FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO



# Using the Android Tablet to Develop a Game Platform for Older Adults

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Masters in Informatic and Computing Engineering

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 $25^{th}July, 2011$ 

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19<sup>th</sup> July, 2011

# Abstract

The aging of the population has become a reality in developed countries. The percentage of older adults in the overall population has been increasing for quite some time and is bound to keep growing. The increase of this population segment opens up opportunities to be explored in areas such as gaming since this is one of their preferred activities.

Age related changes are responsible for modifications in the perception and cognitive systems. However, when properly stimulated, changes can be slowed down or even reversed.

Digital games can have an active role in stimulating the older adults' cognitive function. However, technology is still far from the older adults because age-related changes are not usually considered when designing or because they do not fit the needs of elders.

Touch-based user interfaces have been argued to reduce the obstacles posed by technology to older adults, due to their direct mapping of the input in the User Interface. However, that still remains to be assessed.

This project aimed to create a tablet gaming platform that supports cognitive games. Besides common features such as: user management, this platform provides the tools to store information about the cognitive performance of the player, which can then be used by healthcare professionals to monitor the cognitive state.

Moreover, two prototypes of games have been created to assess the capabilities of the platform and understand how cognitive games can be used in the tablet. Due to its openness, Android Honeycomb was used in the development.

The platform and one of the games were evaluated with end users in a final usability test. The results have shown that, in general, users can use this platform successfully; still, obstacles related with the android OS itself, were found.

# Resumo

O envelhecimento da população tornou-se uma realidade nos países desenvolvidos A percentagem de idosos na população geral tem vindo a aumentar desde há algum tempo e deverá continuar a crescer. O aumento deste segmento da população abre novas oportunidades em áreas como os jogos que podem ser exploradas, visto que esta é uma das suas actividades preferidas.

Ocorrem mudanças relacionadas com a idade sobretudo nos sistemas percepcionais e cognitivo. No entanto, quando a pessoa é correctamente estimulada, a velocidade da progressão destas mudanças pode ser atrasada ou podem mesmo ser revertidas.

Os jogos digitais podem ter um papel activo na estimulação da função cognitiva. No entanto, a tecnologia ainda está longe dos idosos, visto que as mudanças relacionadas com a idade não são consideradas quando esta é desenhada ou porque não se adapta às necessidades dos idosos.

Tem sido discutido que interfaces baseadas em toque reduzem os obstáculos colocados pela tecnologia aos idosos, uma vez que mapeiam as acções do utilizador directamente na interface. No entanto isto carece de verificação.

O objectivo deste projecto é criar uma plataforma de jogos para tablets que suporte jogos cognitivos. Além de funcionalidades comuns, como gestão de utilizadores, esta plataforma providencia as ferramentas que permitem a monitorização da performance cognitiva do jogador, que podem então ser usador para monitorizar estado das suas funções cognitivas.

Em adição, dois protótipos de jogos foram criados para avaliar as capacidades da plataforma e entender como os jogos cognitivos podem ser usados no tablet. Devido à sua abertura, o sistema operativo Android Honeycomb foi usada no desenvolvimento.

A plataforma foi avaliada em conjunto com um dos jogos junto dos utilizadores a quem se destinava num teste de usabilidade final. Os resultados mostraram que, no geral, os utilizadores podem usar a plataforma com sucesso, no entanto, foram encontrados obstáculos relacionados com o sistema operativo android em si.

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# **Abbreviations and symbols**

PSP	Playstation Portable
Nintendo DS	Nintendo Dual Screen
OS	Operating System
iOS	iPhone Operating System
PDA	Personal Digital Assistant
2D	Two Dimensions
3D	Three Dimensions
OpenGL ES	OpenGL for Embedded Systems
SGL	Scene Graph Library
ANR	Application Not Responding
NDK	Native Development Kit
FEUP	Faculdade de Engenharia da Universidade do Porto
SD-Cards	Secure Digital-Cards
PC	Personal Computers
XP	Extreme Programming
API	Application Programming Interface
AI	Artificial Inteligence
FPS	Frames Per Second
BSD	Berkeley Software Distribution
WYSIWYG	What You See I What You Get
ADT	Android Development Tools
WLAN	Wireless Local Area Network
SQL	Structured Query Language
GUI	Graphical User Interface

## ABBREVIATIONS AND SYMBOLS

# **Chapter 1**

# Introduction

### 1.1 Context

The project consisted of the development of a prototype for a game platform running on tablets, with games that are adapted to older adults' characteristics. This dissertation was proposed by Fraunhofer Portugal and developed in this research centre's facilities. The project was divided in two components: the usability of the system, which was the object of study of another student at the same centre, and the design and development of the prototype of the actual system, which is the object of study in this dissertation. This project's idea came from new trends observed in the evolution of the world population. Population is aging. Mostly in the developed countries we have been watching the number of newborns decrease while the older population tends to live longer. This is not necessarily a bad thing, as living longer gives us more time to do what we like and be with whom we love. As people grow older and retire, they have more time to dedicate to themselves and their needs in life. Having fun is something that older adults value and explore through various activities, for instance games. These games are mainly physical, played with cards, boards or even pen and paper. But as it becomes more widespread in today's world, many elders are already learning and using technology to communicate or for entertainment.

Game companies can take advantage of this to explore a new market in which to place their products. However designing a game for a young or middle aged person is not the same as doing it for an older adult. There are factors that must be taken in consideration that are not present in younger players but absolutely need to be considered for older adults. As we age, a number of health problems can afflict us: our body starts to fail, our senses and capacities decay and we are more likely to suffer from health conditions. These health conditions can make a person depend on others to accomplish simple tasks

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that not long ago were seamless to that person. In the case of many conditions, with early detection it would be possible to treat them or at least reduce their impact in the person's life. However, the support infrastructure needs to be able to respond to the increased necessities of assistance of the aging population.

In our project we propose to join both ideas described above to create a product capable of providing fun and enabling the older adult to enjoy games, while at the same time storing data from the game that could be used to evaluate the evolution of the user's capacities. Moreover, research has shown that it is possible to stimulate the elder's cognitive abilities through games, which would make this not only a potential monitoring tool but could also provide a way to exercise the older adult's cognitive functions integrated in its daily activities. Ideally the user would not even need to know or care that his abilities were being monitored or trained. We have chosen to use the tablet as the device in which to run this platform. This was mainly for three reasons. The first one is mobility. Tablets are a mobile platform that can be transported nearly anywhere and with an autonomy that allows them to be used without being connected to the power grid for around 8 hours at a time (depending on the device and usage). They are also fairly light and have a relatively large screen for a mobile device. The second reason is its primary input method. Tablets make use of a touch screen to receive input and to present its interface to the user. Touch screens are a direct input device and have the potential of being a simpler interface for older adults than the traditional combination of keyboard and mouse found in most computers. The third and last reason is that the Tablet is a relatively new and unexplored platform that holds a great potential to be developed in the future. New ways to use the Tablet's components responsible for interpreting and transmitting data from and to the outside are still appearing as people imagine new days to use this data to create innovative applications.

The project was developed integrating some agile practices that we believed could make the development process faster and more adaptable to change. This was necessary since the requirements were not well defined in the beginning of the project. We started by exploring the platform and creating a few simple prototypes that implemented some of the functionalities that we predicted would be present in the final application. With this we intended to save time when we finally developed the final application by using what was already done. Still, as the requirements changed, we ended up not needing to implement all the functionalities we had planned in the beginning.

The application we developed consists of a platform where users can play any game from the list of games available. The platform stores information about the user that is currently playing it so each user must register himself in the system before he can start any game. Users can play in two modes: single and multiplayer. The multiplayer mode allows a group of up to four users to play the games in turns and compare their scores at the end of each game. The games available in the platform are divided in four categories:

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Games with Images, Games with Videos, Games with Words and Games with Music. The platform comes with two games in the Games with Images category: a game to match images, where the user has to remember the images he has already seen, and a game to find an image, where the user has to remember where he saw the image last time. The platform contains mechanisms that allow it to save the user's moves in the game, the positions where the user touched and whether this was a correct touch or a repetition, as well as some commentary about the touch.

We think that it is worth mentioning that our application has the following characteristics:

- 1. It uses Direct Input Devices to make the interaction with older adults as simple as possible, and reduce their anxiety towards the device;
- 2. It is developed on a Mobile Platform so that it can be transported and played anywhere;
- 3. Presents a Unique Interface with a design that accommodates the changes that older adults experience as they age;
- 4. It is Expandable so that more games can be developed and added later;
- 5. It has Variety inside each category so that the user is not limited to a game of one type;
- 6. It provides Feedback on the user's actions in the game;
- 7. Provides Rewards to award the user's performance in the games;
- 8. Promotes Social Interaction through the multiplayer mode and the rewards system by making users discuss and compete to get a higher score.

We believe that there are two more characteristics that a game platform like this should have, but that were not implemented in this version of the platform:

- 1. It should have Goals to keep the user engaged in the game
- 2. It should be Customizable, by having the option to use images, sounds or videos that are familiar to the user

In the end, we conducted some tests with the final users, asking them to try the prototype of the application and obtained some promising results. The problems that we encountered were mainly related with some of Android's features which would have to be changed in order for the platform to be truly adapted to their characteristics.

#### Introduction

## **1.2** Contribution

Our contributions in this project consisted of:

- A scientific paper submitted to the ACE 2011 conference entitled: "The Use of Tablets as a Gaming Platform for Older Adults". In this article we explained the project, the way we believe games can be used to improve older adults lives and how technology can help in that department. We also talked about the methodology used to gather requirements, and the procedure adopted to interact with older adults and obtain data that could later be used in the application. It also explained the basic idea for the platform and the ten principles we decided would be most important for the application to follow. This article can be found in appendix B.
- A prototype of the system designed specifically to adapt to older adult's needs. The prototype tried to be as faithfull as possible to the specification of the system. The specification was developed by identifying what characteristics the system should have to appeal to the older population, identifying what kind of games they prefered and performing tests with older adults and watching how they interacted with low fidelity prototypes of the system that helped us draw conclusions about what functionalities should be mplemented and how.

## **1.3** Structure of the document

This dissertation is divided in seven chapters. Each chapter discusses a different subject, although some of them approach more than one to make the connection between sections clearer. The second chapter approaches the subject of the target population for our system, the elderly, explaining the changes that older adults experience as they age and the way thoses changes can be slowed down. It also talks about the games that older adults play and some that have a positive effect on their health and can be used to exercise the elder's cognitive function among other things. The third chapter is about the elder's relationship with technology and explains the device used in the project, the tablet. In the fourth chapter we explain the methodology used in the project in its different stages. The fifth chapter contains information about the implementation of the platform, its structure and the requirements that were set for the final prototype. The sixth chapter contains information about the older user. The seventh chapter contains the conclusion and future work that could be developed to improve the application.

## **Chapter 2**

# **The User: Older Adults**

The population of the developed world is getting older. In Europe, the percentage of elderly population has been increasing in the last few years[UN02]. At the same time, families are changing and fewer older people live with their children than did in the past. There are now more people living either alone or with similarly-aged spouses [GS03] [ED03]. This generation of older adults is getting closer to technology. The number of older adults using technology has been increasing incredibly. For instance, in the US, older adults are the fastest growing demographic and also the largest-growing group of internet users[HC08]. However, there are still many more young users of technology than older adults[ZB05]. The older population has different characteristics and needs from younger generations[SC00] and that should be addressed when designing for them[SW09]. However, in the process of designing software to fit the needs of the public, seniors specific characteristics are often overlooked. As a result, the final application, however popular among mainstream users, may be completely unnusable by older adults. There are currently not many applications for computers in general designed with the elder's characteristics in mind. Since this project is aimed at older adults, we felt it was necessary to understand the older user's strengths and limits to be able to design something adapted to this segment of the population. Since elders are older and more wiser, they have a different view on life than younger users, so designing for the elderly is different from designing for a middle aged user, a teenager or a child. For an application to be successful, it should enable the user to perform the wished task. Otherwise it will probably enjoy little acceptance.

### 2.1 Older Adults' characteristics

Normally, when we get older our body and mind start to wear down. A common individual is born, grows and reaches its optimum physical and mental abilities around the 20's, and after maintaining these abilities for some time that varies from person to person, he starts to age at a normal rate, until around the 45-55 when the deterioration rate rapidly increases. The body becomes less able to regenerate, reflexes become slower and movement is harder. People also start to experience more difficulty in sensing, understanding and interacting with the world around them. The changes that older adults go through as they age can be divided in percepition, cognitive and psychological changes.

#### 2.1.1 Perceptional changes

The most common age related perception changes experienced by older adults include hearing and vision impairments and an increased probability of suffering from several diseases such as arthritis, hypertension, heart disease, diabetes and osteoporosis[AP11].

Vision degradation is a common problem that arises with age. It can be experienced as a part of the natural aging process, with the appearance of problems such as Presbyopia or the loss of the eye's ability to focus to see near objects[KE09a]. In addition, elders are also likely to develop Glaucoma, a disease that may lead to blindness due to an increase of fluid pressure inside the eye[KE09b]. Although Glaucoma is not a normal part of the ageing process, it is the result of a condition to which the elderly are more exposed due to their age. The most affected visual capacities are peripheral vision, susceptibility to light and reduction of upward and downwards gaze. Peripheral vision gives us the ability to perceive movement in the limits of our vision field, and is connected with the reflexes of a person. Susceptibility to light is the ability to adapt to changes in the luminosity, for instance when coming out of the sun into a poorly lit room. The reduction of the capacity to gaze upward and downward limits the field of vision, reducing the extent to which a person can see above and below its field of vision. All these changes affect the ability of older adults to execute tasks that require good visual skills, such as reading or watching signs on the road from a moving vehicle and become more susceptible to suffer fractures from these accidents[HK01].

Besides vision problems, hearing is also affected by age. This sense, like vision, is very important because while vision allows the user to perceive and interpret the world around him, hearing, coupled with speech, is used to communicate with others and interact with them. And older adults value social interaction, be it with their family or friends[MR10]. Changes in the hearing capacity require adaptation on the part of the person that experiences them, and while some people are able to acquire skills such as lip reading or sign language, to compensate for the imperfect hearing, the elderly are less

likely to master such skills since they require extensive training. A large number of seniors experience Presbycusis, the reduced ability to hear high frequency sounds, which may reduce or even prevent them from hearing. This must be taken into consideration, when designing an application for older adults that uses sound. Hearing problems can disrupt the older adult's functional ability, often preventing them from comprehending speech, and inhibiting the social interaction with others.

As they age, a number of seniors experience a reduction in dexterity and motor coordination[WW05]. In the worst cases, older adults may suffer from Sarcopenia, the reduction of muscle mass and increase of fat in the muscles, that is usually associated with age and can cause the muscles to lose flexibility[HK01]. In either case, the reduction of dexterity and motor coordination can affect the way older adults are able to interact with an application, so they must be taken into consideration when designing for them. It is especially important to consider them when choosing the input device that will be used to interact with the application. There are a number of studies showing that traditional input devices may be more demanding in terms of cognition and motor coordination when compared to direct input devices[NH09], so they may not be the most appropriate for older users.

#### 2.1.2 Cognitive changes

In general older adults are slower and have less working memory than younger adults [PS99]. Abilities like processing speed, memory and reasoning are particularly vulnerable to the effects of aging while others, like vocabulary and general knowledge are less susceptible to be lost.

Working memory is the "cognitive system that includes both the ability to temporarily hold recently received information and a limited capacity 'computation space' in which the materials in memory may be monitored and manipulated" [PS99]. Working memory is a kind of short term memory that deals with information being used to perform the task at hand. This kind of short term memory is limited by natural aging and usually declining as we become older [KC08]. Many researchers believe that the decline of working memory is responsible for the worst performance of older adults verified when doing difficult and demanding tasks that require great effort and resources [PS99]. Long Term memory is also affected by age. It is documented that older adults have a worst performance when consciously trying to remember details from a specific time or event, what is sometimes refered to "episodic memory", and that may make it increasingly difficult to remember the context details. For some time, people believed that long term memory of events that happened a long time ago was less affected by age than the memory of more recent events, and so it was thought that older adults remembered events that happened long ago better than more recent events. However studies have shown that this is not so, both memories

from past and recent events is affected, it just happens that the elder possesses a larger store of information of events from long ago[CM08]. It is believed that this difficulty is related to the decline in the capacity of older adults in forming and using associative connections among events[PS99]. On the other hand their "semantic memory", the memory concerned with the meanings of words and concepts, keeps mostly unaffected, not registering significant changes, when compared to younger adults'[KC08].

The effects of age are also seen on the attention of a person. Older adults have more difficulty on focusing their attention, and are more easily distracted than younger adults. Studies have shown that they have more difficulty ignoring information and are more affected by hearing and visual distractions[PS99]. The result of this is that if an older adults is presented with a lot of information, he can be overwhelmed and unable to successfully process all the information, or at least take a lot more time to do so.

#### 2.1.3 Psychosocial changes

There are many stigmas involving older adults. Many people think of older adults as mentally ill and depressed, which is not true. While some older adults may experience these feelings, it is not accurate to classify a person as senile or depressed just because he or she is old. Feelings of depression may originate from different causes. For instance, older adults are more prone to suffer from negative life events such as the loss of loved ones or discovering they suffer from a chronic condition[MS02]. They also need to adapt to their physical limitations and functional impairments. As they age, older adults experience a loss of independence, no longer being able to execute tasks that they did easily before and depending on the help of others to be able to successfully complete them. Driving is a good example of such loss of independence, since older adults may become unable to travel and start depending on others to take him where he needs to go. This may have disabling consequences for the person and leave the elder feeling useless and depressed[MS02].

Elders also have a more developed sense of who they are and know their own limits better than younger adults. This may be a result from accumulated years of experience that give them an insight about themselves. Since, as they grow older, their capacities change, older adults learn how to know themselves and to evaluate what they are able and unable to accomplish. This helps them redefine the image they have of themselves, accommodating it to fit their new reality and accept it[HK01].

Older adults maintain a well established closer group of relatives and friends than younger adults. These are important people to them and from whom they derive the most pleasure. As they age, and opposed as what happens with younger adults, their circle of friends tends to get smaller instead of bigger since it is inevitable that some of those relationships will be lost. Adding to the loss of friends and family, elders are less likely to participate in meaningful social and intelectual activities[CH06].

## 2.2 Cognitive Training

Studying the decline that older adults experience in terms of mental vitality as they age has one particularly interesting application: finding ways of preventing this decline, or at least delaying it. It would be invaluable for the older population to know how to preserve their cognitive functions or to prevent the spread of diseases such as Alzheimer and other kinds of dementias[CH06]. Even though there is still not much knowledge on how to delay the decline of the cognitive function, some studies suggest that social engagement and absorbing leisure activities may play a role in maintaining the cognitive faculties of a person[CH06]. It was suggested in recent studies that cognitive decline may be related to changes in the neural plasticity of the brain[LG09]. There are however exercises that have been shown to have some results in delaying this decay. These are some of the most commonly used until recently:

- 1. **Strategy training** This kind of training consists usually in identifying tasks that older adults have more difficulty doing and training them into using strategies that will help them increase their performance. This method was very used to train memory for instance, by teaching elders of mnemonics to help them remember for instance shopping lists, but are also used to improve inductive and spatial reasoning, goal management and verbal or non-verbal search processes. This kind of training may find good results in the performance of the task, or similar tasks, but overall doesn't seem to improve on everyday tasks that don't relate directly to those trained.
- 2. **Multimodal approaches** This kind of training consists in changes of lifestyle, that challenge the older adult in ways he doesn't normally experiences. Examples of this kind of training could be, participation in classes that teach new skills, engaging in demanding activities that stimulate cognition such as bridge or participating in volunteer work. This type of training may also have a social component that helps insert the elder in the community and also can be enjoyable for the older adult. Sometimes this shows some results, however they usually are small, although they transfer to other tasks, and their complexity makes it hard to pinpoint exactly what is the factor responsible for the improvement.
- 3. **Cardiovascular training** This type of training consists in having older adults exercising themselves. Studies have shown that older adults in good physical condition have usually better performance in tests for reaction times, motor learning and cognitive assessments. These results may be related with others about animal

research that showed that aerobic exercise is associated with neurogenesis, the creation of neurons, and angiogenesis, the creation of new blood vessels. The benefits of this kind of training are most noted in tasks that exercised their executive function. Although they have been shown to make relevant improvements, with high transference, they are not available for older adults with physical limitations.

4. **Process training** This kind of training consists in training participants in a set of tasks that put a heavy load on a specific cognitive process without explicit strategy training. They then measure the transfer effects on a set of untrained tasks that put the same cognitive process under heavy load. These processes show good transference and improvements, but sometimes it can be hard to analyse and choose the tasks that should be undertaken to put a heavy load on specific cognitive processes that are to be trained.

#### [LG09]

All these methods are behaviour-based approaches to cognitive training. New and promising studies have used neuroimaging data to guide and assess cognitive interventions. In these studies, neuroimaging data is used to design the most effective interventions for each person and present a personalized program of training. This data has also been used in some studies as a means to interpret more specifically the results of one of the previous methods of training, allowing them to extract more specific exaplanations as to the results of this training.

#### 2.2.1 The Brain Fitness Program

The Brain Fitness Program was developed by Merzienich and colleagues at "PositScience". It was a program based on the belief that the aging process affected the nerual plasticity of the brain leading to the decay in the cognitive functions that older adults experience. They also believed that the brain could be reabilitated by training through "heavy repeated exposure to specific, progressively changing, corrective stimuli"[MM07]. This kind of training situates itself in the already explained "process training" but uses exercises that are meant to reverse the so called "negative plasticity" that increases neural noise (changes in the brain that are thought to result from declining sensory systems). It is considered one of the precursors to the new studies involving neuroimaging data. The Brain Fitness Program was created as a means to improve auditory processing which, in turn, improved both memory, focus and thinking. The creators of this program developed it into a software application to be run on a computer, since they believed this training to have characteristics that would be more easily conveyed through this device:

- 1. **Deliver precise stimuli** The applied stimuli needs to be incredibly precise and scientifically exact to be effective. As experienced by the first attempts to delay cognitive decline, if the brain is only weakly or mildly stimulated the training will probably have little positive effects or show no results at all. So the stimuli should be designed to directly simulate the areas of the brain that are supposed to be targetted. The stimuli in the Brain Fitness Program includes synthetic versions of phonemes as well as syllables, words and sentences specially processed to emphasize the parts of the brain that should be stimulated. A computer has advantages here since it can deliver the stimuli more clearly and to a broad audience.
- 2. Adapt dynamically to individual performance Training the brain should be done at the top of the person's capacity. It should evaluate the person's ability and challenge her to push them further. Since every person has different abilities, the training should be personalized to adapt to each person's performance. A computer can use algorithms to evaluate and adapt to the person's evolution, perhaps assessing better than a human trainer could.
- 3. Make the brain perform thousands of controlled decisions The computer can make the brain perform thousands of decisions in a short amount of time. This has a great value in stimulating the brain while delivering the training program.
- 4. **Give recognizable consistent rewards** Rewards are the most basic effective way to reinforce positive behaviour. When we receive a reward, our brain releases dopamine, a neurotransmitter that is a gatting factor in learning and memory. So a reward after a correct answer or behaviour will likely trigger the creation of a memory and encourage the person to keep training. Computers can be used to deliver immediate rewards and feedback about the person's performance.
- 5. Be available to those who need to use it By creating a training program that is not so complex to administer and doesn't require constant monitoring of the person's progress by an expert using complex analyses or tools, it will cut the costs of access and make it available to an increased number of persons. A computer is also an advantage since the program can reach any person with access to a computer that can run the program.

## 2.3 Games and the elderly

Given that the population is aging and that older users are starting to adhere to using computers, game producers might find in this segment of the population a new, nearly unexplored, market for their products. Most games that elders play are still real life games such as card games, domino, chess, etc. However video games have also started to take their place in the older adult's life[SA10]. The notion that older adults were not receptive to the adoption of new technologies is a stereotype that is not completely true. It has been shown that elder users are open to the use of new technologies, as long as they find benefits in using them. So, to be directed at them, technology and games should appeal to their interests and accomodate what they perceive to be important. For instance, elders may not be receptive to technology that tries to substitute face-to-face communication, which they value a lot, but may adopt those that would provide additional support for that interaction[LL09].

Older adults play games for a number of reasons; while some do it just them to keep themselves busy and mentally active, others think of them as an enjoyable way of spending time, allowing them to stay connected socially[LL09][TA07]. But digital games have not only the potential for entertainment but also for improving their mental and physical wellbeing[LL09], for instance by incorporating cognitive training into the game.

Studies have shown that video games can have benefits for the mind, if they challenge the player to take decisions and exercise several areas of his brain. This suggests that games could become a very effective tool for cognitive training, since they provide many of the features that make this kind of training successful: task variability, feedback, adaptativity and motivation[LL09]. Tests have already been conducted either using off the shelve games or by using laboratory developed games that target specific skills with surprisingly good results[LL09]. These studies with video games have shown to have several positive effects, that range from improving the elder's cognitive and perceptual capacities to improving visual selective attention[GF08] by helping to improve attention span, hand-eye coordination, motor skills, short-term memory, problem-solving and reaction time[JL09]. The advantages of video games are that if games are designed for older users, they can provide training in a seamless way while at the same time maintaining the elements of games that make the user experience a fun time and enjoy the game.

#### 2.3.1 The Wii Console

The Wii is a game console that uses a remote as its input device. Most games in this console have the characteristic of requiring a substantial amount of physical activity to play. Some of its games also include a social component, requiring the user to create an avatar and fostering social interaction between players. This console has the added value of allowing the player to both exercise and socialize while he is playing. For all this, the Wii is a good example of a console that includes training in the games in a seamless way. The Wii also brings benefits in improving hand-eye coordination and balance, two important functional abilities whoose enhancement can help reduce the incidence of falls in older adults[JL09]. Some games allow players to simulate doing sports, using characteristic gestures of those sports, that older adults may be unable to practice due to their

high physical requirements. This may have positive psychological effects, improving their self-confidence and happiness with themselves[JL09].

However, nowadays, there is an incredibly small number of computer games adapted to be played by older adults. We have already seen that these users have characteristic that differentiate them from the younger generations. And these differences can, in some cases, make the games created for younger players unsuitable for older players, for instance because they present small objects on the screen and prompt the user to make rapid movements or react quicly to changes[LL09]. Another problem is the heterogeneity of the user group. Two persons don't experience the decline of their functions the same way. There may be users that have huge problems in vision, and have no problems at all with hearing, and others that experience no problems seeing and have huge difficulties hearing. Others may have problems in both areas and some may not have any problems at all. This has to be taken into consideration when designing for elders.

#### 2.3.2 Good Practices for Designing an Interface for Older Adults

The article that presents the Brain Training Program, describes some decisions that the authors took while implementing this program. These decisions were taken by Merznich and the other authors of the program to make it more older user-friendly. We believe they are important for they transmit us the knowledge these authors have about the field and provide us with guidelines on how to develop a project with somewhat similar character-istics. They can be summarized in the following items:

- 1. Use only one type of input device Using many different input devices might increase the dificulty to the user. The creators of the program designed it to be used only with the mouse to reduce nervousness, and the exercises didn't require the user to double-click, an operation that is sometimes hard for older users [WW05].
- 2. Use a big button size Using bigger buttons serves two purposes: helping people with vision impairments notice the button and helping people with motor problems clicking the button, by providing a bigger surface for clicking. For some tasks of dragging and droping, the creators of the program ended up increasing the borders of the button, as they found out it helped elders perform the task.
- 3. Use the full screen for the program This also serves two purposes; it gives the program a bigger area to interact with the user, which allows the controls and text displayed to have bigger dimensions, which has the advantages already described in the previous item, and prevents distractions, which is of great value for older adults have difficulty in focusing their attention and are easily distracted, since there are no other programs showing when the user interacts with the program.

- 4. Use colors with a good contrast This is important since older adults tend to suffer a yellowing of the lenses in their eyes, as they age, that can make the colors difficult to distinguish. It should also be noted that there must be a balance so the contrast isn't too pronounced as to provoke eye fatigue in the older user.
- 5. Use supporting peripherals if needed When conditions can be adverse, it may be suitable to provide peripherals in order to achieve a better interaction with the person and increase the chances of the program having the desired effects. Since the Brain Training Program used sound for a lot of the exercises, and some older adults experience hearing difficulties, the program came with headphones and allowed users to change the volume of the application.
- 6. Use a suitable text size As happens with buttons, text size should be large, being that the recommended size by NIA is at least 12 points. Using large text sizes helps users with vision impairments. Also text on the screen should be left-justified, sans serif, short, clear and consistent.

## 2.4 Summary

We chose the older adult as the user to focus on this project because of the already mentioned growth that this group of users has been experiencing. Such growth, in the context of the general aging of the population and combined with the reduction of the number of births, is predicted to put a high strain in the healthcare system. With such an increase in the number of elders needing help, providing good quality health care becomes incredibly important. One way to try to alleviate the burden would be to encourage and provide means for older adults to remain active. For an elder to remain active it is necessary to prevent or treat the impairments and conditions that older adults experience as they grow old and that limit or impede their ability to function properly. These impairments and diseases can change the user on three levels: physical, cognitive and psychosocial. By remaining active and through training, older adults can slow down the progress of the decline of their functions on many levels. For instance cardiovascular training can help maintain their physical abilities such as the motor function; strategy, multimodal and process training can be useful in maintaining the elder's cognitive functions and multimodal training, when the user is inserted in the community, can help keep the older adult's social skills and ability to socially interact with others. Older adults are also becoming more adept at using computers. Evidence of this is the increasingly high number of elders that are using computers and the internet. Computers are seen as any other tool, so if elders see advantages in using them, they will adopt and learn how to use them. The Brain Fitness Program was a computer program created in a lab from studies about the plasticity of the brain. Its purpose was to create a system capable of delivering a training program that was

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capable of reducing and maybe reversing the changes older adults experience with age, using a computer to reach a broad base of users. This tendency of using computers for training of the cognitive processes can also be exploited through digital games. It has been shown that some games are fit to be used for training, and that they even possess the added benefit of providing fun and social interaction, which motivates the user to continue the training, while maintaining the necessary components for a successful training program such as variation of exercises and tasks, delivering feedback on completed exercises and adaptating the exercise for the person undertaking it, maximizing training efficiency. The Wii is a good example of a program that can be used for training of the older adult in a seamless way, because he while playing the game, he exercises himself. However, games must respect some design guidelines regarding to the user's abilities or the user may not be able to interact effectively with the game, which could ruin the user experience, maybe even discouraging the user and failing to deliver the intended training.

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# **Chapter 3**

# **The Tablet Device**

### 3.1 Elders and Technology

#### 3.1.1 Tablets and the elderly

In general, older users don't use computers and the internet as much as younger adults. Many studies have tried to evaluate why this happens and there seem to be many reasons [WH10]:

- Lack of perceived benefit Older adults often perceive that they have no benefit in using computers, either because the technology doesn't meet their needs or they don't understand it enough to appreciate the benefits it could bring them. Currently, this is believed to be the most important reason why older adults don't use computers.
- 2. Lack of interest and motivation This can be connected with the little value perceived by the elder, or just reflect its unwillingness to spend time learning how to use the technology.
- 3. Lack of knowledge Some older adults don't use computers because they don't know how and are concerned that they don't have the knowledge necessary to use or learn how to use computers. Some even believe that their limited knowledge of the english language, when english is not their first language, will prevent them from learning.
- 4. **High Cost and Becoming Obsolete Fast** Some elders don't use the computer because they can't afford it, or think it is too costly for them. It was believed for some time that it was cost rather than lack of perceived benefit the main reason why elders

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didn't use computers. They also fear that once bought, the computer's hardware will become outdated very fast.

5. **Physical and Cognitive Problems** Eyesight problems and arthritis in the hands can also prevent elders from using a computer, preventing them from watching the screen and restricting their movements.

Studies have shown that the elder's attitude on aspects such as towards computers in general tends to become more negative with age[CS98]. And as a person's attitude can greatly influence his or hers acceptance and use of technology, older users may be more reluctant towards computers. On the other hand, it has been verified that when they start to use them their attitude changes, and the more experience with computers the elder has, the better its attitude towards them becomes[CS98].

It is harder for older adults to interact with a computer, partly because of the changes that the elders experience. Dexterity, Vision and Motor Coordination are affected by age in most cases, and can contribute for the elder to make mistakes[WW05]. Besides, interacting with a computer can be a cognitively demanding task. If there is too much information present at the screen, it can be harder for older adults to filter and ignore uninportant information, and it can overwhelm the user[ES04].

Experience can also change the capacity of the older adult to interact with a computer, since older adults are usually novices in dealing with technology and novices experience greater cognitive demands to execute tasks than experts, and are more likely to make mistakes. The elder has a more negative emotional response to mistakes than the one experienced by younger users. The older user is normally afraid of making mistakes and damaging the computer, specially when they don't understand how it works. This increases the older users' anxiety, which tends to be high when interacting with computers[WH10] [WW05].

Many factors contribute to the user's perception during the experience of using a computer. One of the first obstacles seniors find when interacting with computers is the input device used. We can distinguish two kinds of input devices [JF08]:

- 1. Direct Input Devices
- 2. Indirect Input Devices

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Indirect Input Devices, like the mouse of a computer, are characterized by requiring a transformation between the action executed by the user and the resultant action performed on the device. Using the computer's mouse as an example, the user moves the mouse in a surface, which translates into movements of the cursor on the screen of the computer. So, for example, to start an application in a computer, a user would have to move the mouse, watching the progression of the task on the screen, until the cursor pointed to the desired application and click, or double click, the mouse's button, which would then launch the application. This kind of input devices was normally associated with WIMP (Window, Icon, Menu, Pointing device) user interfaces and is still widely used in desktop and laptop computers.

Direct Input Devices are not necessarily new, but they have reached a point where affordability, availability and consumer acceptance converge to make them reach a huge number of users[JF08]. These alternative devices are called "direct" because they allow the user to have a more direct interaction with the device. Contrary to "indirect" devices, they are characterized by not requiring any transformation between the actions of the user and the action performed by the device. Because of this characteristic, their use requires little hand-eye coordination, little training and has minimal spatial demands [WW05]. As an example of this kind of devices we have touchscreens, touchpads, voice recognition, wearable interfaces, etc. They open a new range of possibilities for expanding the way people interact with computers, creating richer experiences for users. Instead of having to develop the necessary skills to manipulate a pointing device, a novice user can use a touchscreen, applying an already existing motor skill to interact directly with virtual objects on the screen.

From a comparison of direct and indirect methods made by Roger et al [RF05] we can see some of the advantages and disadvantages of both. While direct devices generally need less training and are better suited for novice users or those that do not want to memorize commands, indirect devices are more precise and users with more experience prefer them for longer periods of use. Direct devices are also considered to be easier to use because of their reduced cognitive and coordination demands.

Since direct devices have reduced cognitive and coordination demands when compared to indirect devices, they can, in some situations, be more adequate for the interaction with older adults. There are some age-related studies showing that older adults have problems when interacting with a computer using traditional "indirect" devices, especially when they have some kind of disability such as Arthritis or Parkinson [NH09]. In [WW05], the performance of young and older adults, when using a mouse to interact with the computer

#### The Tablet Device

was compared and it was found that the senior participants experienced difficulties when the task they were performing involved clicking or double clicking the mouse.

### **3.2** The Evolution of Mobile Devices to the Tablet

The use of mobile devices has increased greatly over the last few years. Since the creation and development of the first generation of widely used cellphones, people gained access to a technology that allowed them to communicate from virtually anywhere on the planet (as long as it was within the coverage area of a telephone tower) to virtually anywhere on the planet. This changed the way people saw the world[FA08]. Suddenly you could be anywhere and talk with someone many kilometers away from you, without the need for them to be in a particular place using a device restrained by a cable. Problems could be solved much more efficiently and comfortably, and even more important, you could solve them in your spare time.

PDA's appeared later. While the first ones were very simple computers used just as organizers, to keep track of meetings or events and to take notes, they evolved into more complex computers, able to exchange data over a network and connect to the Internet. Smartphones combined features of PDA's and cellphones, so that a person only had to carry one device to make calls, send text messages, keep its calendar updated, take notes, keep their contacts information, etc. Since they were even more advanced it was even possible to play games or send and receive emails[SL10].

With the advances in miniaturization techniques, nowadays smartphones have characteristics similar to those found in personal computers not many years ago[SI11]. There are already some that can even render 3D games with low or medium graphics. In the future it is expected that these devices can run games that rival those of the PSP or Nintendo DS[SI11]. But miniaturization and technological advances did not develop only PDA's or smartphones. Portable computers experienced a similar evolution, as they became more powerful and more portable. We even saw a new kind of portable computer arise, the Netbook. Netbooks have smaller dimensions than traditional portable computers and they present lower hardware capacity in terms of disk space, memory and processing power. They are mostly used to reach the web, do minor tasks, play not very demanding games, etc...[LS09].

More recently a new kind of device appeared: the Tablet. While some advocate that its conceptual idea was born decades ago[HO10], and the first tablets were available for a long time, the truth is the Tablet had never reached the projection it is getting nowadays.
#### The Tablet Device

It is important to distinguish between two kinds of Tablet PC's; the slate and the convertible. Much like the name implies, the slate looks like a writing slate and doesn't have a dedicated keyboard. Convertibles, on the other hand, resemble modern laptops with the difference that the screen is a touch screen, and as such can be used as an input device. The screen can also be rotated and hide the dedicated keyboard to expose only the screen, which doesn't happen normally in laptops[WP07].

Since this platform is getting so much attention and is suffering such an evolution, from now on we will consider only the slate Tablet. With the launch of the first slate Tablet, Apple's iPad, in April of 2010 the Tablet market was brought to the spotlight and the interest showed by the public prompted a lot of companies to create their own Tablets to compete with the iPad. HP, Samsung, Blackberry, Coby, Motorola and Dell are some of the companies that either already launched a model of Tablet or intend to do so soon[DA10].

To accompany this new device several Operating Systems (OS) were launched. Apple used the iOS, which was already running on the iPhone and adapted it to the iPad, Blackberry created a new version of Blackberry OS and Google released a new version of Android (the version 3.0 of Android was created specifically with Tablet support in mind). With such diversity, there is not yet one single OS used as a standard in all Tablets and predictions are that it should not appear soon[DL11b].

Tablets aim to position themselves in the market between smartphones and netbooks. They have bigger dimensions than smartphones and are smaller than netbooks. They are also very light, and their processing capacity is also between smartphones and netbooks. The Tablet can be designed to target a wide range of consumers and used to run a lot of different applications, from messaging applications, enabling you to communicate with other people by email or instant messaging, browsing applications, used to reach the information in the internet, business applications that allow you to manage remotely services like your bank account, to games and multimedia applications.

Some consider 2011 to be "the year of the Tablet" [CM11] because, even though it is still very early to tell how the Tablet will fare this year, predictions from companies such as Deloitte and Gartner point towards the increase of the success of this device in the market[DL11a] [GA10]. While this success is mostly driven by iPad's sales, Android Tablets are becoming increasingly popular with the public and among developers[EB11], and it is expected that with the release of new Tablet's soon Android Tablet's sales will go up[BW11].

## **3.3** Tablet's Characteristics

There are already a huge number of Tablets available in the market, and many more will be released in the future. These tablets vary in their prices, weight, size and operating systems. There are tablets with sizes that range from the seven inches in diagonal of the Samsung Galaxy Tab[SA11] that weighs 380 grams to the 11,6 inches of the Wetab[WT11] that weighs one Kg. There are other tablets with characteristics between these two like the PlayBook from BlackBerry[BB11] with a diagonal of seven inches and weighing 425 grams, the Samsung Galaxy Tab 10.1[SA11] with a diagonal size of 10.1 inches and weighs 599 grams, the Motorola Xoom[HP11] with a diagonal of 10.1 inches weighing 730 grams or the first Tablet released, the iPad[AP11a], with a screen diagonal of 9.7 inches weighing 680 grams. These tablets run either the Android platform, the iOS, the WeTab OS, the BlackBerry OS or Windows seven Professional. All of them have a touch screen as primary input device as well as an acceleration sensor (accelerometer) and battery times that go from five hours (HP Slate) to ten hours (iPad), depending on the intensity of use of the device. Most of them have Bluetooth integrated and are able to connect to the internet either by Wi-Fi or 3G. Some include even a SD card reader that adds more memory, ports that allow the connection to a computer or other devices and a camera to take pictures or capture video[DS10].

Tablets, running a version of the Android platform, are able to run some of the applications already available for Android smartphones[JP10] and the iPad has already a huge diversity of applications developed specifically for it[AP11b]. However, we can aspire to a lot more than just using an application created for the smartphone scaled to fit a bigger screen (or worst using just a smaller window the size of a smartphone screen). While doing that might still provide us with a pleasant experience (although sometimes this does not happen), applications designed specifically to the Tablet can take advantage of its characteristics to provide a better experience for the user. The tablets' much bigger screen area can present to the user a lot more information than he could obtain from a regular smartphone screen[AD11a]. For example, the email service. While on a smartphone when you open the Mail application you see the list of emails in your mailbox and you need to click one for the whole screen to show the contents of the email, on the Tablet the screen can be split in two, showing the list of emails on one side and the full email on the other.

## **3.4** Tablet's uses

Recently, the Business Insider conducted a survey of how iPad owners used their iPad tablet in their life. Even thought these kinds of surveys can be a little biased, since most

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responders are usually supporters of the device being analyzed, their findings are still interesting to give insight of how the device is being used. According to this survey most people use the iPad to browse the web and access communication services like email or social networks such as Twitter or Facebook. This survey also shows that most of the people that participated used the iPad to read books[FG10]. As Chris Bogan mentions in an article about the iPad[CB10], this is a great device to consume media, watching movies, listening to music, etc. As mentioned in the previous article and also stated in a study developed by Sam Gliksman[SG11a], where iPad's were used by students to evaluate if they could be useful in the classroom, the tablet may not yet be ready to be used as a production device. That may change in the future, with the development of software more adapted to production in tablets, with functionalities to help the user be more productive[SG11b]. For example, the iPad is already used by musicians but with the development of software, specific for the creation and editing of music in tablets, more of them will probably take advantage of this device[PK11].

## 3.5 Tablets, smartphones and netbooks

The tablet is competing in the market with both smartphones and netbooks. As mentioned earlier, tablets are mainly used for consumption, either of entertainment or utilities, and the same happens with smartphones[DG11]. Netbooks, on the other hand, are considered to be the most productive of the three, since they very portable and provide a more traditional, laptop-like interface that users are used to[CM10]. Specifically they possess a physical keyboard, which is regarded as more easily to interact with than a virtual one, perhaps because of the feedback that the person obtains when pressing the keys. Still, there are already some netbooks that have tablet-like functionalities.

Even though all of them are very portable when compared to other bigger devices such as desktops or laptops, a smartphone is the more portable device, due to its reduced size and the fact that it can be transported anywhere. However, its size limits the components that it can use so its processing power is normally the lowest among all three. A tablet can come in many sizes but is usually bigger and more powerful than a smartphone, with the tradeoff of reducing its portability. Bigger tablets can have 12 inch screens that make them even less portable than small netbooks, while smaller and lighter tablets (like the Samsung Galaxy Tab) can be more portable than most netbooks. The regular size varies, but is set at around a screen with a 10 inches diagonal.

The battery life of a netbook and a tablet are comparable, being both around ten hours (depending on the model), but with an intensive use, such as keeping the screen turned on for a long time or using bluetooth and wlan, of the device this time can be severely

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reduced. For smartphones the battery is an important issue since their size does not allow them to have very powerful batteries and an intensive use can deplete them quickly in most cases[BC10]. Still, in normal circunstances, smartphones don't consume much battery and they can last for far longer than tablet's or netbooks.

In terms of storage, netbooks are still the best device since their memory can match that of some laptops, reaching the few hundreds of gigabytes. Tablets and smartphones on the other hand have less built in capacity, and resort mainly to SD-Cards to increase their storage[JN11].

#### **3.5.1** The Tablet in the Project

We chose to use the tablet because of this device's characteristics, one of the most important being Mobility. Due to its relatively small dimensions [PB10], a tablet can be transported nearly everywhere and used whenever necessary [TG07]. This can be a benefit when dealing with older adults since most of them experience some degradation of their motor skills and it may be easier for them to transport and use a device that doesn't weigh a lot and has a reduced size.

The tablet possesses an autonomy comparale to the one of a laptop and smaller than the one achieved by a smartphone. The tablet's higher power comsumption is justified mostly by its touchscreen having bigger dimensions than the one on a smartphone and, as such, needing more power to function. Even though a smartphone has a lot of the functionalities present in the tablet and is more portable, we believed the smartphone not to be the most suitable device for this project, mostly because of its reduced screen size that we thought would not provide enough space for seniors, as opposed to the tablet's.

The tablet has a touchscreen that can provide a more natural interface since the user can interact with items on the screen by simply touching them [JF08]. Since we also wanted to take advantage of the possibilities that direct input devices with Natural User Interfaces opened, we considered that they would be the best way to approach the senior population, and the touchscreen used by the tablet seemed a great fit for the project [NH09].

The last factor contributong to the decision of using the tablet was the novelty of the device, and lak of studies conducted in this platform, that we believe has promising chara-teristics that could be explored with older adults.

# Chapter 4

# Methodology

In this section we will describe a little about the methodology used in this project. Methodologies are used to guide the development of sotware products. In the beginning of software development, when projects were very small, a single developer could take care of all the steps of the programming. At that time there wasn't any defined software process to be followed. With time and the increase in complexity of software, new processes were needed to manage the development of software by teams. These processes were designed to make the development of software more efficient and reduce the failure rate of projects. Next we present some of the more known methodologies for the development of software, by the order that they were developed: waterfall methodology, incremental development (spiral model), agile methodologies and user centered design. We then describe the methodologies used in our project, both for the development of software and for the conducted tests with older adults.

**Waterfall Methodology** Waterfall methodologies were introduced in the article by Dr. Winston W. Royce in 1970[WR70]. Waterfall, one of the first methodologies that appeared, was a model that did not accomodate change well. In fact, the only way it tried to account for change was by creating risk predictions, which made the design stage become even larger. The process would flow from one phase to the next only when all the checkpoints and deliverables were already completed[CK10]. Because it progresses from one phase to another, always closing the one before, it is a sequential and highly restrictive process. Even though some variations exist to the model, a game developed using a waterfall methodology would pass through some form of the following phases[CK10]:

- 1. Concept
- 2. Design

- 3. Code
- 4. Assets
- 5. Test and Debug

As we can see in figure 4.1, in this method, the design occurs very early in the process and the testing is only done in the end. This can have some problems, for instance if a problem arises during testing that invalidates the design, the project is put back a lot of time and may need to be restarted almost from the beggining. Besides, the later a problem is detected, the more costly it becomes to correct a mistake. That is why, in projects like this most of the time, the initial phases were spent developing and writing plans about how the software would be built.



Figure 4.1: Waterfall Model

Waterfall methodologies are better suited for managing teams that have a great need for supervision either because they have a great number of elements or less autonomy, . They can also be used in big projects where the communication is bad and the requirements are known and well understood[AK11].

**Iterative Development** Iterative Development methods were introduced in the article by Barry W. Boehm in 1988[BB88]. The spiral model was developed as a response to the

waterfall methodology. The methods used in this model divided the project in iterations of smaller length instead of one single huge iteration for the entire project. The idea of the methodology is for each iteration to contain a all the phases of development. This way, we could say that each cycle contains kind of a small waterfall cycle that repeats itself along the methodology. So, instead of taking all decisions in the beginning of the project and testing in the end, they occur much more often, and it is possible to correct mistakes and change the design with fewer costs for the project. Usually these methodologies develop a simple version of the software that is going to be developed and incrementally augment it, by adding new functionalities or developing already existent ones. Besides the spiral model, shown in figure 4.2 there are also others iterative methodologies, such as the incremental model, however these processes have the same basic idea: use a cyclic process containing all the stages of development to extend functionalities rather than develop the whole program in one go.



Figure 4.2: Spiral Model

Agile Methodologies In 2001 a group of experts gathered and created the agile manifesto. This group decided to collect the best of the so called lightweight methods for developing software and create the practices that make up what we currently know as agile methodologies. These methods were called agile because of their ability to respond fast to change. The focal aspects of agile methodologies are simplicity and speed[AW03]. These methodologies also use iterations to divide the scope of the project in small releases with a rapid development cycle. There are a huge number of practices and methodologies considered agile. All of the approaches have different characteristics which can have advantages (and disadvantages) to a project. The developers using these methods should evaluate the specific project for which they are to be applied and choose those that will have the greatest advantages for them. In an agile project, the objective is to deliver value to the client as soon as possible. So they value code production more than plan development and view artifacts such UML designs only as support for the coding activity. Agile methodologies adapt well to software development projects where the requirements are not completely specified at the beggining and are likely to change along the project's lifecycle. There are two kinds of agile methodologies that complement each other[SC11]:

- 1. Project management methodologies, such as
  - Scrum
  - Lean
  - DSDM (Dynamic System Development Methods)
- 2. Software development methodologies, such as
  - XP (Extreme Programming)
  - FDD (Feature Driven Development)
  - ASD (Adaptive Software Development)

Project management methodologies are methodologies that the manager or the developer team can implement to determine the roles and responsibilities of each element of the team and increase the chances of succeeding in an agile project. Software development methodologies are methodologies and practices followed by the team to create the software during development.

**User Centered Design** In user centered design, like the name implies, the user is at the center of the design process. This methodology makes suggestions and defines principles that designers should adapt to their particular case and follow while designing. User centered design stresses the need to fully explore the needs and desires of users and intended uses of the project. Actual users are involved in the design process to increase acceptance

and success of products. Often the products are tested in the context where they were designed to be used[AK04]. There are many levels in which users can be involved in the design, and many techniques that can be used/citekn:abraskrichmar04:

- Background Interviews and questionnaires These occur more often at the beggining of the design process and are used to collect data of the needs and expectations of users as well as evaluate design alternatives or prototypes;
- Sequence of work interviews and questionnaires Should occur early in the design process to collect data about the operations that will be performed with the product;
- On-site observation Used to collect information about the environment where the product will be used. Usually occurs early in the design process;
- Focus groups Includes parties with interest in the project to discuss issues and requirements of the product. It usually occurs early in the design process.
- Role Playing, walkthroughs, and simulations These are used to evaluate alternatives designs and gain additional information about the user's needs and expectations. It is used early and in the middle of the design process.
- Usability testing Occurs often in the final stages to collect data and measure the usability of the system.
- Interviews and questionnaires Happens in the final stages of design to collect data about user satisfaction with the product.

One of the most important techniques used in UCD (User Centered Design) are usability tests. These kinds of tests are conducted with the actual users, asking them to use some prototype or simplified version of the product and try to achieve five principal goals:

- Improve the product's usability
- Involve real users in the testing
- Give the users real tasks to accomplish
- Enable testers to observe and record the actions of the participants
- Enable testers to analyze the data obtained and make changes accordingly

While UCD is a methodology created to improve the design of a product and adapt it to the user it is meant to target, it can be incorporated in a process of development that uses iterations, to both complete and improve its success. The incorporation of this methodology can help assure that the final product will have real use for the user[AK04].

# 4.1 The Project

In the beginning of the project there was not a clear definition of what would be the final application's requirements, since they would ultimately be defined by what we learned from the elders; for instance how they liked to play games and what games they liked to play. Because of this we were aware that, in an early stage, the requirements would be volatile and could change easily. So, by identifying that we needed to accomodate change, we decided to use a mixture of user centered design to create and evaluate the design of the final application and agile methodologies to cope with the changes in the requirements that would arise during the duration of the project. By using the same analysis made by Mishra and Mishra[MM11] we described our project as:

- 1. The scale of the project was small.
- 2. Project complexity was medium
- 3. Little acquaintance with the domain
- 4. Initially there were insuficient requirement specification
- 5. Requirement volatility was high in the beginning
- 6. Quick release was not important to have an edge in the market (however there were time constraints on the project)
- 7. There was one small development team
- 8. Near the start, the reliable estimate of effort and cost was difficult

We can see that given these characteristics of the project, agile methodologies are the best choice over other methods, mostly because of their ability to adapt when the project changes.

# 4.2 Prototypes of Features

In a first phase, while we were still conducting research with the elders, we decided to delay the development of the final application until we had a better understanding of older users and could devise clearer requirements. However, we started prototyping, from early stages, some features that could agilize the future development of the application, since the code that we created could later be reused and save us time. For this purpose, we devised a set of prototypes to test and explore the features we deemed might be worth considering for the final application. A more detailed description of the prototypes is available in Appendix A. These features were:

- 1. drawing images on the screen
- 2. doing background processing through a service
- 3. using the multitouch framework
- 4. using the camera and notifications
- 5. using the accelerator sensor
- 6. playing sounds
- 7. using an outside game library

Even though not all of the features explored in these prototypes were ultimately used, the ones that ended up being chosen were implemented faster because it was, for the most part, only necessary to reuse the code and adapt it. We tried to give a stand-alone function to each prototype, so that the final result was not just a functionality, but an application in itself. For instance to implement the playing sounds feature, instead of a simple screen where we would press a button and hear a sound, we created an application that showed a piano on the screen and played a sound when a key was pressed. We believe that this gave us a more focused purpose and set some restrictions that we would need to adapt to. That gave us a clearer understanding of what creating an application for Android entailed. In addition it might expose some problems that we could find and avoid in the final application.

## **4.3** Prototypes of the User Interface

At the same time that we started prototyping the features, we started making usability tests with the final users. These tests were meant to test various hyphotesis for the interface of the final system. Information gathered from these tests ranged from which games should be available and which icons should be used to how the system would present the information on the screen. All tests were done using low fidelity prototypes in paper, representing the screen of the tablet with the system's interface. For each screen in the final application, we tested a representation of the user interface, and in several cases we ended up using various alternatives and seeing which one would have a better reception with the older users before we decided in the final design.

Each test was conducted by a group of two persons. While one asked questions and explained what we expected that the participant did in each task, the other took notes, registering relevant events of the test. The tests were conducted on-site, by going to a healthcare facility and asking users to participate in our tests, while they were developing their daily activities. More details on each test that was conducted can be found in the Dissertation developed by Ana Vasconcelos[AV11] since the design of most of these tests was designed by her in the scope of her project.

# 4.4 The Final Application

When we started the development of the final application we had to choose which methodologies from the agile set to implement. While we did not think that it was necessary to implement the whole scope of one methodology, since both the development team and the project size were very small, some Software Engineering practices we adopted are adaptations from Extreme Programming (XP):

- 1. **Define features** Although XP recommends creating user stories to describe each feature, we used simply the requirements to guide the implementation process. Although simple, when used in conjunction with the prototypes of the interface, they described the features and allowed us to know what they were meant to do with sufficient detail to be implemented. The prototypes of the interface were used to design and model the way the application would appear to the user.
- 2. **Prioritize features** After defining the features, we prioritized them, to define which would be implemented first. This was an important part of the iteration since it informs the developers about which are the most important features that have the most value to the client. All other features will be implemented later and only if changes in the requirements do not render them obsolete, in which case they are dropped altogether.
- 3. **Development** After prioritizing the features that were going to be developed we had to actually develop those features. Features were developed one at a time, going to the next feature only when the previous were developed and tested. The deveopment phase was developed in a cycle of Design, Develop, Test and Refactor. During the Design phase we decided which features woud be implemented next and designed how they would be developed. In the Develop phase we would implement these features. The Test phase would then be used to test if there were no errors in what was implemented. The final Refactoring phase was used to improve the code that was produced, maintaining its behaviour but modifying its structure in order not to have repeated code and create a more maintainable program.
- 4. **Testing and Debugging** After the implementation of a new feature, the application was tested to discover bugs and any problems it might have caused. For some features, however, it was not needed to test the entire application, since they were included in one module that run independently from the others and testing could be limited to that module.

- 5. **Refactoring** As one of the practices suggested by XP to improve the quality of code, refactoring was done often. This is a practice that is sometimes regarded as wasteful and unnecessary, since it normally takes time and produces no new features, hence no value to the client. However it is a crucial process to maintain code readability and keep adding new features. Otherwise the project might reach a point when code is so patched up and mended that it is many times more costly to add a new feature than it would be if there had been refactored in earlier stages. Not refactoring also increases the potential for bugs in the code that can be costly to discover and resolve. In the project, each time a new feature was added, the need for refactoring was evaluated and if it was found that refactoring might be needed, the next feature would wait until the refactoring was done.
- 6. Following Coding Standards One important aspect of the coding process is using standards and ensuring that all code respects these conventions. Respecting these standards creates a consistent style of programming across all the software and makes it easier to understand[RM04] [MM09]. Some issues should be addressed when writing good code:
  - Layout Several aspects need to be considered when defining the layout of the code. A maximum number of lines of code should be defined per file to prevent them from becoming huge and complex. Subdivisions to partition the code should be used so that the structure does not become too crowded. For the project, we did not define a maximum number of lines since we used one file for each class and by the structure of the platform itself, the code did not cause any file to become too huge and complex. We enforced some conventions, mostly related to the Android's structure and best practices, designed to limit the code's complexity.
  - **Commenting** Comments can help others understand the code. Ideally the code should be clear enough that the developer can understand what it does just by reading it. Sometimes this is not possible so the code should always have comments with extra information. This information should not explain what the code does, but instead how it does it. It can provide a little of context by describing what is the effect of the code in the construct it belongs to. Comments were used in the beginning of each file to explain the general purpose of the class and any particular information that should be registered about it, and in each function to explain its role and how the function works.
  - Naming and Coding conventions The name of functions and variables should provide information of what their purpose is. We used Java's rules of Camel Case. Recently a study compared the advantages between using Camel Case

and using underscores to improve programing comprehension. This study recognized that even though the second made recognizing names faster, using the first made the intervenients of the study indentify them more accurately[BD09]. Other conventions were used, such as always using variables on the right side of comparisons, since equality operations can easily be mistaken with assignments and produce errors that are hard to discover, and always delimit if statements with brackets to prevent mistakes.

In this project we followed these rules whenever possible. However, sometimes, coding standards need to be sacrificed for the benefit of performance. For instance, the use of getter and setter functions for private fields inside a class where they can be accessed directly is not recommended in Android since it makes obtaining that variable's value many times slower than accessing its value directly. On the other hand, not doing it may lead to errors if one is not careful. These kinds of decisions must be weighted and decisions should be made accordingly to the context of the application they apply to.

# 4.5 Test of the Final Application

The final test of the application was conducted in a group of two persons in the same format as the usability tests of the prototypes of the user interface: while one asked questions and explained what we expected he did in each task to the user executing the test, the other took notes, registering relevant events of the test. The results of the test result mostly of direct observation from the interaction of the user with the platform and questions asked to the user as a way to determine why he did things one way and not the other if we felt it that was necessary.

The protocol of the test can be described as follows: we started by asking the user to participate in our test. Then, we explained it would not take long, the duration would be ten minutes at most, and it would be done on a tablet. All the user had to do was to try to execute some tasks that we presented to him. If the user agreed to participate, we emphasized that the user should not worry if he could not perform the task we asked him to, since we were only evaluating the platform with which he would be interacting and not his performance on the task. We also informed him that if he was confused or did not know what to do, he should try to find in the interface help and clues that could help him and only when that failed ask for our help.

In the end of the test we conducted a small questionaire with the users, to understand what was their impression about the system. The questions were the following:

• Did you enjoy the experience? We admited either Yes or No as answers.

- Did you find it challenging to complete the tasks? We admited four answers to this question: No, 1-2 tasks, 3-4 tasks and All tasks.
- If there was a tablet available here at the center how often would you use it? We also admited four answers: Never, Seldom, Often and Very Often.

# **Chapter 5**

# **The Game Platform**

# 5.1 Specification

The specification's objective is to produce a complete and unambiguous specification document. Ideally it would describe accurately what software customers want, so that software suppliers can understand and develop it. The specification can provide various specific benefits:

- Be the basis for the agreement between customers and suppliers The description of the system functionalities in this document can help verify if the software fits their needs and how it can be modified to meet their needs
- Reduce the development effort Both parties must consider carefully the requirements, which helps clarifying them and avoids redesigns in the future.
- Provide a basis for estimating costs and schedules By describing the product it works as a realistic base to estimate costs and the scheduling of the work.
- Provide a baseline for validation and verification The documents for validation and verification can be developed much more productively and the compliance of the product can be measured against this document.
- Facilitate transfer Facilitates the transference of the product to other parts of the organization or to new customers.
- Serve as a basis for enhancement Serves as a base for enhancement for the finished product because it describes the product instead of the project that developed it.

[IE98]

# 5.1.1 Requirements

The specification contains the functional and non-functional requirements. The functional requirements describe in detail what are the functionalities of each module, what it will do in the end. The Non-Functional Requirements describe the restrictions that the final product must respect. In the end, it should be possible to evaluate if the requirements were met. Functional requirements most often are measureable and it is straightforward to evaluate if the product complies with them. Non-functional requirements can be slightly more difficult to measure and it might be necessary to define special metrics for this evaluation.

## 5.1.1.1 Functional Requirements

# • Application Management:

- 1. Change user data
- 2. Remove user
- 3. Change brightness of the screen

## • User Management:

- 1. Create a new user
- 2. Take a picture for the new user
- 3. Choose an already exisiting user
- 4. Choose only one user
- 5. Choose a group of users
- 6. Users can not edit their profile
- 7. Users can not delete users
- 8. See the classifications of a player in the system

# • Game Management:

- 1. Choose a category
- 2. Choose a game from a category
- 3. See game description

# • Game Launcher:

- 1. Launch a game
- 2. Pause a game
- 3. Continue a game

- 4. See the classification of the players during a game
- 5. Store the information of a game in events in the database
- 6. Provide an interface that can be used by games to be developed

# 5.1.1.2 Non-Functional Requirements

**Usability** As the platform is meant to target older adults, usability has to be one of the main concerns of the platform. The interface should be simple and not present more information than it needs to so that it does not confuse the user. It should follow usability standards for older adults, such as big controls and font sizes, and should follow whenever possible the mobile platform's standard practices, when they do not clash with the standards for older adults.

**Performance** It should run fast and without pauses. When an operation that takes more time is started, it should show a progress bar to let the user know that there is work being done in the background. Otherwise the platform and games should run fast and without making the user wait too much, or he might get bored and stop playing. The system should also not execute unnecessary operations, that could waste battery and system resources.

**Extensibility** The system should be extensible and make adding new games easy by creating an interface that can be extended. This way most of the process of storing and receiving information can be abstracted, leaving the developer with the task of creating only the logic of the game that is being developed, and not worry too much with the connection with the platform.

**Robustness** The system should be robust and not fail during gameplay. This is specially important in the case of older adults because they may lose interest in the platform if they see it does not work well, or think they have done something wrong and stop using it, fearing they might damage it further.

# 5.1.1.3 Use Cases

A Use Case describes a scenario in which a user interacts with the system being defined to achieve a specific goal or accomplish a particular task[KW97]. It shows which functionalities each class of users that interact with the system can access. In our system we have two kinds of users: Elders and Healthcare Providers. In figure 5.1 we can see the Use Case diagram describing the functionalities that the system presents to each type of user.



Figure 5.1: Use Case Diagram

# 5.1.1.4 Actors

Actors are the classes of users that can interact with the system. In our system there are two kinds of actors:

- Older adult
- Healthcare provider

We designed the platform to be used by older adults and this kind of user has access to all the functions of the system, except those that can change the settings of the platform itself. The healthcare provider is a special case of older adult that has complete access to all features of the system. While there are no mechanisms to prevent an older adult from entering the areas meant for the healthcare provider, a warning should appear informing that he should not be accessing that area unless he is a healthcare provider and knows what he is doing. It is expected that this warning should be heeded by older adults, and if the user disregards it, he risks causing loss of data from the application.

# 5.1.2 Design

While designing the system developers plan how the system will function, how each feature will be implemented and create the system's architecture. The system architecture can be used to shows the components that constitute it and explains its behaviour.

## 5.1.2.1 Database Description

The diagram in figure 5.2 describes the database used by the platform to store data. This database is constituted by five tables: User, Category, Game, Play and Event.



Figure 5.2: Database Diagram

**User** Represents the Player in the System. Stores the player name and the path to an image of the user, that is stored in the file system.

**Category** Represents a category of games in the System. Each category can have many games. The only information stored in the category is its name.

**Game** Represents a game in the System. Stores the game name, the game description, the id of an image representing the game and the intent that can be used to launch that

game. The game image is stored in the resources of the system because it should only change when the application is updated. Each game belongs to only one category.

**Play** Represents moments where a game was played. A play must store the game that was played and the user that played it. It is intended that this class stores some information about the game that was played. Such information must be general enough so that it can be used by more than one game, and specific enough so that it can use the information gathered to access information about the person. For this purpose it stores various values that can be useful: the time when the game started and the time when it ended, can be used to calculate how much time the user took to complete the game; the score that was gained and lost can be used to understand if the user has started failing more often or if he is right more times. Also the number of times an action was repeated, the number of times the wrong action was performed and the number of times the right action was done. It also stores a boolean indicating if the game was finished or abandoned in the middle, which can be used as an indication if the user likes the game or not. Each Play has many Events, that store information about events in the game.

**Event** Represents an event in the game. Each event is associated with a Play and consequently with a Game and a User. Events can be used to replicate the sequence of actions of a user in a game, and as such, they store the time at which they occured, an x coordinate and an y coordinate, so that information can be gathered about where the user pressed the screen if it was a screen press, and a description of the event, that can be used to give more details about the kind of event that occured.

## 5.1.2.2 Modules

The application is divided in five modules: Application Management, User Management, Game Management, Launcher Management and Games as depicted in figure 5.3.

**Application Management** This module is responsible for keeping and changing the settings of the application, as well as function as a base for the application. It comunicates with every other module in the platform (and indirectly with the games). All inter-module operations pass through this module and the only module that is not directly connected to this one contains the games that will be played. Communication between modules is done through the Application class, since it is a global class available in all modules, and also using intents, a structure made available by the Android Operating System. This module contains the class responsible for the interface between the application and the database and all other modules access the database through this interface.



Figure 5.3: Communication between modules

**User Management** This module is responsible for handling the creation and presentation of the information of users registered in the system. It allows the player to choose the user he wants, from the ones already in the system and to create a new user if he is not already registered in the database or to see the classification of a user in the system. This module communicates with the Application Management module to access the database and send information of which player was chosen.

**Game Management** The Game Management module is responsible for presenting to the user the category and games available in the system so that he can choose the game he wants to play. Like the User Management module, this module comunicates only with the Application Management module to access the database and send information of which game was chosen.

**Launcher Management** The Launcher Management module is responsible for launching the game. It also contains interfaces that can be used by games to facilitate and abstract some of the details of creating a game for the platform. This module communicates with the Application Management module to access the database and store the data collected from the game. It also communicates with the Game module by sending information in the intent used to launch the game.

**Games** The Games module is responsible for the functioning of the games. If more games are added to the platform, they should be included in this module. This module communicates with the Launcher Management module by information sent and received through the intents used to launch the games.

# 5.2 Development

The developed project consists of a game platform that is designed to be used by older adults. In this platform the elder can create its own user, to represent him in the system, and choose that user to play games that are available in the platform. The platform was created to run in a tablet device with a screen of around 10.1 inches diagonally and with the version 3.0 or higher of the Android Operating System. We chose Android because it is an open-source platform that makes it easy to develop applications for smartphones and tablets. It uses a modified version of the Java programming language, optimized for minimal use of the system resources. The interesting thing about Android is that all applications have access to the same services, and applications developed by third parties have access to the same services as core applications. So it is possible to write a new application to substitute a core application, because the interface that is available is the same for both.

## 5.2.1 The Android Operating System

## 5.2.1.1 The Android Structure

Android is a platform created by Google and used in mobile devices, mainly smartphones but that is starting to be popular in tablets too. It is one of the most used platforms in the market, and it is predicted that it will grow more than twice the rate of its major competitors in 2011[CA11]. This is mostly because prices of Android smartphones are coming down due to the huge number of vendors creating devices that use this platform. Android tablets are also increasing their share on the market, with predictions that they will grow even more until 2015[GA11]. The structure of the Android platform is divided in five layers, as depicted in figure 5.4 each providing a different set of functionalities that, when put together, create a complete operating system (OS)[AD11f].

The most basic layer is a Linux implementation (version 2.6) that provides the core systems for the OS. Memory management, process management, network stack and driver model are all managed in this layer. It allows all the superior layers to abstract the kind of hardware that is running by offering a consistent interface[RM10]. The superior layer contains a set of native libraries written in C/C++ which can be used by the applications on the superior layers to increase their functionalities. These libraries offer the ability to add features such as: SQL database support using SQLite (a powerful and light relational



Figure 5.4: Android architecture

database engine), 2D and 3D graphics using SGL (2D) and OpenGL ES (3D), Media Codecs that provide support to many formats commonly used for capturing video and images, etc. On the next layer there is the Android Runtime. This layer holds the Dalvik virtual machine, which is optimized for minimal use of the system resources. Each application will run on its own virtual machine and have one process assigned. On top of the last layer we can find the Application Framework layer. This layer provides the API to be used by developers to write their own applications, and gives them access to the functionalities of the device using managers, such as the Resource Manager to access non code resources like graphics, the Notification Manager that allows applications to display alerts in the status bar, the Activity Manager that controls the life-cycle of the applications, etc. One great thing about Android is that applications created by users have access to the same interface used by core applications, which means they can create applications with the same or even better functionalities. The final layer is the applications layer. Normally any device already has a set of pre-installed applications but the users can always create their own or download more from the web and this layer is where those applications reside.

There are four main components that can be used to create android applications[AD11g]:

- Activities
- Services

## • Broadcast Receivers

#### • Content Providers

Activity Activities are the building blocks of android applications. They are the only component with a direct interface with the user and usually have a well defined task inside an application. Android manages activities in a stack; each activity that is called is put on a stack of activities. If a new activity is opened or an older one accessed it is put on top of the stack. If one activity on the stack is closed it will be taken out of the stack. Each activity can hold views, which are the contents of the window that is shown on the screen when the activity is active. As it is shown in Figure 5.5 an activity can implement a lot of methods to be called during its lifecycle. One of the interesting things in the Android platform is that its resources can be separated from the code. Interfaces can be designed in xml files and then inflated when the application starts. All the elements used in these xml files are then instantiated when the inflation occurs and can be accessed by the code of the applcation to change the interface. The great advantage here is that it is possible to divide between the logic of the application and the interface. When an activity is on the foreground it is Active. Whenever an activity is still visible on the screen but covered by another it is Paused, and whenever it is not visible, it is said to be Stopped. Since Android supports multiprocessing, an activity can still be running but not be the main activity showed on the screen. In this case its process can be killed if there are not enough resources on the system to keep it running.

**Fragment** A fragment is an element that appeared with Android 3.0, and that was created specifically with the tablet's characteristics in mind, since tablet pc's screens are much bigger than smartphone's. With fragments it becomes possible to take advantage of those differences by creating different areas in the screen and putting different content in those areas. The simplest way to explain the fragment paradigm is to use the example of an email application. In a smartphone emails appear in a list with the email title and some other information that, when the user presses an email, is then replaced by a screen showing the body of the selected email. In a tablet, the extra space can be used to create an area of the screen where the list of emails is shown, and an area where the selected email's content is displayed[AD11k]. A fragment contains a part of the user interface and attaches itself to an activity. It has its own lifecycle, which is connected to the lifecycle of its activity, with its own methods. The fragment allows the application to have fewer activities, and for each activity to be an independent self contained component, as it was designed to be. It also includes a back stack of fragments that handles fragments transitions and saves the state of the fragment, making the action of going back much easier for the developer to implement[DH11].



Figure 5.5: Activity lifecycle

**Service** Services are used to implement long running processes in the background. An Activity can create a Service for something that will outlive it and run in the background, instead of creating a new thread. The advantage of using Services is that they will have a higher priority regardless of what happens to the Activity that launched them, so they are more likely to keep running even in times when the system has to handle a heavy load. In image 5.6 we can see the lifecycle of the two types of services along with the methods that can be implemented. An example of a long running service is a music player. The music is started and then the service keeps playing the music in the background. Whenever the user wants to change the song an activity can bind to the service and make the change and then unbind. The service keeps running after the activity unbinds, until the music is stopped or finishes playing.



Figure 5.6: Service lifecycle

**Broadcast Receiver** A broadcast receiver is a component of the application that reacts to broadcast announcements and does not possess an interface with the user. These announcements can be started from other applications or from the system to inform that something has happened (time zone has changed, battery is low, battery is fully charged, a picture was taken, etc). In response to an event, a Broadcast Receiver can launch an activity, launch a service or use the notification manager to alert the user. An example of a broadcast is when a new call is being made. In this case more than one Broadcast Receiver can be started, and have access to the information of the number that will be called. The number can be changed by an intermediary Receiver that determines that the user is calling from outside the country and adds the country prefix to the number.

**Content Provider** A Content Provider makes sets of data available to other applications. Instead of methods being called directly, it creates a maintainable API that can be accessed using a Content Resolver. Inside the Content Provider the data can be in a SQL

Database, in the file system, or any other manner since this is not important to the application accessing the data. One example of a Content Provider that is often used in mobile devices is the one holding the Contacts information, since this information is shared by a lot of applications.

## 5.2.1.2 Good practices in the creation of Android Applications

Since Android is a platform meant to be used in mobile devices it is useful to consider that there will be some restrictions to the environment where applications will run. The most common aspect to consider is Hardware-Imposed Design: Compared to desktop or laptops, mobile devices have relatively low processing power, limited RAM, limited storage capacity, small screens with low resolution, high costs associated with data transfer, slow data transfer rates with high latency, unreliable data connections and limited battery life. There are some good practices that should be carried out to improve various aspects of an Android application. Below some of the practices to improve performance, responsiveness, seamlessness and security are described.

**Design for Performance - Be fast and efficient** In an environment where hardware restricts software, being fast means not wasting the device resources, like its battery, which leads to efficiency. The two basic rules to achieve efficiency are: do not do work that you do not need to do and do not allocate memory if you can avoid it. While these rules can be applied to programming in any environment, the restrictions inherent to Android make them critical[AD11b].

**Design for Responsiveness - Be responsive** An application that implements all the good practices for performance described above can still be frustrating and not give a good experience to the user. Users expect applications to respond to their actions and for this to happen, they have to be able to receive feedback whenever they interact with it. If the user perceives that the application is sluggish, hangs or freezes for significant periods of time or takes too long to process input, the application probably has a responsiveness problem[AD11c]. Network access, complex processing and file input or output are the main reasons why applications take so much time to respond[RM10]. The main thread of an application should take as little time as possible to execute otherwise it may not be able to handle input events or intent broadcasts[AD11c]:

**Design for Seamlessness - Ensuring a Seamless User Experience** After making the application fast and responsive the goal should be achieving a consistent user experience. Applications should strive to cooperate with both the system and other applications to provide a seamless experience to the user. This includes not degrading the applications

performance over time, taking a consistent and intuitive approach on usability and integrate applications cleanly with the Android environment[RM10].

**Design for Security - Developing Secure Applications** Security must be a significant concern when creating an application for Android. The Android platform possesses some built-in methods meant to increase security while the user is using the device. Android makes sure that all applications are sandboxed and each one runs in their own virtual machine having no access to other application's environment. In addition, they are required to publish the permissions that they need to execute[RM10].

### 5.2.2 Implementation

At first our idea was to create a game for older adults. However, as we interacted and learned more about the elders to which the platform was destined, we came to realize that elder's do not like to play the same game repeatedly for an extended period of time. By what we observed from their experience while using non-digital games, elders like to have variety in the games they play, except in the case of games such as cards or dominoes. In interviews with the caregivers, these also emphasized the importance of stimulating elders through a variety of different games.

After acquiring this information, we decided to shift the focus of our application from a game to a game platform. Instead of creating one single game that the older adults would probably use for some time and then put away when they were tired of playing the same game, we felt that a game platform with multiple types of games, that the elder could choose from, would provide more variety and entertain the elder for longer. Moreover, a game platform would be extensible, so it would be possible to create new games for the platform and update it, increasing the number of games available.

## 5.2.2.1 Description of the Platform

The entire application runs locally in the device once it is installed, with no need for an internet connection. Its structure is divided in packages and, generally, each package contains a portion of the platform's functionalities contained in its own activity. Each package belongs to one Module, and they are distributed as is shown in figure 5.7.

## Package 'app'

Activity MenuAct The package 'app' belongs to the Application Management Module and is the main package of the application, containing the classes that compose the basic structure of the platform. In this package are stored one activity, MenuAct, that is central in the architecture of the platform. This activity, considered the main activity



Figure 5.7: Structure of the Application divided in modules and packages

of the platform, is responsible for showing the initial screen of the platform and launch all other activities. After launching a new activity, the main activity awaits for it to end and return a result, and reacts accordingly with this result. In the way the platform was designed, the result of an activity indicates which is the next Activity to be launched if there is one activity that should be launched immediatly after the last one. A failure to indicate the next activity to be launched causes the main activity to present the main menu screen. For instance, after the user chooses which users are going to play the game, the ChoosePlayerActivity finishes. The program then returns to the MenuAct that launched ChoosePlayerActivity with a result indicating that the ChooseGameActivity should be started next. If however the player presses the back button while in the ChoosePlayer-Activity, the activity will end with no indication as to which activity should be launched next, so the main activity will present the main menu screen to the user. The platform was designed this way so that the execution of an activity could be idempotent; there are no side effects when launching an activity, (except setting information for the launch of the game, which is stored in the Application and has no conflicts with other Activities), no other activities are called that can interrupt the execution of an activity and when an activity ends, it returns to the one that started it.

We wanted to maintain a consistent look on the application, to help the user to know how to navigate the application so we defined that the left menu would appear the same in all activities, except in games, where it could be modified. As such we created a

class extending activity that would function as a base for all activities in the platform, ActWrapper and that created the screen with the menu, leaving to the activity the rest of the screen to change as it pleases. Every activity with a user interface extended this class and used fragments to control what was showed on the main part of the screen.



Figure 5.8: Screenshot of the Left Menu - The Left Menu contains the buttons Ajuda (Help), Ouvir (Hear), Jogador (Player), Classificação (Classification) and Voltar (Back)

The left menu, seen in figure 5.8, is constituted by six buttons: the first is the Help button, that should present the user with an explanation of what he can do in the activity that he is seeing at the moment. The second is the Hear button, that was created to help users that can not read and translates the words on the screen into speech using a Text to Speech engine present in Android. The third button is the Player button, which allows the user to see which player or list of players is selected at the moment. The fourth button is the classifications button, which shows the points that each user in the list of players has won in the game. The fifth button is not atributted and is hidden in all activities that use the left menu. Finally the last button is the Back button, a button meant to replace the back button of the Android platform, since its size and location were not adequate for older adults. So we disabled the default back button that Android provides and used our own button, much larger so that older adults could see it, and with an image and the word "Back" so that it is easily recognized.

The initial screen presented by the MenuAct activity is showed in figure 5.9. Besides the already mentioned function of launching activities responding to the result of the previous activity, the MenuAct activity presents to the user an interface with three buttons: Play Alone, Play in a Group and Consult Classifications.



Figure 5.9: Screenshot of the Initial Menu - The Initial Menu contains the buttons Jogar Sozinho (Play Alone), Jogar em Grupo (Play in a group) and Ver Classificação (See Classification)

While the third button allows the user to consult the classifications of the users in the system by launching the ShowClassificationAct, and then returns to the initial screen, the first two buttons function as the gateway for the platform. The button Play Alone starts the activity ChooseGameAct, and allows the player to select a user to play a game. The button Play in a Group starts the same activity but instead of choosing only one user, the player must choose a group of two or more users to play.

**Class DBAdapter** We also used a class contained in this package to construct and interact with the database. Each time it is instantiated the DBAdapter class verifies if the database is already created. If it is, it creates a new connection to the database, otherwise creates a new clean database. All the operations of insertion, removal, update and retrieval of data in the database are done throught this class, using a simple and consistent interface to interact with all the tables in the database.

## Package 'classification'

Activity ShowClassificationAct The package 'classification' belongs to the User Management Module and contains an activity that shows the user its position in the overall classification table. It accesses the database and creates a list of all players in the system, retrieving their scores from every game that they ever played and adds these values to

obtain the overall score of each player. When the user decides to finish vieweing of the scores, he must press the back button on the left menu.

## Package 'player'

Activity ChoosePlayerAct The package 'player' also belongs to the User Management Module and contains the activity responsible for allowing the player to choose the users that are going to play the game. This activity accesses the database to retrieve the list of users and show them on the screen. Loading the users from the database and the images from the SD card is an operation that can take some time to complete, since each user contains an image that must be shown on the screen. So this operation is done resorting to an AsynchTask, a structure that allows the user to execute operations in a different thread, and a progress bar is shown while the task is being performed. Since only a few players are shown at any given time and the cost of keeping images in memory is very high, only the images being displayed are kept in memory. When the user changes the list of players that are being showed, the images from the new players are loaded and the screen is refreshed. Since maintaining the list of players in memory does not take as much resources as keeping the images, we chose to keep all the user's data in memory as a cache instead of loading it from the database each time we need to find new players. The user can either choose to play with only one player, or create a group to play the game. If he chooses to create a group he will be asked to choose at least two players up to a maximum of four, to form the group. If he chooses to play alone, he will only need to select one player to be able to start the game. Figure 5.10 shows the interface when the player chooses only one user to play and Figure 5.11 shows the interface when he must choose a group of users. The center of the interface is similar, and the only element that is different is the bar on the right which can show only one user or more than one. The "Play" button is never showed until the user selects a valid number of users for the option he has chosen.

The "New Player" button is used to create a new player if the user is not yet registered in the system. To do so it uses the front faced camera to snap a photo and presents it to the player as depicted in figure 5.12 so that he can preview it and choose to keep it or take another as seen in figure 5.13.

The process of creating a new user is finished when the name of the new user is entered. The name must not yet be in the database and not be left blank, or the system will not accept it. Figure 5.14 shows the screen to input the name of the user.

Once the player has chosen the user or list of users that are going to play, the activity stores that information in the Application so that any activity that needs the information can access it.



Figure 5.10: Screenshot of the Menu to Play Alone - The Menu to Play Alone presents the buttons Criar Novo Jogador (Create New Player) and Play (Jogar) when a person is selected

## Package 'game'

Activity ChooseGameAct The package 'game' belongs to the Game Management Module and contains the activity responsible for the functionality of choosing the game that is going to be played. This activity accesses the database and retrieves a list of categories for the user to choose. This list is shown on the screen and the user must then choose which is the category of the game he wants to play as shown in figure 5.15.

After the category is selected, the games with a category that matches the one chosen are presented to the user. The user is then prompted to select the game that he wishes to play as seens in figure 5.16.

Once the user has chosen the game that information is stored in the application so that any activity that needs that information can access it. The retrieval of both the category and the games to be shown in the screen are done using an AssynchTask, through the same model used in the activity ChoosePlayerAct. Also, only the images from a few games are kept in memory. When the images change, they are reloaded from the disk and a progressbar is displayed.

#### Package 'launch'

Activity GameLauncherAct A special case is the GameLauncherAct activity whose package 'launch' belongs to the Launcher Management Module. This activity does not



Figure 5.11: Screenshot of the Menu to Play in a Group - The Menu to Play in a Group presents the same buttons that can be seen in the Menu to Play Alone: Criar Novo Jogador (Create New Player) and Play (Jogar) when a person is selected

present an interface to the user. Instead it works as an intermediary between the main activity and the game that is going to be played. It retrieves all the information about the user or users that are going to play the game and launches it. After each player finishes its game, it receives and stores the information collected in the database before launching the game again for the next player. When the last player finishes the game, it gives the user the choice to change player, change game or play again with the same settings, returning the chosen alternative to the main menu which will then act accordingly. In this package an abstract activity is also contained that should be extended by games, AbstractGame. This activity is specially helpful since it contains methods that allow the developer to abstract from the way information is stored and passed to the launch activity. The game activity simply calls these methods in the correct places according to its logic to record the information it wants to store, without needing to know how the information is being returned to the launch activity. This is done to minimize mistakes in the information transference from the games to the database and expedite the process of creating new games. It also takes care of including the left side menu automatically, so that the game only needs to customize it in any way it wants.

**Packages 'gamepair' and 'gamefind'** The packages gamefind and gamepair contain games for the platform and belong to the Games Module. They both extend AbstractGame activity and make no customization to the left menu. The package gamepair presents a
#### The Game Platform



Figure 5.12: Screenshot of the Menu to Take a Picture - Presents the button Tirar Fotografia (Take a picture)

matching game where the user has to find pairs of cards with the same image in them. The objective is to find all the matching pairs for each image, in the least amount of tries possible. If the user turns two images that do not match, they stay up for a few seconds and then return to their initial position, however if they match, they stay up until the end of the game as seen in figure 5.17.

The package gamefind presents a game where the screen is divided in quadrants and the user sees an image in one of them for a few seconds. After the time ends, the image disappears and the user has to identify the right quadrant where the image was located. The game repeats this steps five times.

# 5.3 Summary

This chapter starts by presenting the specification of the game platform we have been developing, specifically by presenting the requirements that the platform must respect, both functional and non-functional, for each module of the platform and by presenting the use cases that show which functionalities are available for each kind of actors that we considered would use the system. Then it introduces the architecture of the platform by showing a diagram describing the structure of the database and explaining the different modules that constitute the application. Not many details are given about the physical architecture since the application executes only locally in a tablet device. After a brief introduction of the Android Platform and the best practices that must be respected when

## The Game Platform



Figure 5.13: Screenshot of the Menu to Accept a Picture - Presents the button Aceitar Fotografia (Accept Picture) and Tirar outra fotografia (Take another picture)

designing for this platform, the structure of the platform is then explained in more detail, giving an overview of the principal classes in the platform, their function and rationale.

## The Game Platform



Figure 5.14: Screenshot of the Menu to Insert the Name - Presents the buttons Criar (Create) and Não Criar (Do not Create)



Figure 5.15: Screenshot of the Menu to Choose the Category of the Game - Available categories are Jogos com Imagens (Games with images), Jogos com Palavras (Games with Words), Jogos com Música (Games with Music) and Jogos com Vídeo (Games with Video)



Figure 5.16: Screenshot of the Menu to Choose the Game - Presents the games Jogo dos Pares (PairGgame) and Jogo de Encontrar (Find Game)



Figure 5.17: Screenshot of the Pair Game

# Chapter 6

# **Testing the Platform**

Testing is an important part of creating any computer application. By testing we can find bugs in the code, discover unexpected sequences of actions that were not considered and the system is not ready to handle and correct them. Without testing the final program, it is not possible to confirm that the program does what it is meant to do.

Testing in itself can not show that a program is correct, since it is impossible to test for every possible input and every path that a program can take. The testing should occur so that the developer finds as many problems as possible. As stated by Kaner et al[KF11], "A test that reveals a problem is a success. A test that did not reveal a problem is a waste of time.".

There are many kinds of testing that can be performed on a system. From testing if a small component behaves as expected for different sets of inputs to monitoring the system during an execution to find memory leaks or evaluate performance, or even execute trials with the users to whom the system is destined, in order to find problems that can potentially ruin their experience while using it. There are many types of testing:

- **Informal Tests** This is the kind of testing that is done by the developer as he writes the code. While writing the code the developer compiles and tests the code periodically.
- Formal Tests Formal tests are similar to informal tests but they are more structured. Automated scripts should be created for each module to test exhaustively all its features and functions. Ideally tests should exercise all code paths, but this is often difficult to do correctly. There are three main types of testing: positive tests, which test for expected behaviors, negative tests, which test for unexpected behaviors and try to generate error-handling conditions. Finally ad-hoc tests are random tests where the tester "plays" with the system and tries to get expected results.

- Unit Testing This is the first wave of testing. It is a kind of clear-box testing because the developer should use his knowledge of the module to design the tests. The tests should be done separately and be simple, to prevent finding errors in the test module instead of the model. Normally unit tests are used to run formal tests of the system.
- **Integration Testing** The next phase of testing is integration testing. In this phase a new module is integrated with the existing system to see if any problems arise. Integration tests can be performed by either the developers of the new module or members of the test team. In the first case the test is a clear box test, while in the second it becomes a black box test.
- **System Testing** The system should stay functional. If a component is not yet implemented or a functionality is not yet available, a stub can be created. The testers should be able to test it at anytime because these tests provide feedback of what can be improved in the system. At this stage most of the errors found are architectural design errors or errors that were not found during the integration phase.
- Usability Testing This kind of test is done with the testers, preferably the users that are going to use the system later to ensure that the system can be used successfully. This kind of test is performed on the interface of the system, so it should be designed and tested early in the project cycle, for instance by using low fidelity prototypes to emulate the system or other equally valid strategies. This way, it is more likely that the final tests with the users will not find usability problems, an important advantage since it can cost a lot more to fix these problems in later stages of the development of the system.

[RM04]

# 6.1 Testing during Development

In this project we developed two kinds of tests in parallel; usability tests of the interface to find and correct any problems of usability that could exist, and tests on the system during the development phase, to try to find and correct as much bugs as possible in early stages. The usability tests were developed to make sure that the system could be used by older adults. On the other hand, the testing of the system was developed to improve the code and correct bugs so that the platform becomes as robust as possible.

In the beginning of the project the platform was not yet ready for testing so usability tests were developed resorting to paper prototypes of the system. We presented these prototypes to the users and asked them to interact with them as if it was the real system we were developing, and providing the animations ourselves. We used this kind of prototypes since they were a valid way of testing our designs for the interface and identifying

problems that they could present to the user. If we had used the system to actually do the tests, we would have to wait until it was nearly finished, and then change it accordingly.

We tested the platform while we were developing it in two ways: through usability testing of low fidelity prototypes, used to test the interface with the user, and through testing done throughout the development of the prototype of the system. Since the development was divided in modules, each one farily independent from the others, we took a "create and test" approach; a minor test was done whenever a change that justified it was produced inside a module, working up to the moment where the module was ready to be delivered. We chose not to develop formal tests for these minor tests mostly due to the fact that almost all of the operations were performed through an interface with the user and it would be difficult and time consuming to develop such tests satisfactorily. Still, we did test the interface in a less formal way, through a list of tests where each test would scroll through the functionalities available. Even if these tests did not explore all possible paths in each function, they explored the most relevant ones, providing an indication that the new changes had not broken old functionalities. We left more extensive tests for the end of each module. When each module was ready, we executed integration tests with the remaining system to find any bugs that might have been introduced by joining the new module. We would also perform extensive tests inside the module to catch as many bugs as possible. We executed it in any way that we imagined it could break, resorting to white box tests (tests conducted by the developer to exercise a system, in which the tester has knowledge of how the system works and tries to run through as much paths inside the code as possible) and to black box tests (tests where only the inputs and results of the system are considered), by putting ourselves in the shoes of the user and using the system from that perspective to try to find any errors that could still persist. At this point, each test did not need to encompass the whole system, only points where it interacted with other modules needed to be evaluated and exercised to verify that the system was working properly; for instance, the Game Management module that allowed the users to choose games in the system, only had contact with the application management module, and no overlapping at all with the User Management module that allowed the users to create and select their user, so we did not needed to test those functionalities when we joined the new module to the system. However, since we refactored a lot of code as a result of the development process to make improvements in the structure of the platform, we ended up conducting tests to verify that the whole system was working as it should at the end of each integration phase.

# 6.2 Final Test

When the platform was functional we decided to test it with real users to see how well they would interact with it. For this purpose we designed a set of tasks that the users would need to accomplish:

- Choose Single Player Mode
- Create a New User
- Choose a User to Play
- Choose the Pair Game
- Finish the Pair Game

# 6.2.1 Choose Single Player Mode

The first task that we asked the user to accomplish was entering the single player mode from the main screen of the platform. We would first initiate the application for the user and the main screen would be shown on the screen. The user should then press the button 'Play Alone' in order to start Single Player Mode. This task meant to introduce the user to the platform, give him confidence (being a relatively easy task that could be performed very fast), and at the same time verify if he would recognize the buttons on the screen as 'clickable' elements. It could also be used to access the capacity of the user to recognize the left menu as a set of additional options e could use to navigate the system. Figure 6.1 shows where the user should press to start the task.



Figure 6.1: Screenshot of the Initial Menu - The user must press the button Play Alone (Jogar Sozinho) to complete the first task

# 6.2.2 Create a New User

After the last task was accomplished, the platform displays a menu that allows the player to choose the user that is going to play. The second task consists of creating a new user in the platform. This task is more complex than the last one since it consists of four subtasks:

1. **Start creating a New Player** The first task consists of the player finding and selecting the button 'Create New Player' from the current menu as can be seen in figure 6.2. This button is located below the images of the users of the platform and clicking on it will show a new menu on the screen.



Figure 6.2: Screenshot of the Menu to Play Alone - The user must press the button Create New Player (Criar Novo Jogador) to start the task

- 2. Take a Picture The next subtask consists of taking a picture to be stored in the database and represent the user in the system. This device will show on the screen a preview of the images that are being received from the camera. The user must then press the 'Take Picture' button on the bottom of the screen for the picture to be taken as can be seen in figure 6.3.
- 3. Accept the Picture Once the picture is taken, the preview screen will no longer show the image from the camera and present the picture intead. The user may then accept the picture by pressing the 'Accept' button as we can see in figure 6.4.
- 4. Write the Name After the picture is accepted all that remains is for the player to write the name of the user that he is creating. The name must not already be in



Figure 6.3: Screenshot of the Menu to Take a Picture - The user must press the button Take Picture (Tirar Fotografia) to continue the task

use by someone else and must not be left blank. He must then choose the button 'Create' as can be seen in the figure 6.5.

The objective of this task is to determine if the player is able to create a new user in the system and determine if there are any problems with the Menus that need to be addressed, so that the users can complete the creation process on their own. As all the other menus, it also has the possibility of using the left menu for support and navigation.

## 6.2.3 Choose a User to Play

After creating the new user, the screen returns to the menu to select the user that is going to play. At this time the user should be able to choose the user he just created since he is already on the system. It could be the case that the user is not visible on the screen, in which case the player must press the arrows on the screen to navigate the list of users and find the one they want to choose. This can be seen in figure 6.6. After the user is selected the 'Play' button will become visible and the user must press it to confirm the selection. This task's objective is to discover if the user would be able to use the interface to select users and start the game.

## 6.2.4 Choose the Pair Game

After choosing the 'Games with Images' category, the user must now choose the game he wants to play. This task is subdivided in two smaller tasks: Choose the Category and



Figure 6.4: Screenshot of the Menu to Accept a Picture - The user must choose the button Accept Picture (Aceitar Fotografia) to continue the task

Choose the Game.

- Choose the Category This subtask consists of choosing a category from the screen. The screen should present four buttons, each with its own category, and since the Pair Game's category is 'Games with Images', the user must choose the correspondent button, as can be seen in figure 6.7. The objective of this subtask is to discover if the user understands the menu and is able to choose the category of the game he wants to play.
- Choose the Game In this case we asked the user to select the 'Pair Game', under the category 'Games with Images'. The screen shows all the games in the system that belong to that category, as can be seen in figure 6.8. We expected the user to be able to find and choose the Pair Game. When the pop-up asking if the user really wants to play that game the user must choose the 'Play' button. The objective of this task is to discover if the user understands the menu and is able to choose the game he wants to play, based on the location and characteristics of images and names showed on the screen.

## 6.2.5 Finish the Pair Game

When the game starts the user sees a set of cards that he must select in order for the image in that card to be showed. Whenever a card is selected, the card will show the image that it contains, as can be seen in figure 6.9. The user must then choose another card and if

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Figure 6.5: Screenshot of the Menu to Insert the Name - The user must choose the button Create (Criar)

the images on both cards match, they will remain up, otherwise the images will be hidden again. The user must find all the matching pairs in the game. The game will inform him that he won and show the number of points that he scored. The objective of this task is to evaluate if the pair game was implemented in a way that the users can understand its interface easily and interact with it.

# 6.3 Results of the Final Test

In Table 6.1 we can see the results of the test, divided by task:

Participant	Choose Single	Create a	Choose a	Choose the	Finish the	
	Player Mode	New User	User to Play	Pair Game	Pair Game	
A	С	СР	С	С	С	
F	С	СР	С	С	С	
And	С	СР	С	С	С	
J	С	СР	С	С	С	
Ad	С	СР	С	С	С	
L	С	СР	С	С	С	

Table 6.1: Table of Results from the Tasks of the Test

- C Completed
- CP Completed with Problems
- NC Not Completed



Figure 6.6: Screenshot of the Menu to Play Alone - The user must press the picture of one of the users on the screen, or the arrow on the right to see more users, to be able to choose the user that was created

# 6.3.1 Choose Single Player Mode

All the participants completed this task successfully. All the participants seemed to find the button that they were supposed to play without any problems, and the only event we observed was that one of the participants inadvertedly touched with his hand in the back button of the tablet with his hand while trying to reach the desired button on the screen.

## 6.3.2 Create a New User

- Start creating a New Player All the participants accomplished this subtask successfully. All of the participants were able to find and press the desired button with no problems.
- **Take a Picture** All the participants completed this task successfully. Most of them liked this feature and expressed happiness in being able to take their own picture to use in the game, while a few said they were not prepared to take a picture and after taking the first picture rejected it and took another.
- Accept the Picture All the participants accomplished this task successfully. Some participants choose not to accept the first picture they took and decided to take another that "looked better".



Figure 6.7: Screenshot of the Menu to Choose the Category of the Game - The user must press the category Games with Images (Jogos com Images) since this is the category of the game to be chosen

• Write the Name None of the participants was able to finish this task completely since none of the users could write its name successfully in the system. When the users pressed the buttons on the virtual keyboard of the tablet, they pressed either too hard or for too long, causing the keyboard to show the modified version of the letter that they were trying to write. In the first two trials there was also a problem when trying to use the backspace key, since the user ended up pressing the enter key instead, submiting an incomplete name. No problems were observed while the users were trying to find the letters of their name on the keyboard.

## 6.3.3 Choose a User to Play

All participants accomplished this task successfully. None of the participants had problems locating his own image, however the selection operation had the same problem than the 'Write the Name' subtask: the users pressed the button for a long time and the system started a drag and drop operation for the user to image to the position of the player on the right of the screen, instead of showing a pop-up asking the user if he really wanted to choose the selected user. This seemed to confuse the user and it took some of the participants some tries untill they were able to complete the task.



Figure 6.8: Screenshot of the Menu to Choose the Game - The user must press the button Pair Game (Jogo dos Pares)

## 6.3.4 Choose the Pair Game

- Choose the Category All participants accomplished this task successfully. It did not seem to present any difficulties to the participants, except in the fact that some did not remember what was the category of the Pair Game so we had to remind them again.
- Choose the Game All participants accomplished this task successfully. Some hesitated a little at the moment of pressing the image of the game, since it did not look like a button.

## 6.3.5 Finish the Pair Game

All participants accomplished this task successfully. Some had more difficulty remembering the location of the images so they took longer to finish the game and had a lower score. There was a problem when a user pressed the back button of the platform and exited the platform before he could start playing, so he had to choose 'Play again' in the next menu. There were also some cases where a few participants touched with their hands on the screen while reaching to press a card, which caused the wrong card to turn and confused the user.



Figure 6.9: Screenshot of the Pair Game - The user must find all the matching images in the game, by pressing them in pairs, to finish the game and terminate the test

# 6.4 Questionaire

We can see the results of the questionaire in table 6.2. When we asked the first question: "Did you enjoy this experience?", all the participants answered affirmatively. To the second question however there was no unanimity, with five participants answering that they did not find it challenging to complete any of the tasks, and one of them answering that had experienced difficulties in one or two tasks. When we asked them how often they would use a tablet if they had access to one in the center, one participant answered that he would seldom use it, two that they would use it very often and three answered that they would use it often.

Participant	Question 1	Question 2	Question 3
A	Yes	No	Often
F	Yes	No	Very Often
And	Yes	1-2 tasks	Seldom
J	Yes	No	Often
Ad	Yes	No	Often
L	Yes	No	Very Often

Table 6.2:	Table	of Resu	lts from	the	Questionaire
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# 6.5 Participants

The test was conducted in the facilities of a day care center in Rio Tinto in Porto, Portugal. The participants consisted of six elders, one male and five females, with ages between 77 years old and 84 years old and an average 80 years old. The tests were conducted there since we had already been doing usability tests for the project in the same location. All the participants were healthy older adults, experiencing the normal consequences of age, with no known serious pshysical or psychological diseases. All the participants were retired and no longer working, and all of them spent their days in the day-care center, returning to their home at the end of the day.

# 6.6 Conclusions from the Test

The biggest problem encountered, that prevented participants of the test from completing one of the subtasks correctly, was the lack of adaptation of the keyboard to the older users' characteristics. Everytime that the user kept their finger too long on one of the keys, it would change the character that was inserted, most of the times without the user noticing. From that we can conclude that the Android Tablet's keyboard is not very good when it came to be used by the elderly and that it might be necessary to change the keyboard to a more suitable version for it to be used in interfaces that target older adults. We also noticed that sometimes older adults touched parts of the screen inadvertedly. To reduce the chances of these touches becoming a serious problem, we added verification boxes to the actions of leaving the game and leaving the platform. This way, the user has to confirm that he really wants to leave before executing that action. While this does not prevent such touches from occurring, it limits the harm that they can do and gives the user a chance to recover when he makes a mistake, without having to go through the process of choice again. Due to problems encountered in the menu to choose the user, where the participants would press the image for too long initiating the drag movement and then release the button, expecting the pop-up to a appear, we decided to remove the drag and drop functionality of the menu since instead of helping the user, it was making the interaction more difficult. We added a border of a different color to the border containing the image and the name of the game in order to make it more distinctive and give users a clearer indication of where they should press to select the game.

# Chapter 7

# **Conclusions and Future Work**

# 7.1 Conclusion

The objective of this project, was to develop a game platform for tablets with an interface tailored for older adults. This was done using Android 3.0 Operating System, a new version created specially for tablet devices.

Implementing the prototype was important because it allowed us to understand a little more about the limitations of the android tablet as a device to be used by older adults.

Through the conducted usability test, we noticed a number of problems that we had not anticipated when we design the platform. We were already aware that some of Android's functionalities would not be ideal for older adults, for example the 'back', 'home' and 'last applications open'. These buttons are too small and appear on the corner of the screen where users could press them inadvertently. We also found that, the standard version of Android's keyboard was not very usable for older adults and that it needed to be replaced with a customized version adapted to their characteristics. Otherwise it would be hard for the system to be adopted.

The test showed that the participants liked the experience of interacting with the platform, even though we had some problems with the virtual keyboard, namely with the time that the user press took. They seemed to like that we used pictures of healthcare providers whom they recognized from their daily life in the game that they played.

Since the tablet is still an expensive device most older adults might not be able to afford one, so we believe our platform would be more useful in the setting of a daycare center, where many users could have access to it and share it. This was one of the reasons why the user management module was included. Otherwise the platform would be limited to being used by only one person for each device. Since centers have more economic power, they could provide those elders that attend the center access to tablets with our platform.

We believe that the objective that we set out to accomplish were reached, and that this work can serve as a proof of concept for the game platform we intended to create. In the future, the platform could be extended to improve the user experience and add more functionalities.

# 7.2 Future Work

As future work, we could imagine a number of different scenarios:

A customized keyboard could be developed, with buttons that made a clear distinction between the enter button and the backspace button, one of the problems encountered in the test that we conducted. This keyboard also should not change the letter that was chosen depending on the time that the user spent pressing the button, or maybe increase that time, because older adults tend to press the keys for a longer time than younger users.

The platform could be extended by adding more games that should be created using the provided interface. These games could include new means of training using music, video and words, as well as new different games using images. They could increase the interest that older adults feel in using the platform and include elders with different preferences. For instance, by creating a crosswords puzzle we could attract users that like to do crosswords and were not attracted to other games in the platform.

A system of recommendations could be implemented. This system could use information of the user such as his preferences and aspects of training to create a list of games that the system would recommend for the user to play. This system could give users rewards everytime they played the recommended game, which would encourage the user to play the games that the system indicated he should play.

Some tools to aid the healthcare provider monitor the evolution of users could also be implemented since they could become helpful. For instance, creating a graphical representation to visualize the data obtained from the games. This form of visualization could be a graphic, showing the evolution of the user's performance in the games, over time. This would improve the perception of the evolution of the user's results in the game through time.

The platform could be modified to include the possibility of using a network connection to play a game with more than one user in different devices. This would add a different social component to the platform that might be very appealling to older users since social interaction is something that they value a lot. The possibility of challenging friends or family, that are far away, to play has a potentially great value to keep old connections with friends and increase the interaction between generations, and the platform could take advantage of that.

#### Conclusions and Future Work

The platform could have different versions so that other users did not have to use a version adapted for elders, but had a version adapted to them instead. Adapting the platform to different users and creating a social network around the platform or using an existing social network to connect people, such as Facebook, coud bring a whole new dimension to the game platform, making it more interesting and opening it up to a whole new range of users

Since sometimes the number of devices is limited and they must be shared, an interesting capability would be to allow the user to store and retrieve his profile from the network. This way, if the user could not access the device he usually used, but had access to a different device, he did not need to create a new profile and start over, but could instead just retrieve his profile from the network, and use this device like he would use the first. Conclusions and Future Work

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# Appendix A

A.1 Prototypes

# **Prototype 1 – Manipulate images on the screen**

## Background

The objectives of this prototype were to:

- Explore how several classes and interfaces available in the Android platform works, namely the following classes: SurfaceView, SurfaceHolder, Thread, Canvas, Bitmap, GridView, Sliding Drawer, ImageView and ImageAdapter;
- Experiment on how to create and use a custom View, in this case extended from a SurfaceView;
- Test how the touch detection framework of Android works, specially the MotionEvent class;
- See how many images could be drawn in the Canvas of the View before the performance started to degrade visibly.

The SlidingDrawer is a pattern that can be used when there is not much space on the screen, we want to show less information or we want to maximize screen space. It was used so that the Prototype did not present too many choices at the same time.

The SurfaceView appeared to simplify the use of a pattern identified when creating Android Applications; this pattern consisted in the use of a different thread other than the main thread to do the drawing of the elements in the View. This makes sense since drawing may be time consuming and should not be done in the main thread, or it may slow down the application to the point where it cannot respond to user input. By using a different thread, it is assured that the main thread will be responsive while the View's content is drawn.

The Canvas is an abstraction for a drawing surface and permits the drawing of image resources such as Bitmaps or other drawable resources. In the case of the SurfaceView, the Canvas of the View is provided to the drawing thread that should draw in it and then post it back to be displayed.

# Methodology

The Prototype presented several tools to the user. Each of these tools had a different purpose and effect on the View:

- The CreationTool was meant to create new instances of the selected image on the screen. These images were created when the tool was selected and the user touched the screen. This image was moveable across the screen while the user didn't lift the finger, and once he did, it would stay in the last position.
- The DragTool was meant to drag an image selected by the user and change its position on the screen. It works similarly to the CreateTool after the user has pressed the surface and before it has lifted the finger.
- The DeletionTool was meant to eliminate images from the View, once the user has touched the point of the surface where the image is located.
- The MultiTouchTool was meant to create images in the points where the screen is touched and it is the only Tool that supports Multitouch. When the user presses a point on the screen an image is shown at that point. When the user moves the finger the images follows the movement, and when the finger is lifted, the image disappears.

The architecture of the program was designed to be as extensible as possible. All Tools that were created implement the Tool interface and a set of methods that are called by the Custom View. To add new Tools all that is needed is to implement the interface, get access to the list of Objects provided by MyThread and use the provided API to change it as the new Tool is supposed to.
A SlidingDrawer was used to present the Tools available. When the Drawer was closed, the user was able to see and select the images that could be used in a GridView. When it was open, the images were hidden and the user was presented with a list of Tools and was able to choose which Tool he wanted to use.

## Discussion

It can be concluded that the use of the SurfaceView can simplify the creation of a View where images are drawn using a different thread and that receives input from the touchscreen. By the experience conducted we can see that the impact of drawing the same image many times is very small and that a huge number of objects are supported. Even though the results of this prototype are limited and apply only to a set of small and still images the fact that so many can be drawn without a noticeable loss of performance, can let us appreciate the capabilities that can be achieved by these devices.

## **Prototype 2 - Data sending service**

## **Background:**

In this prototype, the objective was to study how to create a background running service that could be used to send data through to a different device, thus allowing the player to communicate with other players in order to create a multiplayer game.

Processes holding Activities can still execute when their activities are active or paused, which means that they are either the first Activity in the Activity Stack or that they can, at least, be seen on the screen. But once the Activity is stopped and put in the background the system reduces the priority assigned to them. With a reduced priority, the process can be killed at any time, if the system discovers it needs the resources it is using. If all needed lifecycle events of the Application have been correctly implemented and all data of the activity has been correctly saved, killing the process of a background Activity should be transparent to the user, so that when the Activity is started again, it will restore its state and appear as if it had never been killed. So while in the background, the Activity should not be executing any processing but instead, it should start a new service to do that same processing. A service has, at least, service priority, which means its process will only be killed after there are no more background processes and if it is not associated with the active activity or one that is visible. When creating an application, it should be considered using a service for any task that might take more time to process. The tradeoff of using a service is the increased complexity of the communication between the service and the activity. Since these two components can function in different processes, a mechanism to communicate across processes must be used. The Messenger class permits communication between different processes by providing a reference to a Handler in another process, which can then be used to pass messages to that process.

## Methodology:

The prototype was created containing one Activity and one Service. The Activity's interface showed a simple LinearLayout containing an EditText for the user to write a message to send, a Button to trigger the send action of the text in the EditText, and two TextView's inserted in another LinearLayout, to display the messages sent and the messages received by the device. The Activity created two Messenger: one to receive messages from the Service, installing on this one a Handler that refreshed the interface whenever a new Message was received, and another to send messages to the Service, whenever the Button to send was pressed.

The Service created two Messengers to communicate with the ones in the Activity, and it also started a new Thread. While the main Thread would wait to receive a new Message from the Messenger, the new Thread would create a ServerSocket, bound to a specific IP and port that listened for connections. Whenever the main Thread received a new Message, it would create a new Socket that connected to the ServerSocket of the other Thread and sent the contents of the Message through the Socket. The thread containing the ServerSocket would then send the received data in a new Message to the Activity.

### **Discussion:**

The resulting activities could communicate between them, while each one was active. To do this the user had to start the service by pressing the button to receive the port. This would start a ServerSocket waiting to receive connections in the port shown. In the second application the user would do the same, and insert in the appropriate box the port of the other service. From here, the user could already send messages to the other activity, but to receive them he should pass the port to the other activity too.

The communication worked as long as these steps were taken and from this moment on, all messages would be sent without any problems.

While this prototype functioned using the localhost and some open ports to communicate, it would be fairly easy to create a version that communicated through the Internet, by using real IP addresses and open ports. This prototype allowed for two devices to communicate by establishing a connection and sending messages to each other. While in the prototype no tests were made with different devices (since only one device was available), it would be possible to communicate across different devices by connecting and sending the message to the ServerSocket running in the Service of the other device instead of the one running in the same device. This model of communication could be expanded to include more devices by creating a mechanism to register and monitor all the devices present in the communication and sending the messages to all of them, but this wasn't the objective of the prototype.

## **Prototype 3 – Drawing Application supporting multitouch**

## Background/Introduction/Context

The main objective of this prototype was to test how the multitouch framework available in Android worked and could be used in the project. One of the characteristics of tablets is their use of touchscreens as primary input devices, and since the introduction of multitouch technology, all tablets are able to detect more than one touch at a time. Since this capability could be important to include in a future game for the elderly, a prototype was devised to understand and explore how these capabilities could be used in the project.

## Methodology

For this purpose, a drawing application was created. This application allowed the user to use more than one finger at the same time to draw in a canvas. The design of the application was as simple as possible, to keep the screen unoccupied so that the user had access to a bigger drawing area. To accomplish this the options that the user could change were reduced; the only controls that were available were the possibility to change between a few pre-set colors and clearing the screen. These options could be accessed in a menu that occupied a small area on the side of the screen, and everything else was occupied by the canvas where drawing would occur. Also, it was chosen to use a kind of vectorial type of drawing, in which the user had to not only to touch the screen but also move its finger through it for the drawing to take place.

The prototype was created as a single activity. This activity used a layout composed by a GridView and a MyView, a Custom created View using SurfaceView as its base. The GridView included the controls that could be used to change the line color and to clear the screen. Much like in the first prototype, a Surface View was used because it provided a canvas while using a separate thread to do the actual drawing. This helps prevent the case where the application will become unresponsive while drawing operations are being performed, and ignore or take too long to respond to user input. A Custom Thread was also created, containing two ArrayLists. In one of them were stored the Drawings that were currently being used by each user, and the other stored those that were no longer being used, so wouldn't change anymore but still needed to be drawn on the screen. Whenever a user touches the screen with a finger, a new Drawing is created and stored. Everytime the user moves its finger the Drawing object for that finger is retrieved and updated. Whenever the user stops touching the screen, that Drawing is retrieved and stored in the list of Drawings that are no longer being updated.

## Conclusions

Understanding how the class MotionEvent works in Android was crucial in the prototype. This class is used to model the events of interaction with the screen. A few relevant actions were identified when using multitouch:

- ACTION\_DOWN, triggered when the first finger touches the surface
- ACTION\_POINTER\_DOWN, triggered whenever another finger touches the surface
- ACTION\_UP, triggered when the last finger lifts from the surface
- ACTION\_POINTER\_UP, triggered whenever one finger that is not the last lifts from the surface

• ACTION\_MOVE, triggered whenever a finger moves is dragged and changes its position on the surface

Even though the platform allows the differentiation of the first and subsequent touch events, such was not necessary in this prototype so the difference was ignored and both events triggered the same action. During the creation of the prototype we could identify that different devices were able to identify a different number of finger touches on the screen. For instance, when the prototype was tested in a samsung galaxy tab of 7" we identified that this device only identified five simultaneous finger touches, while when we tested it with a samsung galaxy tab v 10.1, we realized that it was able to identify ten simultaneous finger touches on the screen.

Each event contains information about every pointer that is touching the screen and, in addition, some contain information about the pointer that the event relates to. For instance, while an event with the ACTION\_MOVE action contains information about the position of each of the pointers touching the screen, an event with the ACTION\_POINTER\_UP action will also contain information about which of the pointers has been lifted. In events following an "up" action the pointer referred by that action will disappear from the list of pointers provided by the event, while during a "down" action, the new pointer already appears, as well as information as to which was the added pointer.

## Prototype 4 – Application with a Camera and multitouch photo manipulation

## Background

The main objective in this prototype was to explore how the camera could be used in the project. Since the Camera has a great potential value to add to the final application, allowing older adults to take pictures and, for instance, personalize their profile or even take pictures of their environment and customize the way the application looks to them, we believed that it could be an important functionality to add. Recent Tablets have two built-in cameras: one in the front and one in the back. The camera in the front usually has a lower resolution than the one in the back. Both cameras can be used to take pictures or to create videos of varied qualities. We also wanted to test how the notification process worked in android for custom notifications, so we set up a broadcast receiver to execute every time that a picture was taken. This broadcast receiver would then create a custom notification with the notification manager, containing a miniature of the picture that had been taken and the information that a picture was taken.

## Methodology

We designed the application to work in two steps: start by showing a preview of what was being captured by the back Camera of the tablet in the screen. We used a SurfaceView to show the preview because of the advantages it presents: as already discussed in other prototypes, the SurfaceView simplifies using a different thread to draw the objects inside the View. To use the camera, it is necessary to configure it. One of the configurations necessary is the size of the screen that was going to be used. Since the supported screen sizes do not always match the size of the SurfaceView that is being used, it is necessary to choose from the list of available screen sizes which is the size that better fits it. We ended up creating a function to weigh each screen size and choose the best one. This function considered two parameters: the difference between the width and height of the screen and the SurfaceView and the relation between these height and width. This way we minimized the difference between sizes and the distortion that the image on the screen would suffer.

To take a picture, all the user had to do was touch the preview screen. The activity would then detect the click event and take the picture, storing it in a temporary file. After this, the broadcast receiver can detect the event of taking a picture and create a notification. This notification would use the image by reading it from the file.

The second step would then be calling a second activity. This activity would show the picture taken on the screen, and allow the user to manipulate it. This would be done using another SurfaceView, and all the logic would be implemented in the drawing thread.

## Discussion

We created this prototype in order to understand how to use the interface of the Camera in the Android Tablet. We also experienced how to use Broadcast Receivers to create Notifications in the System. Both these features are important and we believed they could be used in the final application. While the Camera API is fairly easy to use, it is necessary to know how to use the lifecycle events correctly. Since there is only one instance of the Camera that can be used at any time, it is necessary to guarantee that the camera is released when no longer needed, or risk that any following calls to the same methods will fail due to the fact that the camera resource is still locked. At the same time it is necessary to verify if the camera is not used after it is released which would make its state inconsistent.

## **Prototype 5 – Level Application to test the Accelerometer**

## Background

The main objective in this prototype was to explore how the accelerometer could be used in the project. We devised an application that would show in the screen information about the data gathered from the sensors in each direction. We believed the accelerometer could later be used by older adults to play richer games in the tablet, taking advantage of this kind of sensor that was introduced in mobile devices to create a better experience for older users.

## Methodology

The accelerometer is accessed by registering a listener with the Sensor Manager Service in Android. This listener is then executed whenever a change is detected in the sensors. There are some modes to receive data from the sensors, and in this prototype we used one that receives the input delayed, in order to both save battery and not react too fast to the user input.

We also created an object in the screen that is manipulated by tilting the screen in each direction. An emulation of the newton's model for attraction exerted by one object over another is used to calculate how this object moves. To do that, we use the values obtained by the sensors to update the gravity that the object is subjected in the x and y axis, causing him to gain velocity over these axis. The position of the object at any given time is printed on the screen, and some graphics indicate what the value of the gravity received from the sensors is. These graphics show how much the value deviates from zero in each direction. We use the inclination of the tablet to simulate what would happen at an object (for instance a ball) on top of a table, if that table was subjected to different inclinations. This mechanism is similar to the one used in games like the ball labyrinth where tilting the tablet applies forces in different direction on the ball, making it change direction.

## Discussion

The accelerometer is a sensor that can have a wide range of applications. It has already been used in mobile devices for applications such as games, to detect falls of the user handling the device, to detect the direction of movement, etc. While this sensor has, undoubtedly, great capabilities, it is an unknown if it can be used by older adults, since most games using this kind of sensor require good reflexes and capacity to think rapidly, two things that are somewhat difficult for older adults. Still we feel that creating this prototype was useful so that if it is deemed necessary to incorporate this feature in the future, we will already have some experience and knowledge about how to use the data obtained from the accelerometer.

## **Prototype 6 – Piano Application to test the sound**

## Background

The main objective in this prototype was to explore how sounds could be used in the project. We wanted to explore how the platform's capacity to reproduce music files could be used in our project. To that end we developed an application that would show a simple representation of a small part of a piano on the screen. By pressing each of the keys in this piano the user would hear a sound associated with that key. In Android there are three ways to play a sound: playing from a raw resource, playing from a file or stream or playing JET content. There are three kinds of constructs that can be used to play sounds: the MediaPlayer that is used to play sounds from a raw resource, file or stream, the SoundPool, which also can be used to play audio from a file and the JetPlayer which can be used to play JET content. While the MediaPlayer class can be used to play normal sound files and streams, it is limited to one source at a time. The SoundPool construct on the other hand, is oriented for files of smaller dimensions, but can be used to play simultaneously more than one file.

## Methodology

Since we were implementing a piano application in this prototype, we wanted it to be able to play more than one sound at a time; otherwise the piano would be limited. Normally, in a piano, the notes that are played linger for a while. If we could not play more than one sound at a time, each new sound would substitute the first, instead of being played at the same time. To obtain this effect we believed that the SoundPool was the best choice. Also, we could use smaller audio files such as midi to play the sounds that we wished, so the fact that SoundPool only can use small files was not a problem. The SoundPool is first initialized with the sounds that then they can be played at any time. Since each sound would have to be played until it consumed itself, we created a new thread each time a key was pressed. This way the sound would be played until the end, independently of what the application was doing at the same time.

### Discussion

Playing sounds is an important feature. Hearing is perhaps, after vision, the most important sense that we have and mobile devices such as tablets possess built in speakers that can be accessed to reproduce sounds. There are a number of games that can be played with sounds, and as we verified in the elder center where we developed our project, games that involve singing songs appeal a lot to older adults. Sounds are also important for those older adults that can't read or have problems seeing, since with the new text to speech capabilities of these devices, they can know what is being shown on the screen. We believe this prototype illustrates shows the capabilities of using the Sound in one of these devices and will speed up the implementation of this feature in the final application.

## Prototype 7 – Matching game to test a game library using a physics engine

## Background

The main objective in this prototype was to explore how a third party library could be used in the project to create games faster for the platform. For this purpose we chose the Libgdx library, one of the most developed at the time that this prototype was being created. To this purpose we designed an application using the physics engine that was implemented by this library. We wanted to implement a game to show the library's capabilities, so we chose a game we had seen in the senior center. In this game, the user would start by seeing a set of objects in a table. After seeing them for a while, one of the caretakers would move the objects around and ask the user to put them back where they were. When the user put the objects in their right places he would win. The game we developed started from a point where all objects were static in pre-determined places. When the user touched the screen, the objects would fall down, affected by the in game physics. The user could then move them around in the screen. In the initial place where the objects were located there would be a shade of the object, and when the user dragged and dropped the object in its initial place, the object would become static again. When all objects returned to the static position the game would end.

## Methodology

We used the Libgdx library to implement this game. This library possesses, among others, one very interesting functionality: it contains a physics engine that allows it to treat objects as physical objects, handling all the calculations automatically and updating its position. The user only needs to set the parameters of the world and object so that they can be used in the calculations. This library has a huge advantage, which was what prompted us to try it in the first place. Since it uses the openGL API that exists both in Android and in other operating systems, it was possible to port one application from one environment to the other. This made it possible for us to create and test applications using only the linux environment and when everything was already implemented pass to Android to do only final tests or any modifications still necessary.

## Discussion

This library allows the users to manipulate various aspects of the platform. Its programs have access to its own API to make games. While this can be a huge timesaver, since a lot of the logic is already implemented, it can also be limitative, since the user is restricted to the functionalities available in this API. Although this library could be used in parallel with the normal API to create games, we choose not to use it because we would lose control over some of the features of the Android Platform inside those games.

# **Appendix B**

**B.1** Article

## **Tablets as a Gaming Platform for Older Adults**

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#### ABSTRACT

The number of games specifically designed for the older population is scarce to inexistent. One of the reasons that contribute to this situation is the stereotype that seniors cannot and do not want to use computers. However, this is not the case, and more and more, elders use technology in their daily life. Older adults are a segment of the population with very different characteristics from the mainstream users for whom most games are designed. Disregarding those differences in the design of the game can make the gaming experience challenging, if not completely impossible for the older adult. This paper describes the research process for the development of a tablet-based gaming platform for older adults. This platform provides a series of casual games that aim at promoting the quality-of-live and well-being of seniors by making available different types of cognitive games. 10 features are identified as good rules of thumb for this platform and the games included in it. The low- and medium- fidelity prototypes of this platform were systematically tested with older adults, and a high-fidelity implementation is undergoing.

#### **Categories and Subject Descriptors**

H.5.5 [Information Interfaces and Presentation]: HCI

#### **General Terms**

Design, Human Factors.

#### Keywords

Human-Computer Interaction, Games, Tablets, Older adults, Elderly Entertainment.

#### **1. INTRODUCTION**

Older people (65+) are likely to encounter computers and other forms of technology in a large number of settings. However, and despite the trend of an increased use of computers, it is still lower among older adults as compared to younger ages [1]. One commonly held belief is that older people are resistant to change

8<sup>th</sup> International Conference on Advances in Computer Entertainment Technology'11, November 8–11, 2011, Lisbon, Portugal. Copyright 2011 ACM 1-58113-000-0/00/0010...\$10.00. Luis F. Teixeira Dep. Engenharia Informática, Faculdade de Engenharia, Universidade do Porto Rua Roberto Frias, s/n 4200-465 Porto, Portugal luisft@fe.up.pt

and unwilling to interact with computer systems, however the majority of studies that examined the attitudes of seniors towards computers indicated that "older people are receptive to using computers" [2]. Therefore there is no valid reason for not considering seniors as a potential target audience for computer applications; on the contrary developing software with these users in mind has the potential to provide them with a wide range of benefits that would otherwise be unreachable.

During the past decades the 'games for adults' industry has suffered a tremendous growth as a consequence of the population ageing and its impact in the economy [3]. This demand on entertainment mechanisms for retirement-age adults has already caught the attention of many researchers who have studied games potential in providing not only enjoyment but also well-being related improvements [4-10]. Their conclusions are optimistic and provide valuable information for future projects within the field.

Furthermore, novel devices that incorporate touch and gesturebased interaction "may afford an alternative and more natural interaction method" [11], easing the use of technology by older adults.

With these premises in mind the authors believe that studying the combination of games with touch-based devices, such as a tablet, can result in a suitable product for older adults, diminishing the current gap between this audience and technology thus promoting its use and the wide range of benefits that it can provide.

Section 2 makes an overview of the changes older adults experience as they age. Section 3 explains how older adults approach games, and start to describe the focus of our project. Section 4 discusses some aspects on the technology used for this project. Section 5 and 6 detail the characteristics and features of the platform that we are developing. Finally, section 7 discusses the research carried out and outlines aspects for future research.

#### 2. OLDER ADULTS

The ageing process is responsible for changes at several levels, from biological to psychosocial. These age-related changes may impact a number of different aspects of older adults' lives and limit the extent to which they are able to perform certain activities. These constraints can also be observed in their ability to interact with computer systems, which are yet to be prepared to accommodate seniors capabilities and limitations. In this section the authors document a number of age-related changes in motor, perceptual, cognitive and psychosocial skills that can impact the user interaction with a tablet device.

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#### 2.1 Motor and Perceptual Changes

Age-related changes affecting perceptual capabilities (e.g. vision and hearing) and motor skills are especially problematic for older adults when trying to interact with computer systems.

Older adults can experience challenges while reading at close distances in result of a condition known as *presbyopia*, "the inability to focus effectively on near objects" [12]. Transitioning from light to dark environments or performing visual tasks under dim light condition at night, can also introduce challenges [13]. Generally, seniors also experience a loss of static and dynamic visual acuity and yellowing of the lens that makes the perception of short wavelength light harder, diminishing the colour sensitiveness in the blue-to-green ranges [12].

Regarding hearing, many older adults, especially men, suffer from *presbycusis* – the reduced ability to hear high-frequency sounds – which challenges the hearing of certain sound such as the 's' sound, causing problems in correctly understanding speech [12]. These changes should also be considered in the design of computer systems as older people may find it challenging to perceive synthetic speech or hear alert sounds such as "beeps or pings" [1].

Age-related changes in motor skills include slower response times, declines in ability to maintain continuous movements, disruptions in coordination, loss of flexibility and variability in movement [1]. The haptic processes, which involve the use of touch to obtain information about the features of an object, can also suffer some changes, specifically the loss of sensitivity in the hands [14]. These motor skills can greatly influence the perception the user gets from interacting with a system, especially when manipulating devices that require great precision.

#### 2.2 Cognitive Changes

Many computer tasks are characterized by having high cognitive demands [1] and for this reason it is important to consider any age related changes on cognitive skills when designing for older adults.

Memory and attention are some of the most important cognitive abilities that may suffer decline with age. The capacity of shortterm memory shows signs of decline with age and is known to affect many complex everyday tasks such as decision-making, problem-solving and the planning of goal-directed behaviours [15]. This is mainly due to the difficulty of older adults to store and manage large amounts of new information [12]. However, unlike working memory, long-term memory is largely preserved in old age [15].

In general, attention is also affected by age. Older adults have shown to have more difficulty in tasks that require divided attention across multiple input channels and are also more prone to being distracted by irrelevant information [12]. These two cognitive constructs – memory and attention – should be highly considered when presenting information to older adults, since they may find challenging to absorb and process large quantities of new information at a time.

Two other relevant skills are spatial cognition and language comprehension. The first is related to the ability of mentally manipulating images or patterns whereas the latter is the ability to interpret verbal information [16]. Both these cognitive skills have shown to decline with age and they can, along with memory and attention, affect the way elders perceive and interpret information.

## 2.3 Psychosocial Changes

Even though people are in general more aware of the physical age-related changes due to their external visibility, psychological and social changes that occur in elders' lives are equally important to consider.

One of the main triggers to social or psychological changes is retirement. Being retired is many times associated to a loss of social importance and power due to the disengagement of an active social role, and presents itself as an open door to old age [17]. This perceived lack of responsibilities towards the society may incite an identity crisis and consequently a loss of self-esteem [18]. At the same time, physical and cognitive changes begin to be more noticeable, affecting one's independence and autonomy, diminishing the performance of daily life activities which can also be psychologically distressing by posing a threat to one's ability to live safely and independently [19].

The above-mentioned problems are yet aggravated by the reduction of the elder social network. For the older individual, the social component is one of the most important means towards well-being, however in old age there is a series of barriers that difficult the maintenance of relationships such as the death of friends and family, personal vulnerability, environmental and contextual obstacles, stress and conflict [17].

While these changes may not seem important for a computer system design, they are indeed worthy of reflection if we wish to design an artefact that appeals to this audience. As an example, older adults that experience feelings of abandonment may recognize the importance of a system that fosters social interaction that will consequently increase its acceptance rate.

## 3. GAMES AND OLDER ADULTS

A game, as defined by Juul [20], is: "a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels emotionally attached to the outcome, and the consequences of the activity are negotiable".

Understanding and considering all the mentioned game elements as well as their impact in the gaming experience should be done at an early stage of a project, in order to carefully incorporate them into the game design. In this section we discuss the relationship between older adults and games, their scope and potential impact and then study the above-mentioned game elements and their design to better adapt to this specific audience.

In many situations, after retirement, leisure activities represent a big part of elderly daily life [21]. There is a wide range of motivations that compel seniors to engage in these activities, like keeping themselves busy and mentally alert, being socially included or just having some fun [5]. Playing is already part of many older adults' routine and even though it is true that the majority of older adults solely play non-digital games, thinking that the games' target audience only consists of children and teenagers is a misconception. In fact, in 2010, the average age of the American player was 34 years old and 26% of game players were over the age of 50 [22].

Games are known to provide fun and enjoyable experiences, through a wide range of different mechanisms that usually appeal to the emotional connection that players feel towards games [23] and are also a way of communication that enables people to relate to each other, interact and spend time together [24]. Their scope of benefits is actually broad and their use as a tool to increase seniors' well-being is starting to gain a significant importance.

A recent example of these benefits is the Wii platform and the spread of 'exertion games'. Jung et al. [9] have studied the effects of Wii games on elders' quality-of-life and their results showed that the overall well-being of Wii players was significantly improved, demonstrating the potential of the Wii to impact on the diverse aspects of elders' lives.

Another aspect in which games can contribute to older adults' well-being is in the area of cognitive stimulation. Increasing attention is being paid to the cognitive effects of playing games, on older people [25][26][7][6][8]. Not all studies were conducted with games specifically developed to older adults, however, even with regular games, results show that seniors who played them were faster in their reaction time [25][26], significantly improved their performance on tests of visual fluency and visual perception ability [8], improved cognitive skills and maintained their self-concept and quality-of-life [6]. Moreover a recent study reported that, in fact, these benefits remain for weeks and can be transferred to everyday tasks [27], indicating that games can help older people to stay mentally fit, thus contributing to their well-being.

## **3.1** Designing a tablet-based cognitive gaming platform for older adults

Combining tablets' characteristics with the aforementioned research results, we recognize an opportunity to study a solution that uses games as a cognitive stimulation tool for older adults. A cognitive game has the main purpose of stimulating cognitive abilities, while maintaining the typical elements of games (e.g. fun, challenge) in order to engage the older adult into the gaming experience.

The first step to develop the best possible solution was studying the relevant cognitive changes that take place with age and that were already described in section 2. Subsequently, it was crucial to understand how to stimulate the affected cognitive constructs. As to do so we analysed cognitive stimulation exercises provided by literature on ageing [28][18] from which we were able to extract patterns of gaming elements, and to relate them with the cognitive construct they intend to train.

Table 1 shows the matrix with the result of this analysis, which acted as a guide for the possible elements to include in a game that aims the stimulation of a specific cognitive construct.

Table 1. Cognitive Exercises Elements and Stimulated Cognitive Constructs

	Cognitive Constructs					
	Working memory	Semantic memory	Attention	Spatial cognition	Language comprehension	Problem Solving
Trivia		Х			Х	
Mimic	Х	Х	х		Х	Х
Patterns	Х		Х		Х	Х
Enigmas		Х	х		х	
Find Differences	х		х	X		
Word Puzzles	х	х	х	X	х	
Sequences	Х		Х			Х
Mazes			Х	Х		

Even though all these categories could be applied to games, we further performed a critical analysis of this matrix, along with a review of the literature, to settle on the most suitable ones for our platform and for older adults. We concluded that trivia and mimic games should not be considered in a first stage, since trivia games have the main purpose of stimulating semantic memory, which is not primarily affected by age. Mimic games would not be suitable because the tablet would be a rather superfluous support for the game play, not providing more than a simple image viewer functionality.

#### 3.2 Gaming Platform Requirements

Gathering requirements for games designed for older adults may be more demanding than the usual process for a more conventional software artefact. On the one hand, game "requirements like *fun* and *absorbing* are not well understood from the perspective of requirements engineering" [29] and, on the other hand, "user requirements are usually elicited by a way of focus group, which is often difficult when working with older people" [30]. Thus, some reflection on the traditional methodologies was needed in order to overcome possible difficulties in the requirements elicitation phase of this project.

To understand games' context of use by older adults we resorted to natural observation in elders' usual get together sites and day care centres as well as informal conversations with them and their caregivers. These steps gave us a deeper insight on older adults' preferences – e.g. group games – and we also received some advices from the caregivers – e.g. if possible provide them with a variety of games. However, to obtain more formal and accurate results, we developed a *game book* to better assess seniors' preferences and difficulties regarding games, in particular games that were designed with the purpose of stimulating cognitive skills. This *game book* concept was developed considering the idea of games as research proposed by Nathan Shedroff [31] and was distributed among the elderly using the same method as the one of cultural probes [32].



Picture 1. Game Book

The *game book* consisted of 10 different games distributed over the following categories: 2 sequence games; 1 enigma game; 3 word puzzles; 2 labyrinths; 2 find differences games.

The *game book* was distributed to a group of older adults consisting of 13 individuals (10 female/3 male) with an average age of 80 (74-88) who were asked to solve the games and return the book to us within a week. When collecting the *game book* we

performed a questionnaire to evaluate their level of satisfaction, difficulties encountered or reasons for not solving a game. This questionnaire was carried out during an informal conversation.

Results showed that older adults felt more engaged in word puzzles and find differences games. This was mainly due to two factors: these games are more familiar to them, as they are usually available in magazines or newspapers (and for some of them these consist of regular activities); and because when assessing game difficulties, they pointed these two categories as the easier ones. This indicated that there might be a correlation between game preference and difficulty, as they tend to favour games that do not imply a great effort to solve.

#### 3.3 The Gaming Experience

Our main concern in this project was to develop a product that users will want to use [33] and will be able to effectively use [34]. Thus, one of most important aspects of the solution is its usability – the ability that a specific user group has of using a product to achieve specified goals with *effectiveness*, *efficiency* and *satisfaction* in a specified context of use. [35] While all of these characteristics are of utter importance, the user satisfaction aspect is crucial if we aspire to develop a product that appeals to an older audience. The perceived usefulness of a system highly relies on the experience the user has when using a product and this is an essential aspect that dictates the acceptance of the final product.

The experience of use is related to the usability of the system, however in games this aspect extends beyond that. Games are about providing fun and enjoyable experiences [20] hence there is a need to understand which are the needed elements and mechanisms to support that, as well as the approach needed to assess their efficacy.

Gámez et al. [36] studied the gaming experience and proposed CEGE (Core Elements of the Gaming Experience) as the necessary, however not sufficient, elements that should exist in a game in order to provide a good user experience. According to their theory "a positive experience (enjoyment) while playing games is achieved by the player's perception of the game and the interaction with it". Furthermore, they specify that the game perception is given by the environment and the game-play, whereas the interaction depends on the player's sense of control, ownership and through the 'facilitators': aesthetic value, time and previous experiences.

From literature research on games, we learnt that the 'casual games' category endues some of the game elements that we believe are more suitable for the older user and that can be related to the ones of enjoyment above-mentioned. Trefry [37] defines the characteristics of a 'casual game' as:

"(1) Rules and goals must be clear; (2) Casual game play adapts to a player's life and schedule; (3) Players need to be able to quickly reach proficiency; and (4) Game concepts borrow familiar content and themes from life."

The sense of control in a game is given to a player as soon as he learns how to manipulate it. For this reason, and because older adults may find decision making more challenging due to their cognitive impairments, game rules and goals must be clear enough for them to understand (as in Trefry definition 1). Moreover, the existence of goals by itself creates motivation and ultimately provides the feeling of accomplishment, which may also influence the value of the game, as perceived by the older adults. In fact, is this rewarding sense that they may experience that produces

ownership, when players understand that their actions in the game have results and a positive (or negative) outcome. Logically a positive outcome will keep the player engaged whereas a negative feedback can lead to frustration. Although a game should be challenging it is important to clearly understand what the player's skills level is in order to adapt the game level of difficulty to it. If that balance is achieved a user should be able to quickly reach proficiency (as in Trefry definition 3) which will reduce the risk of user dissatisfaction. This is especially important when designing for older adults, as they are more unwilling to learn via trial and error and get frustrated more easily [5]. These two characteristics are also connected to the time factor because, contrarily to what one may think, after retirement seniors do not have more free time. In fact they tend to engage in specific routines and have all their activities scheduled in advance [38]. For this reason they are not willing to spend their time in an activity that is unknown to them, thus requiring that the game adapts to their lifestyle (as in Trefry definition 2) and not being time-consuming. Finally, as elders of today do not have previous experiences with games, they tend to misinterpret some game concepts - such as the use of weapons - and favour games that portrait real stories or realistic activities [5][6] (as in Trefry definition 4).

In essence, we consider that 'casual games' provide a simple framework of game characteristics that, according to Gaméz's theory [36], has a number of necessary elements to provide an enjoyable gaming experience to an older audience.

## 4. USER INTERFACES TODAY

How users interact with technology has a huge impact on the way they feel about that experience [39]. Up until some time ago, to interact with computers, users had to use 'indirect' input devices, such as the mouse and keyboard. This kind of input devices is normally associated with WIMP (Window, Icon, Menu, Pointing device) user interfaces and is still widely used in desktop computers.

However, we see now a different range of input devices becoming available. These devices are not necessarily new, but they have reached a point where affordability, availability and consumer acceptance converge to make the devices reach a huge number of users [39]. These alternative devices are called 'direct' input devices, and they allow the user to have a more direct interaction with the device. Contrarily to 'indirect' devices, they are characterized by not requiring any transformation between the actions of the user and the action performed by the device. Because of this characteristic, their use requires little hand-eye coordination, little training and has minimal spatial demands [42]. Touch screens, touch pads, voice recognition, wearable interfaces are examples of this kind of devices. They open a new range of possibilities for designers to expand the way people interact with technology, creating richer experiences for users. Some studies suggest that gesture recognition through touch may be an alternative and more natural interaction method to indirect pointing devices [40].

A comparison between direct and indirect methods performed by Rogers et al. [41] from which we may conclude that while direct devices generally need less training and are better suited for novice users or those that do not want to memorize commands, indirect devices are more precise and users with more experience prefer them for longer periods of use. Direct devices are also considered to be easier to use because of their reduced cognitive and coordination demands. As they age, seniors may experience a reduction in dexterity and motor coordination. And since most of them have never had contact with computer technology, and with the input devices being used, they may experience greater cognitive demands to execute tasks. These two factors can combine and make the seniors' first interaction particularly challenging [42]. Since direct devices have reduced cognitive and coordination demands when compared to indirect devices, they appear to be more adequate for the interaction with older adults. There are some age-related studies showing that older adults have problems when interacting with a computer using traditional 'indirect' devices, especially when they have some kind of disability such as Arthritis or Parkinson [11]. In a study by Wood et al [42], the performance of young and older adults, when using a mouse to interact with the computer was compared and it was found that the senior participants experienced difficulties when the task they were performing involved clicking or double clicking the mouse.

#### 4.1 The Tablet

Tablets have recently risen in popularity. A Tablet can be defined as a device, in the form of a notebook that uses a touch screen as its main input method. The tablet's dimensions are normally bigger than the smartphone's and smaller than the laptop's. It is important to distinguish between two kinds of Tablets: the convertible and the slate. Much like the name implies, the slate looks like a writing slate and doesn't have a dedicated keyboard. Convertibles, on the other hand, resemble modern laptops with the difference that the screen is a touch screen. The screen can also be rotated and hide the dedicated keyboard to expose only the screen, which doesn't happen in normal laptops. For this project, we will only consider slate tablets since they are the format that we believe better adapt to our project. Slate tablets do not possess a physical keyboard but they have software capable of simulating a virtual keyboard on the screen that can be used like a physical one. This has the great advantage that the keyboard is still available when needed, but remains hidden the rest of the time. Not having a physical keyboard also means that the display screen can be bigger and more flexible [39]. So, slate tablets are usually smaller and lighter than convertibles [43].

#### **4.2** The Selection of the Tablet for this Project

We chose to use the tablet for this project because of its mobility. This device is relatively small and can be transported nearly everywhere and used when necessary [43]. This is important when dealing with older adults since most of them experience some degradation of their motor skills and may be more inclined to use a device that does not weigh a lot and has reduced dimensions. The tablet also possesses an autonomy that is bigger than the one of a laptop, and yet smaller than the one of a smartphone. Finally, the tablet has a touch screen that can provide the novice user with a more natural way of interaction since he can interact with items on the screen by just touching them [39].

#### 5. COGNITIVE GAMES PLATFORM

Throughout the process of research and requirements elicitation we became aware that our solution needed to take into account a number of characteristics. Besides the existing guidelines for developing games for older adults [16] and the above-mentioned results regarding the *game book*, we came across additional information that we consider to be an important contribution to this area and that will allow the development of more suitable products in the future. Our solution is based on a gaming platform that will incorporate a series of mini-games, distributed into the categories that most appeal to the seniors. It has two playing modes: single player and collocated multiplayer. Since the games are expected to be played during a short period of time we decided to incorporate the multiplayer mode as a tool to manage player turns instead of allowing two or more players to use the tablet simultaneously. Although that could indeed be an option, when considering that cognitive games can enhance seniors' abilities it is important to note that such effects only take place if a game is played by a single individual at a moment in time. Nevertheless elders can still collaborate to solve a game if they wish to do so.

#### 5.1 Platform Description and Prototypes

During our initial observations at the day care centres and other get together sites where older adults usually meet we observed that they favour games that promote social interaction, i.e. games that require more than one player. Along with that, competition seemed to be a big part of the gaming experience since both game participants and observers commented on the game progress and winning/losing strategies during the game development. When we conducted the *game book* experience we also verified that, despite being told that their results were not being evaluated, the participants requested our feedback on their performance and were fervent to compare scores with their counterparts, which also indicates an acute sense of competition among them. For those reasons we incorporated the multiplayer mode described earlier as well as a reward system so that users are able to keep record of their performance and compare game results.



Figure 2. Paper prototype of the main menu with "play in group", "play alone" and "view scores" options

During the interviews with the caregivers at the day care centre we were told that non-digital games were already part of older adults' routine and that providing variety was a very important aspect. With the exception of some games that seniors play more regularly (e.g. cards, dominoes), they tend to get easily tired of playing the same game for an extended period of time. Further more the caregivers emphasized the importance of stimulating elders through the use of different games. For that reason we developed a gaming platform providing its user with a variety of different mini-games, such as demonstrated in Figures 3 and 4.



Figure 3. Choose Game Category Menu



#### Figure 4. Choose Game Menu

Until now we have designed and tested two different games to be added to the platform. Both aim at stimulating cognitive constructs, in particular semantic memory and attention, and draw their characteristics from the 'casual game' category discussed in section 3.3. In the first one the older adult is presented with a set of similar images for a limited period of time during which he has to identify the one element that is different from the others (in our test this element was smaller than the others, but the differences may vary). Afterwards the screen is cleared and the elder is asked to identify the area in which the different element was located.



#### Figure 5. Game Prototype

The second game that was tested was a matching cards game. The player had to turn two cards at a time in order to find a matching pair. The major particularity of this game was the use of pictures of people that were known to them from their everyday life, such as the caregivers from the day care centre they attend to. We tested the game with both unfamiliar and familiar faces and concluded that elders not only preferred pictures from their acquaintances but also were faster in finishing the game.



Figure 6. Game Prototype with day care centre caregivers' photos

As argued in section 2, there are several age-related changes that may limit the extent to which an older user is able to interact with a system. All through the platform's design process we took those constraints into consideration and assured that fonts and icons were readable and understandable by people with vision impairments, buttons and other touch-based actions were accurately performed by seniors with motor impairments and that accessibility options like *Help* and *Text-to-speech* functionalities were implemented.

So far we have developed low-fidelity prototypes, which have been systematically evaluated with a group of seniors at a day care centre. These tests focused on assessing the overall usability of the system, as well as icons and naming conventions in order to be recognizable by older adults. The implementation phase of the project is in progress and after we have a fully functioning prototype we will run a trial to validate its acceptance by our target audience.

## 6. 10 RULES OF THUMB FOR OUR GAMING PLATFORM

It was our main concern to develop an artifact that holds the needed characteristics for providing an enjoyable experience to our audience. The overall specification and design of the platform, as shortly described in the previous section, considered their characteristics and needs. But there are a number of features we considered of paramount importance, which are as following:

1. Usage of direct input devices, to make the interaction as easy as possible and reduce the anxiety of elders towards technology;

**2. Mobile** platform, so it can be transported and played anywhere;

**3. Unique interface,** with a design that accommodates the changes elders experience as they age;

**4. Expandability**, so that new games can be created, made available and downloaded and play by elders;

**5.** Variety, by providing more than one game in each category enabling elders to choose their favourite;

**6.** Customization, since the games can be adapted to a specific individual through the use of pictures, videos or sounds that are familiar to him;

**7. Feedback,** for the user to know about his actions in the game, so that he knows where he was correct, where he failed and how;

**8.** Goals, to keep the user's focus on the objective of the game and that can act as challenges to keep the user engaged;

**9. Rewards**, to immediately award the user for his performance since the benefits of cognitive games might only be noticeable in the long run; the rewards can also be used to show to friends and keep track of the user's progress.

**10.** Social interaction, promoted by the multiplayer mode and through the reward system as it provides a conversation theme among elders while enabling a friendly competition.

## 7. DISCUSSION AND FUTURE WORK

Due to its expandability, this platform can be complemented in the future with more games and relevant levels of difficulty, so it adapts to a wider group of users. Furthermore, we prepared it to save a series of parameters regarding user performance that may be used not only to track an individual's progress but also as monitoring tools, similarly to the ones studied by Jimison and Pavel [7].

Another aspect that is yet to be fully explored is the cognitive improvements that games can in fact have on older adults. Although games have proven to have that potential, "currently little is known regarding how the schedule of video game practices affects transfer to other perceptual and cognitive abilities" [44]. However, despite the conclusions that future research may reach on the subject, a game should always be a fun and free activity, and imposing schedules could possibly negatively influence the user experience. For this matter a solution that motivates users, opposing to obligate them to play a game is needed. We are currently studying a mission/goals mechanism that would reward users that engage in a specific game playing routine, which could potentially be a solution for this issue.

Finally, however preliminary results have already indicated that the platform satisfies the various aspects of usability as well as its great acceptance by older adults, these results still need further formal validation.

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