log on to the system, having been created simply for recreative group play purposes. Reasonably, it does not record any of the game session's score or time. The third playing mode, online play, was conceived with the idea that, hopefully, one day all seniors will have anytime, anywhere, access to the Internet, and will be able to play these games with friends from afar. Unfortunately, at the present time, it is still not a feasible concept, and as such, this playing mode was designed as a simulated prototype, where an Internet connection was not required, and players would play against a basic computer artificial intelligence agent.

First time players of the solo play mode will require to register into the system. The system will ask the player for his name and a set of digits to serve the same purpose of a password. The next step would be for the player to take a picture of himself using the tablet's front camera, finishing with the request of his gender and age for long-term evaluation purposes. During the registration process, the player will be informed of any information missing or incorrectly inputted.

After creating a profile, or by logging on a pre-existing one, the player will have access to a range of games to choose from and is able to select between 3 difficulty modes: easy, normal and hard. Instructions on how to play are given in each game, as well as the option to exit the game at any time. Finally, at the end of each game, the leaderboard displaying the top 5 scores in that game and difficulty is shown to the player. Additional information specific to each game such as score, time, number of guessed words (in a word-building game) among others are also presented.

Throughout all the experience of using the game platform, a help button with tips regarding the current screen is available to aid the player should he become confused. A back button is also present at all times to exit games and travel back to previous screens.

Figure 4.2 encompasses the described functionalities using a use case diagram.

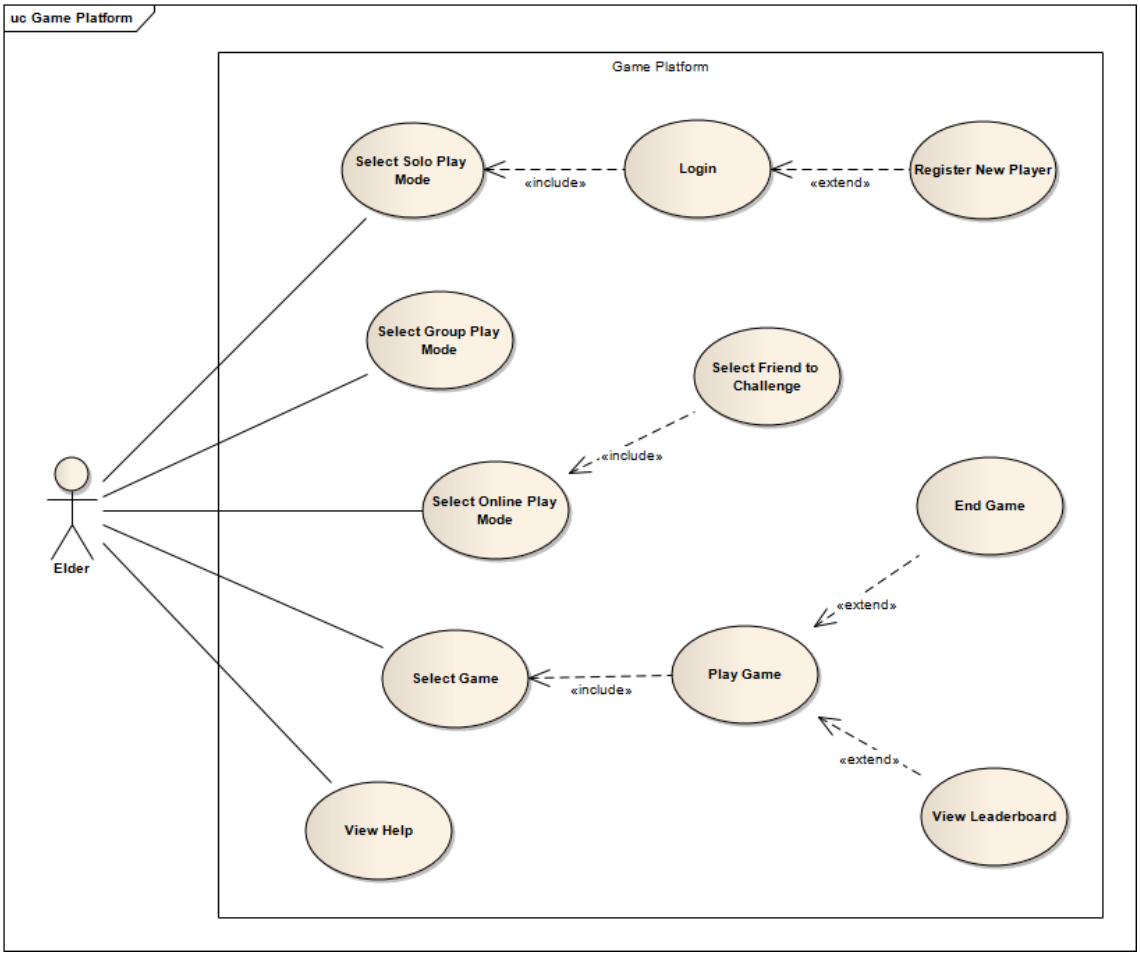

Figure 4.2: Use Case Diagram

4.3.2 Database Design

The database used in the game platform consists of simply two tables: Player and Play. This ensured that cross-referencing between tables would be easily manageable. Diagram 4.3 describes the database in greater detail.

Player Represents the user in the system. This table stores all the information inserted by the user at the moment of registration: an username, a password and an avatar which is stored as the file path of the player's photo in the file system, and is converted to a bitmap at the time of login. Also, the player's gender and age are stored as integer values.

Play Represents a gaming session. This table serves two purposes. The first is to store information to be used in the leaderboard rankings. Data representing which game was played and in which difficulty mode is preserved to be used as search parameters when retrieving the corresponding leaderboard at the end of each game. The total time and score values for that gaming session are also stored. The second purpose for this table is for analysing user gaming patterns and routines. The complete date – Year/Month/Day-Hours/Minutes/Seconds

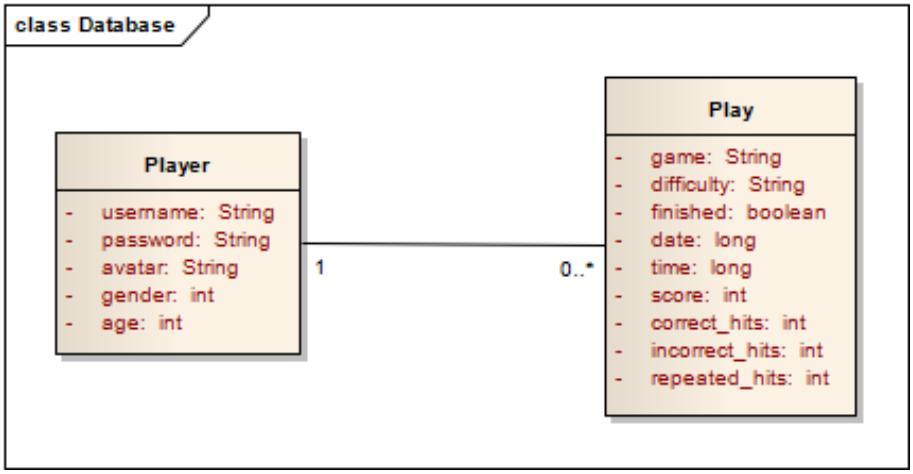

Figure 4.3: Database Diagram

– for that specific gaming session is stored in order to track a player's gameplay activity throughout a set period of time. Also, a boolean value *finished* is saved to check if the player finished the game or left it midway, either by using the exit button in the top bar of the game platform, or by abruptly exiting the application via the Android system. This boolean value may help understand if the player is becoming bored of the game or finds it too difficulty or too easy. The final three integer values: *correct_hits*, *incorrect_hits* and *repeated_hits* represent, respectively , the number of times the player performed a correct action, an incorrect action or a repeated action in that particular game. What represents a correct or incorrect action in dependent of each game and should be decided at the time the game is being designed. For example, in a cards matching game, a correct action could represent a pair of matching cards found, an incorrect action a pair of cards which do not match, and a repeat action a touch event in an already revealed card. Each row entry in this table is associated with a single gaming session and a single player.

4.4 The Process of Design and Evaluation

As described in the previous chapter, the design and evaluation phases of the game platform were performed iteratively (section 3.2.2) using a User-Centered Design approach (section 3.1) which involves the final user in the development phases. During each iteration, the approach began with low-fidelity prototypes created in paper, progressively evolving to the final high-fidelity prototypes implemented in the application itself, with each step being evaluated using the methods described in section 3.2.3. The developed prototypes here explained were distributed in five segments: platform navigation, user registration (and login), a playing card game, a word-building game and the online mode simulation.

4.4.1 Navigating Through the Platform

The user interface prototyping phase started with a comprehensive mapping of the most important features of the game platform. In the initial design phase, the main concern was understanding how information should be presented on screen. Due to age-related changes in working memory, seniors may find it challenging to interpret a large amount of information at a single time. According to the *"7 +/- 2 guideline"* [DFAB03] people can only retain 5 to 9 items of information in short-term memory. Therefore, we decided to split the game platform into two regions: an options bar placed at the top and a content area below where the main activities of the application would take place (Figure 4.4).

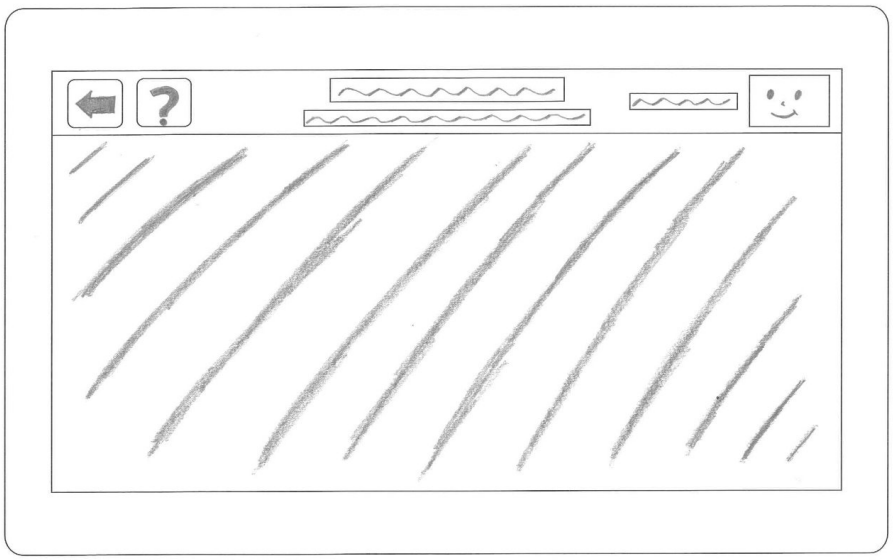

Figure 4.4: User Interface Organization Prototype

The intention behind the options bar was to provide the user with accessibility features spanning all screens of the game platform. This relieved the user of the weight of the most common options, only having to concentrate on the new ones appearing in the main content area. It was first considered placing the options bar on the left side of the screen, but there were two main concerns. One of the main elements to include in the options bar was the current screen title and sub-title, which was not feasible by using a vertical bar. The second reason, discovered right from the start of the usability tests, was that seniors often grabbed the tablet device with both hands on each side of the screen and would inadvertently press any buttons placed there. For that reason the options bar was instead placed on top of the screen, providing ample visibility and being distant enough so as to allow seniors to comfortably hold the tablet device without hindrance.

The top bar featured a maximum of 6 elements: a back/exit button, a help button, the current screen title and sub-title, and if the player was logged on to the system, the player's name and avatar picture. The first prototype of the title screen (Figure 4.5) which already featured the top bar, used either descriptive images or text, depending on each button's intended functionality. However, we found that seniors would often question us about the intended use of a button that

only had an image and no text. After the explanation, they believed it was fairly easy to understand but would prefer the combination of images and text to further convey the intended meaning of a button. Therefore, we re-designed the final prototype for the title screen, featuring all the necessary options, which can be seen in Figure 4.6.

The size of buttons and labels as well as the descriptive texts of all elements in the game platform were selected by seniors participating in our usability tests and by resorting to a user-testing knowledge base available at Fraunhofer AICOS. This previous experience in user-testing accelerated the design process of the user interfaces, as it attested the accuracy of our evaluations.

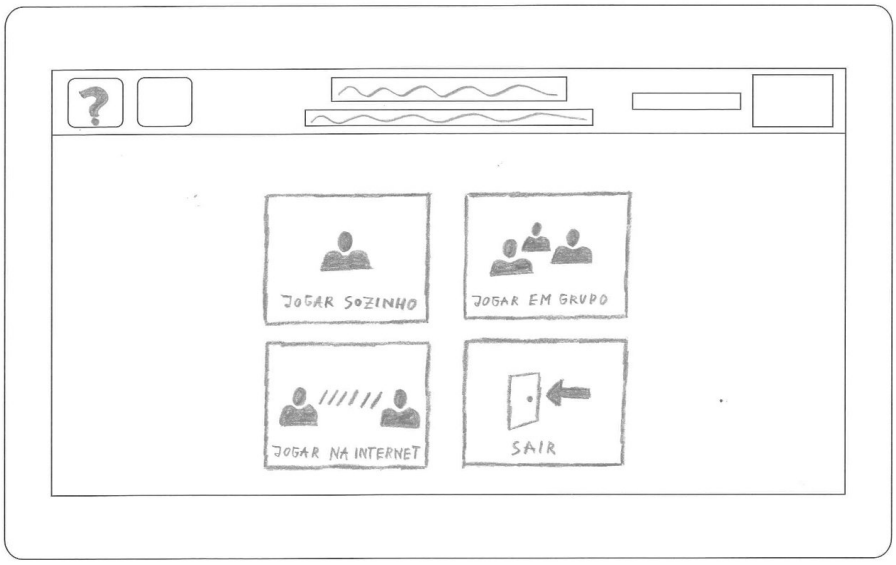

Figure 4.5: Title Screen Low-Fidelity Prototype

Figure 4.6: Title Screen High-Fidelity Prototype

As explained in section 4.3.1, the title screen provided three gaming modes: solo, group and online play. The help button, as well as every other elements in the top bar, was available throughout all screens of the game platform. At any time, had the seniors felt the need for assistance, he could press the help button and a pop-up message would appear (Figure 4.7) displaying instructions on what to do at that specific time. The exit button, as the name indicates, allowed the seniors to travel back to previous screens, which included exit a game during a gaming session. In order to avoid seniors from accidentally exiting a game, or losing all information already inputted during the registration process, we also included a confirmation pop-up message to check if the senior did in fact have the intention of exiting.

Figure 4.7: Help Dialog Screen

Figure 4.8: Game Selection Screen

After the player selected a playing mode, he would be taken to the game selection screen (Figure 4.8). On this screen a list of games was available as well as three difficulty modes for each games: easy, normal and hard. We developed two cognitive training games, one stimulating short-term memory (4.4.3) and another to improve verbal-fluency (4.4.4). Games developed for this platform had the purpose of training the senior player into improving his cognitive abilities by creating a daily routine of playing these games for a few minutes each day. However, the system needed to be able to store the senior's progress, so it was necessary to first create a personal profile, following the procedure explained in the following section of this chapter.

4.4.2 Creating a Personal Profile

One of the most important features to develop in the game platform was a registration module, particularly for two essential reasons. The first was to ensure that the application could record each player's individual progress throughout the cognitive training, which is one of the fundamental purposes for the usage of the game platform. Besides having clear boundaries between each player's personal advancement, creating a personal profile meant that, at the end of each gaming session, the player's score would be recorded in the leaderboard ranking system, generating a healthy competitive environment between seniors, which could help bring them together and foment social interaction among them.

In a first attempt to design a registration module, all information required from the senior player was disposed in a single screen (Figure 4.9), with the idea that a single screen would ease the process, relieving the senior of traversing multiple screens, which could become tiring. However, when evaluating the efficacy of such design with our seniors participants in the usability tests, we came to realize that our initial design did not work very well, as seniors quickly became confused with so many distinct interface elements displayed at the same time.

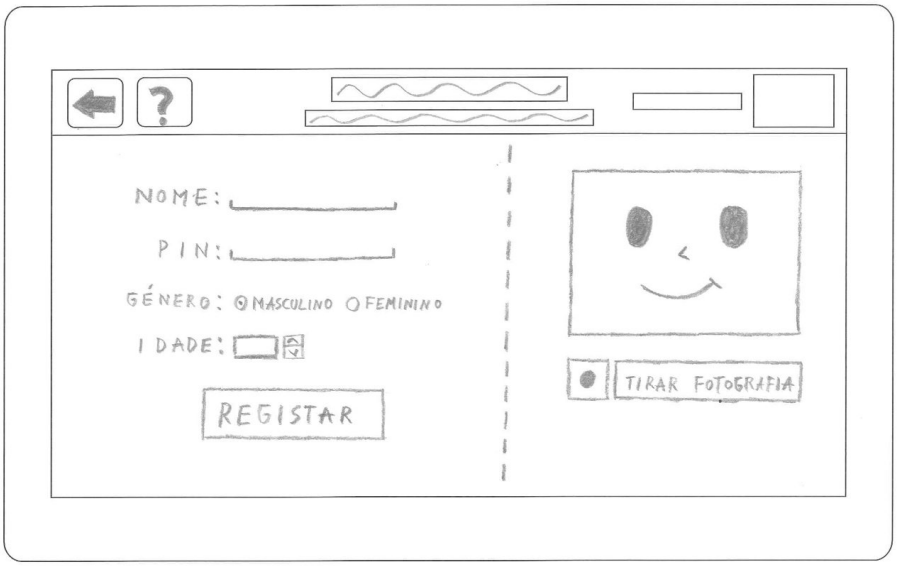

Figure 4.9: Registration - Single Screen Prototype

To amend this problem, it was necessary to spread the registration process into multiple steps. In the first step (Figure 4.10), it was required of the user to choose a username and a password. We asked our participant seniors if they were familiar with computers and the concept of digital authentication. Almost every single one was not familiar with this concept, although they had previously interacted with computers. In addition, seniors found that memorizing a password was difficult due to the possible combination of letters, numbers and even symbols such as hyphens or underscores. Therefore, it was necessary to translate this concept into a more familiar one, and as a result, the elements of username and password were changed into a more easily recognizable *Nome* (Name) and PIN. Since all seniors had previous experience with mobile phones, it was easy for them to understand the concept of a PIN, and had no trouble memorizing it.

Figure 4.10: Registration - Step 1/3

There was, however, another recurrent problem when introducing text data, which was the fact that seniors could not detect where to insert such data. Because the widget provided by the Android framework is a simple line, we introduced the placeholder text *Toque aqui* (Touch here) to alert the user of where to touch in order to insert text data. Still, there was yet a bigger problem to overcome.

Perhaps one of the most complicated problems we have encountered during the whole evaluation process of the game platform was using Android's soft-keyboard. The default soft-keyboard (Figure 4.11) integrated in the Android framework proves to be a very powerful feature when developing applications for a younger, more experienced audience. However, in the case of seniors, it became a serious obstacle in the pursuit of an user-friendly interface. Besides having many unnecessary buttons, the keys on the default soft-keyboard are very close to each other, and are very sensitive to any touch, more often than not inserting the wrong key for the senior. The soft-keyboard in Android is, without doubt, one of top priority components that need an ample re-design in order to be efficient in designing applications for the senior population. However,

due to the complexity and time requirements of such task, we had to comply with the default soft-keyboard for the scope of this project. Fortunately, our senior participants were able to overcome this obstacle to some extent with practice, and comfortably use the game platform.

In the second step of the registration process (Figure 4.12), seniors were invited to take a picture of themselves using the Android's front camera. This step helped them feel more engaged in the game platform environment by conferring a more personal touch to their profile. All seniors were able to take a picture on their first try, and more than once, asked to take another, as the first one "did not capture their best side".

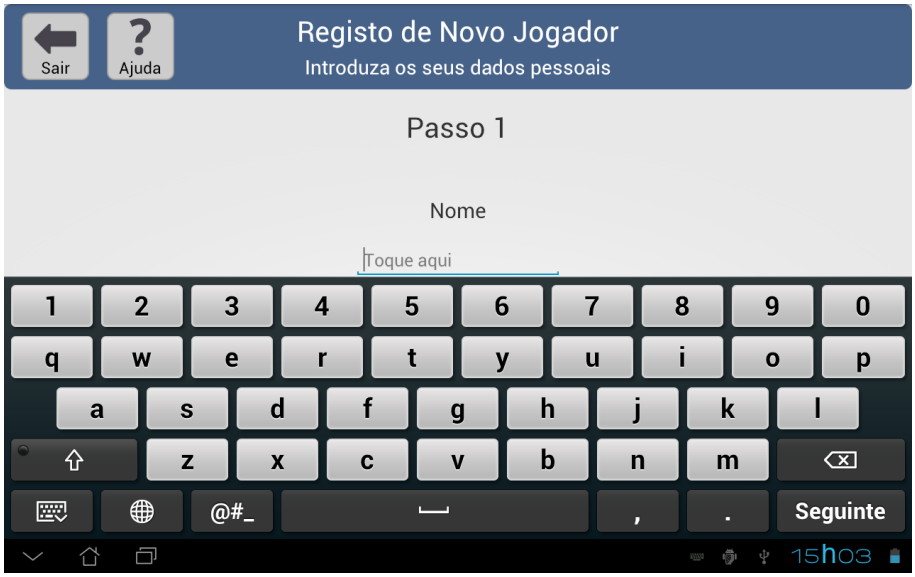

Figure 4.11: Registration - Soft-Keyboard

Figure 4.12: Registration - Step 2/3

The third and final step asked for the senior's gender and age (Figure 4.13). This information was not particularly relevant to seniors, but important for performance evaluation tests conducted by specialists in the area of cognitive stimulation and training. Seniors, once again, did not encounter any problems finishing this step, and the only thing remaining was to confirm that all data was inputted correctly.

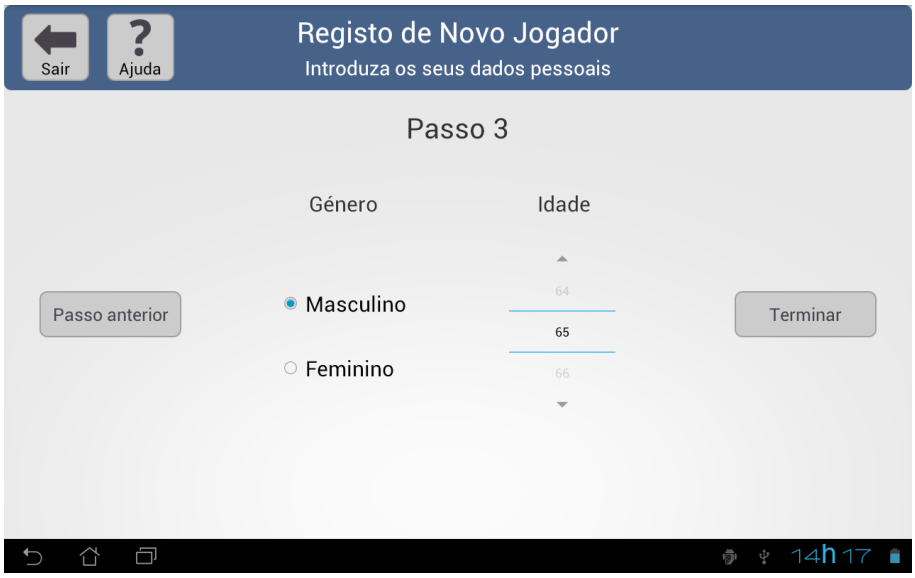

Figure 4.13: Registration - Step 3/3

When pressing the *Terminar* (Finish) button, the system would warn the user of any problems found in the information provided in any of the three steps (Figure 4.14). Common problems included empty fields or fields that did not reached the minimum required length (e.g. a name too short). The system would also warn the user in case he forgot to take a picture in step 2. To fix these problems, the user was required to travel back to previous steps using the left button with the label *Passo anterior* (Previous step). At first, seniors did not understand how to go back to previous steps as the former labels for the buttons were "Step 1", "Step 2" and "Step 3" instead of "Previous step" and "Next step". This created confusion between the step they were currently in and the one they were trying to travel to, as they believed the button label meant that they were currently in that step. That being the case, we decided to switch the labels to "Previous step" and "Next step" which solved the problem. Seniors were then capable to travel between steps without any problem. Title labels on top of each screen were also inserted, which were not available in the first evaluations, to further help seniors become aware of the current step. After the user confirmed that all his personal data was correct, the system created the profile and automatically logged on to the game selection screen. Had the player already created a personal profile previously, he would have been able to log on to the system via the login screen (Figures 4.15 and 4.16).

The login screen presents a similar data entry structure as the registration screen. This maintained consistency and prevented the senior from becoming confused. The senior inserts his name and PIN in the same fashion and logs on to the system by pressing the *Entrar* (Enter) button. In

the event that the inputted data was incorrect, a warning screen would inform the user. When the system acknowledged a valid user, he would be redirected to the game selection screen and his name and avatar picture would be visible on the top right corner of the screen. When the senior wished to log out, he would simply need to press the back button on the top bar to return to the login screen.

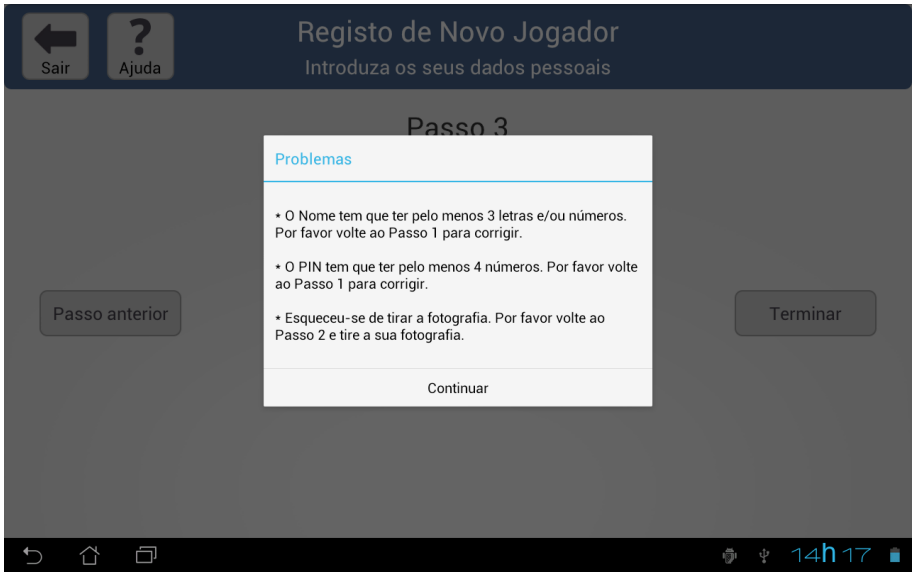

Figure 4.14: Registration - Solving Problems

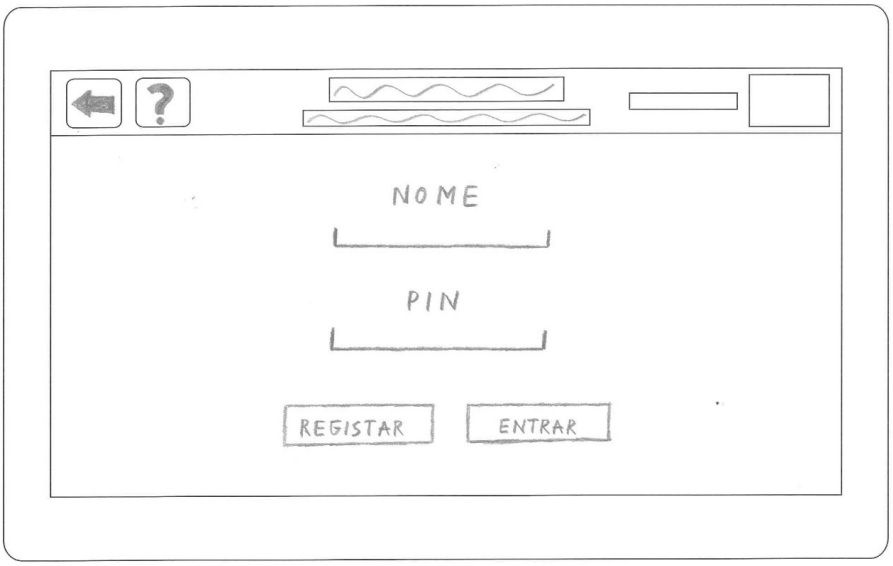

Figure 4.15: Login Screen Low-Fidelity Prototype

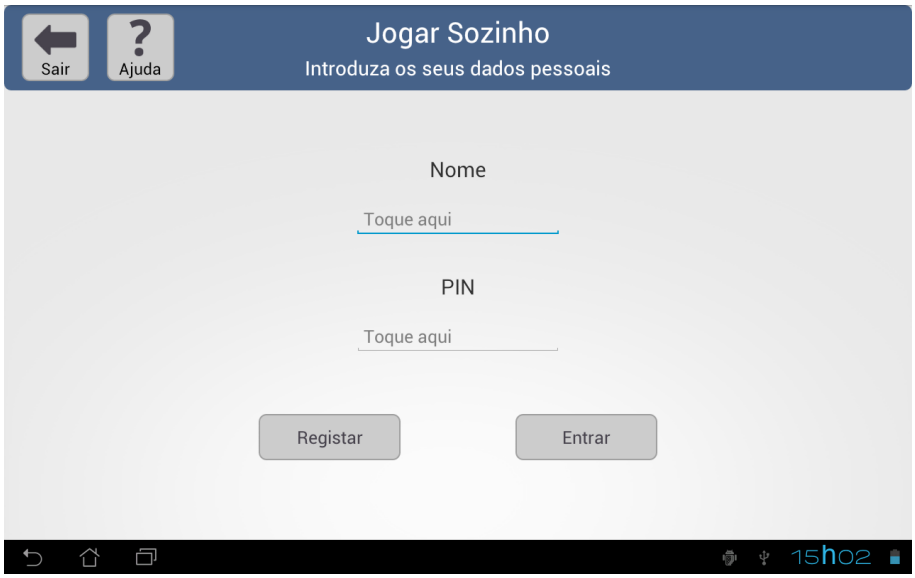

Figure 4.16: Login Screen High-Fidelity Prototype

4.4.3 A Memory Card Game

The first game implemented on the game platform was a card game which main objective was to find all pairing cards of the same symbol. This is well known type of game and was chosen for its simple rules and familiarity with the seniors in our test group. The focus of this game was to train working memory, attention and spatial cognition.

The rules for this game were as follows:

- A game board containing 12 or 24 cards facing down is shown to the player;
- The player then touches two cards, turning them up;
- If the cards match, the player is awarded 100 points and the cards remain faced up;
- If the cards do not match, the player is penalized with -10 points and the cards return to the faced down position;
- The game ends when the player finds all card pairs.

The first prototype (Figure 4.17) represents a small game board with 12 cards (6 matching pairs), and was at first the only layout of the game. However, in later stages of development, when difficulty modes were already implemented, this layout became the easy mode, in virtue of its small amount of cards.

Initially, classic card images (13 figures, 4 suits, 2 colours) were used in the game. Seniors approved this decision and said that they were used to playing many card games, so they were familiar with the classic images. However, during our usability tests, we observed that seniors often mixed cards with similar colours and figures, which amplified the difficulty of the game drastically, and as a result reduced the appeal of the game.

To solve this problem, we came to the conclusion that it was necessary to create a deck of cards with many shapes and colours. The resulting game board can be observed in Figure 4.18. The new board used a variety of distinct shapes and colours to create a big contrast between each other. This time, seniors were able to completely distinguish between each card, lowering considerably the degree of difficulty.

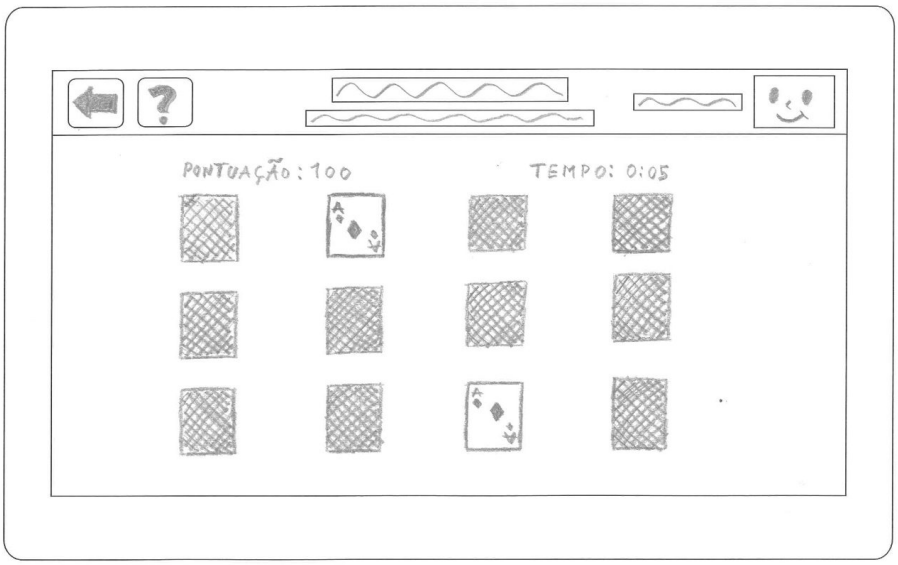

Figure 4.17: Memory Card Game Low-Fidelity Prototype

Figure 4.18: Memory Card Game - Small Board (Easy Mode)

It was now necessary to gradually increase the difficulty of the game in order to appeal to more skilled players. Accordingly, difficulty modes were implemented. The initial small size board was converted to easy mode, and a larger size board with twice the amount of cards was designed to accommodate for a normal and hard difficulty modes. Normal mode (Figure 4.19)

created an extra challenge by increasing the amount of pairs necessary to uncover to finish the game, and hard mode (Figure 4.20) added an extra layer of adversity by removing colours, one of the main attributes that assisted in memorization. Seniors were now able to start playing in a situation which actively stimulated their memory and engaged them into the game, progressively advancing to new and harder difficulty modes.

After a game was finished, the player's total store and time would be displayed, alongside the leaderboard ranking featuring the top 5 scores in that same difficulty mode (Figure 4.21). Seniors who were playing with an active account, would be eligible to feature in the leaderboard in the event that their scores were higher than any of the top 5 positions.

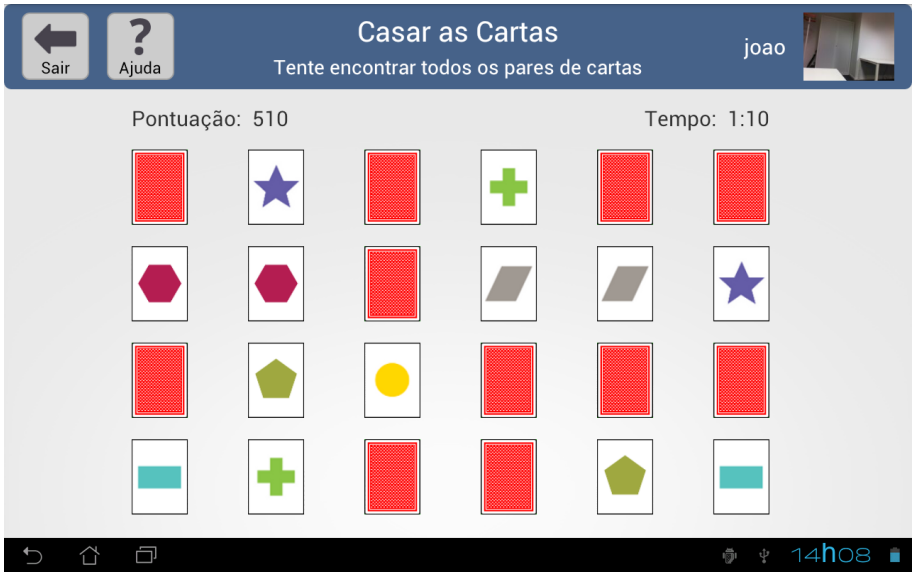

Figure 4.19: Memory Card Game - Large Board (Normal Mode)

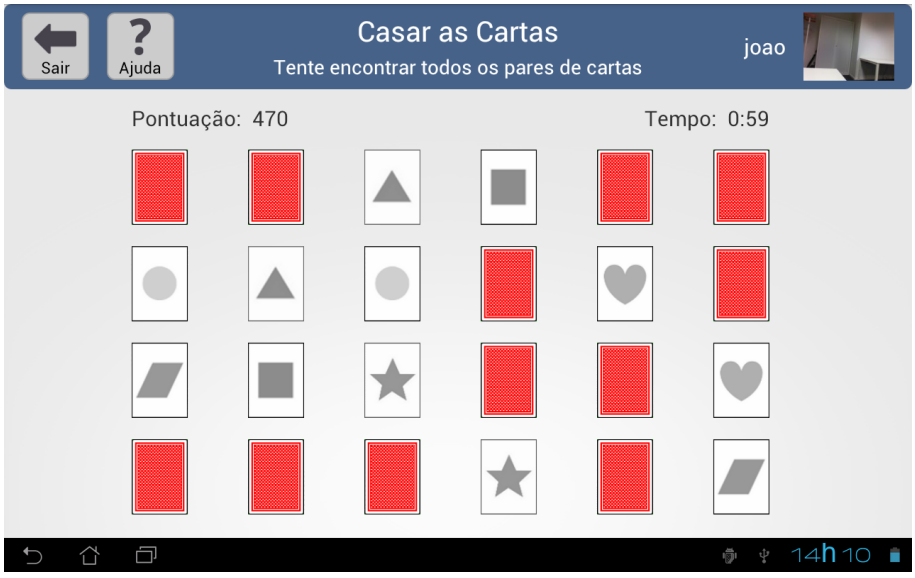

Figure 4.20: Memory Card Game - Large Board (Hard Mode)

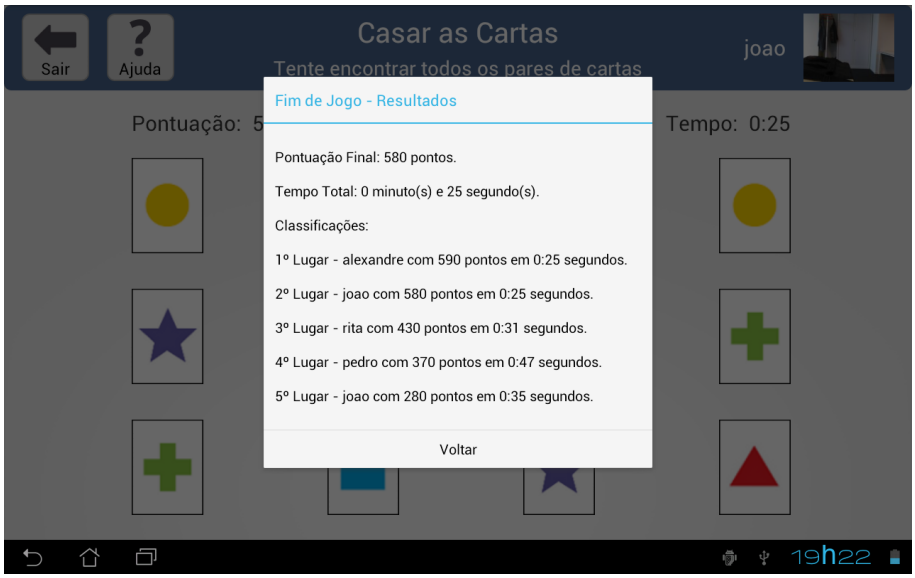

Figure 4.21: Memory Card Game - Leaderboard Ranking

4.4.4 A Verbal-Fluency Word Game

The second game that was developed for the game platform was a word game where the main objective was to create as many valid words as possible, given 7 letters at random. The idea for this game came from the fact that long-term memory is usually not affected by ageing, and would provide a greater amount of variety to each game due to the random assignment of letters. This game focussed on improving verbal-fluency, which describes the rate at which someone can produce words.

The rules for this game:

- 7 letters at random are given to the player;
- The player must then create as many valid words as possible within a 5 minute time frame;
- Words must be composed of at least 2 letters;
- A valid word awards (number of letters * 100) points;
- Using all letters in a single word awards 1000 points;
- No points are deducted from creating a non-existent word or a word already previously created.

It was decided not to deduct points from mistakes during the game so as not discourage seniors from trying to improve their vocabulary by guessing at words they were not fully sure would be correct. The purpose of this game, and of every feature in the game platform, is to encourage seniors to take risks and challenge themselves in every possible way. Therefore, we wanted them to try ever single word that came to their minds, even if they were not sure it was valid, as many times they realized that they knew many more words than they initially believed.

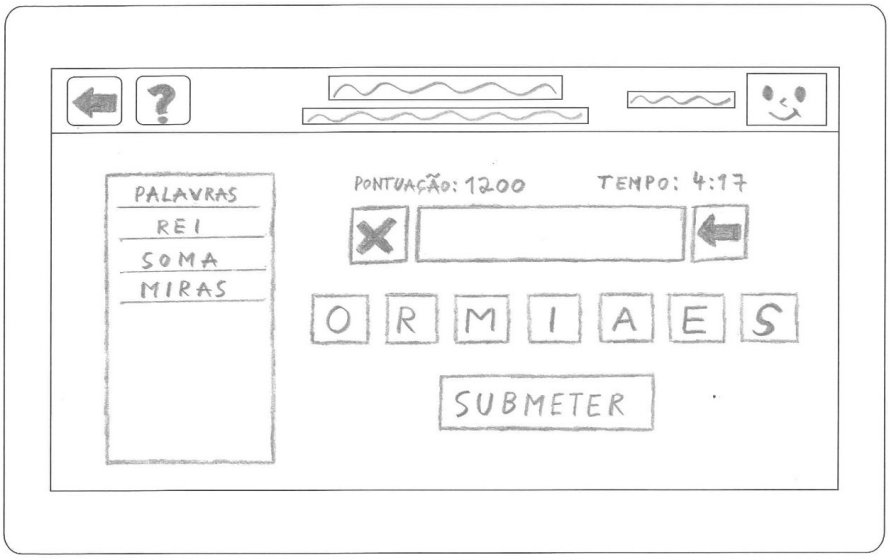

Figure 4.22: Verbal-Fluency Word Game Low-Fidelity Prototype

Our initial prototype for this game (Figure 4.22) did not provide much room for improvement in terms of extras challenges for more expert players. However, extra difficulty levels were necessary as inspiration for seniors to improve themselves.

Words created by players, when submitted, went through a validation process that takes advantage of a dictionary text file with nearly 50.000 words. Using that dictionary, we developed a small script that given 7 random letters, would return how many words could possibly be created. This small script established the possibility of creating multiple difficulty levels, with the number of possible words in a game being the main challenging factor.

The three difficulty levels were generated as detailed in the following tables:

Table 4.1: Easy Mode

No. Vowels	No. Consonants	3 Letters	4 Letters	5 Letters	6 Letters	7 Letters
4 - 5	2 - 3	> 30	> 40	> 30	> 15	> 4

Table 4.2: Normal Mode

No. Vowels	No. Consonants	3 Letters	4 Letters	5 Letters	6 Letters	7 Letters
2 - 3	4 - 5	20 - 30	30 - 40	20 - 30	5 - 10	2 - 4

Table 4.3: Hard Mode

No. Vowels	No. Consonants	3 Letters	4 Letters	5 Letters	6 Letters	7 Letters
1 - 2	5 - 6	5 - 15	5 - 20	5 - 15	1 - 3	1

As can be concluded from the previous tables, difficulty increased as a result of fewer vowels and fewer possible words available. The generator always guaranteed a minimum amount of words and in harder levels also imposed an upper limit. It was possible in every game to compose a 7 letter word, and seniors were encouraged to do so. Three text files containing 1000 rows each, were generated using this script and at the beginning of each game, the system would pick one random row from the correspondent text file. Each row was composed of two elements: a string with 7 letters and the number of possible words using those 7 letters (e.g. "eoritpa 231").

The final prototype designed for this game can be seen in Figure 4.23. Players must touch each letter for it to appear in the middle rectangle. To remove a single letter, the *Tirar* (Remove) button was used, and to erase all inserted letters, the *Limpar* (Clean) button was used. To submit a word, players needed simply to press the *Verificar Palavra* (Verify Word) button, and if it was a valid word, it would appear in the left-side box to remind the user of already validated words. When words would go under the bottom limit of the left-side box, players could slide it to reveal hidden words. All labels on buttons were suggested from our seniors participants during testing phases. Another suggestion from one of our seniors, was to display the number of words still remaining in the game was included, because she said she felt curious on how much more she could have done, if only she knew there were still words available to create. Additionally, 2 letters words became acceptable in the final prototype, whereas at first it was not possible.

Figure 4.23: Verbal-Fluency Word Game High-Fidelity Prototype

After 5 minutes of playing, the results for that gaming session and the leaderboard ranking would be displayed to the player (Figure 4.24). Results included: total score, number of words composed, and as another suggestion from one of our seniors, the final list of created words. Again, seniors playing using their personal profile had the change of featuring in the top 5 positions.

It is worth mentioning that this game was the most popular one among seniors, and the purpose of promoting cooperation and social interaction was highly achieved during the testing phase of

this game. When questioned about why the game was so popular, seniors replied that this game not only required focus like the Memory Card game, but that it also capitalized on the vocabulary knowledge of each person, and that each person's individual life experience contributed to an overall better score in each game.

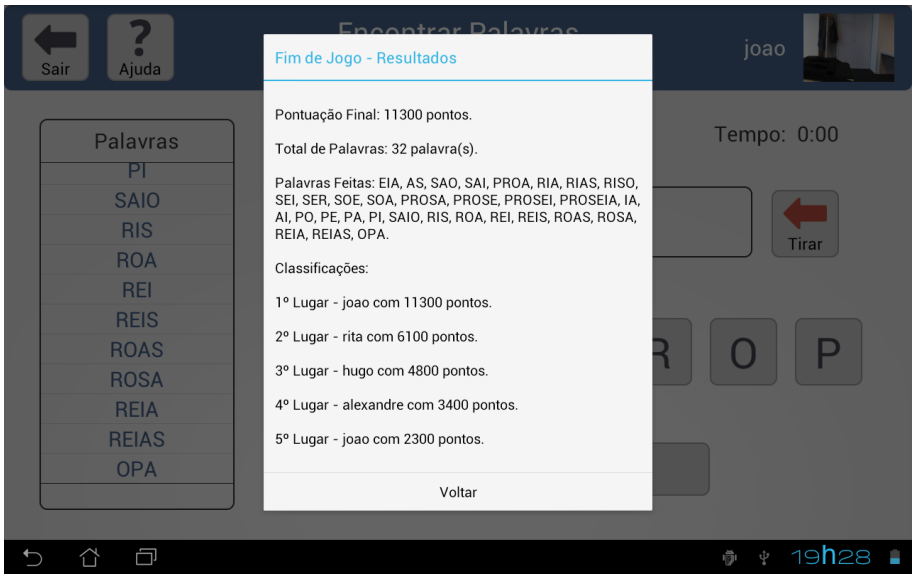

Figure 4.24: Verbal-Fluency Word Game - Leaderboard Ranking

4.4.5 Simulating an Online Game Environment

Since one of our purposes in developing the game platform was also to promote social interaction among seniors, we wanted to try to expand that concept a bit further and delve into the online world. Be that as it may, almost every senior we talked to had little to no experience with the Internet or social networks themselves.

Our objective was not to develop a full-blown social network for seniors, but simply to experiment with the concepts of online social companionship within gaming using a wizard-of-oz simulation (See section 3.2.3). As such, our experiment focused mainly on the gaming component rather than the friend-searching mechanisms. Our senior participants would begin the "online" experience by joining a game lobby where their friends, with whom they had previously connected, would be visible (Figure 4.25). The game lobby high-fidelity prototype presented each friend with a name and corresponding picture to more easily identify each person. The senior would then press the *Jogar* (Play) button, which would start a competitive memory card game.

The layout for the game board remained roughly the same for consistency purposes, but was slightly modified to display the status of both players (Figure 4.26). Each player would be identified with both his name and picture, and each player's score following below. Our senior participants would have the first turn, trying to find a matching pair of cards. Had he found one, he would be given another turn to play, otherwise the other player would have his turn. The player with whom they were playing against was conveyed through his picture as another senior, but in

fact it was the computer who played, picking two cards at random. Each player would try to find the most matching pairs and achieve the highest score. After the game was finished, a pop-up message would display each player's final score and who had won in that round (Figure 4.27).

Figure 4.25: Online Game Lobby Simulation

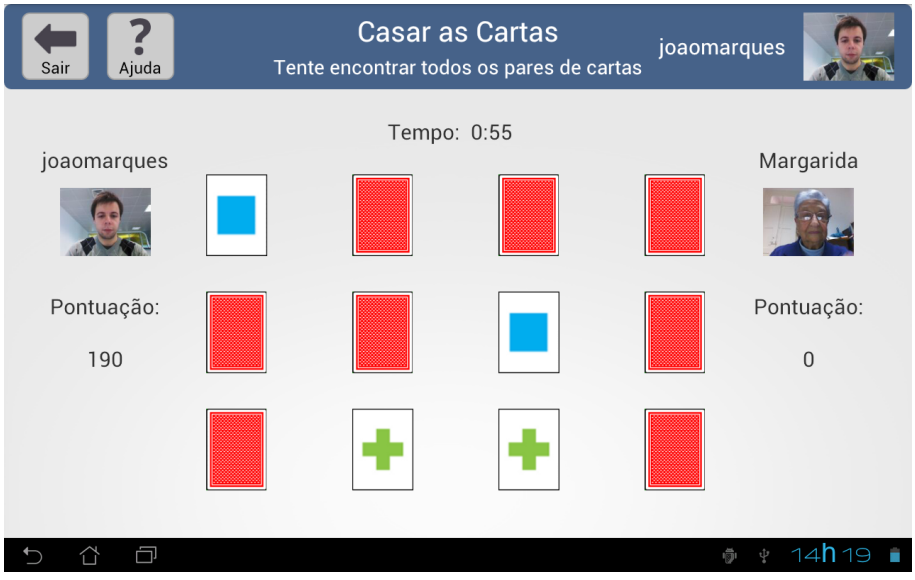

Figure 4.26: Online Gaming Session Simulation

All seniors were able to finish the simulation successfully and gave good feedback on the concept, saying that they would enjoy playing with friends with whom they do not have the opportunity to meet very often. We can conclude then, that the implementation of a real online gaming environment would have good acceptance by seniors, providing that other functionalities such as friend-searching were equally effortless, and could prove to be a great subject of study within a next development step for the game platform.

Figure 4.27: Online Gaming Session Simulation - End Game

4.5 Summary

This chapter explained all steps taken in the implementation of the game platform, since the initial requirements for the tablet device, to the design of the low and high-fidelity prototypes and their user-centered evaluation. The next chapter presents the long-term user interaction results that we were able to obtain, that could shed some light on the reasons that lead seniors to perform certain actions when interacting with the game platform.

Chapter 5

Long-Term Evaluation

Designing user interfaces is a challenging task, and their acceptance depends crucially on the designers experience and intuition. As a result, it is not uncommon that an application does not fulfil the user requirements and shows severe shortcomings in terms of usability, especially in the case of applications designed for an older audience.

Common design processes attempt to increase usability iteratively, repeating multiple design and test cycles, in which the designers observe users interacting with the prototypical application in order to better understand their needs. The main drawback of this approach is the cumbersome and expensive execution and analysis of the test cycles.

To overcome these issues Fraunhofer AICOS has developed the Fraunhofer Usage Mining (FUSAMI) system which significantly eases the task of testing and analysis. The system observes the user interaction and applies analytical algorithms to find and visualize possible design issues, which could have negative impact on user experience.

The following sections illustrate the integration of FUSAMI and other game-specific data extraction solutions into the game platform, which can be used to uncover seniors' patterns of interaction and understand their significance in technology acceptance and cognitive training.

5.1 Analysing User Interaction using FUSAMI

The FUSAMI system offers a rich set of analytical tools that render the information sent from the application in a visual appealing way, using screenshots from the application itself to present complex results in a easy to understand format.

The first step in utilizing this system is to take screenshots of every screen that we wish to monitor, and upload them to FUSAMI (Figure 5.1). If a screen contains dialog windows that are to be monitored as well, extra screenshots should be taken for each window. Afterwards, it is advised to group the uploaded screenshots into different categories, based on the Android activity in which they will appear. For example, a Title Screen category could have one screenshot for the

main content, another screenshot containing a dialog window with help tips and a third one with an exit dialog window. Since all dialog windows appear under the same Title Screen activity, they should be grouped together.

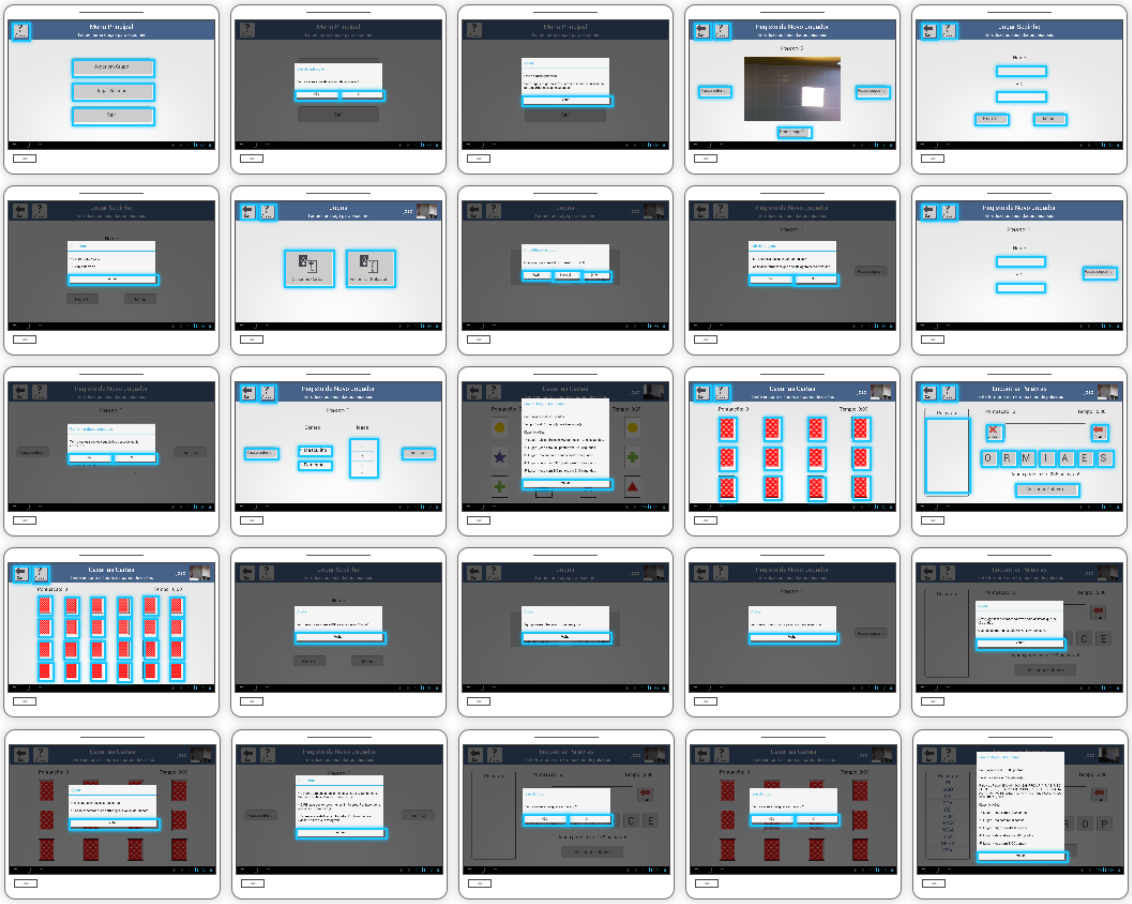

Figure 5.1: FUSAMI - Game Platform Screenshots Overview

The next step consists in wrapping all widgets that we wish to track individually – buttons, text fields, etc. – with a blue-bordered frame (also visible in Figure 5.1). This creates logging frames that ensure that individual data regarding interaction with those specific widgets will be extracted. Each logging frame contains unique identification that is later used when the application is running to send events to FUSAMI, warning it that a specific widget has been pressed by the user.

These steps prepare an application for data extraction regarding user navigation between screens and touch events with its widgets. The game platform, after being imbued with FUSAMI capabilities, was taken to one of the recreational centers where a group of seniors participating in our usability tests spent their days. We left one tablet device with the game platform installed in the recreational center for a full month, under the supervision of the caregivers, and asked them to encourage seniors to play for a minimum of 5 to 10 minutes per day, so that we could withdraw a good amount data to analyze their interaction behaviours with the application.

When one month was completed and we received the tablet device back, all data contained in the game platform was uploaded to FUSAMI to be analyzed. User interaction data in FUSAMI is

depicted by event frequencies and is visualized as a heap map. A heap map indicates, via a colour gradient, the percentage of touch events pertaining a specific screen or widget, ranging from a dark blue meaning little interaction, to a bright red representing the majority of interaction. The heat map visualization can also be used to visualize the time spent in each screen.

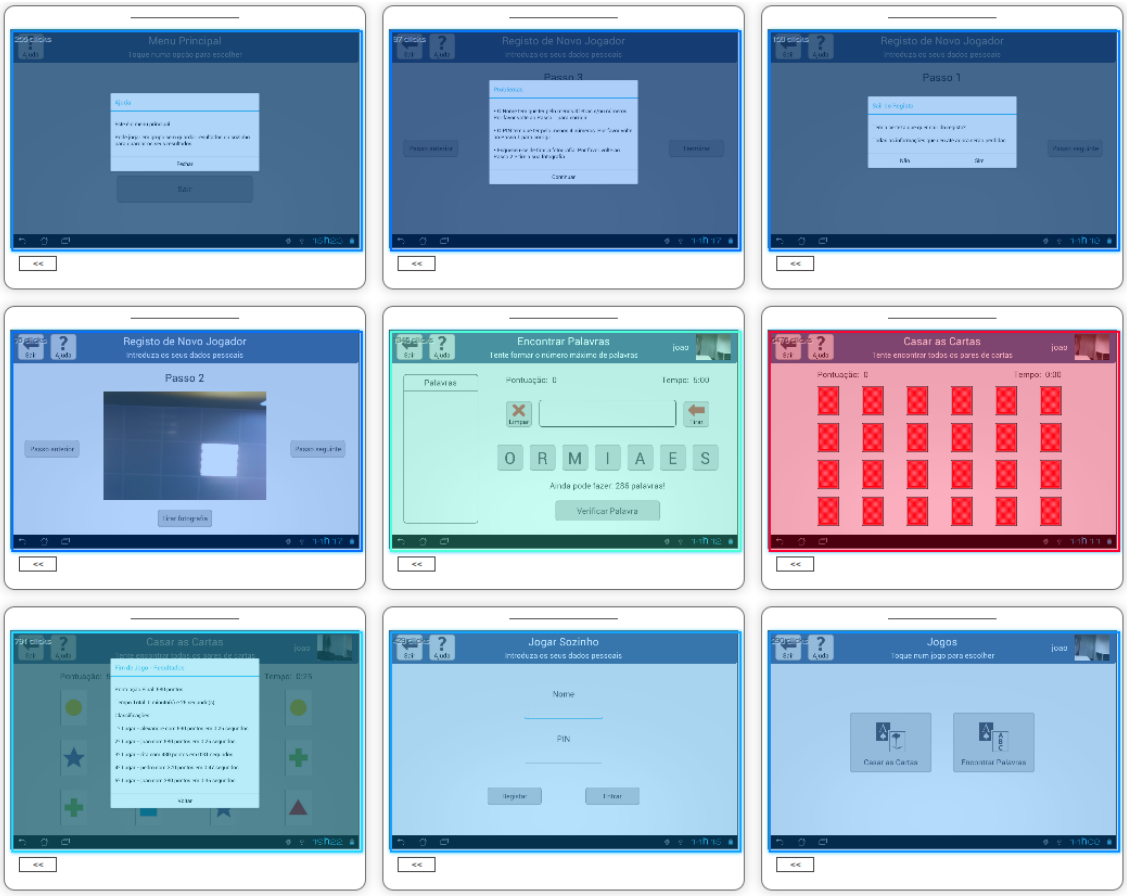

Figure 5.2: FUSAMI - Screen Heat Maps

The game platform was divided into 9 categories: Title Screen, Login Screen, Registration (Steps 1, 2 and 3), Game Selection Screen, Memory Card Game (Small Board and Large Board) and Verbal-Fluency Word Game (Figure 5.2). The user interaction data regarding screen navigation can be seen in the following table:

By analyzing this table we can already gain some insight on how seniors interacted with the game platform. We can clearly see that seniors spent most of their time playing the Memory Card Game in the Normal and Hard difficulty modes, which are the ones that utilize the larger game board with 24 cards. This information could tell us that maybe seniors are finding the easy mode too simple, and that more challenging difficulty modes should be implemented. However, it could also mean that seniors are taking too much time finishing one gaming session, that the difficulty gap may be too wide and the learning curve too steep, which could hinder their cognitive training. We can also observe that the difference in time percentage between each of the registration steps

Table 5.1: Screen Heat Maps Statistics

Screen Name	No. Clicks	Click Percentage	Time Duration	Time Percentage
Title Screen	256	3%	0:34:18	6%
Login Screen	429	4%	1:06:22	11%
Registration Step 1	150	2%	0:19:05	3%
Registration Step 2	76	1%	0:06:29	1%
Registration Step 3	97	1%	0:10:40	2%
Game Selection Screen	290	3%	0:41:44	7%
Card Game Small Board	791	8%	0:41:36	7%
Card Game Large Board	6476	64%	5:05:07	48%
Word Game	1345	14%	1:31:48	15%

seem correct, as inputting a Name and PIN (Step 1) usually takes longer than choosing one's gender and age (Step 3), which in turn usually takes longer than taking a picture (Step 2). This could prove that the registration process is running smoothly and no critical problems have occurred.

We can also try to analyze user interaction on a deeper level by examining widget data. The most important components to analyze were the two games. As we can see in the Memory Card Game depicted in Figure 5.3, every card was equally pressed throughout all gaming sessions, averaging around 250 to 300 clicks each. Although we initially believed that seniors would often choose cards on one side over the other, that situation did not occurred. Optimistically, this is an indication that all areas of the screen are given an equal amount of attention by seniors, allowing developers to make the best use of one of the tablet's biggest advantages: screen size.

Figure 5.3: Memory Card Game - Widget Heat Maps

On the Verbal-Fluency Word Game screen (Figure 5.4), it is also noticeable the equality given to every letter button, further supporting our initial speculation. Perhaps the most apparent issue to analize would be the fact that the left-side word box is seldom clicked. The side box widget had the purpose of keeping in a list all valid words that the senior had already submitted, and could be slided up and down when it became completely filled. The disregard for this list could mean either one of two things: either the purpose of the widget is not clear enough, that seniors do not realize that they can slide it up and down to reveal hidden words, or that seniors never actually fill the list completely, which could be an indicator that the game's difficulty may be too high.

Figure 5.4: Verbal-Fluency Word Game - Widget Heat Maps

All in all, it is important to be aware that FUSAMI, just like any other tool, cannot give direct answers on the reasons behind user interactions with an application. It should always be followed with additional usability tests, and be coupled with data from other evaluations sources in order to achieve relevant results. Nevertheless, FUSAMI proved to be a reliable tool in understanding usability issues regarding seniors' interaction with the game platform.

5.2 Understanding Seniors' Gaming Habits

In order to perform cognitive assessment evaluations on seniors, professional experts in the area of psychology are required to validate the results and attest the relevance of the cognitive training exercises. With the development of the game platform, came forth the idea of helping these professional evaluators in understanding seniors' gaming habits that could provide some insight on their overall performance.

For that purpose, it was necessary to extract performance data from each senior's gaming session, so that it could be filtered, compiled and analyzed. As previously explained in section 4.3.2, each time a senior played a game, the following information was extracted:

date The date on which the game was played;

time The time duration of the game;

score The total amount of points obtained in the game;

correct_hits The number of positive outcomes attained (e.g., uncovering a matching pair of cards);

incorrect_hits The number of negative outcomes sustained (e.g., uncovering an nonmatching pair of cards);

repeated_hits The number of repeated actions performed (e.g., attempting to turn a card already facing up).

finished Whether the player completed the game or left halfway.

As a senior acquires a daily habit of playing the cognitive stimulation games, his standard level of performance will start to become apparent. From that point onwards, it will be possible over time to assess improvements and declines in performance and evaluate the reasons behind them. The data retrieved from each senior could be presented by plotting a graph. Due to the time constrains of this project a graph generator was not implemented in the game platform, but all data is already being extracted from each game and for each senior who creates a personal profile. Figure 5.5 represents a possible low-fidelity prototype for the graph visualization module and exemplifies the average score achieved for the player during a one week period.

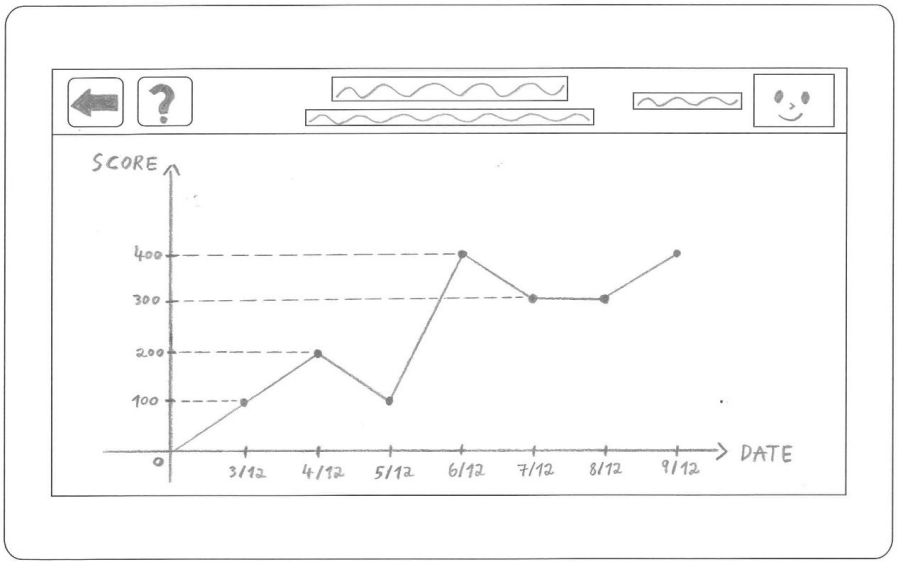

Figure 5.5: User Data Graph Prototype

Using information retrieved from the game platform, a professional evaluator could determine if any formal cognitive evaluations would need to take place to verify initial suspicions from a first analysis of the data. Also, members from the senior's family could use this tool to be aware of any unexpected deviations in performance, and seek guidance from professionals.

5.3 Summary

FUSAMI did indeed prove to be a powerful tool in uncovering usability issues in the game platform, and how the information provided could be helpful in finding solutions to those issues. Alongside FUSAMI, other mechanisms from within the game platform itself could prove to be useful when analyzing seniors' performance in the long-term on a personal level and apply specific adjustments to each different person as they become necessary.

In the next chapter, we will review the research process adopted during the course of this project, and discuss some of the constrains and limitations that we encountered when working with an older audience. From that discussion, we will present some of the lessons that were learnt and could be useful for future encounters with the same audience in future projects.

Chapter 6

Discussion

6.1 The Research Process

Designing a system to match the requirements of a specific audience such as the senior population has significantly more challenges and constraints than when the audience is wider in age groups and technology knowledge. For this reason, it was crucial to adopt a UCD methodology in order to understand all the limitations and specific needs that this target audience carried. To better understand our user, we resorted to a literature review on which we identified a wide range of age-related changes to the mind that could constitute an obstacle to the design of the game platform.

Following on our study, we reviewed a number of projects that attempted to use modern technology devices to engage seniors in digital games with the purpose of stimulating their intellectual abilities and teaching new subjects and concepts, while also promoting social interaction among themselves with games that required the attention of multiple players.

In the initial phases of designing the game platform we conducted a recruitment process to interview potential seniors that could become participants in the usability tests. During this process, we engaged in a series of formal and informal conversations in which we assessed their knowledge and acceptance of modern technology, their intellectual capabilities and their willingness in helping us design an appealing game platform.

We then began developing low-fidelity prototypes that allowed us to test the usability of the system as well as element position – text, buttons, icons, among others. By not developing a high-fidelity prototype on the application right from the start, any usability issues and problems with the interface can be solved and re-arranged at any moment, easing the process and allowing the exploration of new ideas and concepts without a great volume of work. Also, seniors find these paper prototypes less intimidating than handing them a high-tech device in a first contact with the system, which is of utter importance so their are able to understand its purpose and give favourable feedback to allow a continuous improvement throughout all phases of design.

Using all the feedback we were able to retrieve from our usability tests, the prototypes then evolved into a fully functional application directly implemented on the tablet device. By using the application in its digital form, we were able to evaluate some aspects that are not possible when using paper prototypes, such as touch-based interaction. We were able to confirm that seniors easily adapted to the tablet device and that its natural and intuitive interaction paradigm is a better choice than more traditional ones such as the keyboard and mouse.

Finally, at the later stages of development, we integrated the FUSAMI system into the game platform, in order to capture usability issues that are less perceivable when applying regular usability tests. One tablet device was entrusted for one month to one of the recreational centers that we worked with, to automatically extract data on seniors' interaction with the game platform, in order to further improve the system.

Having the opportunity to work directly with our target audience provided us with the means necessary to design and implement an appealing application that seniors enjoyed and felt engaged in interacting with, as well as gather evidence on their ability to use new technologies and learn new concepts in an efficient way.

6.2 Evaluating with Seniors: Difficulties and Constraints

Performing evaluations with seniors has its inherent difficulties and can at times be a very challenging endeavor. The first obstacle begins even before the evaluation tests can take place. Having access to this particular audience is not easy, but with the help of previously established partnerships between Fraunhofer AICOS and recreational centers we had the opportunity to recruit several seniors to participate in our usability tests and have a direct contact with our target audience.

The next challenge we faced was the fact that some seniors were not willing to participate in the tests, usually due to a very strict and defined daily routine, which they were not pleased with changing. Also, due to the fact that this project involved playing games that required focus and a stable cognitive condition, some seniors were not able to participate due to physical and psychological difficulties. However, with the help of the caregivers, the psychologist who performed the initial cognitive assessment exercises, and previous experience in recruiting seniors at Fraunhofer AICOS we were able to identify a group of fully capable seniors that could participate in the tests and provide us with the feedback that was needed to design a successful application.

Managing the available time to perform the tests was also a major concern during the iterative process of development and evaluation. First, we only disposed of approximately two hours at a time to perform the tests with the seniors in each center. This required a careful planning of all the activities that we wished to carry out with each senior. However, during the evaluations more often than not seniors would begin talking about several topics of their daily lives, which prolonged the initial time allotted for each participant. Aligned with the recurring situation where not all participants were present at the center when the usability tests took place, thus requiring

extra appointments with only a few seniors, the evaluation process took a significant amount of effort to finish in good time and with the necessary results.

6.3 Lessons Learned

Throughout the development of this project, there were a number of different challenges that required specific solutions considering the target audience that the game platform was designed for. By progressing through each phase of the project alongside our seniors participants, we believe we were able to devise some guidelines that can be used in future experiences with this group age:

- **Games should be simple to learn and enjoy**. In most cases, seniors never had the opportunity of experimenting with modern technology, either by a lack of interest or due to the high cost of the devices, and as such playing digitals games is usually an activity which they are not familiar with. This can cause anxiety in seniors and provoke feelings of self-doubt in their abilities, resulting in an unwillingness to try new activities. By providing simple objectives and simple mechanisms in the games, the starting phase becomes an easy entry point for new players, and at later stages the degree of difficulty can be progressively increased while still maintaining the enthusiasm of seniors.

- **Games should be adapted to resemble real-world activities**. Although most seniors had never experimented with digital games, every single one of them had played card games, crossword puzzles and other well-known physical games. By adapting games which they were already familiar with, seniors were able to start playing almost without any help and were showing signs of enthusiasm right from the beginning of the tests.

- **Images should be used whenever possible to aid in communication**. We found that in most cases, the simple use of an image had more impact on the seniors and helped them understanding the meaning of a feature, than by simply using text. Although sometimes images are not clear enough to single-handedly convey the intended message, the combination of images and text in buttons and other widgets of the game platform proved to strike the correct balance necessary to create a fluid interaction with the system.

- **Indirect feedback should be taken into account during evaluations**. During the usability tests that were performed with our senior participants we sometimes noticed that, even though there were some difficulties in completing certain tasks, seniors would not always say so, possibly because they did not want to act like a burden to us or feel inferior to their senior colleagues who were also participating in the same evaluation tests. Therefore, it was crucial to try to detect any indirect feedback – such as facial expressions and body language – to realize if any concerns or problems were arising, and take the necessary precautions by stepping in and asking them if they were having trouble performing the specific task, or even giving them a simple tip to help them progress.

Chapter 7

Conclusions and Future Work

As technology evolves, it becomes increasingly possible to use that technology to provide the senior population with better living conditions, which could help slow down the many changes that come with ageing. However, as modern devices grow in functionality and accuracy, so does the complexity in handling them effectively. For that reason, seniors often find it difficult to embark into the digital world and realize all the benefits that it can bring to every single aspect of their lives. To achieve that purpose it is necessary to design systems that meet their needs and specific characteristics and consider both their capabilities and limitations.

This thesis had the objective of designing, developing and evaluating a tablet-based gaming platform for seniors that aimed at stimulating their cognitive capabilities and promoting social interaction. Via an extended research of our target audience and the potential that digital games can have in improving people lives we presented a solution which we believe has the potential of acting as a first step towards embracing new technology by means of the tablet device, which provides the user with more natural and intuitive interactions, while increasing their overall well-being through cognitive and social stimulation.

For further improvements to the game platform, more games would prove to be very beneficial to the cognitive training of senior users. Games that target other areas of the cognitive domain, possibly incorporating different senses than touch and vision, such as games that use sound as their main mechanism of interaction. Also, extra difficulty levels could be created to leverage the learning curve and so produce a more effective cognitive training program. In addition we believe that reward mechanisms such as achievements and badges could prove to be efficient instruments in helping seniors engage in playing more often, regarded that such mechanisms are simple to understand and appealing to players.

A series of evaluation parameters was integrated into the mechanisms of each game (sections 4.3.2 and 5.2) to analize seniors' performance and act as helpful resources in determining cognitive alterations throughout their training period. To aid in organizing those parameters and displaying

them in a more read-friendly form, the implementation of a graph generator would be highly beneficial.

Building upon the concept of an online mode that was experimented through a wizard-of-oz evaluation test (4.4.5), a deeper research on the subject should be performed to attest its long-term viability. A friend-search module that would be simple to use could be implemented, similar to those commonly used in social networks nowadays. In this mode, leaderboards could display rankings at a global level and reward elements such as achievements, badges and trophies could be exhibited to other players to promote interaction between seniors.

Finally, one very critical issue recurrent during our usability tests was the "senior-unfriendly" soft-keyboard provided by the Android framework. Many improvements could be made to the soft-keyboard, starting by removing all unnecessary keys such as symbols and enlarging touchable areas on each key. The best option would probably be to create a new soft-keyboard from scratch and iteratively test it with senior users, similar to the evaluations performed during the design of each feature of game platform.

As technology designed specifically with the senior user in mind is still in its primal years, we believe that the results of this thesis compose a valuable contribution to the HCI community and will hopefully become a reference in future research and projects in the same area.

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