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A Controlled Virtual Reality Exposure Therapy Application

Dissertação no âmbito do Mestrado Integrado em Engenharia Eletrotécnica e de Computadores orientada pelo Professor Doutor Paulo Jorge Carvalho Menezes e apresentada ao Departamento de Engenharia Eletrotécnica e de Computadores da Faculdade de Ciências e Tecnologia da Universidade de Coimbra.

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A Controlled Virtual Reality Exposure Therapy Application

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Never memorize something that you can look up.

Albert Einstein

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Abstract

Exposure therapy (ET) is often used as a therapeutic process to treat a psychological disorder. Usually, this type of therapy is challenging to apply traditionally as the therapist must expose the patient safely to the cause of the disorder. ET can be safer by merging this concept with virtual reality (VR) and developing a VR therapist-controlled exposure therapy application (VRET).

This work consists of two applications to serve as tools for the therapist. The first is a clinic-only VR application to monitor the patients' reactions and physiological signals and allows the therapist to observe and interact with the patient's VR environment. The objective is to determine the patient's level of anxiety when confronted by the phobic element. This clinic-only application runs at the therapist's computer, and the patient will use Oculus Rift as the VR headset.

Since ET is a gradual and repetitive process, the second application created consists of a follow-up application. The patient confronts the phobic element at home at different anxiety intensity levels prescribed by the therapist in the previous consultation. This application can be used either during the therapeutic sessions or, as mainly designed for, at the patient's home. It will act as homework for the therapy sessions and allow the patient to practice at home. It consists of a serious game with entertaining components and a strong focus on teaching and training. This at-home VR application is available for Android and only needs a smartphone VR headset.

Resumo

A terapia de exposição (TE) é uma técnica de terapia comportamental frequentemente utilizada como tratamento de distúrbios psicológicos. No entanto, aplicar este tratamento tradicionalmente é complicado, pois o terapeuta tem de expor o paciente à causa do distúrbio de forma controlada. A TE pode ser mais segura fundindo este conceito com a realidade virtual (RV) e desenvolvendo uma aplicação de terapia de exposição controlada pelo terapeuta de RV.

Este trabalho consiste no desenvolvimento de duas aplicações para o terapeuta. A primeira é uma aplicação de RV exclusiva para uso clínico, serve para monitorar as reações e sinais fisiológicos dos pacientes e permite que o terapeuta observe e interaja com o ambiente de RV do paciente. O objetivo é determinar o nível de ansiedade do paciente diante do elemento fóbico. O terapeuta tem acesso à aplicação através do computador e o paciente através do headset de RV Oculus Rift.

Como o TE é um processo gradual e repetitivo, a segunda aplicação desenvolvida consiste numa aplicação de acompanhamento. O paciente confronta o elemento fóbico em casa em diferentes níveis de intensidade de ansiedade prescritos pelo terapeuta na consulta anterior. Esta aplicação pode ser utilizada durante as sessões terapêuticas ou, como principalmente uso, na casa do paciente. Funcionará como lição de casa para as sessões de terapia e permitirá que o paciente pratique sozinho. Consiste num jogo sério com componentes de entretenimento e um forte foco no ensino e treinamento. A aplicação está disponível para Android e precisa apenas de um capacete de RV para smartphone como acessório.

List of Figures

List of Tables

Contents

1

Introduction

The evolution of Virtual Reality-based technologies allows the application of new medical procedures that otherwise were complicated or downright impossible. Mental health is one of the areas where this is applied and where this work will focus.

Every year, anxiety disorders affect nearly 18.1% of adults and are still registered as one of the most commons mental disorders [1]. Anxiety can become a daily obstacle for those who suffer from it, as it introduces significant distress, with consequent impairment in their quality of life. It is also a problem for society since as untreated mental health disorders become more severe, social and economic costs will increase [2].

1.1 Study Relevance

Numerous authors have shown that virtual reality experiences are similar to real ones as virtual reality scenarios can induce some sensations almost identical to the ones felt in the real world [3] [4]. Behavioural therapies use of virtual reality increased, particularly therapies that expose the patient to anxiety triggers. Learning, habituation, desensitization, or others will help manage anxiety in daily life. Long term studies show the effectiveness of virtual reality to exposure therapy in the treatment of phobias [5].

Exposure therapy has proved its efficacy in the last 20 years [2] [6]. Nevertheless, the traditional application of this treatment does not please everyone. Most patients fear the in-real-life confront with the phobic element and, depending on the disorder, the therapist may have a problem maintaining the sessions private and consequently violating the patient-client boundaries [7]. Therapists also avoid live exposure due to the time-

consuming sessions and the work around it, for instance, catching and keeping an animal in the clinic for later reuse [8]. When compared to traditional exposure therapy, virtual reality counterparts tends to be accepted by both parties and seen as more ethical and helpful [2]. They are also considered safer, and in most cases, as effective as traditional exposure [6]. The fact that the needed elements are not physically in the medical office and exposure therapy is still an option is a tremendous advantage of virtual reality exposure therapy [7].

Two notable disadvantages of virtual reality systems have been their high price and cybersickness [9] [10] [11]. However, the development of this technology in recent years led to a cost reduction and increased quality, making these issues continually less significant. With the release in 2016 of new and more inexpensive virtual reality headsets, clinical trials find high levels of user satisfaction [6], leading to increased use of this technology in the mental health area.

It is commonly known that virtual reality and exposure therapy are helpful with anxiety disorders such as zoophobia, acrophobia, social anxiety and others [12]. A phobia is a type of anxiety disorder, an intense, irrational fear when facing a particular situation, activity, or object [13]. However, psychologists who specialize in other conditions like eating disorders, attention deficit hyperactivity disorder (ADHD) and obsessive-compulsive disorder (OCD) also believe virtual reality exposure therapy can be an alternative treatment with success [14].

Two steps characterize the obsessive-compulsive disorder. First, recurrent, unwanted, and seemingly bizarre thoughts, impulses, or doubts evoke affective distress. Second, repetitive behavioural or mental rituals are performed to reduce this distress [15].

OCD is difficult to diagnose because a large variety of symptoms happen in the patient private domain and are often unacknowledged [16]. So, in this case, virtual reality can provoke symptoms such as anxiety in patients. This disorder is challenging to diagnose because the patients must recognize most of their symptoms, as most happen in their private domain. It can lead to misdiagnoses or extremely long diagnoses.

Since this disorder is a multidimensional condition [17], virtual reality exposure ther-

apy can also help in some of the obsessions such as having doubts, difficulty making decisions or worrying about things out of order whichever the concept of order is to that individual. An OCD compulsion may be represented by repeatedly switching the lights and appliances, or closing/opening doors [18]. So, it is feasible to create a virtual reality environment that allows the patient to do some tasks while the therapist observes. Because the patient is alone in the virtual reality domain is more likely to have a manifestation of the disorder. However, some symptoms are not visually, so by having a healthy group of people performing the same tasks as an OCD patient in a virtual reality environment, the OCD patient' physiological signals can be compared to the outcomes of the healthy control [19]. So, virtual reality exposure therapy can also help reduce the diagnoses time and the probability of misdiagnosis.

Another treatment that virtual reality exposure therapy can help with is exposure therapy for attention deficit hyperactivity disorder. It is a childhood-onset neurodevelopmental disorder characterized by age-inappropriate inattention and hyperactivity/impulsivity symptoms. It affects around 5–10% of children and has a significant negative impact on mental health, family functioning, and educational attainment [20] [21]. Virtual reality exposure therapy can help in symptoms such as starting tasks but having difficulty finishing them, problems in maintaining attention when performing tasks, and difficulty waiting for the right turn [22].

Nowadays, the main question is no longer if virtual reality exposure therapy is indeed as effective as *in-vivo* exposure therapy, but how to engage the patient to keep working on himself and not giving up for lack of interest.

The concept of computer games has been emerging as a powerful new economic, cultural, and educational force [2]. Serious games, unlike traditional computer games, are alternative educational or psycho-therapeutic tools that go beyond mere entertainment [23] and are an effective medium for creating a non-threatening and engaging learning environment [24].

It has been proven that serious games can change behaviour [2] and reduce disorder-related symptoms [25]. Actively engages the player and promotes change within a safe virtual environment [23], eliminating both the privacy issue and the out-of-control elements

that worried the therapists. Since it has an entertaining form, the ethical conflict of provoking fear in the patients is also toned down and is more acceptable between professionals. These games place their goal outside themselves. According to the self-determination theory, two types of motivation may influence the retention of a person in one activity - extrinsic motivation and intrinsic motivation [23]. From a gaming perspective, extrinsic motivation leads to material rewards or cheering messages for other players. For instance, when the player receives fictional coins to purchase bonuses or elements in the game. In contrast, intrinsic motivation is based on personal interest. The final reward is related to each individual [26]. Serious games thrive on intrinsic motivation since the player must have personal goals to succeed. The different levels of the serious games are achieved with the acquisition of skills or therapeutic progress [2]. If the players have a clear purpose and the goals and levels of the game are clearly defined, then the game is well accepted, and the engagement is enhanced [24].

The use of serious games and gamification principles to promote treatment for mental illness had high levels of feasibility and acceptability among both users and providers [24]. The current problem is no longer the effectiveness of virtual reality and the application of exposure therapy but the user experience itself that can lead to more positive or negative results [27].

To have a good user experience, the game must give a good sense of presence. The sense of presence depends on the person's mental state, so the virtual reality environment tries to get the person to reach that state of immersion through certain and coherent stimuli. Having a virtual task to focus on improves the sense of immersion and therefore improves the sense of presence by distracting the user from real-world distractions [28]. More levels of depth can achieve a more significant immersion in the virtual reality world [29]. For instance, a virtual reality task that reaches other stimuli other than vision allows the user to deeper immerse in a fictional environment [30]. Moreover, the simple existence of physical laws such as gravity also has its impact [30][29]. The sense of presence in a virtual reality environment can make the difference between learning by watching (for example, a 2D video) and learning by doing without the consequences (for example, for a medical surgery) [31].

1.2 Main Objective

This work aims to propose a VR-based application that can be used in a therapeutic context and thus facilitate the therapist's work and help the patient reach a level of well-being by overcoming constraining anxiety and phobias. To this end, a serious game is proposed that allows the user to have fun while learning how to manage their anxiety in the presence of whatever triggers it. The serious game presents different anxiety intensity levels, keeping the therapist in control of the exposure. It will aim at anxiety disorders and others such as obsessive-compulsive disorder and attention deficit hyperactivity disorder, creating the potential for the therapist to personalize it to the patient's needs.

1.3 Related Work

The application of virtual reality can follow quite different approaches. Some aim to develop an application for smartphones to be used at home without a therapist's presence or consultation. These applications can sometimes be a serious game or a selection of virtual reality scenarios that the user needs to explore. In this case, the progress achieved is measured by the user or by the application itself. However, this can worsen the situation by exposing the user to levels of disturbing elements that he/she is not prepared to face, thus incubating the fear even more.

The problem perceived with the current home-use application is that it does not engage the user to come home after a day of work to use it. It is a big problem with exposure therapy, as it requires constant exposure to the anxiety source to overcome the problem eventually. Other commonly used approaches consist of applying virtual reality in-clinic sessions with the constant presence of the therapist that walks through all the stages with the patient and maintains complete control of the exposure level throughout the session.

Some examples of startups using virtual reality to treat various mental conditions that require the constant presence of the therapist or a professional are:

- Oxford VR [32] - developed cognitive virtual reality therapies for psychosis and fear of heights.

- Psious [33] - developed a platform for therapists that provides VR experiences that adapt to a patient's biofeedback in real-time. The therapist can see what the patient sees in the virtual reality environment in real-time while receiving data on the patient's level of distress so the simulation can be adjusted accordingly.
- Cognitive Leap [34]- developed assessment tools and therapies for children with attention deficit hyperactivity disorder (ADHD).
- Rendever [35]- developed VR tools for the cognitive stimulation, socialization, and therapy of adults living in elderly care facilities.

Some examples of startups using virtual reality to treat various mental conditions at home without a therapist constant control:

- Limbix [36] - developed a virtual reality system for healthcare institutions that treat fears, addiction, depression and teaches mindfulness and meditation.
- MindCotine [37] - developed an exposure therapy that helps people quit smoking.
- AppliedVR [38] - developed virtual reality therapies that treat the pain and anxiety associated with physical illnesses.
- oVRcome [39] - developed an exposure therapy with virtual reality to overcome phobias and social anxiety in the privacy of the patient's home.

The clinic application of this work is similar to the Psious virtual reality application. However, the developed application also consists of a base for the smartphone application.

The smartphone application is different from the applications exemplified above as it consists of a serious game and not a set of tasks or environments in which the therapist monitors and controls the anxiety intensity without being present.

1.4 Contributions

The work developed consists of a clinic application and a smartphone application.

The clinic application is meant to be used only with the therapist presence and consists of the therapist analyzing the patients' reactions to the virtual reality representation of the

phobic source.

The smartphone application is developed to be used by the patients at home after a clinic session. This application is a serious game that focuses on helping the patient learn how to manage their anxiety in the comfort of his home but safe as the therapist chooses the exposure level. Because it has a game format, the patient is more easily engaged in playing than a simple repetitive simulation allowing constant and gradual safe exposure.

As an addition, a short paper about the smartphone application, added in the appendix, was written and accepted in the GRAPP 2022 event.

1.5 Document Overview

This dissertation is organized as follows:

- **Chapter 1** describes the relevance of this work, its main objective and related works.
- **Chapter 2** explains key basic concepts needed to understand this work.
- **Chapter 3** presents the clinic application.
- **Chapter 4** presents the smartphone application.
- **Chapter 5** discusses the results obtained from the smartphone application.
- **Chapter 6** concludes the dissertation and indicates follow-up work, considered relevant in the future.

2

Background

This chapter aims to provide the reader with basic knowledge about the key aspects of this work.

2.1 The Concept of Exposure Therapy

Exposure therapy is a psychological treatment developed to help people confront their fears. When people are fearful of something, they tend to avoid the feared objects, activities, or situations. Although this avoidance might help reduce feelings of fear in the short term, it can worsen the fear over the long term. In such situations, a psychologist might recommend a program of exposure therapy to help break the pattern of avoidance and fear. Exposure to the feared objects, activities, or situations in a safe environment helps reduce fear and decrease avoidance.

Exposure therapy has been scientifically demonstrated to be helpful for a range of problems, including phobias, social anxiety disorder, obsessive-compulsive disorder, post-traumatic stress disorder and generalized anxiety disorder.

There are several variations of exposure therapy. The psychologist can help determine which strategy is best for each patient. These include:

- In-vivo exposure: Directly facing a feared object, situation, or activity in real life.
- Imaginal exposure: Vividly imagining the feared object, situation, or activity.
- Virtual reality exposure: Virtual reality technology is a safer and more practical alternative to in-vivo exposure.

- Interoceptive exposure: Gradually bringing on harmless physical sensations, yet feared.

2.2 Unity overview

Unity is a development environment used to create 2D, 3D, AR and VR applications, which can be deployed to the web, game consoles, mobile devices and personal computers. It can be described by two basic concepts:

- Scenes: each scene contains its environment, obstacles and decorations, which, in turn, are collections of game objects, essentially allowing the simulation organisation in pieces. Using scripts, a new scene can be loaded. The game objects within the scenes have various components like having a rigid body or a sprite that dictate their behaviour, such as gravity or appearance, respectively.
- Scripts: Unity allows the user to create runtime and design-time scripts using C#, with an object-oriented type of programming, using an implementation of the standard Mono runtime. A script can be applied to a game object as a component to control and monitor certain aspects.

Another essential part of Unity is the assets. From the Unity website, [40]: ”A Unity asset is an item that you can use in your game or project. An asset may come from a file created outside of Unity, such as a 3D model, an audio file, an image, or any other type that Unity supports. Some asset types can also be created within Unity, such as an Animator Controller, an Audio Mixer or a Render Texture.” Without assets, the development of a project would need a lot more time. This project uses version 2020.3.6f1 of Unity.

2.3 Equipment used

2.3.1 Oculus Rift

Oculus Rift (Fig. 2.1) is a virtual reality device for video games developed and manufactured by Oculus virtual reality. It is a head-mounted display type visual system with

integrated headphones, an external positioning sensor, remote control and cables for PC connection.

It integrates three gyroscopes that allow it to monitor the orientation of the user's head and a pair of headphones that can be collected if the user does not want to use them but are advised to use to simulate audio 3D.

Figure 2.1: Oculus Rift

2.3.2 Virtual Reality Headset for smartphones

Smartphone virtual reality headsets (Fig. 2.2) make use of smartphones to provide a virtual reality experience. When using a virtual reality app, the smartphone's display is split in two, and an image is duplicated on both sides of the screen. The screen will be right in front of the user's eyes, with a set of lenses that create a sense of depth.

Figure 2.2: Examples of virtual reality headsets for smartphones

3

Clinic Application

The clinic application was the first step made towards the goal. This application is the initial step for the therapist to know what level of exposure the patient should be submitted. The therapist can analyse all the angles they wish to see and if the patient has good progress by analysing his/her reactions and physiological signals.

3.1 Requirements specification

The requirements for the clinic application are:

- to be used in a clinic environment: the therapist needs to analyze in real-time the patient reactions
- to be anxiety-related disorders versatile: having a flexible application will benefit more people.
- to be controlled by the therapist: the application offers the security of being supervised by a professional.
- the therapist to be able to observe the patient reactions and movements: to help obtain a better diagnosis.

3.2 System Overview

The clinic application is the level zero of the smartphone application where the therapist can interact with the virtual reality environment where the patient is, the in-real time

physiological signals and observe his/her movements and perspective. So, this application highly focuses on its two perspectives: the patient virtual reality environment and the back office of the therapist (Fig 3.1).

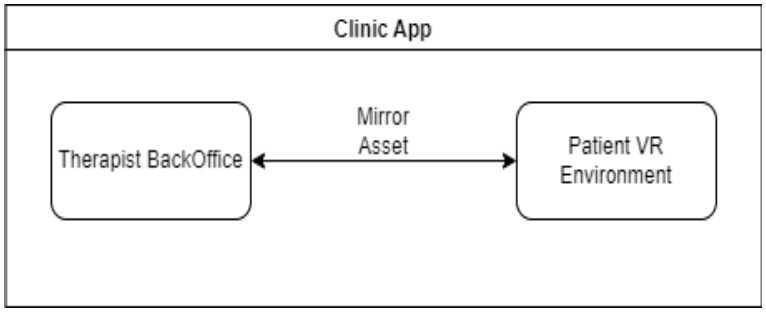

Figure 3.1: Clinic Application Scheme

The therapist uses a computer and has access to several controls that change some elements of the patient virtual reality scenario whenever it seems fit. This back office also allows the therapist to save and analyze the in-real time physiological signals of the patient, which helps to detect anxiety-related triggers and prevent overexposure. The Fig. 3.2 represents the scheme of how the back office aspires to be.

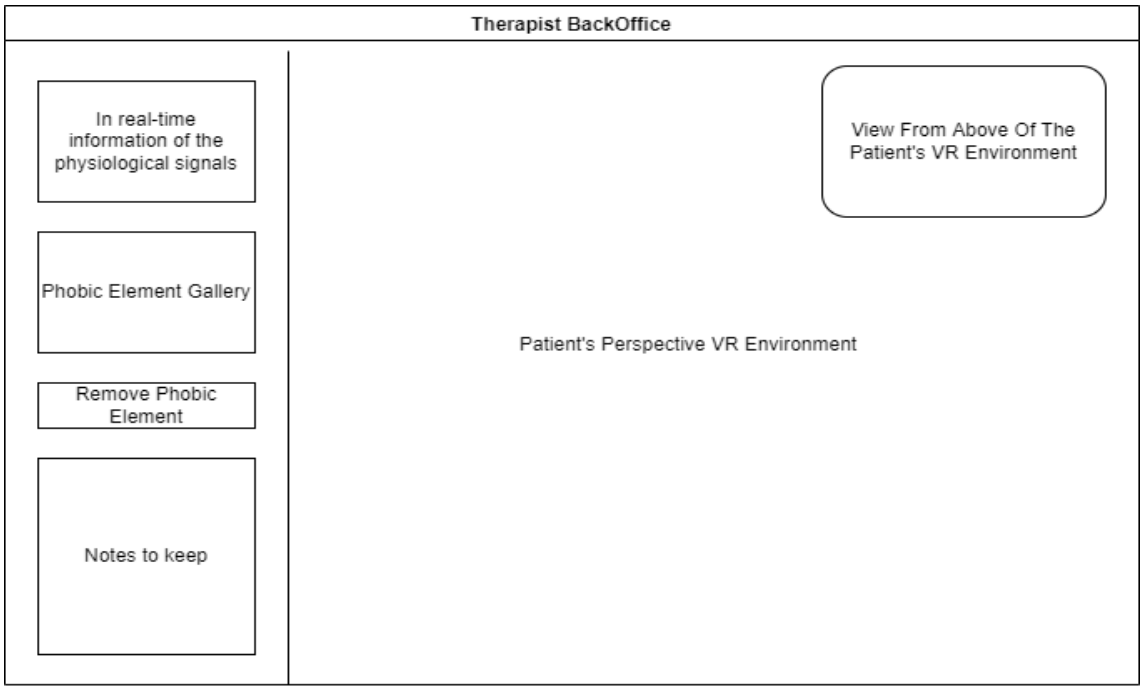

Figure 3.2: Therapist back office Scheme

The patient uses a virtual reality headset like Oculus Rift to play and explore this virtual reality environment. This scenario presents some activities/tasks for the patient to

complete while the therapist collects the information needed.

This application allows a better comprehension of the patient's level of anxiety when in the presence of the phobic element, helping the therapist choose which level of exposure to submit to the patient in the following steps of exposure therapy.

3.3 Breaking down Therapist-Patient Perspective

The clinic application is a tool to help the therapist situate the patient in the anxiety intensity spectrum accordingly to their anxiety source. It starts with a menu where the patient waits until the therapist sets as ready to start the analysis (Fig. 3.3). Once the therapist initiates the examination, he/her have access to the back office, and the patient starts in the middle of a virtual reality room.

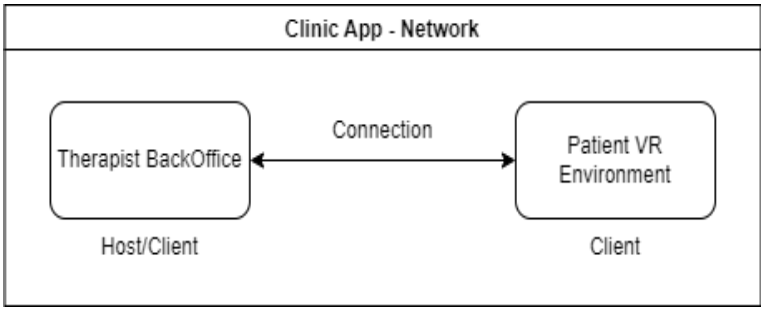

Figure 3.3: Mirror Connection

The connection between the back office and the virtual environment of the patient is made through the asset "Mirror" from the Unity asset store. "Mirror" is a high-level Networking library for Unity, compatible with different low-level Transports.

This application consists of the main menu and two scenes that communicate with each other. The menu establishes the connection between the host (therapist) and the client (patient). Once the connection is set, both will show as "ready", and the host can start the session. With these connections, the patient is in the virtual reality environment, and the therapist can interact with it via the computer back office.

3.4 Designing the Patient's Virtual Reality Perspective Environment

As mentioned, the application proposed can be divided into two scenarios: the therapist back office and the virtual reality scenario for the patient. Both interact, but the therapist's back office can see two different patient perspectives and directly interact with that environment. The patient cannot alter the virtual reality environment as the back office is capable.

The patient's surroundings consist of a living room with a couch, a television, and a secretary (Fig. 3.4). The therapist will interact with some of the objects present in this scenario.

The virtual reality patient' scenario structure was developed using the ProBuilder tool from Unity. This tool manipulates the polygons of a chosen shape. To build the walls, the 3d form of a cube turned into the walls. Doing this made it possible to minimize the number of polygons, optimizing the structure. In this scenario, almost all the objects presented were handmade, and the meshes were merged. The rest, such as the couch, were downloaded from the Unity asset store. The exterior was made utilizing the terrarium tool. The exterior helps to increase the sense of presence as if the patient left the room, he/she would not fall into nothingness.

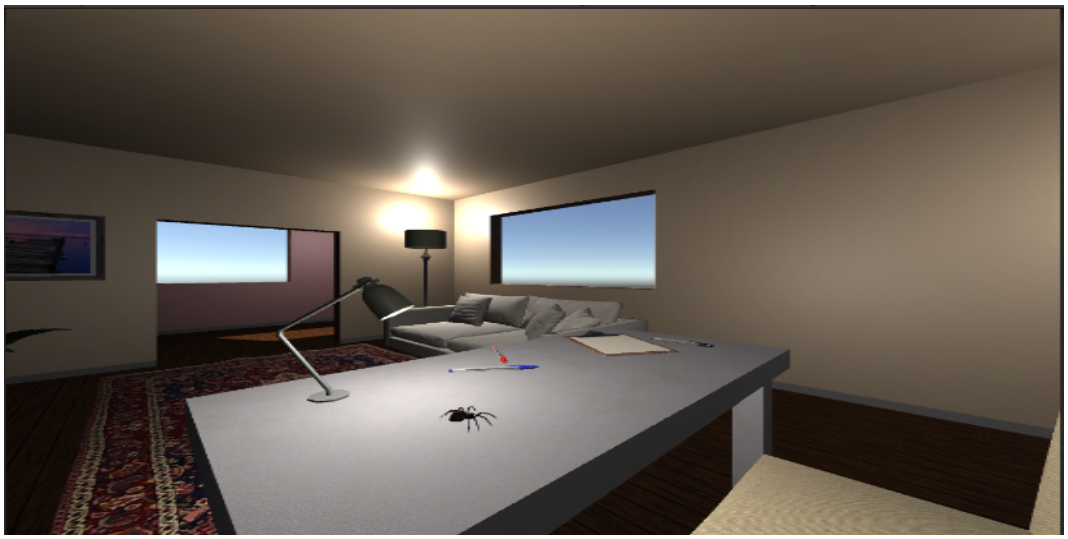

Figure 3.4: Patient virtual reality perspective

3.5 The Therapist's Back Office and Tools

The back office can offer different tools to help the therapist analyze the patient's current situation. It presents a first-person perspective and a bird-eye perspective of the virtual environment of the patient room (Fig. 3.5). It also allows the therapist to see the real-time physiological signals of the patient as the session progress.

The therapist can place (or eventually remove) the phobic element wherever desires - close or far from the patient. The phobic element can move towards the patient or stay animated in the same place, creating the sense of being alive (if it is a living creature). The therapist can select where he/she wants to place the phobic element by clicking the mouse's right button on the first-person perspective and the mouse's left button in the bird-eye perspective. When the therapist spawns the phobic element, it appears on the patient scenario in the equivalent location clicked.

The therapist also controls the television, as he can turn on and off the video currently playing, choose what video to display and change the audio volume. He/she also has control of the room's lights, turning them on and off as he wishes.

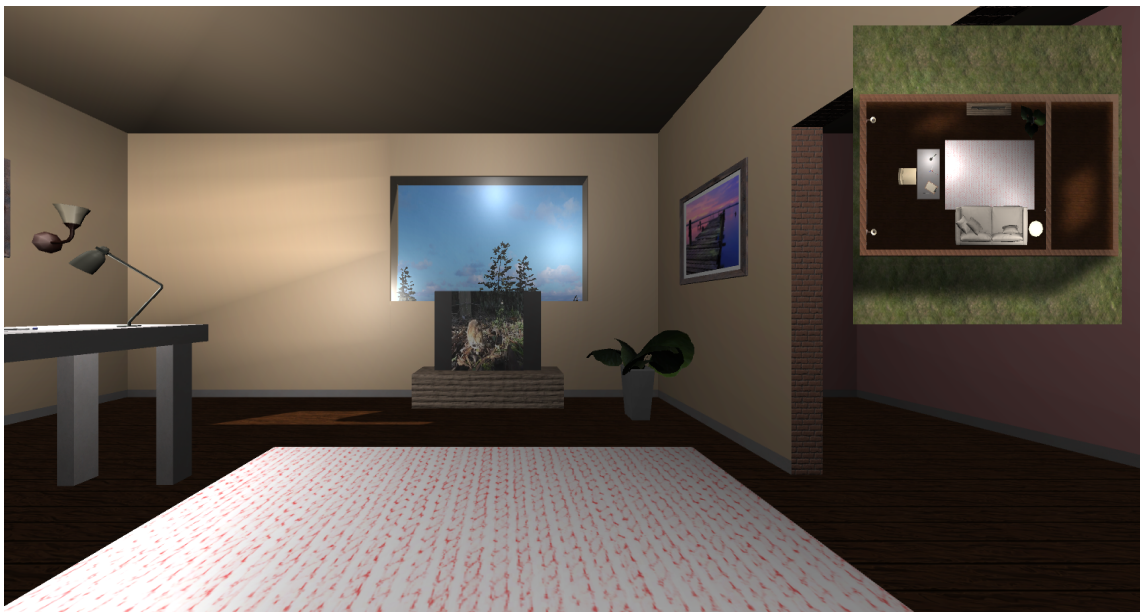

Figure 3.5: Therapist's view of the patient virtual reality environment.

3.6 Results

The development of a multiplayer network application required a support that was no longer available, the UNet from Unity. As such, it had to be made from the ground up. This necessarily delayed the progress, given the complexity involved. As a new asset was found available on the Unity Store, it seemed an excellent opportunity to use it. The available documentation shared similarities with the previously discontinued one. Later, unfortunately, it was found to have significant bugs, and a considerable amount of time was put in to find how to make things function the way it was meant to without taking the direct path. One of the worst problems encountered was that the network behaviour of the Unity prefabs only performed well from the direction host/client to the client. Any direct communication started at the solo client was immediately seen as an error from Unity, and the network properties were inactivated.

Even with the problems stated previously, some work was still possible to develop.

The application currently allows the therapist to initiate the session and place spiders (phobic element chosen) at a chosen location of the virtual reality patient environment. The back office also has two patients' perspectives, first-person and bird-eye.

The last implementation consisted of presenting the patient's representation in the back office and its orientation. Unfortunately, this was not possible to complete because the asset "Mirror" had problems communicating in the direction client to host. As the patient moved, it was supposed to see the direction he/she was facing in-real time with an object representing the body in the therapist's back office. Since it was impossible to send data from the client to the host, it did not allow to send the patient's position and orientation to the therapist back office. However, the implementation was thought and almost finished, but it was impossible to test it.

Figure 3.6: Clinic Application Results. At the left is the patient view. At the right is the therapist back office.

4

Smartphone Application

With the aim of allowing the patients to continue the exposure treatment at home while keeping the therapist's supervision, it was decided to develop an application for a smartphone, exploring its wide penetration with the population. With a virtual reality headset for smartphones, such as google cardboard, any smartphone can become a virtual reality device.

The application consists of a serious game to help the patient learn how to manage the anxiety in a safe and controlled environment. The therapist controls the level of exposure of the phobic element to the patient. It can be used with and without the presence of a therapist.

4.1 Base Requirements

In comparison to the previous application, it was added two requirements to the base requirements:

- to be used in a smartphone: smartphones are a prevailing device, and they will allow the application to be mobile and achieve a max of individuals.
- to be anxiety-related disorders versatile: having a flexible application will benefit more people.
- to be controlled by the therapist: the application offers the security of being supervised by a professional.
- to be used without the constant presence of a therapist: the patient can use this

application freely, without time restraints.

4.1.1 Smartphone Related Requirements

Since it is a smartphone application, some requirements concerning the interaction and optimization are:

- use of low-poly objects: low-poly is a polygon mesh in 3D computer graphics with a relatively small number of polygons. The number of polygons in a mesh is essential in optimizing performance but can give an undesirable appearance to the resulting graphics.
- interaction only consists of the position of the user's head: peripherals devices other than the virtual reality headset will not be utilized to limit the expenses of using this application.
- aiming to require the smallest space possible to move in real life: the patient's environment is unknown, so the application needs to provide maximum comfort and easier usage.
- to be easy to download and play: the patient may not have a great knowledge of technologies, so this application must behave like others by being available on Playstore.
- to be intuitive: the gaming experience of each individual is different, so it is necessary to build an intuitive application so that even the most inexperienced users can use the application.

4.2 Designing a Friendly Space for Exposure Therapy

The concept explored is the development of a serious game to facilitate the application of exposure therapy for both the patient and the therapist. The design of the virtual reality environment can integrate exposure therapy with different kinds of disorders.

Due to its high popularity among all ages and its versatility, the game ”Escape Room” is one example of how this serious game can present itself. The player needs to com-

plete several tasks and gather clues to escape the current room. By changing routines and adding new clues, the patient will be constantly entertained and stimulated to maintain engagement. It prevents disinterest and consequently keeps the patient exposed. If the patient loses interest, he/she may not maintain the treatment, and the therapeutic progress will decrease.

The concept of this game may trigger some disorders like claustrophobia, so it can be changed to other possible less anxiety-prone games such as treasure hunting.

The escape-room scenario (Fig. 4.1) creates the perfect context to contain multiple and different mini-games where the disturbing elements are included. This also allows the patient to pause between exposures without leaving the virtual reality environment to remain calm if necessary. Consequently, he/she will not lose any sense of presence by staying in the virtual reality ambient while processing the emotions.

In the case of arachnophobia, the anxiety disorder that will serve as an example throughout the article has a phobic element, the spider, so there are mini-games that only show images of it, and others present themselves with a virtual representation of the animal. At the moment, the phobic element can be easily replaced by following the steps in the appendix.

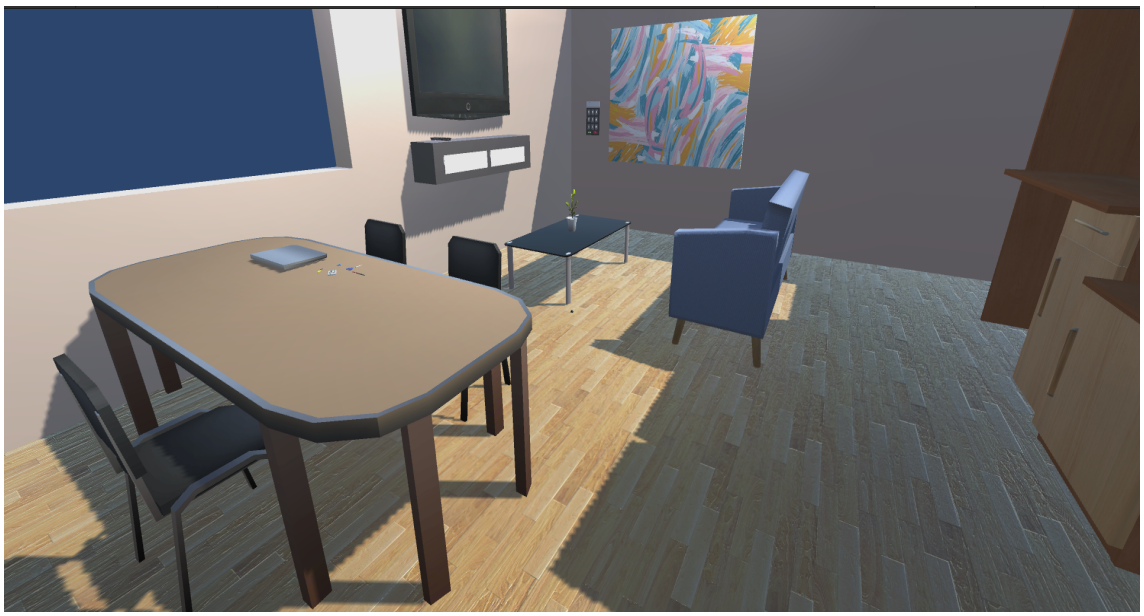

Figure 4.1: Escape Room VR environment

Each mini-game addresses a different anxiety level and has small therapeutic goals. Since the patient must have a gradual exposure to the phobic elements, the patient can be exposed slowly from images to videos to the actual virtual presence with the mini-games.

4.3 Design and Implementation of a Virtual Comfy Space for ET

The mobile application developed has to address some complex issues in terms of displacement and interaction within the game. As for the home usage, the patient will use it in a cardboard configuration; therefore, no joysticks, gamepads, or other game controllers should be considered. Consequently, the only possibility is to use the head orientation to support the interaction with the VR environment in its various aspects, as will be discussed below.

This limited interaction form presented some challenges in the game's development, such as only moving the head and avoiding fast movements to prevent motion sickness. As reported by [6], people who suffer from mental health illnesses tend to be more prone to cyber-sickness, so this was a subject that received particular attention. So, the mini-games chosen are not speed-oriented, and the movement between locations is similar to closing and opening the eyes to avoid significant shifts in the user orientation.

4.4 Interact With The Virtual Reality Environment

To interact with the VR environment, the patient can search for specific points that will light up to let him know that there is the possibility to interact with and a small pointing sphere will change colour to the inverted colour of the object that it is in the background. The sphere simultaneously represents the player's pointer and is the interaction element. Its collision with the active elements of the virtual world is exploited to enable the player to select objects, move within the game space, or interact with the mini-games.

Whenever the sphere is placed on top of an active element, it immediately starts inflating, showing the interactive control, and activating the element after a while.

Some places are essential to the game flow, such as where a code can be inserted or where the mini-games are playable. Because of this characteristic, small blue moving circles are placed in those specific locals to grab the attention of the player that it is critical to move at some point to that location, as can be seen in Fig 4.2. The player can not play the mini-game from across the room or even from the wrong point of view.

Since interaction is limited, and motion sickness is an issue, travelling to different places in the room consists of a fade-in and fade-out. As the screen slowly turns black, the user changes position and fades out in the correct location, maintaining the rotation and height of the player. The player can only move in the ground plane.

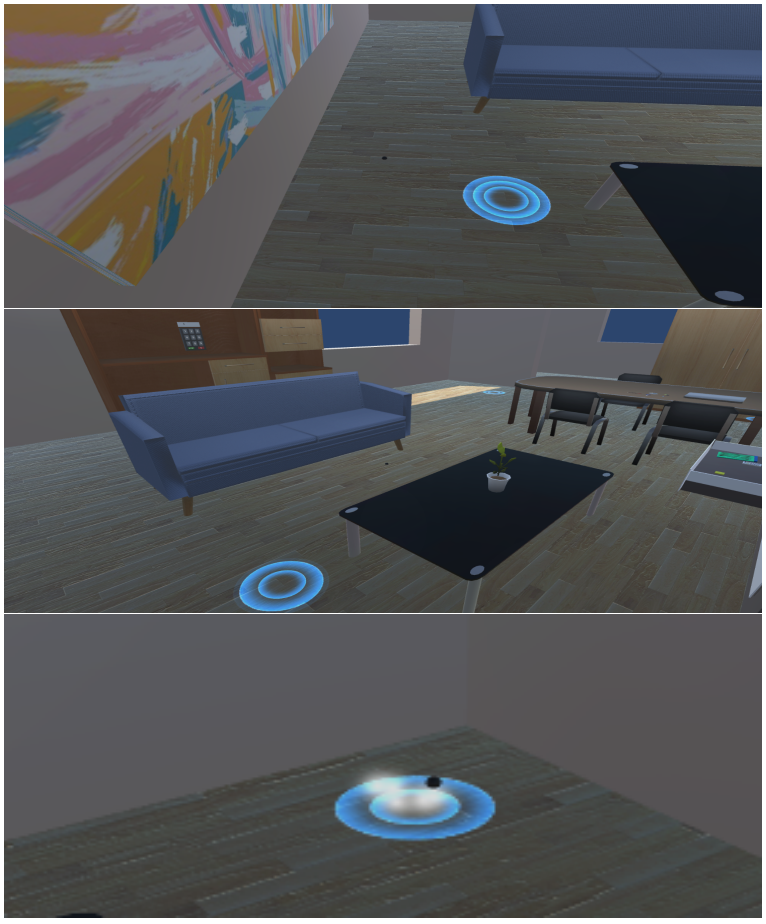

Figure 4.2: Teleport circle

The SelectionManager script is the main script in charge of all the interactions. It manages the selection of the objects and what happens once they are triggered.

4.5 The interaction with the mini-games

The serious game is sequential with an exposure ladder where some have a lower anxiety level, and others are more intense. In the higher difficulty, all implemented anxiety sources are present. The game itself also has some variations between plays, such as different images and random placement of the matches in the case of a memory matching game card.

Since sometimes the patient can have more difficulties in an exposure given by a specific mini-game, the therapist can request the patient play only that mini-game without playing the full serious game. For that, there is the possibility of playing individual mini-games.

The interaction between each mini-game also needed to be analysed to create a random yet sequential relation. A digital code is provided to the player and acts as a bridge between the mini-games upon completing each one. The codes are presented differently, forming a final colour code to unlock the last door and finish the escape room (Fig 4.5).

The codes of each mini-game are randomly generated at the start of the script of each mini-game. The DifferenceGame script generates a three-digit number that will be the unlock code to find the differences mini-game and the MemoryGame script to the memory card matching mini-game and the MazeGame script to the maze mini-game too. The KeyPadColor script randomly generates the final colour code as it sets the colour of the prefabs where the codes of the mini-games are.

The mini-games also present hints once finished, like where the code is or where it is to be inserted. For instance, as can be seen in Fig. 4.4, once the drawer is opened, a line of sparkle particles flow to the correct keypad. If the code inserted is correct, it will change colour to green. If not it changes colour to red (Fig 4.3).

The static mini-games such as memory card matching and puzzles are played similarly.

Spark particles appear where the player is staring at and like moving, the interactive sphere increases and when full, the game develops.

In the case of the ”find the differences game”, the spark particles do not show, and the sphere does not increase unless it is to press the hint button. However, it is still necessary to

Figure 4.3: Final Keypad

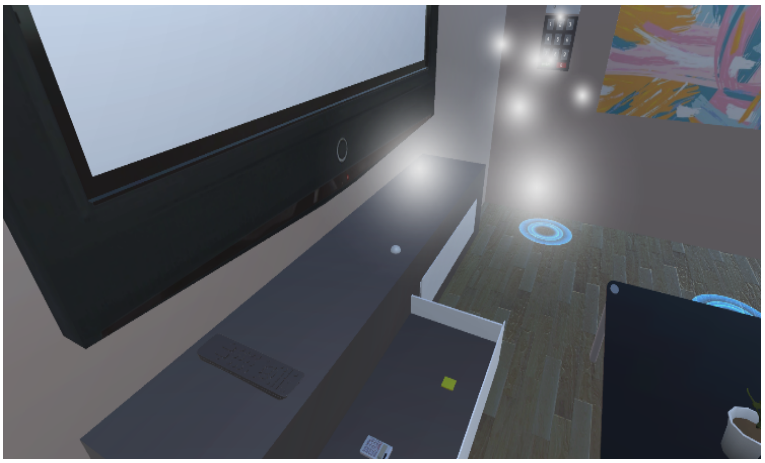

Figure 4.4: Game hint

wait two seconds looking at the same spot to play. It happens to avoid giving the different location away.

On more dynamic mini-games, like the maze, the phobic element follows the interactive sphere, and the game is played by controlling its location.

4.6 Breaking down the Exposure into Mini-games

The mini-games serve to expose the patient to the disorder element. The time between each mini-game act as a pause of exposure or even as a panic emergency escape. The patient can leave the mini-game, take a break wondering the virtual room and resume it when calmer, preventing the break of the sense of presence.

Figure 4.5: Code of a mini-game in a red note

The serious game starts with all the mini-games hidden. When the patient inserts the codes onto the keypad, the corresponding mini-game uncover itself. Each one executes isolated, being coordinated by the main script. This format enables the therapist to require the patient to play only one of the mini-games without playing the escape room.

The chosen mini-games to develop in the concept of ”Escape Room” and arachnophobia are:

- Memory Card Matching
- Find the Differences
- Maze

4.6.1 Memory Card Matching Mini-game

In the ”Memory Card Matching” mini-game (Fig. 4.6), the user has constant contact with different images of its anxiety source. When playing, if the cards turned do not make a pair, they turn themselves back. As the game proceeds, the number of images exposed increases, and the anxiety may make it harder to complete. The mini-game leads to the necessity to memorize a determined image’s position and details to correspond with its duplicate. This mini-game also allows the player to decide if he wants to see the inanimate disorder related element. In order to keep the challenge level constant between game sessions, each image position is randomized at the beginning of the game. After completing

all the matches, a code appears in the room. This code will lead to the next mini-game.

Figure 4.6: Memory Card Matching Mini-game and keypad

The Memory Card Matching mini-game code consists of the Memory Game script and the MainToken script. The Memory Game script generates clones of the token prefab and associates the pairs randomly. A token is a card in the game. It also contains the different functions used in the logic of the mini-game. The MainToken script associates the sprites that represent pictures of the phobic element and contain the behaviour of each card.

The main script controls when the game begins and manages what card the player selects to turn.

The logic behind this mini-game can be seen in Fig. 4.7. There are two types of sprites, the back sprite and the other four sprites that consist of the phobic element pictures. The mini-game begins with the cards showing only the back sprite, and as the cards turn, with the AddVisibleFace function, the visible sprite becomes the phobic element picture. The

RemoveVisibleFace function is used when the cards turn back, and the back sprite has to be visible once more.

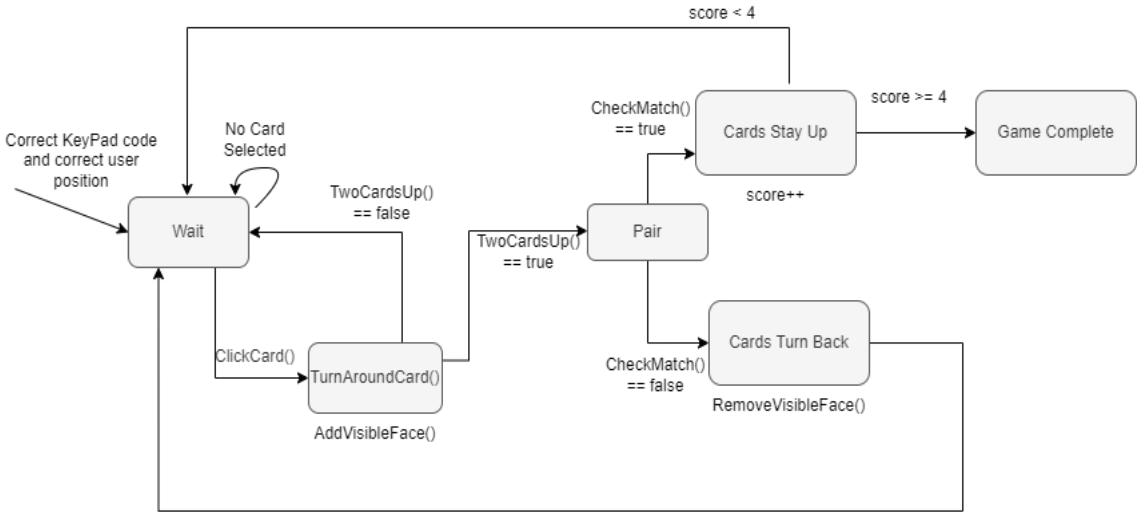

Figure 4.7: Memory Card Matching Mini-game Logic

4.6.1.1 Puzzles Mini-games

Thought to substitute the memory card matching game to offer more diversity, these two kinds of puzzles offer similar therapeutic exposure: a rotating puzzle and a slide puzzle. The therapeutic goal is to assemble the image related to the anxiety source gradually.

Nine pieces of the same image constitute the rotating puzzle (Fig. 4.8), and the player needs to rotate each one, 90 degrees at a time, to build the final image and complete the mini-game.

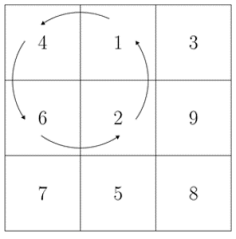

Figure 4.8: Scheme of rotating puzzle

The slide puzzle (Fig. 4.9) consists of 8 pieces of the same image and a blank spot of the same size as the other parts of the image. The player must move the pieces within the available space until the final image appears.

These did not make the final application. However, these puzzles are worth mentioning as they were planned and started to be developed. They were not implemented due to their apparent similar therapeutic goal and to prevent the game itself from being too time-consuming to play.

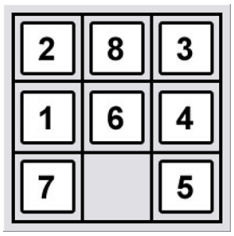

Figure 4.9: Scheme of sliding puzzle

4.6.2 Find the Differences Mini-game

The ”Find the Differences” mini-game (Fig. 4.10) consists of two very similar images with slight differences between them, which the user has to find and mark.

The game starts hidden behind a closet. After acquiring the code from the memory matching card game, the player can insert it onto the keypad, and the mini-game appears. To play, the user selects a position on the left image. After waiting two seconds, if it corresponds to a difference, a red doughnut will target the spot as found. If not, then nothing happens.

If needed, a hint feature will help the player complete the mini-game. The hint consists of the phobic element moving towards the difference’s position. Depending on the level of exposure, this element can be the phobic element. In the case of arachnophobia, a spider shows the patient where one of the differences is. The animated phobic elements show a neutral white sphere if the patient is playing the lowest intensity.

The DifferenceGame script controls the ”Find The Differences” mini-game. This script manages the selection of the differences pair (as the selection can occur on each side of the picture) and the phobic element actions to show the remaining differences. The differences are a transparent cube prefab and are spotted as the main script recognises them as selected. When the selection by the user happens, a red doughnut shape marks the difference, one on each side of the picture.

Figure 4.10: Find the Differences Mini-game

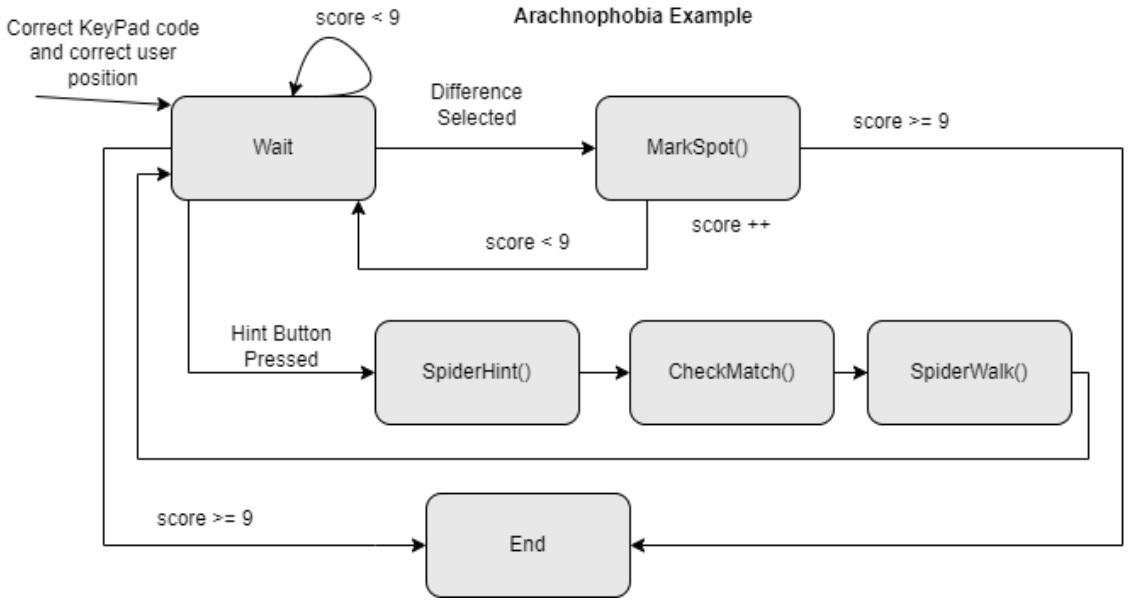

Figure 4.11: Find the Differences Mini-game Logic

4.6.3 Maze Mini-game

The maze (Fig. 4.12), according to the selected disturb, may have different aspects. For instance, to OCD, the lines are not straight, and some lights turn on and off while passing on a specific part of the path. For ADHD, distractions such as random blinking lights or sounds can easily make it harder for the patient to concentrate on the task. Suppose it is arachnophobia or other small animal-related phobias. In that case, the phobic element follows the position of the user's head, and the goal is to lead the animal to the end of the maze without it touching the walls. The maze path shuffles between predefined

paths. Along the maze, there are several platforms. The phobic element must touch every platform, or the final colour is not provided.

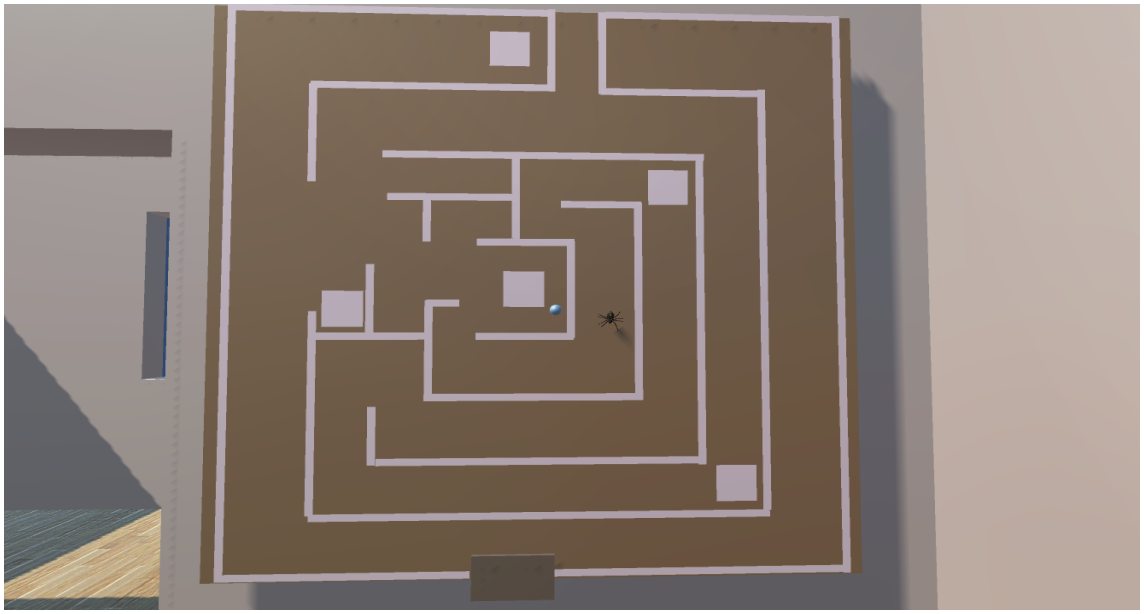

Figure 4.12: Maze Mini-game

Figure 4.13: Spider - phobic element

The MazeGame script is in charge of the control of the maze mini-game. It manages the move of the phobic element, its collision with the platforms and walls. It also increases the mini-game score when the phobic element collides with a platform, turning the platforms green.

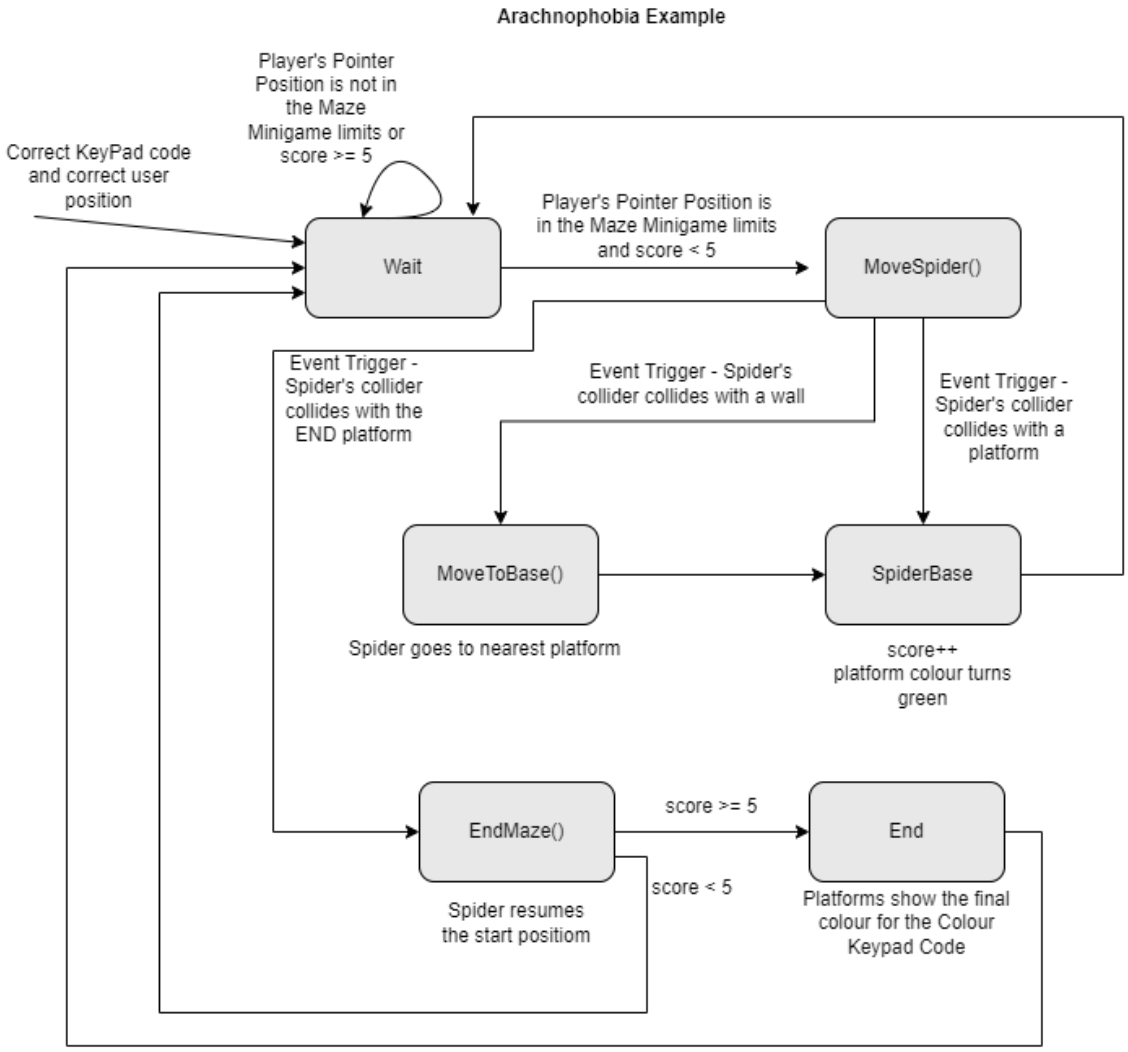

Figure 4.14: Maze Mini-game Logic

4.7 Keeping a Record of the App Data

The smartphone application can only be used by the patients whose therapist has access to this database (Fig. 4.15). The application requires each user to register first for the therapist to maintain some control over the exposure. So, before each session, the patient needs to log in (Fig. 4.16).

The registration consists of the patient's basic information, which will help the therapist better recognize the patient subject in question. This information includes name, username, email, password, birth date, gender and the therapist code itself. The login, however, will only require the email, password, and therapist code (Fig. 4.17). If the ther-

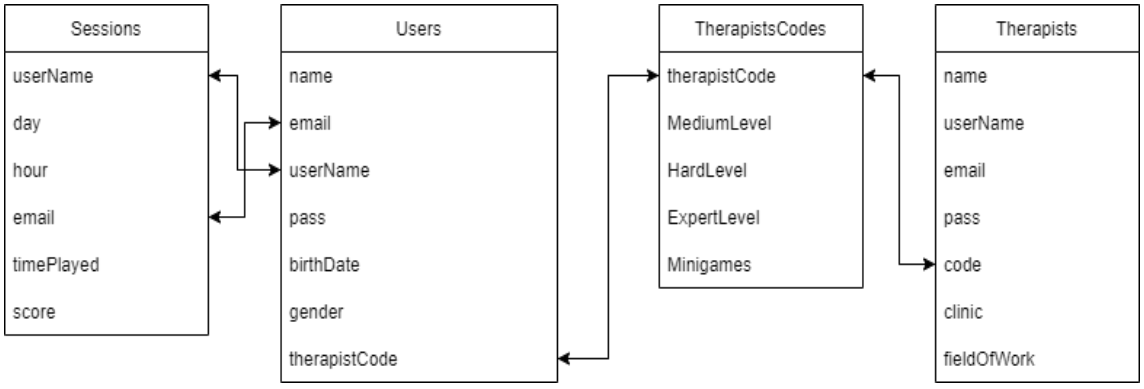

Figure 4.15: Database

apist changes, the last input allows the patient to update his register. The new therapist will have access to the future data, and the previous therapist will no longer have access to this patient. The codes provided by the prior therapist will also no longer unlock the levels and mini-games.

Both the register and the login procedure require an internet connection. However, suppose the internet is off after the user addition or recognition process is completed. In that case, a local file is saved in the user's smartphone with the information associated with the last session played. Later, when the internet connection is again established, and the application is opened, this file will be uploaded to the database and deleted from the user's device. The login is not allowed without an internet connection to prevent users who may share the device from corrupting the data. Two different patients could end up with the sessions saved only in the last login committed.

Each therapist has access to 5 codes, the code that represents the therapist itself and will associate all the patients to the therapist, the codes that unlock the game's levels (medium, hard and expert) and the code that unlocks the independent use of the mini-games (Fig. 4.20).

The sessions information saved consists of the player's username and email, day and hour at the moment, time played from the beginning of the game until the exit of the application and score.

Even though this application is a game, it has an implicit goal, thus being a serious game. So, this score is not a competitive gaming score but the progress the patient has

made along with the game. Like moving from spot to spot and entering the correct code onto the keypad, each movement adds one point to the final score. The completion of each mini-game grants one hundred points times the mini-game score. The Memory Card Matching mini-game gives four points, the Find The Differences mini-game awards nine points and the Maze mini-game grants a minimum of five points.

4.8 The Therapist Role on a Connected App

The presence of a therapist in this process is highly important. It does not need to be a constant presence, but one-off checkups. The progress made by the patient needs to be analysed, and with those conclusions, the therapist decides which level of anxiety intensity the patient plays at home. The therapist has access to the patient progress by a database as seen in the previous section. When the patient logs in, a code provided by the therapist is inserted, and that data is saved and can be accessed later by the therapist.

The patient must play at least once every session for the therapist to evaluate the progress. The physiological signals such as the heart rate and galvanic skin response will also target that evaluation.

During the development of the presented work, meetings with psychologists clarified the patients point of view and how to help and not overexpose them to the anxiety source. The therapist must evaluate the situation step by step, so the exposure remains controlled. So, to facilitate and help keep track of the patient progress, he has access to the scores of each mini-game and the total time of play of each patient. It is then possible to know how many times throughout the time-off sessions the patient played and the difficulty they faced.

4.9 Starting The Application

The start of this application (4.16), as mentioned, consists of two options, register or login (4.17). After this, the user can play the complete ”Escape Room” game or play only the mini-games.

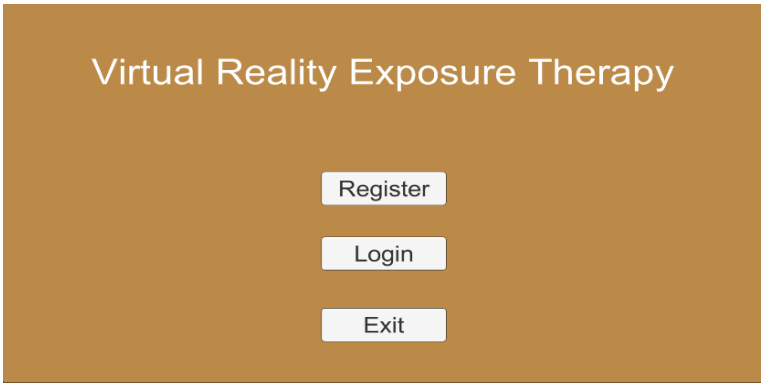

Figure 4.16: Initial menu

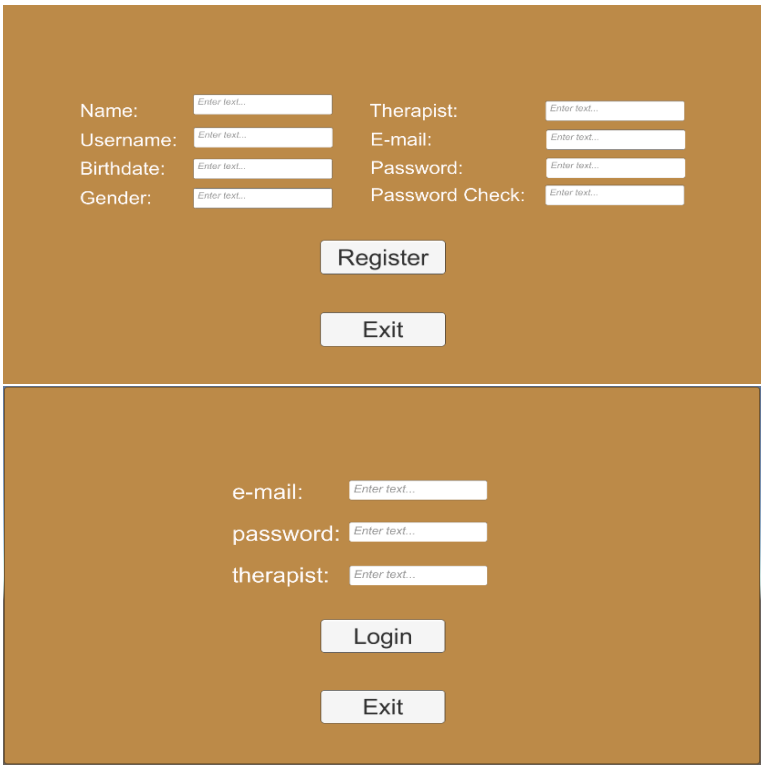

Figure 4.17: Register and Login

If the user selects the ”Mini-games” option, the menu presents the mini-game options. After inserting the correct code, there is an explanation of the mini-game (Fig. 4.19) and the opportunity to play only that mini-game (Fig. 4.18).

If the user selects the ”Escape Room” option, a disclaimer, as seen in Fig. 4.20, is presented. Then the user can choose the level they wish to play and insert the corresponded code.

Figure 4.18: Selection of the Mini-games

Figure 4.19: Explanation of Memory Card Matching Mini-game

4.10 The various anxiety intensity levels

The application has four levels of anxiety intensity. The ”Easy” level only presents the phobic element in pictures (in the Memory Matching Card mini-game). It is the lowest exposure of the game and is present in all the following levels.

The medium intensity level introduces the phobic element in a cartoon video displayed on the TV. Next, the ”Hard” level shows the phobic element VR representation in the Find the Differences mini-game and Maze mini-game.

The last level, the ”Expert” level, has the phobic element VR representation present in every mini-game and close to the codes.

Figure 4.20: Selection of the level of "Escape Room" game

4.11 Configuring and Uploading the Application to Google Playstore

Google Play is a digital distribution service for applications, games and others, developed and operated by Google. It is the official app store for the Android operating system and provides digital content. It allows anyone with a smartphone to easily download an application uploaded to this service. For this reason, the smartphone application developed was uploaded to Google Play and is currently in the internal testing phase to easily be downloaded and tested.

To upload the application to Google Play, it was necessary to use Android Studio to update both the software development kit (SDK) and the application programming interface (API) to level 30. Google Play console does not accept android application packs (.apk) or application bundles (.aab) with an API of less than 30. However, Unity and android applications have some incompatible problems. Because of the update of the API, the building Gradle of the application had to be outdated, as the current Gradle is not compatible with API's levels above 29. Gradle is a build automation tool for multi-language software development. It controls the development process in the tasks of compilation and packaging to testing, deployment, and publishing. The java development kit (JDK) and android native development kit (NDK) also needed to be installed outside the unity for the application build.

Once the smartphone application was successfully built, the unity project was exported

from unity and imported into Android Studio to associate a key to the application, as the Google Play console required. This led to another situation, as the instructions on generating a signed bundle by Android Studio were incorrect. To generate a key is necessary two different passwords, one to protect the folder where the key stands and the other to unlock said key. Accordingly to the instructions, the passwords must be different and is considered invalid if they are identical. However, as found later, the generated key was only successfully created once the passwords were identical.

The steps reported above required plenty of time and research, as they were not errors well reported, and it was necessary to search and try multiple approaches to find the correct path.

The application is currently in the tests process of the Goggle Play console, but the presentation to be displayed in the Playstore is complete.

4.12 Preliminar Validation

4.12.1 Game / Usability analysis

The serious game was tested by ten individuals. At the end of each test, the individuals filled a User Experience Questionnaire (UEQ), a Flow Short Scale Questionnaire and an open answer questionnaire to obtain information about the individuals.

The User Experience Questionnaire is frequently used to measure the user experience with a specific product. It evaluates the user experience in six categories: attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. If a category is above 0.8, it has a positive evaluation, and above 1.5 is considered an excellent result. The results are presented in figures 4.21 and 4.22. It presents the average classification of each category and its standard deviation. The attractiveness, efficiency, stimulation and novelty categories were all classified as excellent, although with a high standard deviation due to the sample size. The perspicuity and dependability had slightly lower scores with 1.225 and 1.375, respectively.

Perspicuity refers to how easy it is to get familiar with the application and how easy

it is to use it. The application is a virtual reality serious game, and in the open answer questionnaire, most of the individuals lack experience with virtual reality, so, being a virtual reality ”Escape Room” game, it was expected some difficulties in interacting with the environment at first try. Dependability refers to how in control of the interaction the user feels. The serious game is a compilation of puzzles and codes, so some individuals felt they did not have control of the situation is not far from reality.

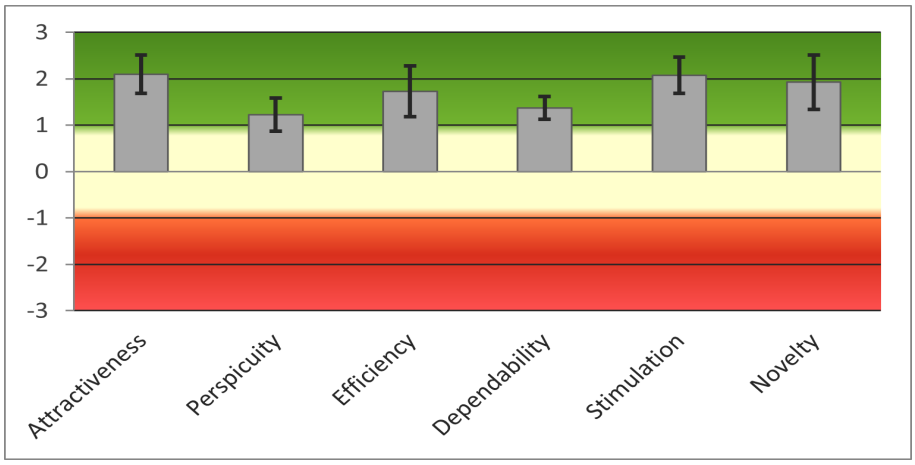

Figure 4.21: User Experience Questionnaire Results.

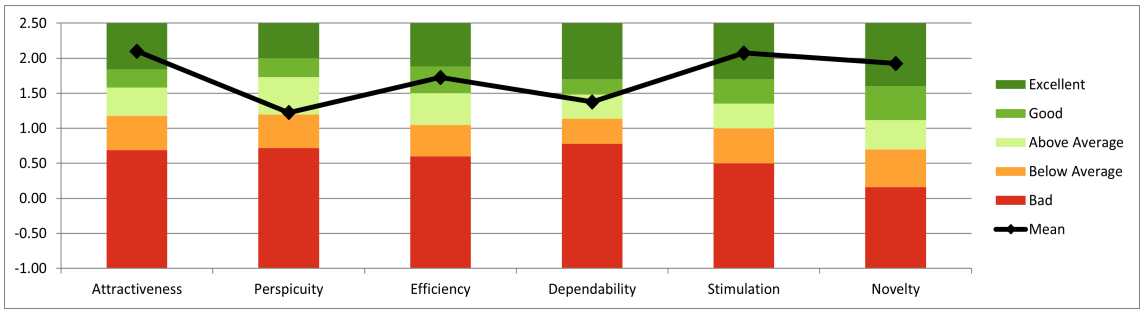

Figure 4.22: User Experience Questionnaire Benchmark.

The Flow Short Scale Questionnaire evaluates three aspects of the application on a scale of 1 to 7: flow, anxiety level and challenge level. Flow level indicates if the user feels engaged while playing the game and feels like the activity is intrinsically exciting and takes pleasure and enjoyment while involved. Anxiety level translates to how much anxiety the users felt while playing the game and challenge level to how challenging it was with 1 being too easy and 7 too hard.

The results with the average and standard deviation of each category are presented in table 4.1. The challenge level was considered close to perfect (with 4 being a perfectly

adequate challenge level). The anxiety level was not high, but it presented a relatively high standard deviation. In the open answer questionnaire, three individuals said to have anxiety problems such as anticipation anxiety. This may explain why such a high standard deviation. A flow level of 5.04 indicates that the users mostly enjoyed playing the game. However, some aspects could be improved, such as adding descriptions of how the mini-games are played and maybe a scene without any game to allow the user to know the virtual reality environment.

	Average	Stardard Deviation
Flow	5.04	0.527
Anxiety	3.867	1.124
Challenge	3.9	0.568

Table 4.1: Flow Short Scale Questionnaire Results.

Based on the results, some alterations were made to the current application, like more clues inserted into the game and some reported bugs fixed.

5

Discussion

From the pilot experiment, it was extracted some valuable information such as missing details and bugs.

From the User Experience Questionnaire, it was possible to conclude that the overall looks and interaction in the simulation is satisfactory. This is a crucial aspect to take into account because the more people test a product, the more reliable the results are, and having them enjoy the time spent with that product is a means to attract more people into testing it.

However, there is a max of interpretation possible to acquire since this is an exposure therapy application for people with specific anxiety disorders, and the tested individuals do not suffer from this condition. So, it is only possible to semi-conclude that the application provoked some anxiety and distress, maybe implying a good sense of presence and immersion.

6

Conclusion and Future Work

Exposure therapy is one of the best behavioural therapy techniques used to treat anxiety disorders. It can be challenging to apply traditionally as the therapist needs to feel a minimum of control to safely expose the patient to the phobic element. This treatment can be securer by integrating this concept with virtual reality.

The therapist can monitor the patient's responses and physiological signals with the help of the clinic-only use virtual reality application. It allows the therapist to observe the virtual reality environment of the patient, interact with it, and check the level of anxiety the patient presents when confronted whit the anxiety source.

Since exposure therapy is a gradual and repetitious process, the follow-up application pushes the patient to face the phobic element at home at different levels of anxiety intensity prescribed by the therapist in a previous consultation. This application acts as homework for the therapy sessions and lets the patient safely practice at home.

The clinic-only application runs at the therapist's computer and uses Oculus Rift as the virtual reality headset. The at-home virtual reality application is currently available for Android users; unfortunately, it was not possible to develop for IOS users due to a conflict with the Unity plugins. The serious game has entertaining components and a strong focus on teaching and training.

This type of application can be the starting point for many people to learn how to manage their anxiety and live life in a much better state of mind. As the chosen game design can be multifaceted, the opportunities are endless. Not only can different disorders like arachnophobia, post-traumatic stress, obsessive-compulsive disorder and attention deficit

hyperactivity disorder be improved, but the therapist can adequate the game to each patient depending on the presented disorders and the best anxiety intensity levels for each one.

So, an advantage of this application is that the therapist can eventually select several phobic elements and choose their intensity. The vision explored with this serious game application was anxiety disorder, namely fear of insects or small animals typically found in our homes. Suppose the patient has arachnophobia and melissophobia (afraid of bees), but the fear of spiders is far more intense than his/her fear of bees. In that case, the therapist can advise the serious game with the lowest anxiety intensity level for arachnophobia and a higher level for melissophobia.

The type of serious game chosen in this work was an ”Escape Room”. However, in the future, this concept can be developed in other genres too for those whose anxiety disorder impossibilities this style of game, for instance, claustrophobia. Other opportunities for serious games to develop this concept are ”Treasure Hunt” or ”Monopoly” to help more disorders.

The application can be as versatile as helping diagnose obsessive-compulsive disorder and attention deficit hyperactivity disorder in the future. Therapists worldwide believe that virtual reality can go beyond helping to manage anxiety by helping complex diagnoses.

This concept can be significantly explored and develop a unique tool for therapists by helping them battle this mental health disturbance that is so present in our day to day life and is increasing with by day.

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Appendix

How to change the phobic element

.1 Memory Card Matching Mini-game

The phobic element representation consists of four pictures. These pictures are square cropped and imported to the Unity editor. The next step is to turn these pictures into sprites and add them to the Memory Game prefab as inputs to the MainToken script.

.2 Find The Difference Mini-game

The phobic element consists of an animated prefab. To replace it, add the new phobic element animated prefab to the DifferenceGame prefab and add it to the currently named ”Spider” GameObject input.

.3 Maze Mini-game

The phobic element consists of an animated prefab. To replace, add it to the Maze prefab. Drag the MazeGame script from the old phobic element prefab to the new one and delete the old prefab. Finally, update the ”Spider” input field of the script to the new phobic element.

A Controlled Virtual Reality Exposure Therapy Application for Smartphones[a]

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Keywords: Virtual Reality, Exposure Therapies, Serious Games, Smartphone VR

Abstract: Exposure therapy (ET) is often used as a therapeutic process for the treatment of a psychological disorder. Usually, this type of therapy is challenging to apply traditionally as the therapist must expose the patient safely to the cause of the disorder. To help surpass this problem, a virtual reality (VR) application was developed to support exposure therapy. As these therapies are based on a gradual and repetitive process, with this application, the patient can be exposed to the phobic element at different levels of anxiety intensity as prescribed by the therapist. This application was designed to be used either during the therapeutic sessions or at home. While using it in therapeutic sessions, it allows the therapist to include the analysis of physiological signals, escape movements, or other reactions during the exposure. At home, as homework for the therapy sessions, it will allow the patient to keep training what was learned during therapy. It is being developed as a serious game for smartphones, and users will only need a cardboard-like VR headset.

1 INTRODUCTION

The evolution of VR-based technologies is allowing the application of new medical procedures that otherwise were complicated or completely impossible. Mental health is one of the areas where this technology is being applied and where this work is focusing on. Every year, anxiety disorders affect nearly 18.1% of adults and are still registered as one of the most commons mental disorders (Saloni Dattani and Roser, 2021). Anxiety can become a daily obstacle for those who suffer from it, as it introduces significant distress, with consequent impairment in the quality of life. This is also a problem for the society since, as untreated mental health disorders become more severe, social and economic costs tend to increase (Botella et al., 2011).

Numerous authors have shown that VR experiences can be compared to real ones as VR scenarios can induce some sensations similar to the ones felt in the physical world (Penn and Hout, 2018). VR is being increasingly used in behavioural therapies, in particular in exposure therapies that consist in exposing the patient to anxiety triggers, so that learning, habituation, desensitization, or other, will help overcome or, at least, help in the process of managing it in the daily life. Long term studies show the effectiveness of VR to ET in the treatment of phobias (Krzystanek et al., 2021).

Exposure therapy has proved its efficacy in the last 20 years (Botella et al., 2011; Anderson and Molloy, 2020). Nevertheless, the traditional application of this treatment does not please everyone. Some patients fear the in-real-life confrontation with phobic elements and some therapists also tend to believe that in real-life exposure can be unethical by provoking uncontrollable fear to their patients and, depending on the disorder, by not being able to maintain the sessions private and violating the patient-client boundaries (Miloff et al., 2019). Therapists also avoid *in-vivo* exposure due to the time-consuming sessions and the work around it, for instance, catching and keeping a spider in the clinic for later reuse (Hinze et al., 2021). When compared to traditional exposure therapies, virtual reality counterparts tend to be accepted by both parties, and seen as more ethical, and helpful (Botella et al., 2011). They are also considered safer, and in most cases, as effective as *in-vivo* exposures (Anderson and Molloy, 2020). Another advantage of a VRET is the fact that it can be conducted in an medical office, even if the elements to be explored cannot be physically there (Miloff et al., 2019).

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One notable disadvantage of VR systems is their high prices. The development of this technology in the past four years, has led to a cost reduction and increased quality, and that makes this issue continually less significant. With the recent release of new and more inexpensive virtual reality headsets, clinical trials are more common and find high levels of user satisfaction with VR (Anderson and Molloy, 2020). Although cybersickness is still one of the major obstacles, considerable improvements in the devices' quality make this issue increasingly less significant. Also in this respect, the careful design of applications (Patrão et al., 2015), and the fact that most exposure scenarios do not need fast displacements in the VR space, may contribute to reduce the percentage of users experiencing this type of discomfort.

It is commonly accepted that VR and ET are useful with anxiety disorders, especially for disorders such as zoophobia, aerophobia, acrophobia, among others. However, psychologists who are specialized in other disorders like eating disorders, ADHD and OCD also believe VRET can be an alternative treatment with success (Lindner et al., 2019). In the case of OCD, VR is capable of provoking symptoms such as anxiety in patients and compare the results to healthy control. So, with the help of VR, therapists can recognize OCD symptoms and diagnose this disturb easier (Van Bennekom et al., 2021). Nowadays, the main question is no longer if VRET is indeed as effective as *in-vivo* ET, but how to engage the patient to keep working on himself and not giving up for lack of interest.

Since the concept of computer games has been emerging as a powerful new economic, cultural, and educational force (Botella et al., 2011), serious games are also becoming more popular among people of all ages.

Serious games, unlike traditional computer games, are alternative educational, training, or therapeutic tools that go beyond mere entertainment (Lievense et al., 2021) and are an effective medium for creating a non-threatening and engaging learning environment (Fitzgerald and Ratcliffe, 2020). It has been proven that serious games can change behaviour (Botella et al., 2011) and reduce disorder-related symptoms (Lau et al., 2017). It actively engages the player and promotes change within a safe virtual environment (Lievense et al., 2021), eliminating both the privacy issue and the out-of-control elements that worried the therapists. Since it has an entertaining form, the ethical conflict of provoking fear in the patients is also toned down and is more acceptable between professionals. This type of game places its goal outside the game itself. According to the self-determination theory, there are two types of motivation that may influence the retention of a person in one activity - extrinsic motivation and intrinsic motivation (Lievense et al., 2021). From a gaming perspective, extrinsic motivation leads to material rewards, or cheering messages for other players. For instance, when the player receives fictional coins to purchase bonuses or elements in the game. On the other side, intrinsic motivation is based on personal interest, the final reward is related to each individual (Fischer et al., 2019). Serious games thrive on intrinsic motivation since the player must have personal goals to succeed in the game. The different levels of the serious games are achieved with the acquisition of skills or therapeutic progress (Botella et al., 2011). If the players have a clear purpose and the goals and levels of the game are clearly defined, then the game is well accepted, and the engagement is enhanced (Fitzgerald and Ratcliffe, 2020). The use of serious games and gamification principles to promote treatment for mental illness had high levels of feasibility and acceptability among both users and providers (Fitzgerald and Ratcliffe, 2020). The current problem is no longer the effectiveness of VR and the application of exposure therapy, but the user experience itself that can lead to more positive or negative results (Tao et al., 2021).

The application of VR can follow quite different approaches. Some aim to develop an application for smartphones to be used at home without the presence and/or without the consultation of a therapist. These applications can sometimes be a serious game or a selection of VR scenarios that the user needs to explore. In this case, the progress achieved is measured by the user or by the application itself. However, this can make the situation worse by exposing the user to levels of disturbing elements that he/she is not prepared to face, thus incubating the fear even more.

The problem we perceived with the current home-use application, is that it does not engage the user to come home after a day of work to use it. This is a big problem with exposure therapy, as it requires constant exposure to the anxiety source to eventually overcome the problem. Other commonly used approaches consist of the application of VR in-clinic sessions with the constant presence of the therapist that walks through all the stages with the patient, and maintaining full control of the exposure level through out the session.

1.1 Contributions of the Paper

This work presents the development of a immersive application to promote learning and coping with anxiety, tuned for a specific clinical case. The ultimate

goal is to facilitate the therapist work and help the patient to reach a level of well-being by overcoming constraining anxiety and/or phobias.

To this end, a serious game is proposed that allows the user to have fun while learning how to manage his anxiety in the presence of whatever triggers it. The player levels up in the game as the therapeutic goals are met and according to the therapist. This serious game will aim at not only anxiety disorders but also other disorders such as OCD and ADHD, making it possible for the therapist to personalize it to the patient needs.

2 DESIGNING A FRIENDLY SPACE FOR ET

The concept explored is the development of a serious game to facilitate the application of ET for both the patient and the therapist. The patient can comfortably use the application at home by only needing a smartphone, and a VR headset for smartphones, such as Google Cardboard.

The design of the VR environment can integrate ET with different types of disorders elements. VR is commonly associated with anxiety disorders.However, psychologists believe that VR can also help other non-anxiety related disorders, and this serious game aims to meet those expectations.

Due to its high popularity among all ages and its versatility, the game "Escape Room" is one example of how this serious game can present itself. The player needs to complete several tasks and gather clues to escape the current room. By changing routines and adding new clues, the patient will be constantly entertained and stimulated to maintain engagement. It allows to prevent disinterest and consequently keep the patient exposed, as if the patient loses interest, the therapeutic progress will decrease. However, as the concept of this game may, on itself, trigger some disorders like claustrophobia, it can be changed to other possible less anxiety-prone games such as treasure hunting.

The escape-room scenario creates the perfect context to contain multiple and different mini-games. The disturbing elements are to be included in those, allowing the patient to take a break between exposures without leaving the VR environment and consequently not losing any sense of presence. In the case of arachnophobia, the anxiety disorder that will serve as an example throughout the article has a phobic element, the spider, so there are mini-games that only show images of it, and others present themselves with a virtual representation of the animal. Each mini-game addresses a different anxiety level and has small therapeutic goals. Since the patient must have a gradual exposure to the phobic elements, with the mini-games the patient can be exposed slowly from images to videos to the actual virtual presence.

3 DESIGN AND IMPLEMENTATION OF A VIRTUAL COMFY SPACE FOR ET

The mobile application developed has to address some complex issue in terms of displacement and interaction within the game. As for the home usage, the patient will use it in a cardboard configuration, therefore no joysticks, gamepads, or other game controllers should be considered. By consequence the only possibility is to use the head orientation itself to support the interaction with the VR environment in its various aspects, as will be discussed bellow.

This limited interaction form presented some challenges in the game's development, such as playing only moving the head and avoiding any fast movements to prevent motion sickness. As reported by (Anderson and Molloy, 2020), people who suffer from mental health illnesses tend to be more prone to cyber-sickness, so this was a subject that received particular attention.

3.1 Interact with the VR environment

To interact with the VR environment the patient can search for specific points that will light up to let him know that there is the possibility to interact with and a small pointing sphere will change colour to the inverted colour of the object that it collides with. The sphere simultaneously represents the point where the player is looking at in the game, and is the interaction element. In fact, its collision with the active elements of the virtual world is exploited to enable the player to select objects, move within the game space, or interact with the mini-games. Whenever the sphere is placed on top of an active element it immediately starts inflating showing the interactive control, and activating the element after a while.

Some places are important to the game flow, such as where a code can be inserted, or where the mini games are playable. Because of this characteristic, small blue moving circles are placed in those specific locals to grab the attention of the player that it is important to move at some point to that location as can be seen in Fig 1.

Since interaction is limited, and motion sickness is an issue, so travelling to different places in the room consists of a fade-in, turning the screen slowly black, and a fade-out in the correct position, turning the screen slowly back to the initial state, maintaining the rotation and the height the player was in. The player can only move in the ground plane.

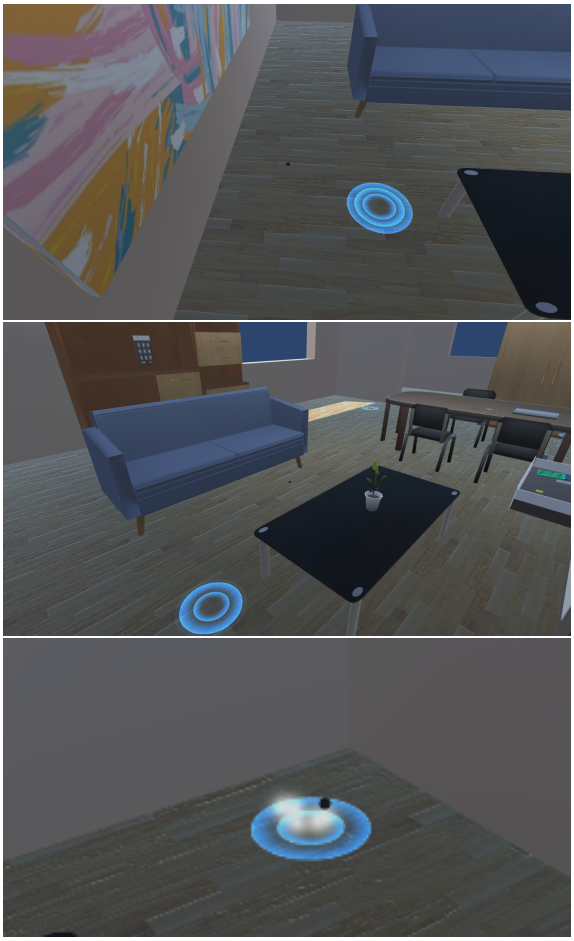

Figure 1: Teleport circle

3.2 The interaction with the mini-games

The serious game is sequential with an exposure ladder where some have a lower anxiety level and others are more intense. In the higher difficulty, all implemented anxiety sources are present. The game itself also has some variations between plays, such as different images and random placement of the matches in the case of a memory matching game card.

Since sometimes the patient can have more difficulties in an exposure given by a specific mini-game, the therapist can request the patient to play only that mini-game without the need to play the full serious game, and for that there is the possibility playing individual mini-games.

The interaction between each mini-game also needed to be analysed to create a random yet sequential relation between them. Upon completing each one, a digital code is provided to the player and acts as a bridge between the mini-games. The codes are presented differently, forming a final colour code to unlock the last door and finish the escape room (Fig 2). The mini games also present hints once finished like where the code is or to where it is to be inserted. For instance, as can be seen in Fig 4, once the drawer is opened a line of sparkle particles flow to the correct keypad. If the code inserted is correct it will change color to green, if not it changes color to red (Fig 3).

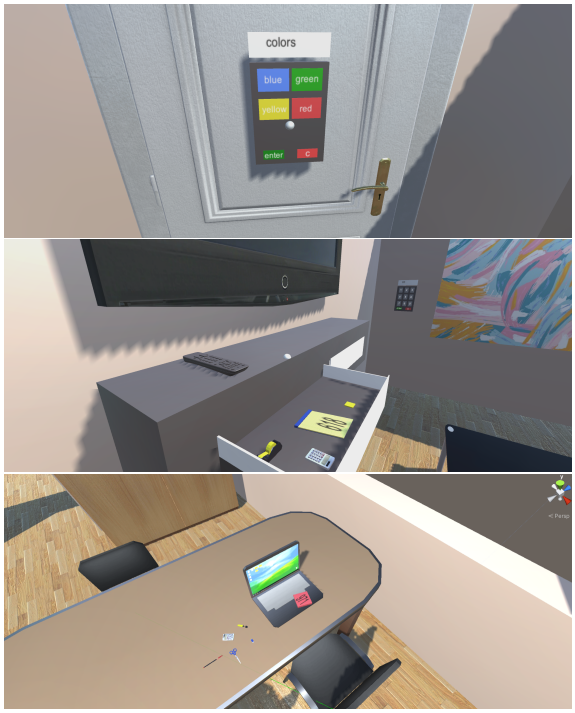

Figure 2: Color Code Keypad and Codes found.

The static mini-games such as memory card matching and puzzles are played in a similar manner. Spark particles appear where the player is staring at and like moving, the interactive sphere increases and when full the game develops. In the case of the ”find the differences game”, the spark particles do not show and the sphere does not increase unless it is to press the hint button. However it is still necessary to wait two seconds looking ate the same spot to play. This happens to avoid giving the difference location away. On more dynamic mini-games, like the maze, the phobic element follows the interactive sphere and the game is played by controlling its location.

Figure 3: Correct and wrong color code inserted.

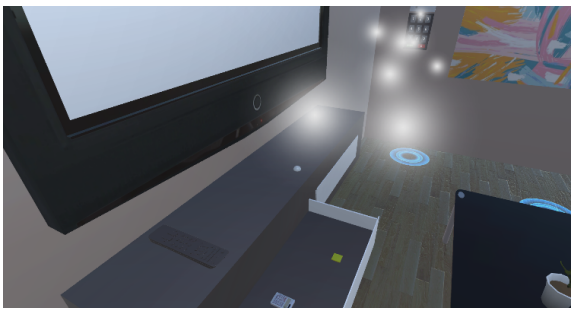

Figure 4: Hint after opening drawer.

4 BREAKING DOWN THE EXPOSURE INTO MINI-GAMES

The mini-games serve to expose the patient to the disorder element. The time between each mini-game act as a pause of exposure or even as a panic emergency escape. The patient can leave the mini-game, take a break wondering the virtual room and resume it when calmer, preventing the break of the sense of presence.

The serious game starts with all the mini-games hidden. When the patient inserts the codes onto the keypad, the corresponding mini-game uncover itself. Each one executes isolated, being coordinated by the main script. This format enables the therapist to require the patient to play only one of the mini games without it being necessary to play the escape room.

The chosen mini-games to develop in the concept of ”Escape Room” and arachnophobia are:

- Memory Card Matching
- Find the Differences
- Slide Puzzle
- Rotating Puzzle
- Maze

In the ”Memory Card Matching” mini-game (Fig. 5), the user has constant contact with different images of its anxiety source. When playing, if the cards turned do not make a pair, they turn themselves back. As the game proceeds, the number of images exposed increases, and the anxiety may make it harder to complete. The mini-game leads to the necessity to memorise a determined image’s position and details to correspond with its duplicate. This mini-game also allows the player to decide if he wants to see the inanimate disorder related element. In order to keep the challenge level constant between game session, each image position is randomized at the beginning of the game. After completing all the matches, a code appears in the room. This code will lead to the next mini-game.

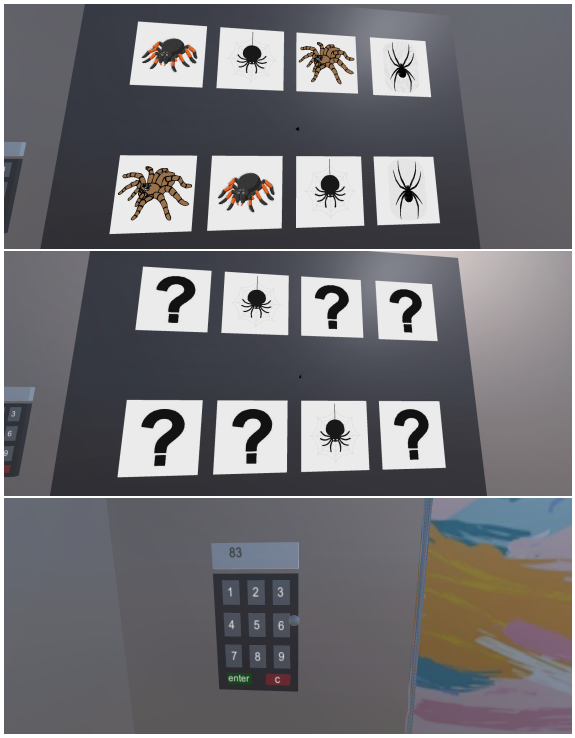

Figure 5: Memory Matching Card Game.

The ”Find the Differences” mini-game (Fig. 6) consists of two very similar images with slight differences between them which the user has to find and

mark.

The game starts hidden behind a closet. After acquiring the code from the memory matching card game, the player can insert it onto the keypad, and the mini-game appears. To play, the user selects a position on either the images. After waiting two seconds, if it corresponds to a difference, a red doughnut will target the spot as found. If not, then nothing happens.

If needed, a hint feature will help the player complete the mini-game. The hint consists of the phobic element moving towards the difference's position. Depending on the level of exposure, this element can be the phobic element. In the case of arachnophobia, a spider shows the patient where one of the differences is. All the animated phobic elements show a neutral white sphere if the patient is playing the lowest intensity.

Figure 6: Find the Differences Game.

The maze (Fig. 7), according to the selected disturb, may have different aspects. For instance, to OCD, the lines are not straight, and some lights turn on and off while passing on a specific part of the path. For ADHD, distractions such as random blinking lights or sounds can easily make it harder for the patient to concentrate on the task. If it is arachnophobia or other small animal-related phobias, the phobic element follows the position of the user's head, and the goal is to lead the animal to the end of the maze without it touching the walls. The maze path shuffles between predefined paths. Along the maze there are several platforms. The phobic element must touch every platform or the final color is not provided.

The last two mini-games are two different kinds of puzzles: a rotating puzzle and a slide puzzle, but the therapeutic goal is similar, making the patient gradually assemble the image related to the anxiety source. Nine pieces of the same image constitute the rotating puzzle, and the player needs to rotate each one, 90 degrees at a time, to build the final image and complete the mini-game. The slide puzzle consists of 8 pieces of the same image and a blank spot of the same size as the other parts of the image. The player must move the pieces within the available space until the final image appears.

Figure 7: Maze Game.

5 THE THERAPIST ROLE ON A CONNECTED APP

The presence of a therapist in this process is of high importance. It does not need to be a constant presence, but one-off checkups. The progress made by the patient needs to be analysed, and with those conclusions, the therapist decides which level of anxiety intensity the patient plays at home. The therapist has access to the patient progress by a data base. When the patient logs in, a code provided by the therapist is inserted and that data is saved and can be accessed later by the therapist.

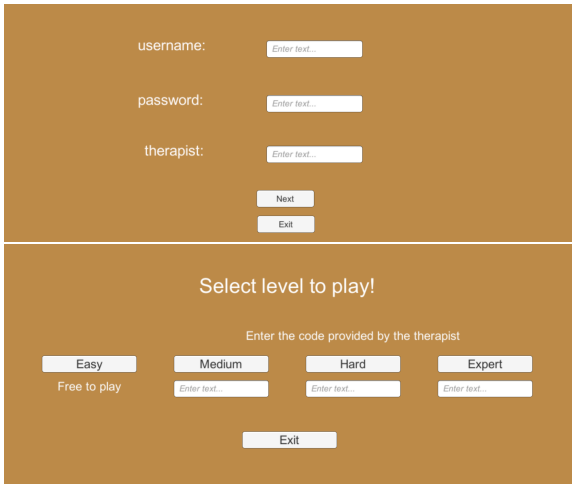

Figure 8: Login and game options.

The patient must play at least once every session for the therapist to evaluate the progress. The physiological signals such as the heart rate and galvanic skin

response will also target that evaluation.

During the development of the presented work, meetings with psychologists clarified the patients point of view and how to help and not overexpose them to the anxiety source. The therapist must be able to evaluate the situation step by step so the exposure remains controlled. So, to facilitate and help keep track of the patient progress, he has access to the scores of each mini-game and the total time of play of each patient. It is then possible to know how many times throughout the time-off sessions the patient played and the difficulty they faced.

6 PRELIMINAR VALIDATION

6.1 Game / Usability analysis

The game was tested by 10 individuals. At the end of each test, the individuals filled a User Experience Questionnaire (UEQ), a Flow Short Scale Questionnaire and an open answer questionnaire to obtain some information about the individuals.

The UEQ is frequently used to measure the user experience with a certain product. It evaluates the user experience in six different categories: attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. If a category is above 0.8 it has a positive evaluation and above 1.5 is considered and excellent result. The results are presented in figure 9. It presents the average classification of each category and its standard deviation. The attractiveness, efficiency, stimulation and novelty categories were all classified as excellent, although with a high standard deviation due to the sample size. The perspicuity and dependability had slightly lower scores with 1.225 and 1.375 respectively.

Perspicuity refers to how easy it is to get familiar with the application and how easy it is to use it. The application is a virtual reality serious game and in the open answer questionnaire most of the individuals lack of experience with VR so, being an VR "Escape Room" game it was expected some difficulties in interacting with the environment at first try. Dependability refers to how in control of the interaction the user feels. The serious game is a compilation of puzzles and codes, so the fact that some individuals felt they did not had control of the situation is not far from the reality.

The Flow Short Scale Questionnaire evaluates three aspects of the application on a scale of 1 to 7: flow, anxiety level and challenge level. Flow level indicates if the user is feeling engaged while playing the game and if he feels like the activity is intrinsically interesting and takes pleasure and enjoyment while involved with it. Anxiety level translates to how much anxiety the users felt while playing the game and challenge level to how challenging it was with 1 being too easy and 7 too hard.

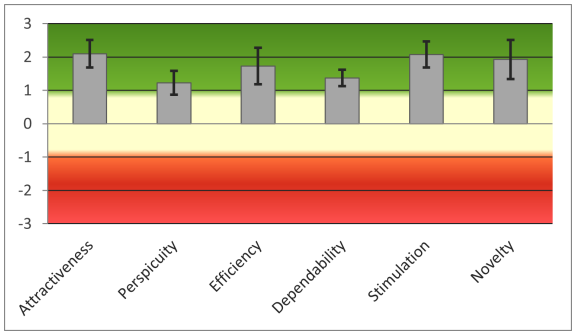

Figure 9: UEQ Questionnaire Results.

The results with the average and standard deviation of each category are presented in table 1. The challenge level was considered to be close to perfect (with 4 being a perfectly adequate challenge level). The anxiety level was not high but it presented a relatively high standard deviation. In the open answer questionnaire three individuals said to have anxiety problems such as anticipation anxiety. This may explain why such high standard deviation. A flow level of 5.04 indicates the users mostly enjoyed playing the game but some aspects could be improved such as adding descriptions of how the mini games are played and maybe a scene without any game to allow the user to get to know the VR environment.

	Average	Stardard Deviation
Flow	5.04	0.527
Anxiety	3.867	1.124
Challenge	3.9	0.568

Table 1: Flow Short Scale Questionnaire Results.

7 CONCLUSION

Exposure therapy is one of the best behavioural therapy techniques as it allows the user to explore the disorder in a safe and controlled way. This paper we presented a serious game for that purpose, that explores VR to expand the range of disorders that the treatment can reach and allow the patients to train at home and expose themselves to the anxiety source according to their therapist recommendations.

This type of application can be the starting point for many people to learn how to manage their anxiety and live life in a much better state of mind. As

the chosen game design can be so multifaceted, the opportunities are endless. Not only can different disorders like arachnophobia, PTS, OCD and ADHD be improved, but the therapist can adequate the game to each patient depending on the presented disorders and the best anxiety intensity levels for each one.

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