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COGNISTIM: PHYSICAL AND COGNITIVE REAL-TIME STIMULATOR USING INERTIAL SENSORS IN A VIRTUAL REALITY ENVIRONMENT FOR ELDERLY PEOPLE

Dissertação no âmbito do Mestrado Integrado em Engenharia Eletrotécnica e de Computadores, Especialidade no Ramo de Computadores

Setembro de 2018

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FCTUC FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE DE COIMBRA

CogniStim: Physical and cognitive real-time stimulator using inertial sensors in a virtual reality environment for elderly people

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Dissertação para obtenção do Grau de Mestre em
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Abstract

The aim of this dissertation is to promote active aging in the elderly people, using sensors to generate real-time interaction with a Virtual Reality (VR) environment. With the development of virtual reality games, we hope to increase user immersiveness in this environment and take advantage of this feature to explore a more effective solution for physical and cognitive stimulation, as well as providing new experiences and contact with new technologies by the elderly people. With this system, we wish to extract metrics for later evaluation of physical and cognitive performance. This project will go through three phases: research, development of the solution and testing directly with groups of users. To achieve that a platform was developed a platform with three VR games to stimulate cognitive and physical functions. The player uses an inertial sensor to interact with the games and all the data is stored for analysis. Sixteen participants tested this project, from three different ages groups referenced as young adults (18-35 years of age), middle-aged adults (36-55 years of age) and older adults (56+ years of age). The goal of these tests was to assess the acceptance of VR technology among the elderly people. An evaluation of the performance, was made from each player and the problems faced through the challenges. The results from this study were very promising as the older adults showed good indicators of acceptance. The performance results were not that good as expected, but were satisfactory for the first experience with this type of technology. The middle-aged adults showed great acceptance as well and with better results. While young adults aced in the performance, as expected, and provided good ideas for improving the project.

Keywords

Virtual Reality, Inertial Sensors, Elderly People, Cognition Stimulation, Physic Stimulation, Exergame, Serious Game, Older Adults, Elderly People

Resumo

O objetivo deste projeto é a promoção do envelhecimento ativo na população idosa, usando sensores para interagir com o ambiente de Realidade Virtual (RV). Desenvolvendo jogos em RV, esperamos aumentar o grau de imersão do utilizador no ambiente virtual. Desta forma, pretendemos tirar vantagem deste ambiente controlado, para explorar uma solução mais eficaz para combater a degeneração cognitiva e física da população idosa, enquanto lhes oferecemos novas experiências através das novas tecnologias. Com este sistema pretende-se extrair métricas que ajudem a avaliar o desempenho cognitivo, assim como o físico. Este projeto está dividido, essencialmente, em três partes: investigação, desenvolvimento da solução proposta, e por fim, os testes ao sistema com utilizadores. Para atingir este objetivo foi desenvolvida uma aplicação com três jogos em RV para estimular as funções cognitivas e físicas dos utilizadores. O utilizador recorre a um sensor inercial para fazer a interação com o mundo virtual e todos os dados gerados nessas sessões são armazenados, para depois serem avaliados. Os testes decorreram com dezasseis participantes, de três faixas etárias diferentes: os jovens adultos (18-35 anos), os adultos de meia-idade (36-55 anos) e os adultos mais velhos (56+ anos). Estes testes tiveram como objetivo a avaliação da aceitação deste tipo de tecnologias entre a população idosa. Foi avaliado o desempenho de cada jogador e os problemas enfrentados para ultrapassar os desafios. Os resultados foram bastante satisfatórios, isto porque, houve bons indicadores da aceitação desta tecnologia por parte da população mais idosa. Apesar de os resultados do desempenho nos jogos ficarem aquém das expectativas, foram satisfatórios para uma primeira interação com este tipo de tecnologia. Os adultos de meia-idade apresentaram um bom desempenho nos jogos, assim como uma boa aceitação desta tecnologia. No que toca aos novos adultos, tiveram um desempenho excelente em cada jogo, como já era de esperar, e foram bastante críticos ao projeto, apresentando boas ideias para melhorar o mesmo no futuro.

Palavras-Chave

Realidade Virtual, Sensores Inerciais, Envelhecimento Activo, Estimulação Cognitiva, Estimulação Física, População Idosa

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List of Acronyms

AAR Android Archive

API Application Programming Interface

BLE Bluetooth Low Energy

DB Data Base

EG Exergames

FPS Frames per Second

GVR Google VR

IMU Inertial Measurement Unit

JAR Java Archive

JNI Android Java Native Interface

MAC Media Access Control

OS Operating System

SDK Software Development Kit

SG Serious Games

UI User Interface

UX User Experience

VR Virtual Reality

65+ older people

1

Introduction

We live in an age where average life expectancy, in 2017, of an European adult, is 75 and 81 years old for male and female, respectively. For the same year the average life expectancy Worldwide for a male and female adult hover around 70 and 74, respectively [1]. In 2010, 8% of the world population were aged 65 or older, close to 524 million people. This number is expected to raise to 1.5 billions people by 2050, which represents about 16% of the world's wide population [2]. Today the number of older people (65+) slightly exceeds the number of children with less than 5 years old. With the growing of elderly population, arises the need to provide active aging tools and activities.

In 2017, the number of smartphone users reached 2.32 billions and it is expected to increase to 2.87 billions, in 2020 [3]. On developed countries, the general population has access to this kind of technology and as we move towards a more informed society, people from all ages engage with new technologies even in older segments of the population.The elderly people are, surprisingly, open to experiment and use new of technologies [4].

Novel technologies are emerging to support and improve the fields in active aging such as rehabilitation, cognitive stimulation, physical stimulation and health-care assistance [4–6]. There are several approaches to these fields, in particularly, for gaming stimulation: smartphone and tablet-based games [4], 3D games/simulations and Virtual Reality (VR) environments with or without interactive sensors.

VR technology allows testing the user's physical and cognitive functions under a controlled virtual world. It has been used to improve recovery of upper limbs functions, with positive results on adults with disabilities caused by strokes [7]. Immersing the user into a virtual environment that simulates different tasks, could have a higher therapeutic impact than repetitive movements [5].

Although promising technology for active aging, VR faces some problems like: excess of wires and cables of the headsets, difficulties to interact with the headset and to adapt to physical controllers. These problems are the major obstacle to adoption of this technology by elderly people. Studies refer that with some improvement to the used VR platforms and equipment it is expected more engagement from elderly people. [6]

1.1 Motivation

With the increasing of computing capabilities on mobile devices and acceptance of elderly people to new technologies, new opportunities are open to develop new tools for active aging. Smartphone devices are becoming more accessible and affordable, so it is an opportunity to extend other approaches and applications, with this type of technology, for even more people. The creation of a platform to improve cognitive functioning and physical activity through a virtual environment, with mobile based VR and sensory data extraction is an opportunity to be explored.

VR is an easy way to take the user into a completely different reality, where they can explore new activities in a controlled environment. Therefore, emerges a new opportunity to explore its effects on active aging and corroborate other implementations like smartphone or tablet-based solutions [4].

Our motivation is to bring portability and a wire free, easy and affordable solution for health-care centers or to users house, enabling its daily use and consequently the improvement of the cognitive and physical functions with VR technology.

1.2 Objectives

Considering the above information, the focus of this project is to provide a wireless, portable and affordable solution of a platform with different VR games to stimulate cognitive and physical functions using data from inertial sensors to make the interaction. The main goal of this platform is to extract data from patients to be used and analyzed by health-care professionals, providing new tools to improve the quality and therefore, the results of their work. In the end, this project aims to provide health-care professionals, with a tool for data extraction of specific parameters to further analyze of the impact of this type of stimulation in the long term. To achieve that main goal, this project has the following objectives:

- Development of VR games for cognitive stimulation;
- Development of VR games focused on physical stimulation, using inertial sensor data interaction;
- Extraction of relevant metrics about the interaction and performance of the user for further analysis;
- Development of a leader-board panel to engage the use of this platform;
- Movement recognition for the different types of user interaction.

1.3 Main Contributions

The main contributions of this project were:

- The creation of three VR games for cognitive and physical stimulation;
- The development of a fully functional prototype, tested for older adults in a nursing home;

- Dataset from the sensor data of each player and session;
- Generation of performance data of each player;
- Development of an Android Plugin for Unity communication with Bluetooth Low Energy (BLE) sensors;
- Assessing the acceptance of the elderly people to VR technologies.

1.4 Outline

This thesis is structured in six chapters. Chapter 2 approaches the state of the art of this field and what has had been doing to cognitive stimulation and also physical stimulation. Explored the use of VR technologies in healthcare and the main results that have been accomplished. Chapter 3 will have as its subject the technologies used in this project, the software and sensor used for the development of the platform. Chapter 4 describes the system development process, explaining the development of the three games and the interaction with the sensors. Chapter 5 will explore the tests to the platform such as the acceptance of the technology and user feedback to the overall project. The discussion of the results takes place in Chapter 6, with the description of the results obtained with this project. In the last chapter, Chapter 7, discuss the conclusions from this project and future work suggestions that allow the improvement of the platform.

2

State-of-the-Art of Virtual Reality Games in Active Aging

Technology has always played a fundamental role in the way it has shaped humanity. Over the years technology takes over our lives and it is present in our factories, transportations, homes, hospitals, basically everywhere. Therefore, it is becoming increasingly mandatory for people of all generations, to have more interactions with new technologies.

Health care is one of many fields that had huge impact from the new technologies and it plays a big role in extending life expectancy. In the next sections, will be explored some applications using these new technologies such as for rehabilitation and occupational therapy, assessing pros and cons of each technology and what might be the future of active aging.

2.1 Serious Games and Cognitive Stimulation

With aging, the Human mind suffers natural deterioration and with that, some of our cognitive functions such as memory and attention are affected. For a long time, cognitive stimulation is used to fight cognitive decline, and as an update to pen and paper methods, new methods and technologies emerge to outbreak this field. One of these methods is Serious Games (SG) that Michael and Chen defined as: "A serious game is a game in which education (in its various forms) is the primary goal, rather than entertainment" (Michael and Chen 2006, p.17) [8]. These games, whose purpose goes beyond simple entertainment, aim to educate and stimulate with physical, social and cognitive activities. The use of serious games in healthcare is increasing and they are used in fields like rehabilitation and occupational therapy. [7, 9, 10]

Past research shows that tablet-based games are well received by elderly people as they were able to easily interact with the platform and complete the tasks proposed to them. Tasks which target stimulation of memory and attention, that usually suffer most decline with age. This was important to validate the acceptance from elderly people to new technologies, although, a strong validation with a wider user audience was needed. [4]

More recent research validates the use of serious games to prevent cognitive degeneration. A web-based platform of serious games shows promising results on the improvement of memory and attention cognitive functions. This type of stimulation through serious games is very popular with elderly people where they are able to exercise the brain while having fun. [11, 12]

These solutions address research for 2-D types of serious games as a tool for improving cognitive functions. Tablet and web-based solutions are very common in this field, however with the emerge of new technologies, new methods are developed and bring new tools to target this problem. In the next section, will be explored a new technology and how it can be useful in this type of problems.

2.2 Virtual Reality on Healthcare

New technologies are increasingly present in healthcare with new ways to approach problems and thereby new solutions and methods. Virtual Reality (VR) is one of these new technologies that are being adopted to solve some problems in healthcare, especially in physical and cognitive stimulation. VR is a good tool for healthcare considering that the virtual world can be designed for a specific purpose or target group. The user can be immersed in a controlled environment to accomplish given tasks and challenges, and with that train, stimulate different areas in physical or cognitive aspects.

Past research shows that VR can be used to manage users pain and distress due to medical procedures. Users were submitted to a VR immersion experience and with that the levels of pain reduced. This type of application could have a huge impact on clinical recovery and helping reducing pain pills intake by patients. Participants from these studies expressed interest in using this type of VR technology during future medical procedures for reducing the pain. [13, 14]

Some studies point out that the use of VR-based stimulation shows improvements in memory and attention functions, that support the effectiveness of VR systems in these types of activities. VR technology is not used only in cognitive stimulation but also in physical stimulation such as rehabilitation using Exergames (EG). [5, 15, 16]

EG are defined by Kooiman and Sheehan as: "video games that require kinesthetic bodily movement" [17]. It is a type of a video game that requires physical activity to interact with the game. These games have been exploited by big players in the game industry like Microsoft with Kinect for Xbox, Nintendo with Nintendo Wii and Playstation with Move. Past research on this topic shows that EG can be use with effectiveness helping to improve cognitive functions, injury rehabilitation, health, fitness and balance [17, 18].

2.3 Interaction with Virtual Worlds

VR technology was proved as a useful tool in healthcare or just as entertainment. To achieve its purpose, the user needs to interact with the system and virtual worlds. Nowadays there are some solutions on the market that are used for some of the projects mentioned in the previous section. The user can interact with the virtual worlds in different ways from a simple button controller, through sensors attached to the body (e.g. Wiimote from Nintendo) or with movement recognition trough optical sensors (e.g. Kinect sensor from Microsoft). For research purposes, new controllers and new approaches are studied from new applications of Inertial Measurement Unit (IMU) sensors to, for example, haptic controllers such as gloves[1], omnidirectional treadmills like Virtuix Omni VR and sensored shoes [2].

Movement recognition is one of the main focus for Human-computer interaction in VR and today's technology tries new approaches for this type of interaction, as already mentioned. These solutions are very promising as they are ready for the market and available to the consumer. Past researches show new ways to interact with the user through a vibrotactile feedback piezo, a miniature actuator that can stimulate the human mechanoreceptors [19]. Another approach to mimic touch sensor was explored through a haptic revolver, that can simulate touch, texture, and shape by customized wheels for each environment, with great response and acceptance [20]. Touch feeling is very important for sensing, however it is the sensing force that determines the characteristics of the material such its stiffness, dimensions, and shapes. Recent study achieved promising results with a haptic controller that can give feedback trough movement actuators and provide the feeling of touching and grasping the virtual objects [21]. This kind of interaction is very important since touch, plays a big role in human response to stimulus from the real world, so it is very important to replicate this sensing to the virtual world.

2.4 Summary

This chapter quickly overviews the main solutions to interact with the virtual worlds and more deeply into the use of games and new technologies in cognitive and physical stimulation. Some of the studies presented in the previous sections are used to put into context the field and others provided useful information on VR acceptance, tips for the development of a good VR experience and some of the background and proved methods for cognitive and physical stimulation.

To this project, the main focus relies on the development of SG and EG for mobile VR headset, like Google Cardboard. This type of technology was not explored for this purpose, so it creates an opportunity to assess the viability for its use in cognitive and physical stimulation, as an effective, portable and low-cost solution.

[1] https://vrgluv.com/,https://haptx.com/
[2] http://www.virtuix.com/products/

3

Technologies

This chapter will explore the technologies and basic concepts necessary for the development of this project. First, it address the basic concepts of Virtual Reality (VR) as well as the used VR technology. The development software used is analyzed and the reasons for such selection explained. Also, we overview the sensors used to make the interaction with the developed system.

3.1 Virtual Reality and Google Cardboard

VR started to receive a lot of attention in the last years and with that new solutions emerged in the market. There are several companies that dominate this sector with distinct approaches that can be divided into three categories:

- Console and PC VR headsets that require a console or PC to run such as Oculus Rift[1], HTC Vive Pro[2] or Sony PlayStation VR[3];
- Standalone VR headsets that do not need a PC or a smartphone and they are seen as the best of two worlds, they are portable and do not rely on external hardware. Oculus Go[4] and Lenovo Mirage Solo[5] are some of the solutions on the market;
- Mobile VR headsets that are portable and that require a compatible smartphone. Samsung Gear VR[6], Google Daydream View[7] and Google Cardboard[8] are known headsets on the market.

For this project these were the main features to be considered while picking a headset:

- Portability;
- Cost;
- Development platform and support community.

After analyzing all the different options, the final decision rested on the Google Cardboard.

[1] https://www.oculus.com/rift/
[2] https://www.vive.com/us/product/vive-pro/
[3] https://www.playstation.com/pt-pt/explore/playstation-vr/
[4] https://www.oculus.com/go/
[5] https://www.lenovo.com/us/en/daydreamvr/
[6] https://www.samsung.com/global/galaxy/gear-vr/
[7] https://vr.google.com/daydream/smartphonevr/
[8] https://vr.google.com/cardboard/

Google Cardboard it is a simple VR headset that is affordable, customizable and available to everyone with a compatible smartphone [22]. It is a headset made only with cardboard, two lenses of 34mm and two magnets to serve as input, with the change in magnetic field on the smartphone magnetometer [23]. Because it is cheap and open source, this platform became a very popular technology. Many applications and new versions of the headset are made for the specific needs of the developer or user. Cardboard has a good community of developers and users that give precious tips and feedbacks. Google also provides a Software Development Kit (SDK) that makes possible the development of applications for all operating systems with different softwares [24].

3.2 Development Software

For the development software, two main solutions were considered: Unity Game Engine[9] and Unreal Engine[10]. A more detailed analysis is made in table 3.1 considering the needs for this project in particular.

Table 3.1: Comparison of Unity Game Engine with Unreal Engine for this specific project. (+) better, (-) worst or (=) equal, comparatively to the other option.

	Unity Game Engine	Unreal Engine
Price	Free License	Free License
Development Language	C#	C++
VR Support	=	=
VR Development	+	-
Prototyping Time	+	-
Cross-Platform	=	=
Community Support	+	-
Graphics Performance	-	+
Game Optimization	-	+
Learning Curve	+	-

Based on the analysis performed on table 3.1, the software chosen was the Unity Game Engine referenced as Unity.

Unity is in constant growth and is presenting good improvements in performance and render graphics capabilities. Unity is a great tool for cross-platform development as it provides support for almost every platform like Android, iOS, Windows Phone, Tizen, PC, Mac, Linux, PS4, Xbox One, PlayStation Mobile, PlayStation Vita, Wii U, tvOS, Android Tv, and Samsung Smart TV and also built-in support is available for the Oculus Rift, VR Playstation, Microsoft HoloLens, VR / Vive and augmented reality trough Vuforia. It is a

[9]https://unity3d.com/
[10]https://www.unrealengine.com/

versatile tool with a smooth learning curve and ideal for small projects, as it is free, has good support for VR and Cardboard, and a great community made it a simple choice. [25]

Unity required a good comprehension of C#, the language used to develop the proposed system.

3.3 Inertial Sensors

VR experiences require an interaction from the user with the virtual environment to a deeper immersion into the experience. To achieve that immersion developers turn to the sensors for gathering data from the real world and interact with the virtual world. Section 2.3 explored different approaches to this type of interaction. The device made by Fraunhofer Portugal[11] called IoTip, was the choice due to the scope of this project and the fact that this device is already used in some of the projects in Fraunhofer Portugal. This wearable device is a combination of Inertial Measurement Unit (IMU), geomagnetic and gas sensors with an integrated environmental unit that has a temperature, humidity and pressure sensors, commonly used in mobile applications such as wearables for fitness and well-being monitoring.

The following table shows the IMU sensors used for this application:

Table 3.2: Technical data for IMU device.

Parameter	Technical Data
Digital resolution	Accelerometer (A): 16 bit Gyroscope (G): 16 bit
Measurement ranges (programmable)	(A): ± 2 g, ± 4 g, ± 8 g, ± 16 g (G): ± 125°/s, ± 250°/s, ± 500°/s, ± 1000°/s, ± 2000°/s
Zero-g offset (typ., over life-time)	(A): ± 40mg (G): ± 10°/s
Bandwidths (programmable)	1600 Hz … 25/32 Hz

This device has 3-axis state-of-the-art accelerometer sensor and 3-axis gyroscope sensor. Table 3.2 shows important information for developing software that interacts with this device, extracted from the manufacturer website, but for confidentially purposes the sensors remain unknown.

Since the wearable is already developed and tested the firmware and hardware of this device does not receive any update or change from this project. Only high-level programming was made for handle the accelerometer data, via Bluetooth Low Energy (BLE), to be processed later on the Android Plugin, which will be explored in the next chapter.

[11] https://www.fraunhofer.pt/

3.4 Summary

Overall, this chapter explores the available options for VR platforms, software development tools and sensors. It addresses the main technological choices made for this project. This project relies on Google Cardboard platform, with its SDK, developed in Unity and C#, and with an IoTip device to add a new interaction, to the head motion provided by Google Cardboard, with the virtual environment. The next chapter explores with more detail the approaches to the development of the project, the problems faced and solutions implemented. The tools mentioned above will be more deeply examined through the development of the project and with problems that emerge.

4

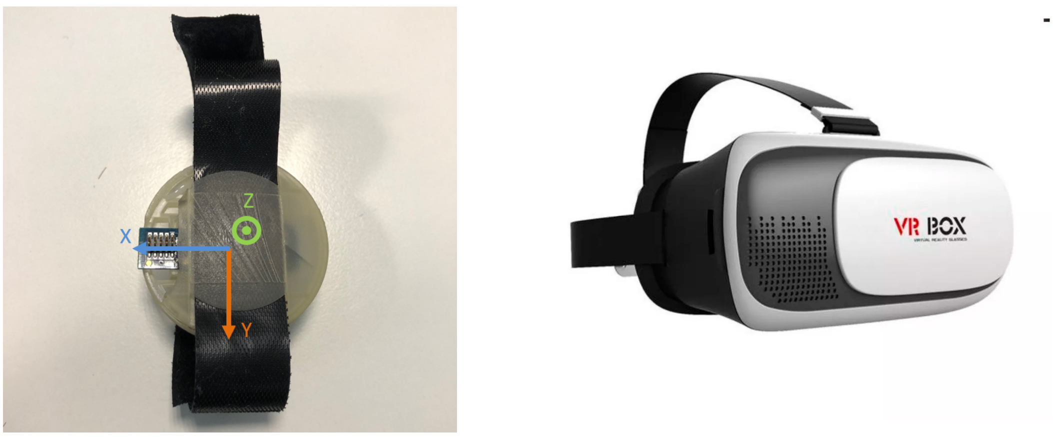
CogniStim Development

This chapter explores the development process of this project. It covers the hardware used for testing and developing the project. Then, in more detail, it addresses the process to make the three games and all the User Interface (UI) and data management. Then it exposes the development of the Android Plugin used to establish the communication between the Android and Unity environments to serve as a bridge for the data gathered by the external sensor. Finally, it presents a general overview of the system architecture.

4.1 Used Hardware

For testing the development of the project was used a Nexus 5 with the following specifications:

- CPU: Qualcomm MSM8974 Snapdragon 800 Quad-core 2.3 GHz Krait 400;
- GPU: Adreno 330;
- Memory: 16GB ROM and 2GB RAM;
- Resolution: 1080 x 1920 pixels, 16:9 ratio (445 ppi density);
- Size: 4.95 inches, 67.5 cm2 (70.8% screen-to-body ratio);
- Operating System: Android 5.0.



(a) (b)

Figure 4.1: Technologies used in this project. (a) IoTip accelerometer axes; (b) VR viewer based on Google Cardboard model.

IoTip device in figure 4.1 (a) and the viewer for the smartphone (b), enable the user to interact with the virtual world. The IoTip device was placed on the wrist of the user, for the maze and the memory card game with the X axes, pointing through the forearm. In the fruit picker game, the device was placed in the lateral side of the thigh, with the X axes pointing through the heap of the user. Figure 5.1 shows an example of a session playing these games and where the device was placed.

4.2 Game Development

This section explores the development of the games that make this platform. For a better understanding of the development process, it will be analyzed chronologically. As mentioned in section 3 the development language in Unity is C#. Before the final versions of these games, many tutorials were made to learn the Unity features and mechanisms as well as scripting in C# (as programming is called in Unity community). All the development was made in Unity for Android Operating System (OS) with Google Virtual Reality (VR) Unity Software Development Kit (SDK) v0.8.5.

All the games start with a 20 seconds countdown timer, as shown in figure 4.2 to give the user the time necessary to set up the headset.

Figure 4.2: The waiting scene that is shown before every game starts.

Figure 4.3 shows an overview to the system high level architecture.

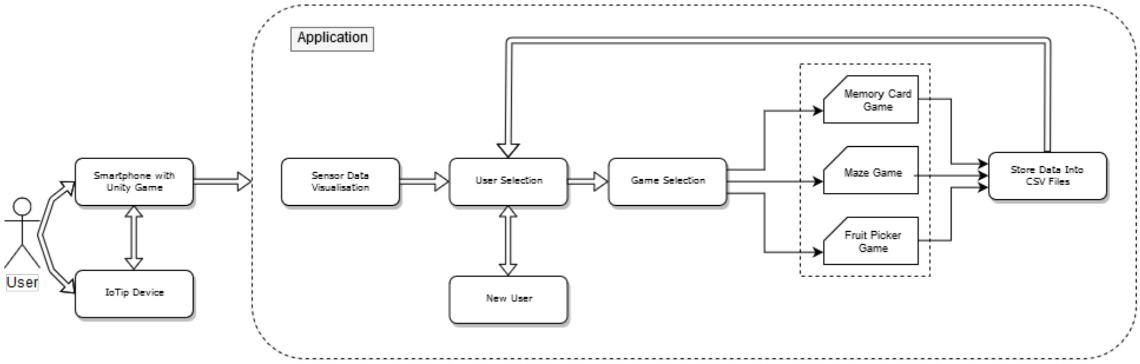


Figure 4.3: System high level architecture diagram, that shows the interaction with the system.

4.2.1 Memory Card Game

The first game developed was the well-known Memory Match or Pairs, where the player has to find the pair of the chosen card among other faced down cards. If the player fails to find the pair, both cards are flipped down to its initial position and if the player succeeds in finding the pair, both cards remain faces up. The winner has to find all pairs or matches for all cards laying on the table.

The motivation for choosing this game was explored and validated in a study mentioned in section 2.1 on the improvement of cognitive functions as attention and memory through this type of games.

Before VR

The development began with the idealization of the game in 3-D, a 4 by 4 card matrix was made, with different, colorful and funny images to engage the player with the game. To achieve that goal was developed an algorithm that generates the grid and shuffles the position of the cards in every session. With that set up the next step was to make the interaction with the cards, via touchscreen, and rotate the card when selected. Unity has a method to make it possible, working with a Raycast that casts a ray from the origin (player position) through the direction from the touchscreen input, as shown in figure 4.5. To check if two cards are a match, Unity has the capability to tag GameObjects (that are the fundamental object in Unity, in this case, a card is a GameObject), so it is possible to compare the two tags to check if it is a match. The back of each card was tagged as ”Back” and the face with the correspondent name of the image, so when raycast collide with a card it will be checked if this card is the only one faced up, if not check if is a match of the other card, otherwise the card maintains its state and the player has to choose another card to find the pair. Figure 4.4 shows the mechanism of the game. For rotating a card was made an animation to flip up or down the face of the card, that can be triggered from the script.

When the game is over, the time that took from the first click until the last pair finding is shown. In the background, was saved the number of misses until finding all the matches and the time to finish the game.

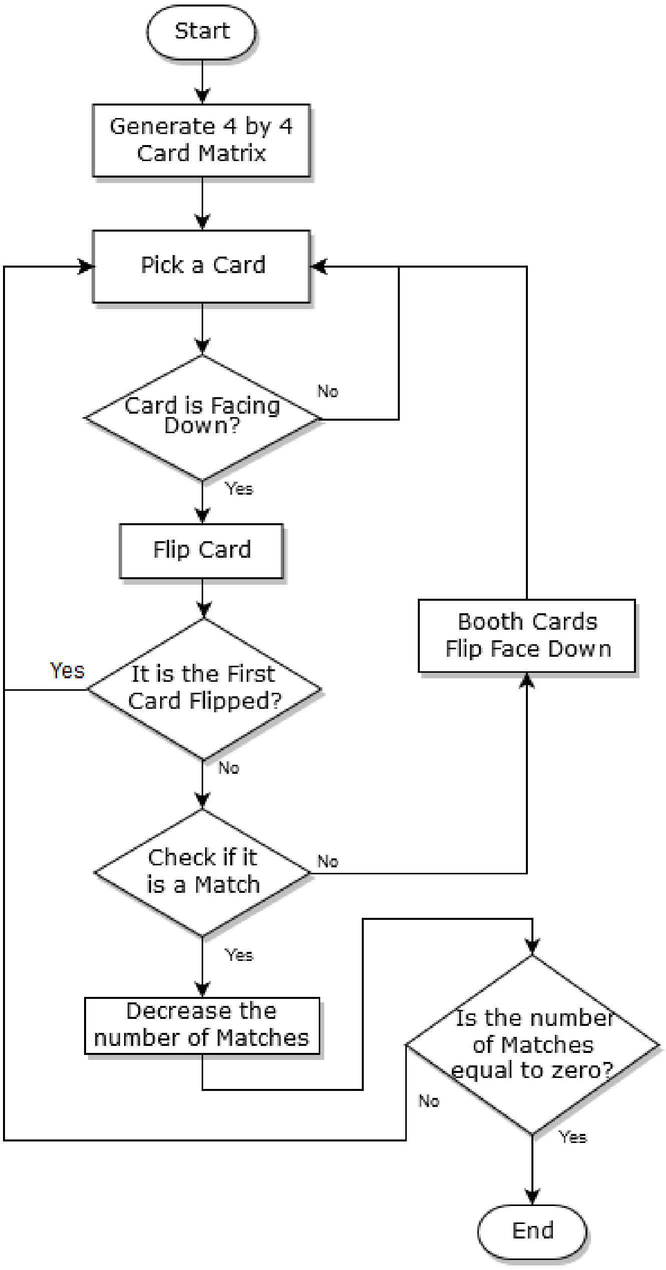
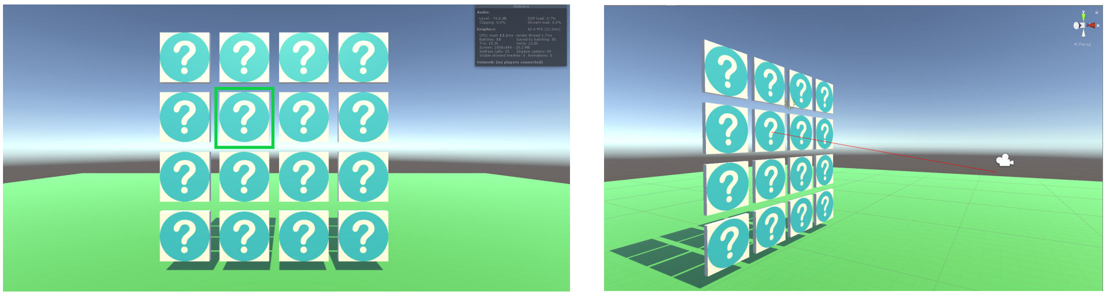


Figure 4.4: Flowchart of Memory Card Game mechanism.



(a) (b)

Figure 4.5: Simulation of a click to flip the card in a prototype of the Memory Card Game. (a) Click on the touchscreen represented by the green square; (b) Player position is represented by the camera and the red line represent the raycast generated with the target position from the click in (a).

After VR

A 3-D version of the game was made, however the main purpose of this project is to use VR technology and to do that, Google Cardboard SDK for Unity was used. With that, it is possible to create VR applications for smartphone using Unity functionalities.

With the Google VR (GVR) Unity SDK package imported into Unity project, some modifications were needed to maintain the functionalities from the previous version to VR. GVR uses a specific raycast from the *GvrPointerInputModule* and the code had to be changed to the physics raycast from Unity to the GVR raycast. After all functionalities were adapted for VR, the game was empty and unattractive. To solve this problem there was a need to create a virtual world more immersive than the previous version, so the main focus at this stage was to create an attractive and immersive User Experience (UX).

To engage with the player the game has to have details and interaction, especially in these type of games that have fewer dynamics. To tackle that a 3-D model of an island as shown in figure 4.6, was made, as well as the palm trees and the seagulls. All of these models were made with Blender[1], which is a free and open-source 3-D creation suite that supports the entirety of the 3-D pipeline as modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation.

[1]https://www.blender.org/

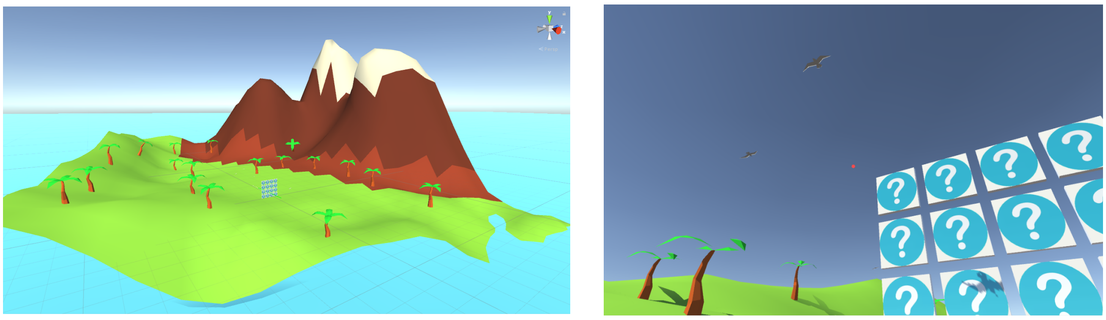


Figure 4.6: 3-D Model of the scenario for Memory Card Game.

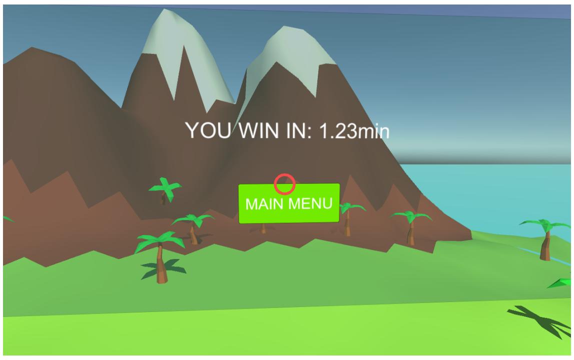


Figure 4.7: Winning Scene.

The choice for an island was due to the fact that transmits calm and stress release. The player is transported to a different reality of a desert island to play the game. This scenario is more complex and attractive than the previous version but lacks an important sense. Sound features like seagulls were implemented that were programmed to fly around and make their noise, and the sound of the sea in the background. These sounds are spatial sounds so that the user can ear a seagull behind the head and give a spatial awareness.

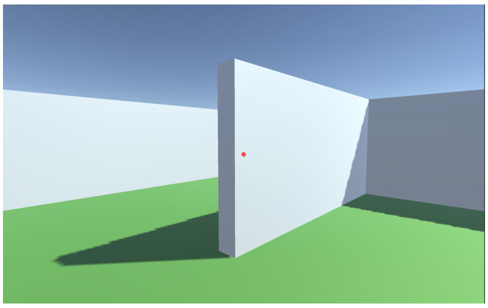
4.2.2 Maze

The second game being developed was the Maze, a VR labyrinth where the player must find the yellow ball to win. It is a simple labyrinth game that gains a new level of difficulty when played in VR mode. When developing this game the proportions were taken into account to give the feeling of an actual wall. The generation of the maze was made via a Unity maze generator available in the Unity asset store [2], and then simplified and adapted for the needs of this project. Every session has the same maze, goal and starting point, so each user has the same advantage as others. This is useful for a validation purpose from the user tests through an analysis result of the time that each user takes to finish the maze.

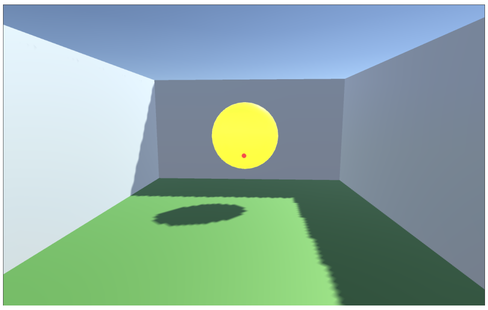
[2] https://assetstore.unity.com/packages/tools/modeling/maze-generator-38689

The development of this game was made in VR since the beginning and the speed of the player was tested to make it comfortable and avoid motion sickness during the session [26]. A click to walk method was implemented, in the sense that the user had to touch the screen to walk.

A session in this game starts with the waiting scene, where the player can try to find a path from the starting point through the goal in 20s. At the end of that 20s the player is transported into the maze and there begins the challenge to remember the path for achieving the goal. For winning the game, the player has to collect the yellow ball at the end in the shortest time. When the player catches the ball it is played a sound to congratulate the winner before changing the scene to the winning scene. This session can be seen in figure 4.8.



(a) Beginning of the Maze.



(b) End of the Maze.

(c) Waiting scene. Blue ball - starting point; Yellow ball - goal

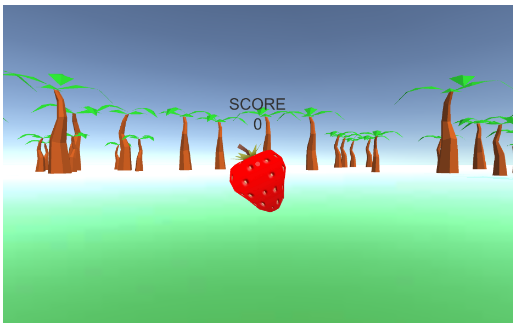
(d) Winning Scene.

Figure 4.8: Player view of the different stages of the game.

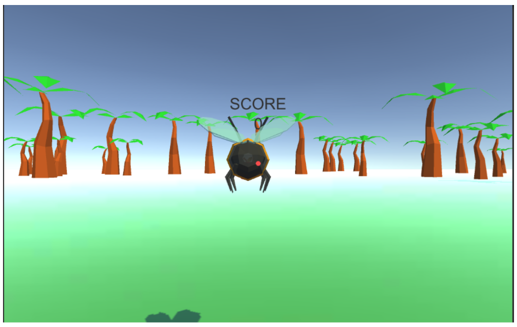
4.2.3 Fruit Picker

The last game developed for this project was a simple game that drives the player for physical activity through the game. It is a simple fruit picker game, where the player has to catch the maximum of fruits without being hit by the bees.

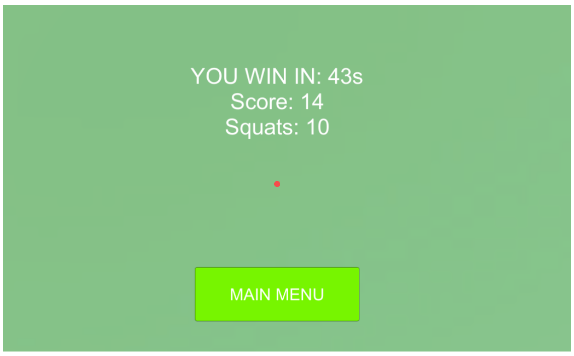
This game uses a free Unity package for the 3-D fruit models[3] and a bee model[4] from Poly by Google. With all the art imported a game mechanism was made and for this case, the player only has two options, upward position (to catch the fruits) or downwards position (to sneak from the bees), that was achieved moving the camera up and down to specific positions in the world. The fruit and the bees were generated randomly, with more probability for the bees to force the player to squat and with that achieve the main goal (by default 10 squats). When the player performs 10 squats the game stops and shows the stats in the winning scene. If the player cannot succeed a losing scene is shown with the same configuration for the stats but with losing information. Figure 4.9 shows a session of the Fruit Picker game.



(a) Player view with fruit.



(b) Player view with the bee.



(c) Winning scene.

Figure 4.9: Player view of the different stages of the game.

[3] https://assetstore.unity.com/packages/3d/props/food/low-poly-fruit-pickups-98135
[4] https://poly.google.com/view/6ktZgxSVVn1

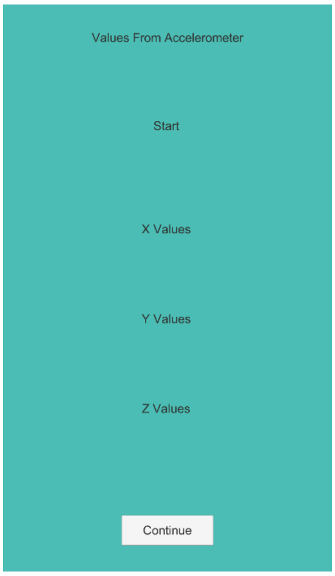
4.2.4 User Interface

The UI of this project was made in a simple way of maximizing the UX. The design is simple and functional. The UI is composed by 4 menu scenes:

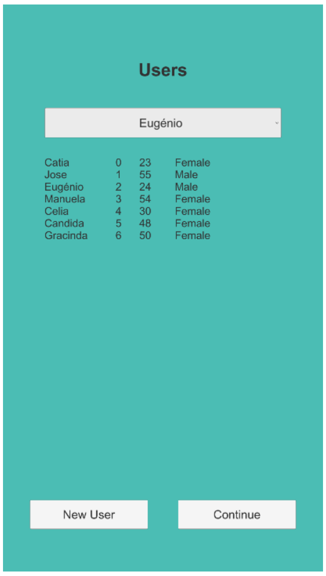
- Plugin Scene - it is responsible for managing the plugin and showing feedback from it, figure 4.10(a);
- User Manager Scene - lists the users, allows to create a new user or choose the user for the section, figure 4.10(b);
- New User Scene - form for the creation of a new user, figure 4.10(c);
- Game Selection Scene - allows the user to select what games to play, figure 4.10(d).

A Data Base (DB) to maintain a record of the users, user sessions and scores was needed, and for this purpose, CSV files provide the necessary solution. When the application runs for the first time there are no users, so the first thing that the player has to do is create a user. Among the creation of the user the application sets up a folder directory as shown in figure 4.11(a), adds the new user to the Users.csv file and creates a new folder for the user with the ID and the name. Each user has its own folder with 4 csv files, as shown in figure 4.11(b):

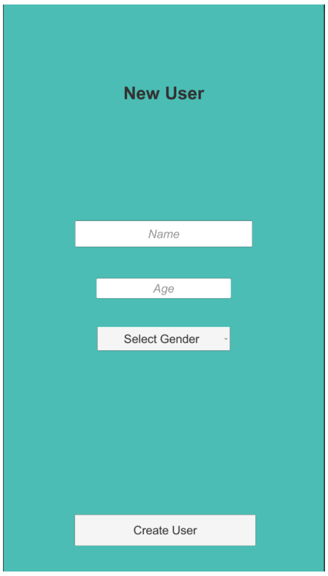
- CardGame.csv - stores the start session time, finish time, score and fail attempts from the sessions in the Memory Card Game;
- FruitPicker.csv - stores the start session time, finish time, score and number of squats made in the Fruit Picker Game;
- MazeGame.csv - stores the start session time and the time to finish the maze;
- Log.csv - logs all the data (time, X, Y, Z) received from the accelerometer in every game and session.



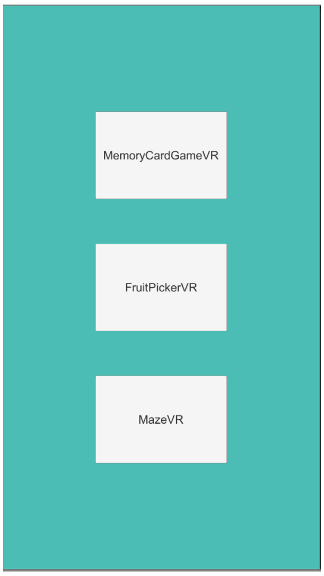
(a) Plugin scene, first scene.



(b) User manager scene, second scene.

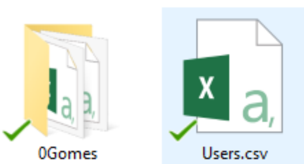


(c) New User form scene.

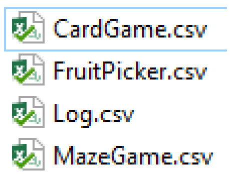


(d) Game selection scene.

Figure 4.10: Different stages of the game from UI point of view.



(a) Resources folder.



(b) User folder.

Figure 4.11: Directory hierarchy for each user.

4.3 Development of Android Plugin for Unity

Unity native does not support Bluetooth Low Energy (BLE) communications, therefore it is necessary a plugin to make that communication available. Every plugin on the Unity asset store is paid, so this is not an option and as the IoTip has its own Android library for managing the connection it would not work with these paid BLE plugins. Therefore, the solution was to make an Android Plugin for communicating with the Unity, it serves as a bridge between the sensor and the Unity project. Development based on Java and Android Studio was necessary in order to achieve this goal.

Google Developers website defines BLE as: ”Bluetooth Low Energy (BLE) is designed to provide significantly lower power consumption. This allows Android apps to communicate with BLE devices that have strict power requirements, such as proximity sensors, heart rate monitors, and fitness devices” [27]. BLE is commonly used in wearable devices due to its low consumption that enhances the battery autonomy. The IoTip device works with BLE to communicate with the central devices (e.g. computers or smartphones), so it is necessary to understand the basics of this type of communication to develop the plugin.

The IoTip device was an internal project from Fraunhofer Portugal. A sample application developed by the institution it can scan for IoTip devices, establish the connection, select the sensors that we want to receive data and then show a real-time chart from these values. Adapting and rewriting this sample application, provided by the institution to an Android Library, enable to successfully scan these type of devices and establish a connection. After the connection was successfully established the application starts to listen to the values from the sensor specified from the wearable device. This Android Library is fundamental to the communication between the sensor and the Unity project.

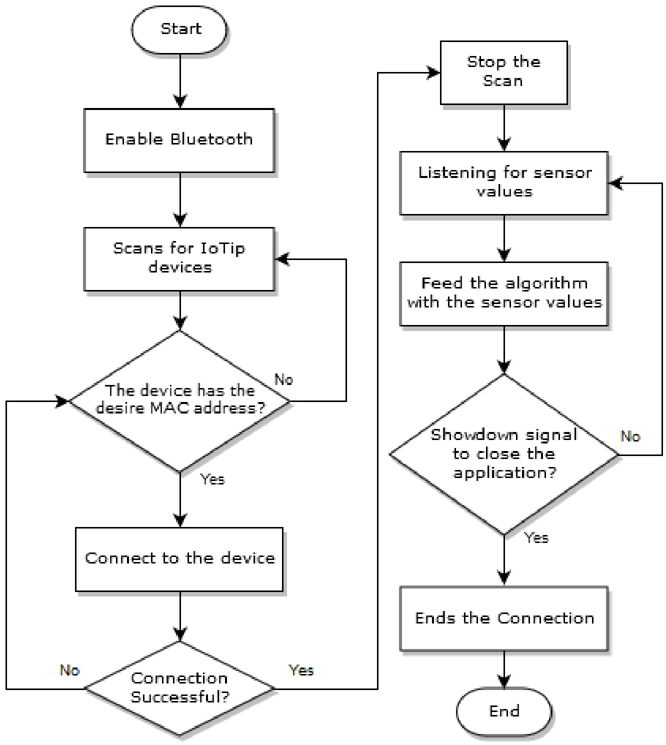


Figure 4.12: Flowchart of BLE Android Plugin for Unity.

The first thing to do was to start developing the Android Library and for now on called Plugin, to be able to establish the connection with IoTip device. As shown in figure 4.12 among the start of the application Bluetooth was enabled and it starts to scan for IoTip devices, it is possible to access the Media Access Control (MAC) address and compare with the given MAC address of the desire IoTip device. The Plugin makes the connection only if the desired device was found and if the connection was successfully established the scanning is stopped.

With the connection established and stable the Plugin starts listening to the sensor values and pass them to the algorithms to detect the desire interaction for each game. As only accelerometer data was used, the algorithms were fed with floats vector of X, Y and Z coordinates from the sensor. One of the functions return a floats vector with the coordinates, which is called by Unity to check if the connection is well established, show the values on the screen and then proceed the game to user selection.

With the Plugin finished, the next step was to test it using the Unity project. Unity supports Android third-party libraries such as Android Archive (AAR) plugin or Java Archive (JAR) plugin. To export the Plugin into a JAR file was used Android Studio, that generate an AAR file and then makes it possible to access the JAR file inside of it, this solution led to a different problem. Unity only supports one JAR file in the project and the Plugin has external dependencies from the the IoTip Manager Library. The use of a ”Gradle script that allows you to merge and embed dependencies in generated aar file” [28] allows to generate the final AAR with all the dependencies merged. So with that final file. The JAR file to use in the Unity could be extracted.

With the Plugin finished and the JAR file ready to use, it is time to go further on the Unity side of the project. To set up the JAR file into Unity project was created a specific directory for the Plugin file, as shown in figure 4.13, the file *classes* is the Plugin JAR file.

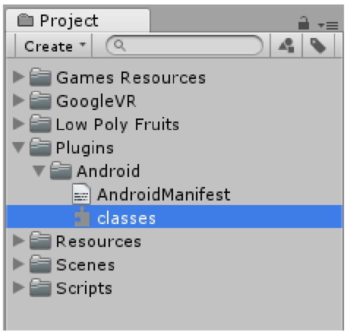


Figure 4.13: Directory of BLE Android Plugin in Unity project.

The Plugin has to be in that specific directory so Unity is able to import that file classes. With the file imported to Unity, it is possible to access the functions of the Plugin to establish the bridge between the Unity Project and the IoTip device. To do that Unity has an Application Programming Interface (API) class that wraps around the Android Java Native Interface (JNI). For accessing the functions on the Plugin Unity loads the android instance of the Plugin into the script using the *AndroidJavaClass* method. Storing that instance in a variable, using it along the code without the need of calling constantly this method to search for Plugin class. After getting the instance the Plugin methods could be called from Unity, using *Call* method of the *AndroidJavaClass*. That method needs to specify the type of data that is required and the name of the Plugin function, as an argument, that returns the type mentioned in the *Call* method. Unity receives data at approximately 60 Hz frequency, that corresponds to the 60 Frames per Second (FPS) that the games are played.

As the application was launched, an initial scene is showed with sensor values in real-time, in that way the user can see that the sensor is correctly connected and can proceed with the game.

Memory Card Game

For this game was developed a Plugin function called ”*changePositionWrist*” to detect the type of interaction used to flip the cards. The player has to rotate the wrist to be able to flip the card in the virtual world. So in this function, if the wrist rotates more than a specific Z value from the accelerometer, returns a boolean to indicate the rotation. That value was tested and adjusted to the target end users, and the user has to rotate the wrist more than 135º, approximately. The figure 4.14 shows a 180º rotation of the right hand and it is easily seen that Z values show a big change, so if the value of Z goes under -5 the Plugin function returns a boolean that will be read by Unity. If the boolean is true and a card is selected, it flips the card, if not nothing changes.

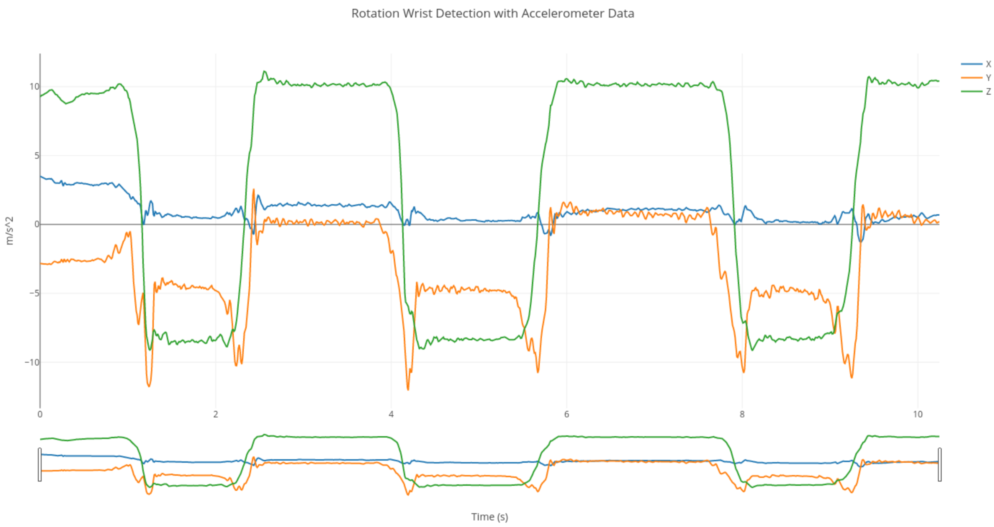


Figure 4.14: Time series chart of wrist rotation data from accelerometer.

Maze Game

The same strategy described before was used in the game as well but with a different interaction. The player has to elevate the arm to be able to walk. In that way, the player does not need to stand up while playing which could be an issue among the elderly people, so with that approach the player can play the game sited. As shown in figure 4.15, it is possible to see that the X values represent the wrist elevation. So if the X value was negative it can be assumed that the wrist was elevated. Unity can access this information by calling the Plugin function "*elevateWrist*" that returns a boolean, true if the wrist is elevated and false if it is not.

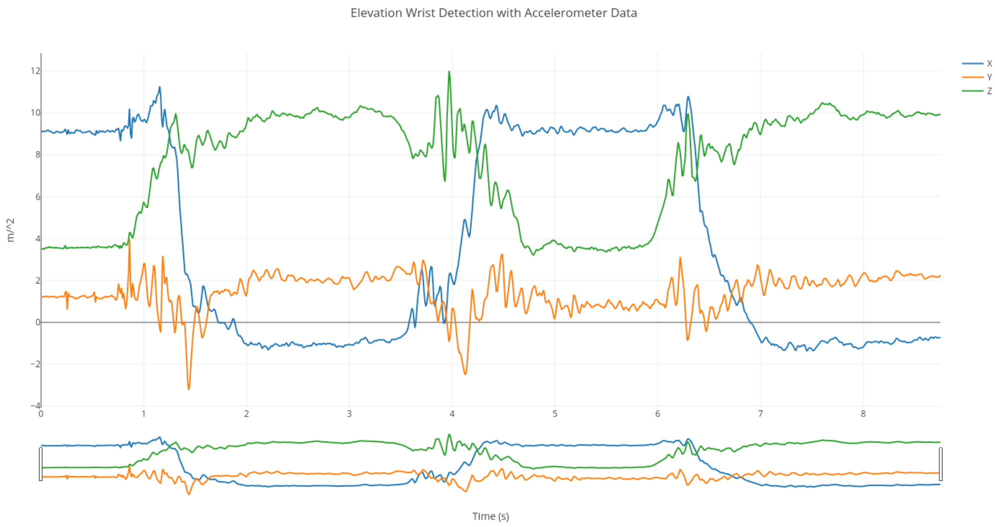


Figure 4.15: Time series chart of wrist elevation data from accelerometer.

Fruit Picker Game

To interact with this game the user has to stand up to collect the fruit and squat or sit down to sneak from the bees. To achieve that the IoTip device was placed on the side of the thigh, where can be easily detect the squat movement. As shown in the figure 4.16 when the Y values go less than -7, the player is sited, when they are greater than -7 the player is in standing position. The players had to squat until they reached the seated position on a chair, due to the lack of mobility of the target users. When a squat position is detected a boolean has returned and in the Unity, the player position can be changed.

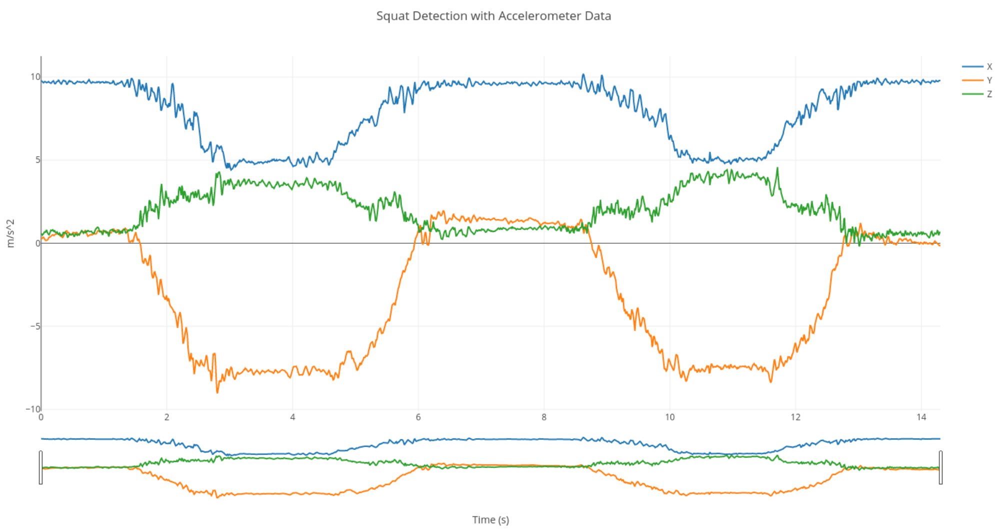


Figure 4.16: Time series chart of squat detection data from accelerometer.

4.4 Summary

This chapter, explores all the stages of the development of the project. Work with three different software (Blender for modeling, Android Studio to develop the Plugin and Unity to wrap up all the components and develop the application) required the learning of two new languages (C# and Java). That learning was crucial to work with the specific wearable device to detect different types of movements and interactions with the system.

The user has two types of interactions, via touchscreen for the scenes before the games where the user can choose the player profile, create a new user and choose the game are 2-D scenes that not require the IoTip device. The sensor is only use to interact with the games, not to navigate between menus. After the User selected the game and wears the headset, the interaction is made via IoTip device, as shown in figure 4.3, the user can interact directly with the smartphone or with the IoTip device that then communicates with the smartphone and respectively with the application. After the game was finished the data generated in that session is saved in the user folder and then the user is redirected to the user manager to begin a new session.

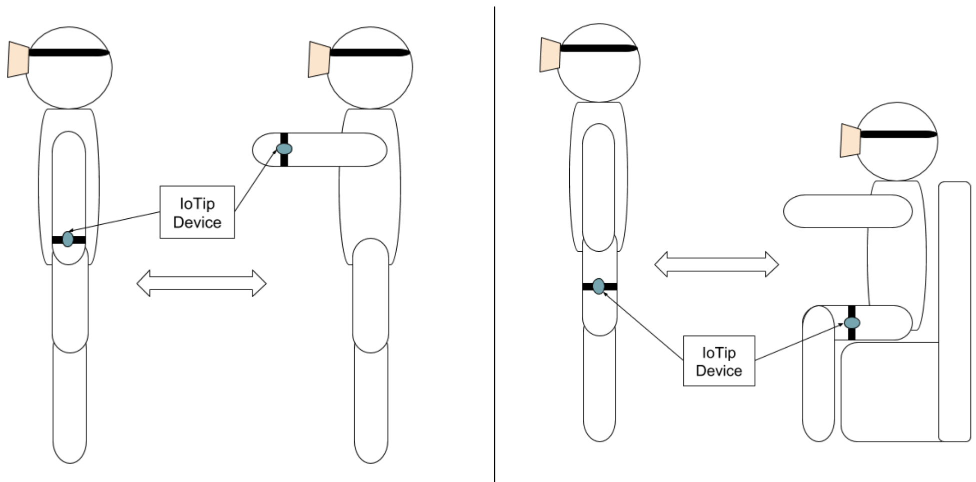
5

CogniStim Tests

This chapter presents the methodology for testing the game with real users, some considerations are taken into account for extracting the best data and result possible. It explores the user group statistics and users feedback of the experience.

5.1 Methodology

One of the objectives of this project was to test with real people, namely older adults, the acceptance of this audience to these types of technologies. Although the target group was older adults, more tests were implemented with two different ages group, which will be explored with more detail in this section. The participants will be designated as young adults (18-35 years of age), middle-aged adults (36-55 years of age) and older adults (56+ years of age). Figure 5.1 shows, an example, of the interaction with the user.



(a) Example of Maze game interaction. (b) Example of Fruit Picker game interaction.

Figure 5.1: Schematic from the methodology used for testing the Maze and Fruit Picker games interaction.

5.1.1 Older Adults

The evaluation of the acceptance of the project was conducted in a daycare center with seven participants (all females) with ages between 67-89 years an average of 81 years, that were requested to play the different games. In these test sessions was made an evaluation of the capacity to finish the game, the acceptance of the type of interaction in each game and the comfort with the headset and Virtual Reality (VR) technology.

At the beginning of the tests, was decided that the Maze game would not be tested and this decision will be discussed in the next chapter. So the participants tested the Memory Card and Fruit Picker games, with some adaptations in the interaction regarding the Fruit Picker. As a physical game, the participants must perform a squat to sneak the bees and the participants showed difficulties in locomotion, so the squat movement was adapted to the elevation of the wrist, to facilitate the interaction. With that change, all the participants were able to test the system. For the Memory Card game a brief introduction on how to play and interact with the game was made. After the players put the headset, oral tips were given to guide them through the game and the same with the Fruit Picker. The two games were played in a seated position.

5.1.2 Middle-aged Adults

Five middle-aged adults participants one (20%) male and four (80%) females with ages between 47 and 55 years and an average age of 52 years, tested the games. At the end, they answered an online form with some questions about the experience.

For Memory Card game the participants remained seated throughout the session and were asked to hold the hand with the sensor face down on the thigh. In that position the movement was more controlled and gives the feeling of flipping the card in the real world.

For the Fruit Picker, a chair was used and the players had to sit down and standing up to complete a squat. With that, the players can safely play the game without the fear of falling or not be able to reach the position of a full squat.

Finally, the maze was played in a standing up position so the player had more freedom of movement to navigate throughout the maze. In all these games, contrarily to the older adults, instructions were only given at the beginning of each game.

5.1.3 Young Adults

Finally for young adults, this group was composed by four males (100%) all 23 years old and followed the same protocol as for the middle-aged adults with a quick overview of each game and how to play it, as well as the form in the end.

5.2 Users Feedback

Table 5.1 shows one feedback given by a participant of the older adults group, that the brightness was too intense and this problem was immediately solved by decreasing the brightness of the smartphone.

A detected problem was with the back face of the card. Some participants (older adults group) do not understand that it represented a back of the card and took a while to understand that to be able to select the cards, the player had to look into the desired card with the red circle cursor and perform the selection movement. For the Fruit Picker game, one of the participants (older adults group) showed the same problem with the head movement controller as in Memory Card game and the other did not understand the game, at first sight. Participants react positively to the sounds of the Memory card game and to the seagulls in the sky, on the Memory Card game. Also, they react well to the fact that they had to catch fruit and sneak from the bees, on the Fruit Picker.

Every participant did not feel any discomfort and liked the experience. This was notorious by observation and through questions throughout and at the end of the game. This represents a qualitative analysis through oral feedback.

After middle-aged adults finish the tests, all the participants answered the forms and the data extracted is shown in figures 5.2 and 5.3. One of the problems that this group faced was the background noise of where the test was made, that disturbed the concentration level in the Memory Card and Maze games. Another problem occurs with one of the cards animations, that turns over immediately even when when the first card was selected. Overall, the comments about the experience were very positive with a great reception to this type of technology. Therefore, it is of great interest to continue this work, making more games to motivate people to engage with this type of projects. The Maze game was very commented due to its type of immersiveness.

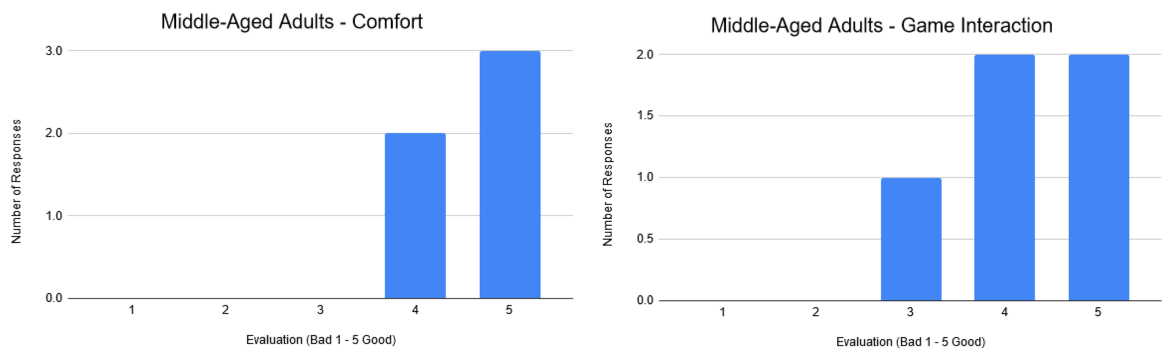


Figure 5.2: Middle-Aged Adults chart for comfort and game interaction evaluation.

From the young adults, a more critic opinion was made and some suggestions are shown bellow:

- Increase the type of movements to interact with the games;
- Increase the speed of the fruits in the Fruit Picker game;
- Creation of in-game tips to the user on how to interact with the game or a mini-tutorial before beginning the game;
- Improvement of the User Interface (UI);
- Put sounds in every game, which makes them more attractive;

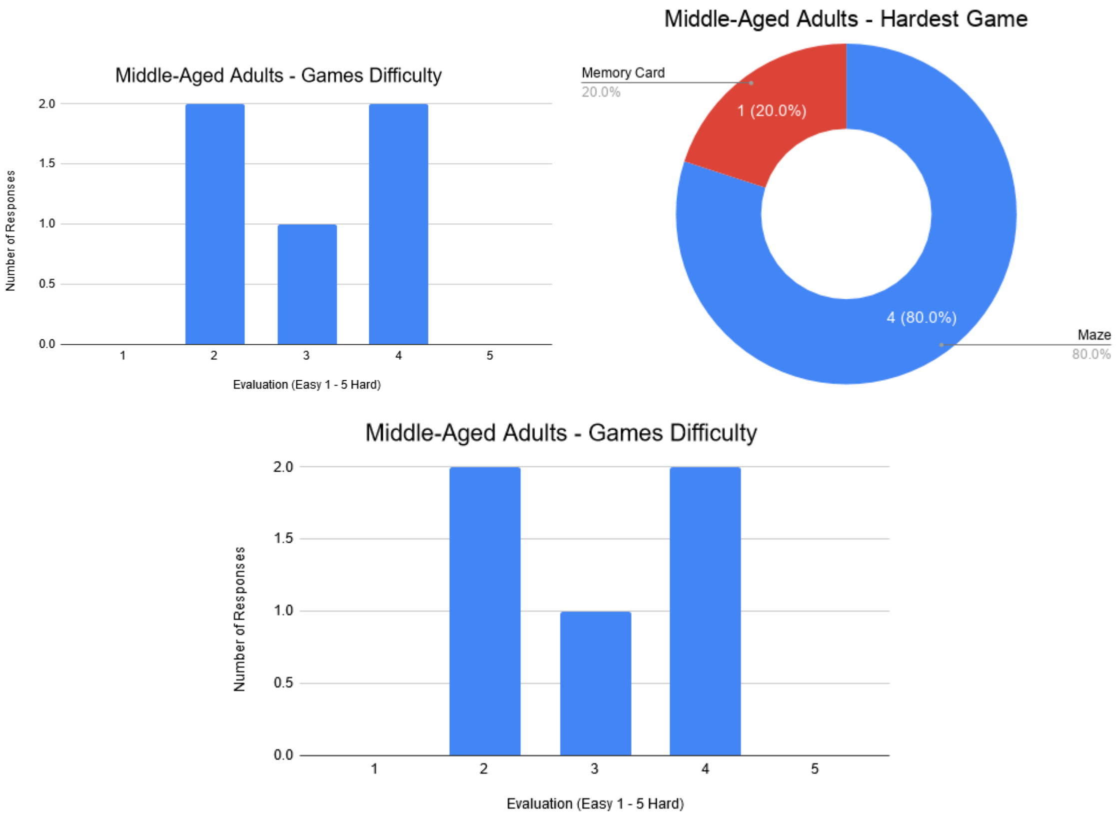


Figure 5.3: Middle-Aged Adults chart for easiest and hardest games, and the general difficulty of it.

- Existence of a feedback of the movement in the virtual world that shows the player, if the wrist was well rotated or in the correct position, and that informs the user that it is stuck in a maze wall.

After a critical analysis of the points to improve, they identify the positive aspects from this experience:

- Intuitive and visually pleasing to the eyes;
- Simplicity of the interaction in each game;
- Good response time between human interaction and the system response;
- A good immersive experience of the Maze game, that seems that the player was even there;
- Liked the Fruit Picker game as it is a funny experience.

The figures 5.4 and 5.5 shows the responses from the young adults to the experience.

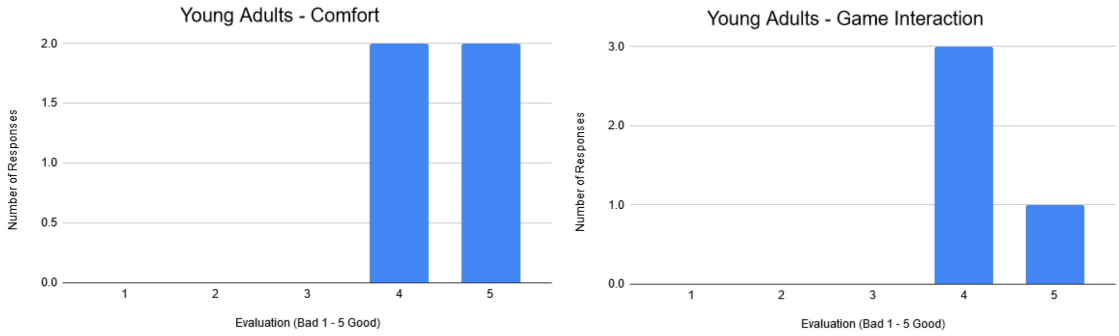


Figure 5.4: Young Adults chart for comfort and game interaction evaluation.

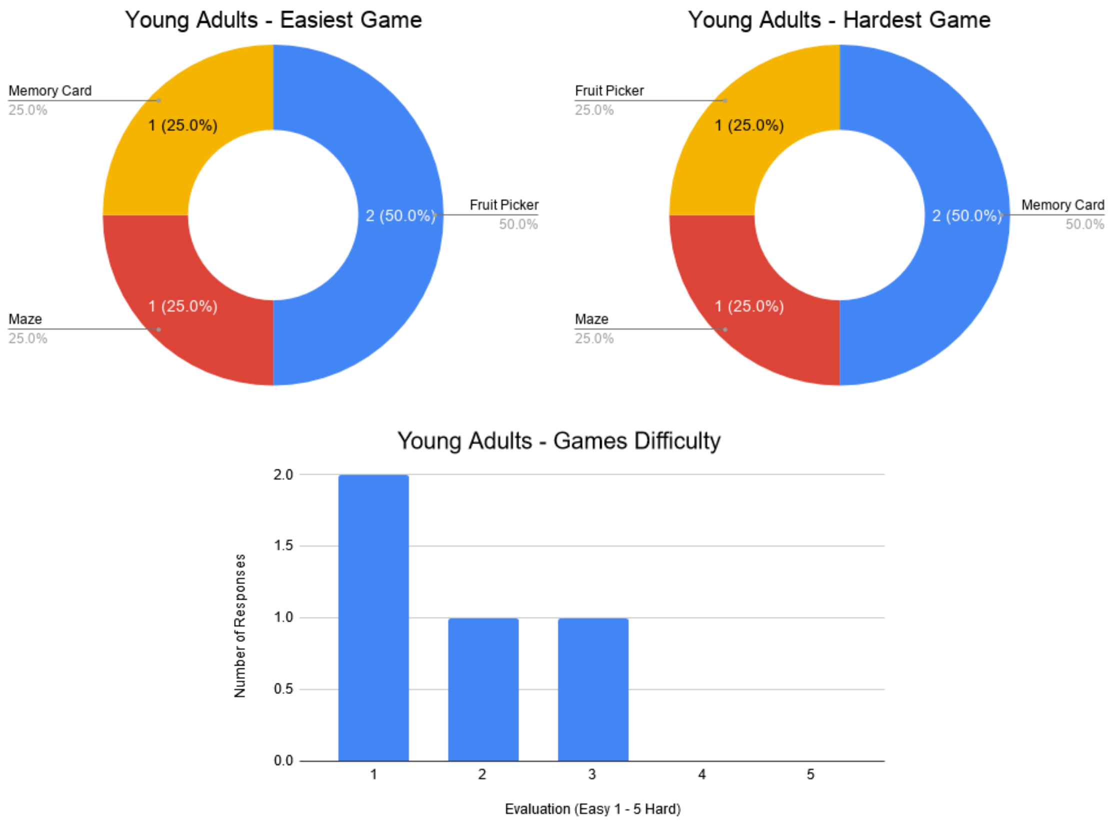


Figure 5.5: Young Adults chart for easiest and hardest games, and the general difficulty of it.

5.3 Results

The data generated in each game to a CSV file are presented in table 5.2. These results in represent only two ages group (young and middle-aged adults) because the older adults did not finish all the games and the data was insufficient to show as these groups. Nevertheless, a very important qualitative data was extracted from the older adults tests and it is presented in table 5.1.

Table 5.1: Assessment of the performance and acceptance of the games from older adults.

	Memory Card Game	Fruit Picker Game
Participants	6 (100%)	7 (100%)
Finished the Game	Found 2 pairs - 2/6 (33.3%) Found 1 pair - 1/6 (16.7%) Found 0 pairs - 3/6 (50.0%)	Yes - 5/7 (71.4%) No - 2/7 (28.6%)
Discomfort	None - 5/6 (83.3%) Brightness - 1/6 (16.7%)	None - 6/7 (85.7%) Brightness - 1/7 (14.3%)
Problems with the interaction	None - 3/6 (50.0%) Difficulties to understand that had to point the head through the cards to be able to select the card - 3/6 (50.0%)	None - 5/7 (71.4%) Took some time to understand the game - 2/7 (28.6)

Table 5.2: Results of the middle-aged adults and young adults group sessions.

		Young Adults Group	Middle-Aged Adults Group
Maze Game	Finishers	4/4 (100%)	3/5 (60%)
	Mean Time (s)	74.40	181.06
Memory Card Game	Finishers	4/4 (100%)	5/5 (100%)
	Mean Time (s)	88.19	263.99
	Mean Fail Attempts	15.0	24.2
Fruit Picker Game	Finishers	4/4 (100%)	5/5 (100%)
	Mean Score	12.5	7.6
	Mean Squats	10.25	11.4
	Mean Time (s)	117.24	66.01

The finishers row shows the number of participants that successfully finish the game, the mean time is the mean time that the players took to finish the game, the mean fail attempts is the mean of the attempts of the player until finding all the pairs and the mean squats and scores mean exactly what they said.

Figure 5.6: One of the participants from the daycare center tests.

5.4 Summary

This chapter, explored the methodology used for testing the prototype project in a real scenario. It assessed the acceptance of the three ages group to VR technology and if they successfully finish the games. The principal focus of these tests was to assess the comfort levels with this technology, the interaction with the games, the difficulties faced through these experience and the acceptance of this technology.

At the end of the chapter, the participants feedback was presented organized by the three ages group to facilitate the results analysis and comparisons between them. The information from the online forms that the participants answered was presented in a chart form and the qualitative information, such as comments, explored in positive feedback and improvement feedback.

6

Results Discussion

This chapter presents an analysis of the previous chapter results from the evaluation system tests. It discusses the decisions made for testing the project and the feedback of the participants.

6.1 Methodology and Results

As presented in chapter 5, the methodology for testing this project was very simple and guided by the author. The participants only interact with the games and not with the User Interface (UI) scenes, because the development of this project was done from the point of view of the caregivers from the daycare homes. So with that in mind, the participants only have to play the games and all the data introduction, selection of the user and the game was designed to be done by the caregivers. That is important to take in mind because this project was a prototype to assess the acceptance of the elderly people to this type of technology, so what is important for this stage is assess the interaction of the user with the Virtual Reality (VR) games and not with the UI developed. Nevertheless, to solve this problem it can be used the in-game tutorials which could help the user to navigate between the menus and help with the interaction with the game. So the player could be more autonomous and reduce the need of the help of the caregivers.

For the older adults as mentioned in the methods section of the previous chapter, the Maze game was not tested for two reasons: the participants had mobility problems, that made it not advisable to keep them standing up for some time, and for the level of abstraction needed to complete this challenge. After beginning the tests, was observed that the participants had some difficulties to understand the easiest games, with no successfully test in the Memory Card game. For the reasons mentioned before, the Maze game was excluded from the tests on older adults, due to its complexity. Also, an important fact to consider is that some of the participants they are not completely autonomous, as reported by the daycare home director.

Although the focus group of this project was the older adults, the assessment of different age groups was an interesting point to explore. The groups were divided as shown in the previous chapter, by ages.

The second most important group results are from the middle-aged adults, they will be the next older adults and the acceptance for this VR technology and the success on these challenges, could be critical to the use of these techniques in the future for preventing the cognitive and physical deterioration.

The young adults group was added to the tests performed with the purpose of comparing the three ages group difficulties, their problems and acceptance of this technology. They also provided a lot of information to improve the games and its interaction with the user.

The table 5.2 shows the mean results from the testing session. An analysis showed a visible performance decrease from young adults to middle-aged adults, and the same with the middle-aged to the older adults. This difference was expected because the younger generations are more comfortable to these new technologies as they have grown with them.

It is normal that the results in older adults are not that good. As a first experience with this type of technology, their interaction was not the most natural and perfect, as expected. This generation did not have contact with mobile phones probably more than half of their lives, so there is a learning curve and adaptation to be made.

This work only considered the first experience with the game. So all participants results follow a standard and can then be analyzed with more criteria. When the user plays the game more than once their performance increases. After the first experience, conditioning as inexperience and ignorance of the type of games and interaction, disappears and the player can be more focused on the game and in its performance.

The table 6.1 shows two sessions of a middle-aged adult playing the memory card game. It is easy to observe that was a huge difference in time, less than 176.56s, and a decrease of the fail attempts. Although there are only two tries, it is a good indicator that over time people become more familiar with these technologies and games, and therefore, improve their performance.

Table 6.1: Results of a middle-aged adult playing the memory card game twice.

Session Time (hh:mm:ss)	Time to Finish (s)	Fail Attempts
23:06:31	381.89	32
23:11:13	205.33	21

Through observation, some older adults had a slow improvement in the adaptation even on the first time playing. After some time, the player needed fewer instructions and the interaction with the game became more fluid and natural. This leads to believe that with more sessions the participants could improve their results.

6.2 Participants Feedback Analysis

The participants provided some feedback to improve the games and experience. The young adults mentioned some key points, one of them was the use of sound in every game. This is a very valid idea that is well received by the older adults, as the memory card game had a lot of interaction and comments about the sea and seagulls sounds, so in fact this is something that engages the player with the game.

Young adults suggested an increase in the speed of the fruits in the Fruit Picker game, which could be a bad idea when elderly people are involved. Each fruit or bee was distanced between a time interval of six seconds, as the time to the player sit down or stand up. This time was proved as an adequate interval to give the user to take the action and in one case in particular, during the tests, the player could not sneak from the bee in time. With that in mind and relying on the fact that this game was adapted to play elevating the wrist, with the older adults, gives an idea of the time needed for this group to take the action. It is a valid suggestion when the target end group is a younger generation, but the times of reaction decrease with aging and these were taken into account.

The creation of in-game tips or mini-tutorials for the player understand how to interact with the game, was a good feedback that could improve a lot the interaction with the game at the beginning. It is something to consider for the final product a better UI, although in this stage of validation of the technology with a prototype that was not a priority to have.

Another suggestion was the creation of a feedback of the movement in the virtual world, and that is a very good idea. That could improve the experience of the games with some visual feedback or even with sound.

6.3 Summary

This chapter discusses the methodology followed for testing the games and the results that were analyzed. The main decisions and approaches to the tests, performed with the older adults, that were those who received more adaptations than had been planned. It also discusses the keys points for a successful experience and how it can be improved, and assessed the results obtained by the different groups. Finally, analyze the participants feedback for improving the games and experience, taken into account and commented by the author and justified some of the suggestions that could not be an improvement since the target public of these project are the older adults.

7

Conclusion

The main goal for this project was to develop a series of Virtual Reality (VR) games for physical and cognitive stimulation among the elderly people. Also to provide a tool for the caregivers, with information about the users progress and solutions for stimulating the brain and also the body. The goal was achieved with a functional prototype that had a good indicator of acceptance among the elderly people and other ages groups, like the young adults and middle-aged adults.

To achieve the main goal of the project a physical stimulation component was necessary and to do that was used inertial sensors to interact with the virtual world. For the sensor to be able to communicate with the game an Android Plugin was developed, that acts as a bridge from the sensor data and the Unity project. This was one of the main challenges of this project due to its lack of documentation and for the specific needs of the sensor used in this project. In the end, all problems were solved and the sensor communicates with the games successfully.

The games developed in this project proved to be useful and its effectiveness on preventing the cognitive and physical deterioration could only be assessed with regular tests for a longer period of time. Although the results from the tests were promising to achieve that.

VR technology was well received by all the ages group and none of them suffered from discomfort, that was one of the main concerns of this project. The participants engage with the games and had good results from their performances in the first trial. This is very positive and could indicate a promising use of these type of technologies on a regular basis for the elderly people and also the middle-aged adults, that can benefit from its use.

From a personal point of view, was very gratifying to work in this project, knowing that I could be helping other people, particularly the older ones, with the use of technology. Design the games for this type of age group was challenging, because it requires a different level of abstraction and to think differently on certain aspects that we take as guaranteed and other generation do not. I had to learn two different languages and work with three different software, and was a great opportunity to learn new things and see all the stages in the creation of a product.

7.1 Future Work

For future work these are some of the ideas and suggestions that were notice for improvement of this project:

- Diversify the test groups and increase the period of time with regular use of the platform, to extract more information about its effectiveness;

- Improve the User Interface (UI);
- Use sounds in every game, that was proved that engage the player;
- Introduce the movement feedback in the game, something that indicates the player the type of movement that is being made;
- Improve and explore new types of interactions using inertial sensor;
- As all the sensor data was stored in a file, that could be studied for trying to detect the amplitude of the movements. This could be a good indicator for detecting the physical activity improvement;
- Develop more games.

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