# A VIRTUAL REALITY SERIOUS GAME PLATFORM TO SUPPORT TREATMENT OF PHOBIA PATIENTS

by

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# Abstract

Phobias are an Anxiety Disorder with a significant percentage of the general population suffering from them. In recent years, Virtual Reality Exposure Therapy has emerged, that aids in the treatment of phobias using audiovisual virtual reality content. The aim of this dissertation was to improve upon the predecessing VRET implementations by utilizing the latest VR devices. The result of this is a prototype software, developed in the Unity Engine for Oculus Rift and supervised by a consulting psychologist, that offers an approachable VRET option to doctors and patients.

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# List of Terms and Acronyms

1. APA: American Psychiatric Association
2. CBT: Cognitive Behavioral Therapy
3. GUI: Graphical User Interface
4. IDE: Integrated Development Environment
5. In vivo: In a real-life situation
6. IPD: Interpupilary Distance – The distance between the two eye pupils.
7. MRI: Magnetic Resonance Imaging
8. NPC: Non-Player Character
9. NPC: Non-Player Character, A Game Character controlled by the computer, not the player
10. Serious Game: A Serious Game is a video game with a primary purpose other than entertainment, such as education, advertisement or medical treatment.
11. Simulation Game: A simulation video game describes a diverse super-category of video games, generally designed to closely simulate aspects of a real or fictional reality.
12. UI: User Interface
13. VR: Virtual Reality
14. VRET: Virtual Reality Exposure Therapy

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Author

Ioannis Kornarakis

# Dedication

Dedicated to my parents, Georgios and Stephania, without whom this could never have happened.

# Preface

This dissertation is original, intellectual product of the author, I. Kornarakis.

# Chapter 1 - **Problem**

## What is a phobia?

### *Definition*

“A phobia is a type of anxiety disorder, usually defined as a persistent fear of an object or situation the affected person will go to great lengths to avoid, typically disproportional to the actual danger posed.” (Bourne, 2011)

Going by Bourne’s definition, a phobia is a disturbance of the subject’s normal functions due to anxiety, triggered by a phobic stimulus. The nature of the phobic stimulus can vary greatly, which leads to different types of phobias, classified according to the stimulus triggering the anxiety.

### *Types*

Phobias can be classified as three distinct categories: Specific Phobias, Social Phobia, recently referred to as Social Anxiety Disorder, and Agoraphobia.

A specific phobia is excessive and persistent fear of a specific object, situation or activity that is generally not harmful. These fears cause such distress that some people go to extreme lengths to avoid what they fear. Examples are fear of flying or fear of spiders.

A person with social anxiety disorder has significant anxiety and discomfort about being embarrassed, humiliated, rejected or looked down on in social interactions. People with this disorder will try to avoid the situation or endure it with great anxiety. Common examples are extreme fear of public speaking, meeting new people or eating/drinking in public. The fear or anxiety causes problems with daily functioning and lasts at least six months. (American Psychiatric Association, 2013)

Agoraphobia is the fear of being in situations where escape may be difficult or embarrassing, or help might not be available in the event of panic symptoms. The fear is out of proportion to the actual situation and lasts generally six months or more and causes problems in functioning. (American Psychiatric Association, 2013) A person with agoraphobia experiences this fear in two or more of the following situations:

- Using public transportation
- Being in open spaces
- Being in enclosed places

- Standing in line or being in a crowd
- Being outside the home alone

(American Psychiatric Association, 2015)

The individual actively avoids the situation, requires a companion or endures with intense fear or anxiety. Untreated agoraphobia can become so serious that a person may be unable to leave the house. A person can only be diagnosed with agoraphobia if the fear is intensely upsetting, or if it significantly interferes with normal daily activities.

In any given year the estimated percent of U.S. adults with various phobias are:

- **7 to 9 percent:** specific phobia
- **7 percent:** social anxiety disorder
- **2 percent:** agoraphobia

(American Psychiatric Association, 2015)

According to (Culbertson, 2016), there are over 530 documented types of phobias while (Olesen, 2016) states the ten most common phobias as:

1. Arachnophobia – The fear of spiders.
2. Ophidiophobia – The fear of snakes
3. Acrophobia – The fear of heights.
4. Agoraphobia – The fear of open or crowded spaces.
5. Cynophobia – The fear of dogs.
6. Astraphobia – The fear of thunder/lightning AKA Brontophobia, Tonitrophobia, Ceraunophobia.
7. Claustrophobia – The fear of small spaces like elevators, small rooms and other enclosed spaces.
8. Mysophobia – The fear of germs. It is also called Germophobia or Bacterophobia.
9. Aerophobia – The fear of flying.
10. Trypophobia – The fear of holes. While not recognized by the APA [1], trypophobia is an “unusual but common phobia” (Cole & Wilkins, 2013).

### *Severity*

The severity of phobias varies among individuals. Some can avoid the phobic stimulus and only suffer mild anxiety, while other can exhibit full-fledged panic attacks. These individuals often report dizziness, loss of bladder or bowel control, tachypnea, feelings of pain, and shortness of breath. (Tamparo & Lewis, 2011)

# How are phobias treated?

## *Brief overview of phobia treatments*

It is generally advised to seek treatment for a phobia when:

- It causes intense and disabling fear, anxiety and panic
- The sufferer recognizes that the fear is excessive and unreasonable
- Certain situations and places are avoided because of the phobia
- The avoidance interferes with the normal routine or causes significant distress
- The phobia has persisted for at least six months

While in recent times medication has been used to treat severe phobia cases, the prevalent treatments are self-help strategies and psychotherapy or “talk therapy” (American Psychiatric Association, 2015). Phobia psychotherapy has a record of working well and results are noticeable in as few as one to four sessions. (Smith, Segal, & Segal, 2016)

## *Treatment types*

There are five main types of Specific Phobia treatment.

***Specific Phobia Treatment Options:***

- Cognitive-behavioral therapy

  **Cognitive-behavioral therapy (CBT)** has been effective in treating specific phobias. There has not been much research on the effects of cognitive therapy alone on specific phobias. Cognitive therapists challenge fearful thoughts and replace them with more positive thoughts. Several studies indicate that real-life (in vivo) desensitization or exposure is the most effective and long-lasting treatment for a broad range of specific phobias. **Systematic Desensitization** includes a process by which individuals unlearn the association between the phobic stimulus and anxiety. Incremental exposure involves the patient's gradual facing of the phobic stimulus through a series of graded steps. As a counterpart to Systematic Desensitization there is also the **Flooding** therapy technique. Flooding is a behavior therapy for phobias and other problems linked to maladaptive anxiety, in which triggers are presented in intense forms, either in imagination or in real life; the presentations are continued until the stimuli no longer produce disabling anxiety; the hope is that by 'overloading'–i.e. flooding the person's psyche with the dread event or object, anxiety is exhausted and the patient learns to cope with largely irrational fears. (McGraw-Hill Companies Inc., 2002)

- Psychodynamic therapy

  **Psychodynamic psychotherapy**, or insight-oriented therapy assists patients to become more aware of the symbolic nature of their anxiety and to explore traumatic past events.

- Group Therapy

  There is little research on **group therapy** for specific phobia disorder. Some studies suggest that group treatment has been effective for dental and spider phobias.

- Medications

  There has been a paucity of research on the relationship between medication and specific phobias. Generally, pharmacotherapy has not been considered to be a treatment of choice for individuals with specific phobias.

- Alternative therapies

  Research shows some benefits for specific phobias with applied relaxation. Some alternative therapies include **immersive virtual reality**, **hypnotherapy**, **eye-movement desensitization and reprocessing (EMDR)**, and **energy balance approaches** such as massage and acupuncture.

(Koenigsberg, 2003)

***Social Phobia and Agoraphobia Treatment Options:***

Social Phobias are accessible to two forms of scientifically validated treatments: **anti-depressant drugs** and **CBT** (Science Writing, Press & Dissemination Branch, 2013).

Similarly, Agoraphobia responds well to **medicine** and **CBT** (American Psychiatric Association, 2015).

As medicinal treatments are strictly confined to medical practitioners and biologists, we will focus on non-medicinal treatments that can be enhanced through technology (Barnett, 2011).

## *Therapy specifications*

*In vivo* therapy for phobias takes place in either the therapist's office or in a public place where the phobic stimuli can be encountered. In the first case, the stimulus is often absent (dependent on specific phobia) and the patient is tasked with imagining it, lowering the actuality factor of the experience, and in the latter case, accessing the stimulus can be:

- Costly
- Embarrassing for the patient
- Physically endangering to the patient, and more often than not
- Uncontrollable.

Following the above specifications we can observe that traditional therapy could be improved if it were:

- Independent of the treatment environment
- Realistic, lifelike, immersive and convincing.
- Available in the privacy of the therapist’s office or patient’s own home.
- Safe.
- Controlled by the therapist and/or patient.

## Problem definition

The problem, that this thesis attempts to offer a solution for, is the lack of a Phobia Therapy tool that can help psychologists treat their patients and that meets the aforementioned specifications.

One of the approaches that both satisfies these specifications and connects Phobia Treatment with the Informatics and Multimedia field is Virtual Reality Exposure Therapy (VRET) (Brinkman, et al., 2013).

# Chapter 2 - **Solution**

## Current VRET-based solutions

### *Overview*

Virtual Reality Exposure Therapy (VRET) is an exposure therapy using artificial or computer-generated sensory experiences, which may be effective for treating phobic disorders. (McGraw-Hill Companies, Inc., 2002)

VRET has been shown to successfully treat a number of phobias, both Specific (Carlin, Hoffman, & Weghorst, 1997; Garcia-Palacios, Hoffman, Carlin, Furness III, & Botella, 2002; Rothbaum, et al., 1995; Shibana, Schelhorn, Pauli, & Mühlberger, 2015; Parsons & Rizzo, 2008) and Social (Klinger, et al., 2005; Winerman, 2005) as well as other Anxiety Disorders (Beck, Palyo, Winer, Schwagler, & Ang, 2007; Krijn, Emmelkamp, Olafsson, & Biemond, 2004; Powers & Emmelkamp, 2008; Wiederhold & Wiederhold, 2005). Variations of VRET include Augmented Reality (AR) Exposure Therapy (Corbett-Davies, Dünser, & Clark, 2012), a home-based VRET system (Hartanto, et al., 2015), using Video Games as a form of phobia therapy (Hawort, Baljko, & Faloutsos, 2012) and others.

Three VRET implementations stand out: The Virtual Reality and Phobias project (Brinkman, et al., 2013), The Virtual Reality Medical Center's approach (The Virtual Reality Medical Center, 2016) and PhoVR (Haworth, Baljko, & Faloutsos, 2012).

The Virtual Reality and Phobias project is a collaboration between the Interactive Intelligence group of the Electrical Engineering, Mathematics and Computer Science faculty of Delft University of Technology and Clinical Psychology section of the University of Amsterdam. The project offers a VRET experience to phobia patients, has experimented with different VR techniques, has aided in many studies supporting the effectiveness of VRET and has developed multiple modules spanning multiple phobias. Delft University of Technology handles the Human Computer Interaction (HCI) and technical aspects of VR part, while University of Amsterdam deals with exposure therapy and the psychological aspects of virtual reality.

The Virtual Reality Medical Center has a functioning, ongoing VRET program situated in San Diego, CA, USA, treating phobia patients. In their own words: "Virtual reality exposure therapy places the client in a computer-generated world where they "experience" the various stimuli related to their phobia. The client wears a head-mounted display with small TV monitors and stereo earphones to receive both visual and auditory cues.” The Virtual Reality Medical Center has received several awards, such as the UCSD CONNECT, Springboard Assistance Winner award in 2007, the NIH, SBIR Showcase for National Institute on Drug Abuse in 2005 and Patients’ Choice Award for 2015.

PhoVR is a VRET system developed in Unity 3D, utilizing Microsoft Kinect to give patients a presence in a Virtual World in which they can face their fears. The system is operated and the patient is monitored through the internet by the clinician and the visual stimuli are presented on a normal display.

### *Learnings*

One thing that can be learned from these three outliers is that, since they have not been updated in a long time and as such they have not taken advantage of recent advances in Virtual Reality, the proposed solution needs to implement state-of-the-art technology. Furthermore, graphic fidelity must be focused on as perception and cognition are highly interrelated (Tacca, 2011), as such, it can be observed that the outliers do not demonstrate high-fidelity graphics, something that in first-person view environments contributes to the user immersion (Khine, 2011). Last but not least, there is not one single implementation that encompasses all capabilities of VR application: immersion, high-fidelity, presence and interactivity, and that is exactly what the proposed solution should aim to do.

## Proposed solution

### *Overview*

The proposed solution, and subject of this thesis, is a Virtual Reality software, designed in the form of a Serious Game, to be used for the Treatment of Phobia Patients. The patients will be introduced to the stimulus of their phobia in a 3D, high fidelity, Virtual environment in which they will be able to move and interact with existing objects around them. To begin with, a prototype will be developed aiming for a claustrophobia treatment in two different scenarios: **1.** Elevator and **2.** Static, confined space, for example, a small storage room, a phone-booth, etc. Both scenarios will have multiple alternate versions to better suit the needs of the patients and the session goal of the therapist. The scenarios will be suited for both Systematic Desensitization and Flooding treatment approaches, depending on the therapist's guidance, and follow a therapy plan created previously (Kostaki, 2015). The Serious Game medium was chosen as it has been proven effective in psychological treatments (Stetina, Felnhofer, Kothgassner, & Lahenbauer, 2012).

Once the prototype is finished, a study will be conducted by a psychologist (Kostaki, 2015) to test the effectiveness of this application on a phobia patient sample. The software will be developed in Blender 3D and Unity 5 with the Oculus Rift VR Device in mind. Once the software has been proved to be effective, the alternative choices for a VR Device, such as the Samsung VR, Google Cardboard and HTC Vive, will be re-examined, taking into consideration their market presence.

Should it be decided that this project should be developed further, it can be enhanced with the addition of Microsoft Kinect support (Microsoft, 2016), biofeedback devices (BIOTRONIK SE & Co.KG, 2016) and other technologies that would help with the immersion of the patient, such as elevating platforms (Bronto Skylift, 2016), omnidirectional control treadmills (Virtuix, 2016), haptic feedback devices (Neurodigital Technologies, 2016) etc.

## *Benefits*

The proposed solution includes all the aspects of other successful implementations. By combining a dedicated VR device such as the Oculus Rift with an interactive game environment, a "physical" presence can be established in the Virtual environment, which would greatly help with the immersion of the patient and the "in vivo" factor of the treatment.

In that regard, the heightened attention to the visual design and creation of high fidelity, realistic assets, also serves to improve the immersion of the user.
Additionally, with the recent upward curve of VR devices development, the acquisition cost of a device is steadily being reduced while the quality of the devices themselves is improving every day, which makes for a relatively cheap, good solution.

Finally, should the treatment studies show this project to be effective in treating phobias, it will be localized in languages where a treatment options like this has been previously unavailable, such as Greek and Estonian.

# Chapter 3 - **Designing the Software**

## Intended Use

Following professional guidance (Kostaki, 2015), it was decided that the software should be used by the patient in conjunction with the treating psychologist: The patient would view, experience and move in the environment in Virtual-Reality, while the psychologist would monitor him and control the scenario, for example, pausing the normal game flow if the patient is getting too agitated, or controlling the behavior of the elevator. The software could also potentially be used by the patient alone, using a controller to interact with the environment, as a form of self-therapy.

The proposed treatment plan for claustrophobia covers two types of scenarios, elevators and other small, closed spaces.  The plan is as follows:

### *Elevators*

a. The patient can approach an elevator and can choose to get in it or not. The elevator is located in a new building and is spacious.

b. The patient goes into the elevator and can see himself inside it in a mirror. The elevator is spacious, with good lighting and soft music, with one other person inside it.

c. A slightly smaller elevator in a new building, but on the outside looks newer than on the inside, as if it is renovated. There is music and slightly less bright lights than before.

d. Same elevator as on the previous scenario, but this time the elevator can get stuck between floors.

e. Old elevator, without a security door, same lights as in the previous scenario, no music.

f. Old elevator with flickering lights, shaking a lot, no music and no security door.

### *Closed Spaces*

a. A small room (2x2 meters), with soft colors, airy and sunny. The patient is standing up.

b. Same room as previous scenario, worse lighting and stuffy atmosphere, standing up.

c. Much smaller room (1x1 or even 0.5x0.5 meters), with moderate lighting, standing up.
d. Very small room (phone booth), moderate lighting, standing up.
e. Very small room (phone booth), bad lighting, sitting down.
f. Inside an MRI machine, lying on the back.

Similar treatment plans would be designed for other phobias, as the aim is to create a complete product that encompasses treatment for numerous phobias.

## Designing process

The first step of designing a software like this, is to write a description of what the software should be and what it should be able to do, and extract from that the actors, use cases, requirements, which will help in the rest of the design process. The text written for this purpose is:

> The goal of this project is to create a Virtual-Reality serious game to help psychologists treat phobia patients. The game should run on personal computers and potentially also on mobile devices. The game should utilize 3D models and graphics to achieve a high degree of fidelity and realism. The user, that could be either the psychologist or the patient, should be able to create a profile that will save all useful data in a patient log. The user should then be able to select a scenario to enter and experience in Virtual-Reality. In the scenario, the user should be able to move around the environment and interact in some ways with it, such as opening doors or activating elevators. The user should be able to, at any time during the scenario, choose to exit it or quit the game entirely. When the scenario has served its purpose in the treatment, the user should be able to finish and exit it.

And the extraction of design elements can be seen below:

**Table 1 Data Extracted from Text Analysis**

| No. | Candidate Class | Type |
|---|---|---|
| 1 | Virtual-Reality | Requirement |
| 2 | Serious Game | Requirement |
| 3 | Psychologist | Actor |
| 4 | Patient | Actor |
| 5 | User | Actor |
| 6 | Personal Computers | Requirement |
| 7 | Mobile Devices | Requirement |
| 8 | 3D Models and Graphics | Requirement |
| 9 | Select a Scenario | Use Case |

| | | |
|---|---|---|
| 10 | Interact | Use Case |
| 11 | Exit | Use Case |
| 12 | Quit The Game | Use Case |
| 13 | Create a Profile | Use Case |
| 14 | Move | Use Case |
| 15 | Finish | Use Case |
| 16 | Save All Useful Data in Patient Log | Sub-Process |

The software used for the textual analysis and all subsequent software analysis diagrams was Visual Paradigm.

The most useful design steps for this conceptualized software would be:

- A Requirements Diagram
- A base Class Diagram of the Game Engine's classes and objects used
- A Use Case Diagram depicting what actions the user can take when using the software
- A Data Flow Diagram, going at least to Level-1, of the entire system
- An activity diagram of the Graphical User Interface.

## Best Practices for Virtual Reality

Best practices are methods that help provide high quality results, and are especially important when working with an emerging medium like VR.

When creating VR content, it is important to focus on creating fun, immersive, and engaging interactions. To be successful, certain practices must be followed in order to avoid eye strain, prevent feelings of disorientation and nausea, and to protect people from motor-visual functioning issues after use.

If VR experiences ignore fundamental best practices, they can lead to simulator sickness in some people. Simulator sickness is a combination of symptoms clustered around eyestrain, disorientation, and nausea. Historically, many of these problems have been attributed to sub-optimal VR hardware variables, such as system latency, but even with a flawless hardware implementation, improperly designed content can still lead to an uncomfortable experience.

Because VR has been a fairly esoteric and specialized discipline, there are still aspects of it that haven't been studied enough for anybody to make authoritative statements, and it is still too young a medium to have established conventions that address every aspect of the experience. This makes user testing of the content absolutely crucial for designing engaging, comfortable experience.

The practices best applicable to this project are listed below:

### *Rendering*

- Maintain VR immersion from start to finish. For example, don't affix an image in front of the user, such as a full-field splash screen that does not respond to head movements, as this can be disorienting.
- The images presented to each eye should differ only in terms of viewpoint; post-processing effects (e.g., light distortion, bloom) must be applied to both eyes consistently as well as rendered in z-depth correctly to create a properly fused image.

### *Minimizing Latency*

- Your code should run at a frame rate equal to or greater than the Rift display refresh rate, v-synced and unbuffered. Lag and dropped frames produce judder which is discomforting in VR.
- Game loop latency is not a single constant and varies over time. Do everything you can to minimize *variability* in latency across an experience.

### *Optimization*

- Decrease eye-render buffer resolution to save video memory and increase frame rate.
- Dropping the eye-render buffer resolution while maintaining display resolution can improve performance with less of an effect on visual quality than doing both.

### *Head-tracking and Viewpoint*

- Avoid visuals that upset the user's sense of stability in their environment. Rotating or moving the horizon line or other large components of the user's environment in conflict with the user's real-world self-motion (or lack thereof) can be discomforting.

- The display should respond to the user's movements at all times, without exception. Even in menus, when the game is paused, or during cut scenes, users should be able to look around.

### *Positional Tracking*

- The rendered image must correspond directly with the user's physical movements; do not manipulate the gain of the virtual camera's movements. A single global scale on the entire head model is fine (e.g. to convert feet to meters, or to shrink or grow the player), but do not scale head motion independent of interpupillary distance (IPD).
- With positional tracking, users can now move their viewpoint to look places you might have not expected them to, such as under objects, over ledges, and around corners. Consider your approach to culling and backface rendering, and so on.
- Under certain circumstances, users might be able to use positional tracking to clip through the virtual environment (e.g., put their head through a wall or inside objects). Our observation is that users tend to avoid putting their heads through objects once they realize it is possible, unless they realize an opportunity to exploit game design by doing so. Regardless, developers should plan for how to handle the cameras clipping through geometry.

### *Accelerations*

- Acceleration creates a mismatch among your visual, vestibular, and proprioceptive senses. Minimize the duration and frequency of such conflicts. Make accelerations as short (preferably instantaneous) and infrequent as you can.
- Remember that "acceleration" does not just mean speeding up while going forward; it refers to any change in the motion of the user, whether in direction or speed. Slowing down or stopping, turning while moving or standing still, and stepping or getting pushed sideways are all forms of acceleration.

- Have accelerations initiated and controlled by the user whenever possible. Shaking, jerking, or bobbing the camera will be uncomfortable for the player.

### *Movement Speed*

- Viewing the environment from a stationary position is most comfortable in VR; however, when movement through the environment is required, users are most comfortable moving through virtual environments at a constant velocity. Real-world speeds will be comfortable for longer. For reference, humans walk at an average rate of 1.4 m/s.

- Movement in one direction while looking in another direction can be disorienting. Minimize the necessity for the user to look away from the direction of travel, particularly when moving faster than a walking pace.

### *Cameras*

- Do not use “head bobbing” camera effects. They create a series of small but uncomfortable accelerations.

### *Managing and Testing Simulator Sickness*

- Test your content with a variety of un-biased users to ensure it is comfortable to a broader audience. As a developer, you are the worst test subject. Repeated exposure to and familiarity with the Rift and your content makes you less susceptible to simulator sickness or content distaste than a new user.

- An independent visual background that matches the player’s real-world inertial reference frame (such as a skybox that does not move in response to controller input but can be scanned with head movements) can reduce visual conflict with the vestibular system and increase comfort.

### *Controlling the Avatar*

- User input devices can't be seen while wearing the Rift. Allow the use of familiar controllers as the default input method.

### *Content*

- Design environments and interactions to minimize the need for strafing, back-stepping, or spinning, which can be uncomfortable in VR.

- Don’t forget that the user is likely to look in any direction at any time; make sure they will not see anything that breaks their sense of immersion (such as technical cheats in rendering the environment).

### *Avatar Appearance*

- When the avatar is meant to represent the players themselves inside the virtual environment, it can detract from immersion if the player looks down and sees a body or hands that are very different than his or her own. For example, a woman’s sense of immersion might be broken if she looks down and sees a man’s hands or body.

(Oculus VR., 2016)

## Finalizing the Design

To design the end-product, some choices needed to be made regarding the software and hardware used. To that end, it was decided that the human models would be created in MakeHuman, additional models would be created in Blender, textures would be created using stock photos, GIMP and AwesomeBump, sound would be edited in Audacity, the software would be developed in Unity 5 and the VR device used would be Oculus Rift. More info on the software and VR device used, along with reasons for choosing them, can be found in the Appendix.

### ***Requirements***

The Functional Requirements of the Software are that it must support Virtual-Reality, that it works on a personal computer and potentially a mobile device, and that it is a Serious Game.

The Virtual-Reality support requirement is satisfied by researching into Virtual-Reality devices, choosing an appropriate one to use, and picking a Game Engine that supports development for that device.

The “Works on a Personal Computer” and subsequently “Works on a Mobile Device” requirements are satisfied by developing on a Game Engine that can build for both platforms. From those functional requirements however, a performance requirement is derived, and that is that it runs “well” on either a personal computer or a mobile device. By “well” it is meant that it runs at a smooth framerate that does not impact the realism of the software. To satisfy that, tests must be conducted on the running performance of the software, and it should be optimized until the performance is deemed sufficient.

Finally, to satisfy that the software is a Serious Game, both aspects of the definition need to be satisfied, first that this is a game, and second that it is a Serious Game.

As a game by itself, it falls under the simulation game super-category of video games. A simulation game attempts to copy various activities from real life in the form of a game for various purposes such as training, analysis, or prediction. Usually there are no strictly defined goals in the game, with players instead allowed to freely control a character (Jones, 1995).

The essential attribute ‘Conflict’ of the game, which is represented in games as the dynamic, human or computer-controlled obstacles which prevent a player from easily reaching their goal (Sauvé, Renaud, Kaufman, & Marquis, 2007), is in this implementation the various functions of the elevators, such as shaking or flickering lights, and the design of the environment itself, in conjunction with the inner conflict of the player stemming from his phobia.

The Predetermined Goal required is to achieve what each scenario expects of the player, be it successfully using the elevator to reach the upper floor or spending an adequate amount of time in the small room.

To be able to classify this game as a Serious Game, while is of course designed to have a goal other than entertainment, it should also be tested for its designed effectiveness by a psychologist and a control group. In this way, both aspects of the Serious Game definition are covered.

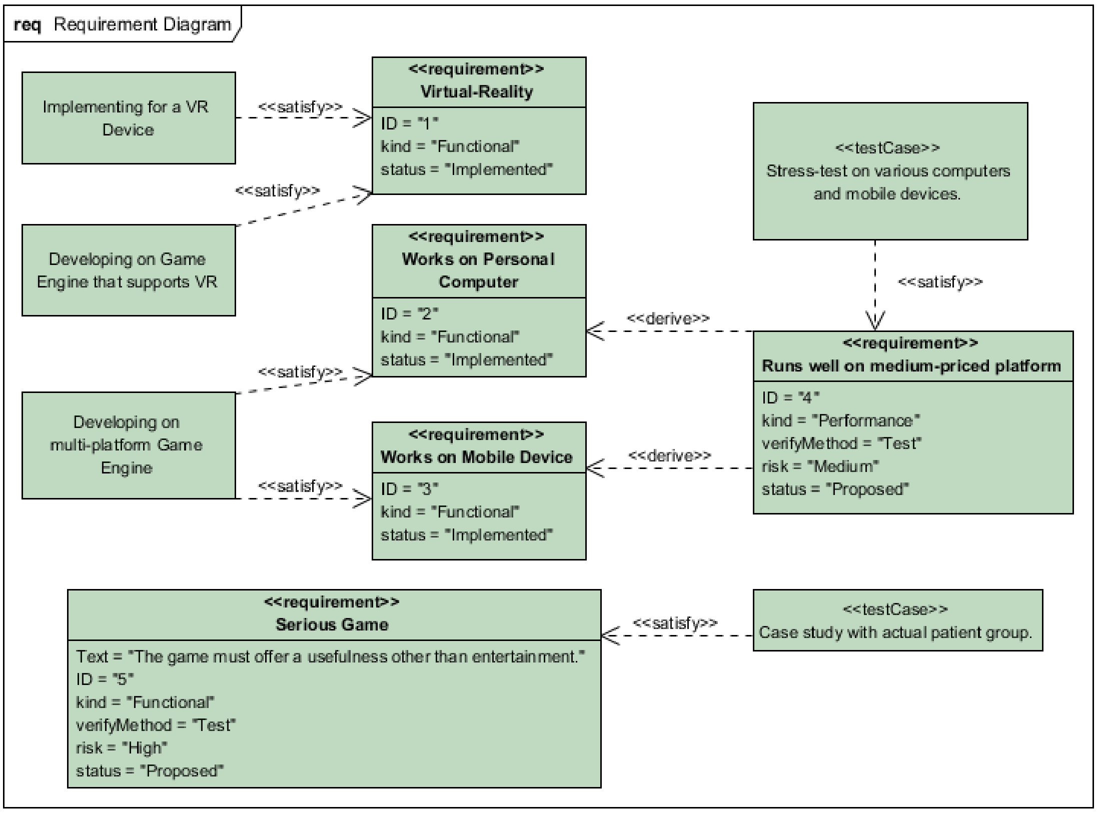


**Figure 3-1 Requirements Diagram**

### *Class Hierarchy*

The Game Engine chosen that satisfies the above criteria is Unity 5. While Unity 5 is developed in a class-centered way itself, the game development editor it offers follows a component based hierarchy system instead. At the same time, this component-centered system stems from a C# class hierarchy system, but that is not very visible to the game editor user. For the above reason it was deemed more sensible to make a Class Diagram of the root unity object, the GameObject, that is utilized throughout the development, along with the various types of components that would be used in this software.

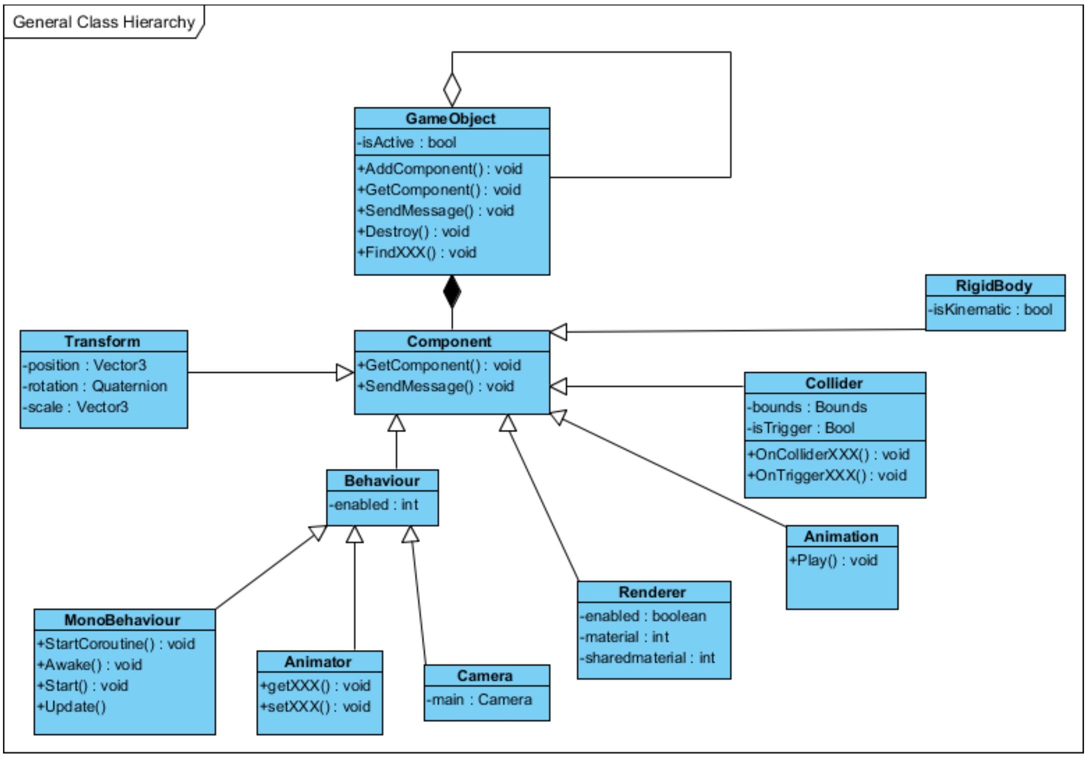


**Figure 3-2 GameObject Class Diagram**

### *Use Cases*

As the user would alternate between two game states, being in the interface or being in a scenario, it was decided that those two states would be represented as two separate systems in the Use Case Diagram. The initial actions that the user can take upon starting the software are to “Manage the Profiles” or “Start a Scenario”. Managing the profiles entails creating new profiles and selecting a profile for the current session. Starting a scenario leads to the selected scenario loading, and the user being able to move freely around it and interact with certain elements. Once already inside the scenario, the user can choose to finish it and return back to the interface.

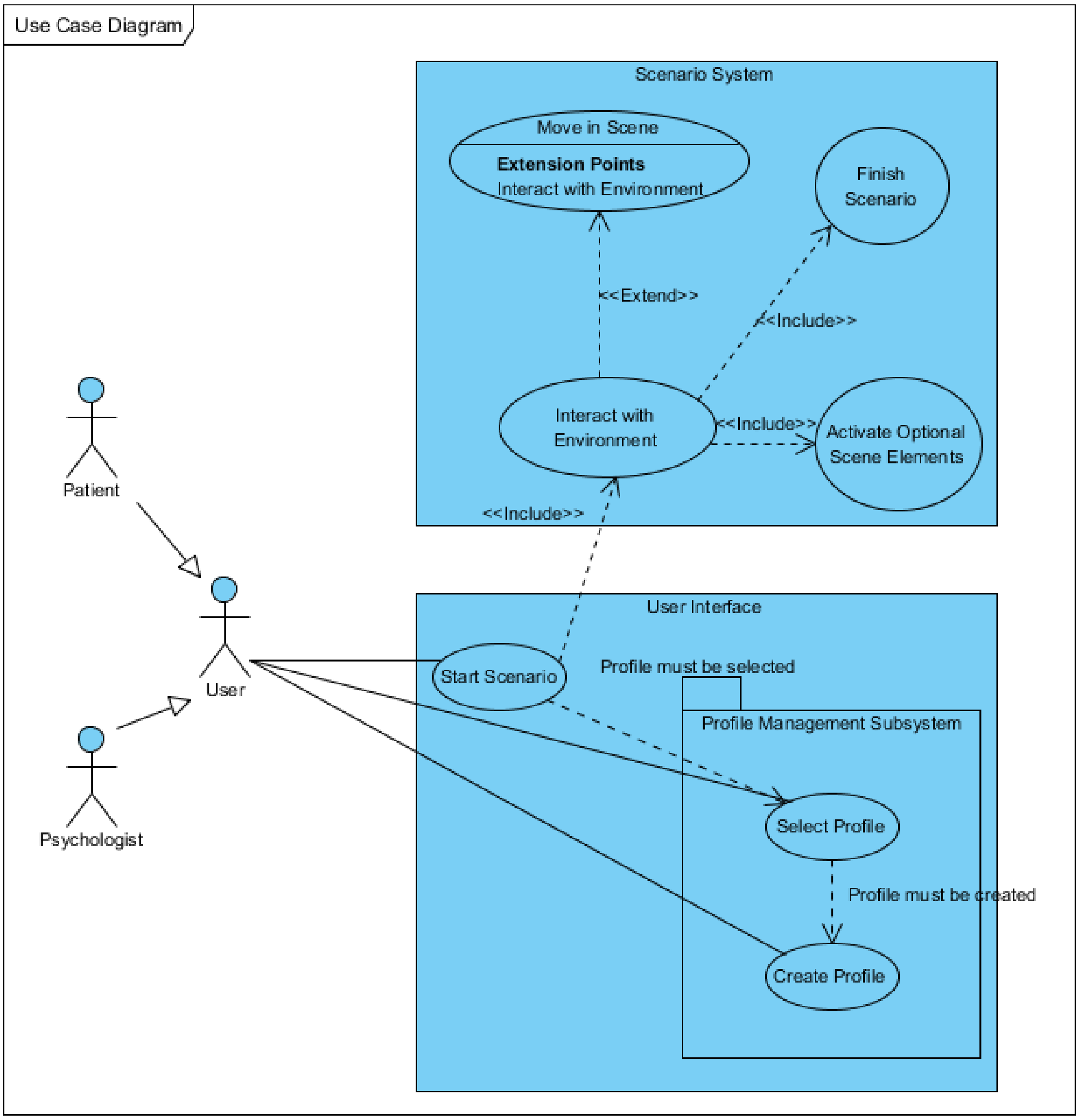


**Figure 3-3 Use Case Diagram**

### *Data Flow*

A Data Flow diagram describes how information moves around the system. For this, a more general overview of the system is required, so thought was given to the Virtual Reality device usage, and the profile system.

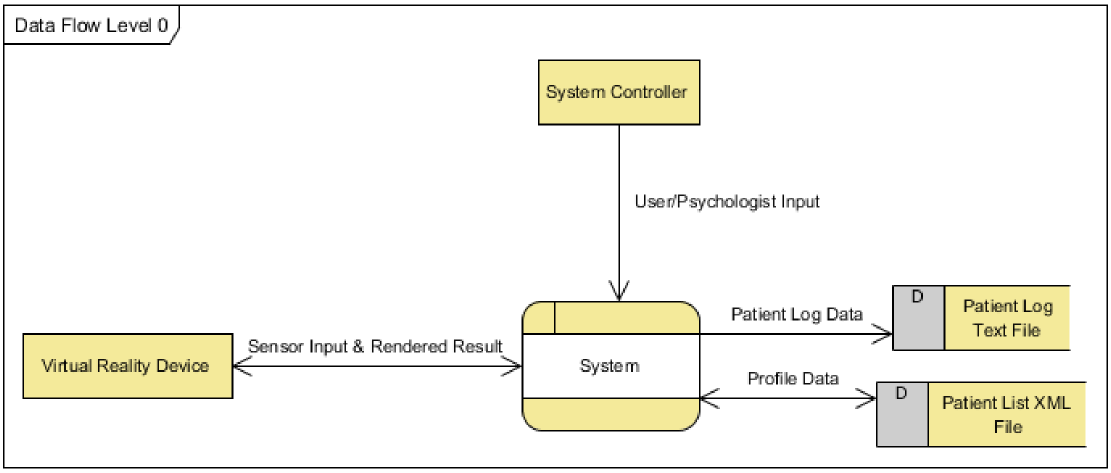


**Figure 3-4 Data Flow Level 0**

As seen in the above diagram, the system takes input from the controller (keyboard, mouse, alternative input devices) and the Virtual Reality device sensors, and outputs to the Virtual Reality device. Additionally, it exchanges data with a storage system, an XML file that stores the patient profiles, and writes data to a Patient Log that would be useful to the supervising psychologist.

The following diagram goes in more depth and visualizes the inner workings of the entire system and more specifically how the individual parts communicate with each other.

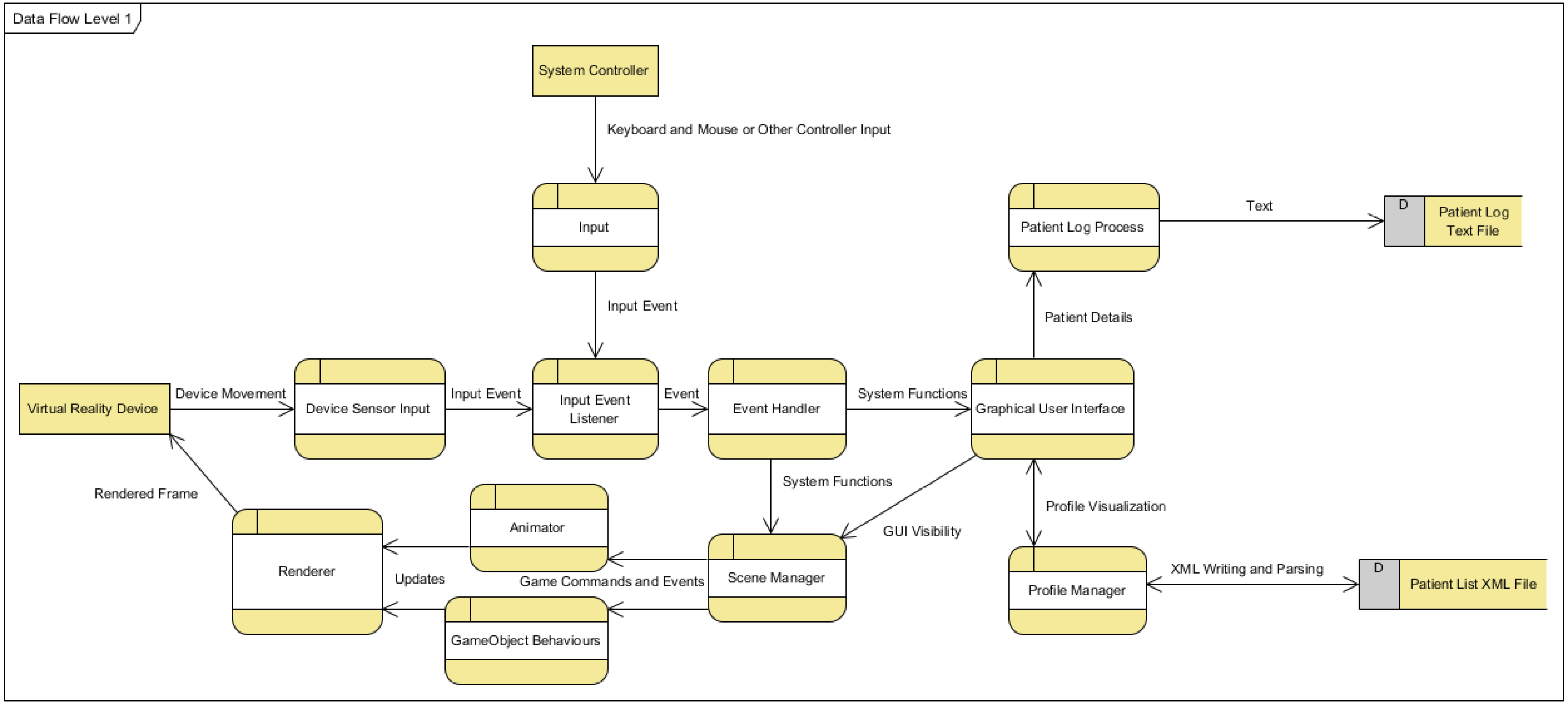


**Figure 3-5 Data Flow Level 1**

In this Data Flow diagram, we can see the VR device captures its own movement through its Sensors, which transfer them as input to the system. Similarly, the more conventional input devices transfer their own input, such as keypresses or mouse clicks, to the system.

Input from both sources are caught by the system's Input Event Listener, which recognizes them and passes the appropriate events to the Event Handler. The Event Handler fires off functions both towards the GUI system and the Scene Manager. The Scene Manager contains everything that is visible to the User.

The GUI functions are used to navigate the interface, as well as connect it with the Patient Log and Profile Manager processes. The Patient Log process outputs plaintext to the Patient Log text file, while the Profile Manager process both reads and writes to the PatientList XML file. As mentioned, the Scene Manager is responsible for everything that the user sees, so the GUI system also notifies the Scene Manager for the visibility status of all parts of the interface.

The system functions interacting with the Scene describe animations and game object behaviors. Examples of those could be the opening of a door and the flickering of a light.

Once everything has processed the information given, the pass any updates to the renderer, so the updated scene can be represented visually.

This visual result is then returned to the Virtual-Reality device so it can be displayed to the user.

### *Interface Activities*

The Interface Activity Diagram below describes all possible actions at every step of navigating the Graphical User Interface. The Interface is divided into two interconnected parts, the Main Menu, which is what the user sees when he starts the software and is located on its own separate scene, and the In-Game Menu, which is overlaid over the Scenario Scenes at runtime.

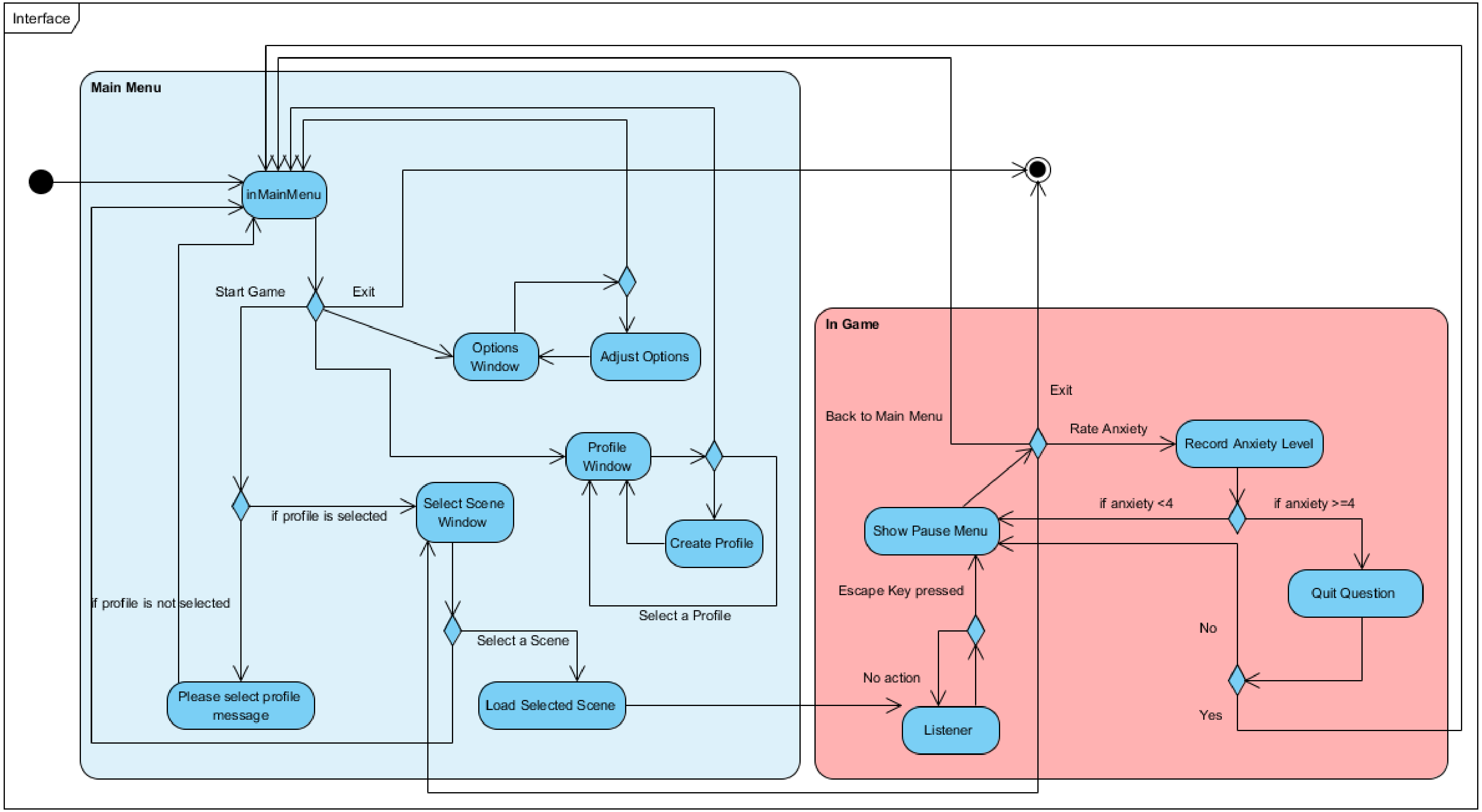


**Figure 3-6 Interface Activity Diagram**

## *Content Design*

Transmuting the Treatment Plan into Game Design and Game Elements can be seen in the table below.

**Table 2 Treatment Plan to Game Design**

| **Elevator Scenario** | |
|---|---|
| **Plan** | **Design** |
| The patient can approach an elevator and can choose to get in it or not. The elevator is located in a new building and is spacious. | Modern, grand reception hall with two modern elevators at the far wall, with soft music playing. The player can walk in the elevator and end the level. |
| The patient goes into the elevator and can see himself inside it in a mirror. The elevator is spacious, with good lighting and soft music, with one other person inside it. | Same environment as before. An NPC is inside the elevator. Player can use the elevator to reach the upper floor and end the level. |
| A slightly smaller elevator in a new building, but on the outside looks newer than on the inside, as if it is renovated. There is music and slightly less bright lights than before. | Apartment or office building. Not new but in good condition. Elevator is smaller and less decorated. Player can use it to reach the upper floor and end the level. |
| Same elevator as on the previous scenario, but this time the elevator can get stuck between floors. | Same building as before. Elevator can stop mid-movement when the physician chooses at the press of a button. |
| Old elevator, without a security door, same lights as in the previous scenario, no music. | Old apartment building with narrow corridors. Elevator is old and plain. Player starts in the top floor and can use it to reach the ground floor. Elevator functionalities remain from previous scenarios. |
| Old elevator with flickering lights, shaking a lot, no music and no security door. | Same environment as before, but with worse lighting and more noise and shaking. |

| **Closed Space** | |
|---|---|
| **Plan** | **Design** |
| A small room (2x2 meters), with soft colours, airy and sunny. The patient is standing up. | Small storage room in the countryside. Mostly empty with an open window. Daylight. |
| Same room as previous scenario, worse lighting and stuffy atmosphere, standing up. | Same room but with half broken shelves and boxes inside. Window is closed. Past Sunset. |
| Much smaller room (1x1 or even 0.5x0.5 meters), with moderate lighting, standing up. | Town square, Britain-style phone booth. |
| Very small room (phone booth), moderate lighting, standing up. | Busy street, Britain-style phone booth. Slightly smaller than before. |
| Very small room (phone booth), bad lighting, sitting down. | Small, uncomfortable restroom, in a public place, i.e.: small restaurant |
| Inside an MRI machine, lying on the back. | Hospital room, player lying on the MRI table. Physician can move the player in or out. |

### ***Framework***

An overview of the whole Framework can be seen below:

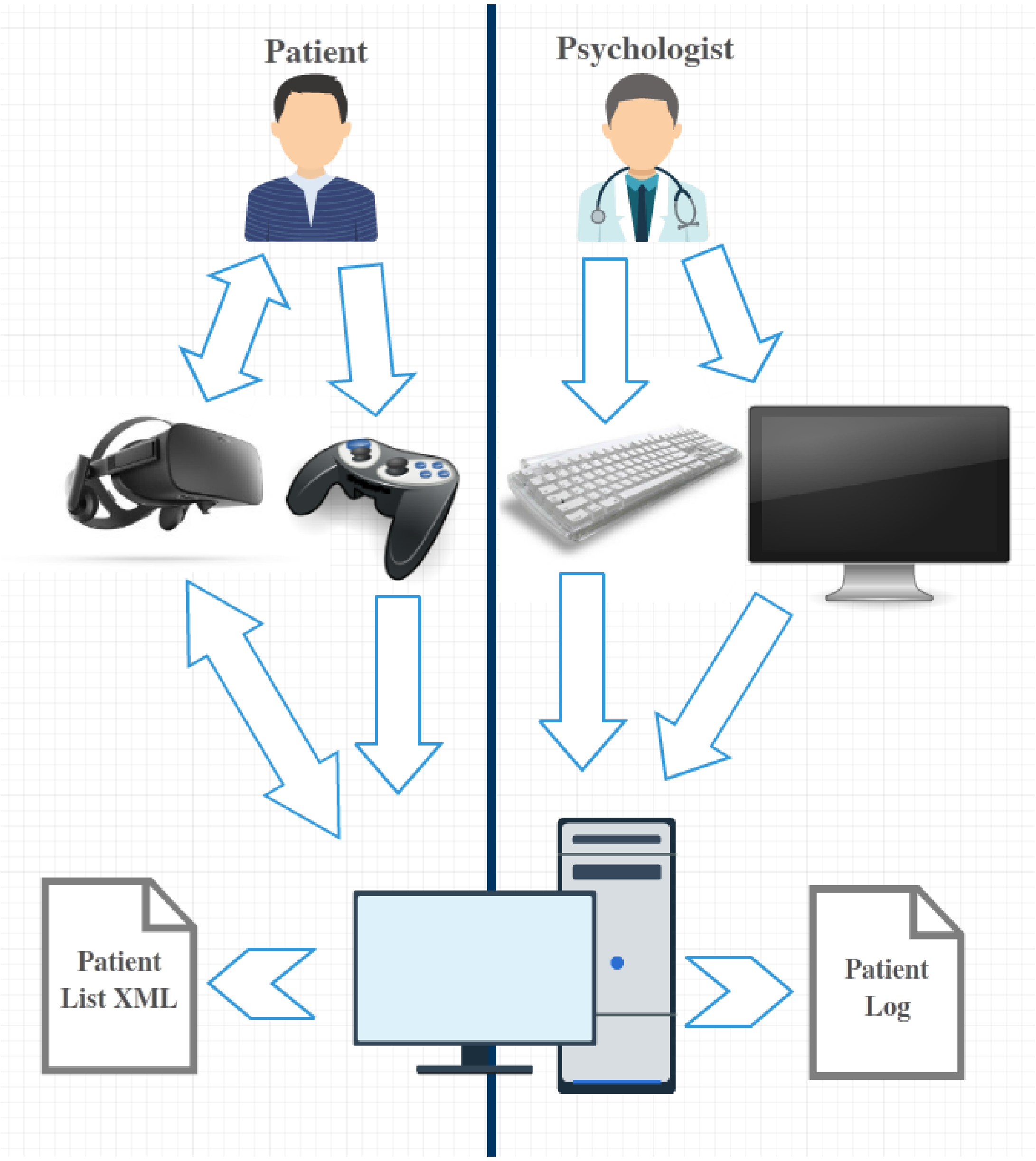


**Figure 3-7 Framework Diagram**

# Chapter 4 - **Development**

## Prototype content

The prototype developed during this thesis only covers one phobia: claustrophobia, the fear of small spaces. All 12 scenarios from the devised treatment plan are implemented. The GUI is fully functional and the Profile system is complete. The Patient Log keeping process is also working but it might need to be extended after initial testing.

The player avatar is also dependent on the gender selection in the Profile, with a male and a female model animated and controllable.

The software visual output is rendered in stereoscopic 3D and viewable through the Oculus Rift device. Movement of the device defines the viewing camera position and rotation, while avatar movement is controlled with a gamepad joystick. Additional game controls, such as activating the elevators or executing scenario-specific functions are delegated to the keyboard. The visual output is also rendered in normal, non-stereoscopic 3D on the monitor.

## Workflow

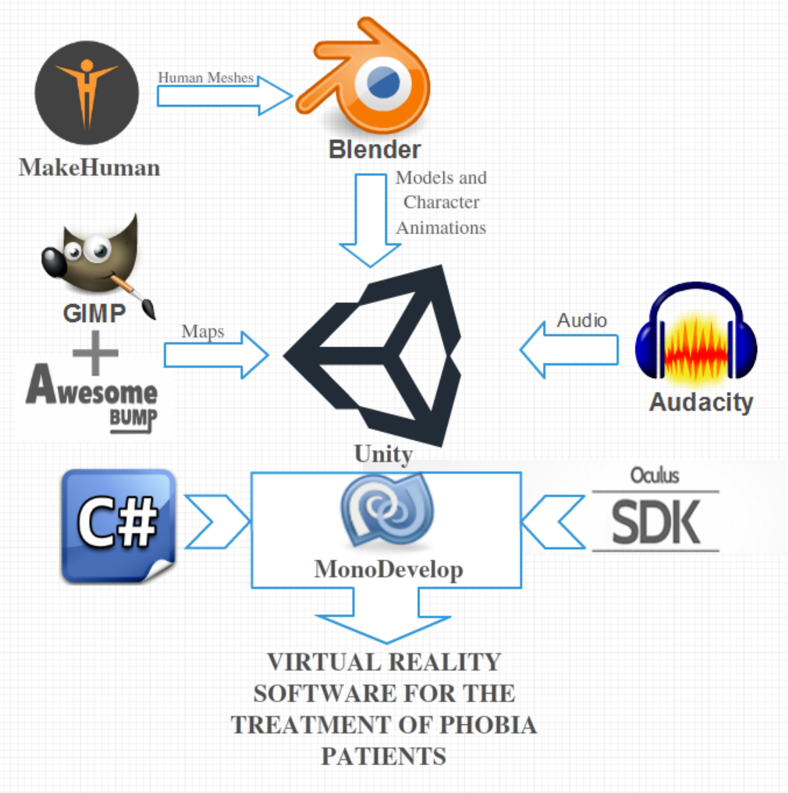

MakeHuman
Human Meshes
Blender
Models and Character Animations
GIMP
Awesome BUMP
Maps
Unity
Audio
Audacity
C#
MonoDevelop
Oculus SDK
VIRTUAL REALITY SOFTWARE FOR THE TREATMENT OF PHOBIA PATIENTS

**Figure 4-1 Development Workflow**

### *Workflow Explanation*

The 3D models for the Avatars and Non-Player-Characters (NPCs) were created in MakeHuman - one male and one female model, designed to be as generic as possible to minimize the effect on player immersion.

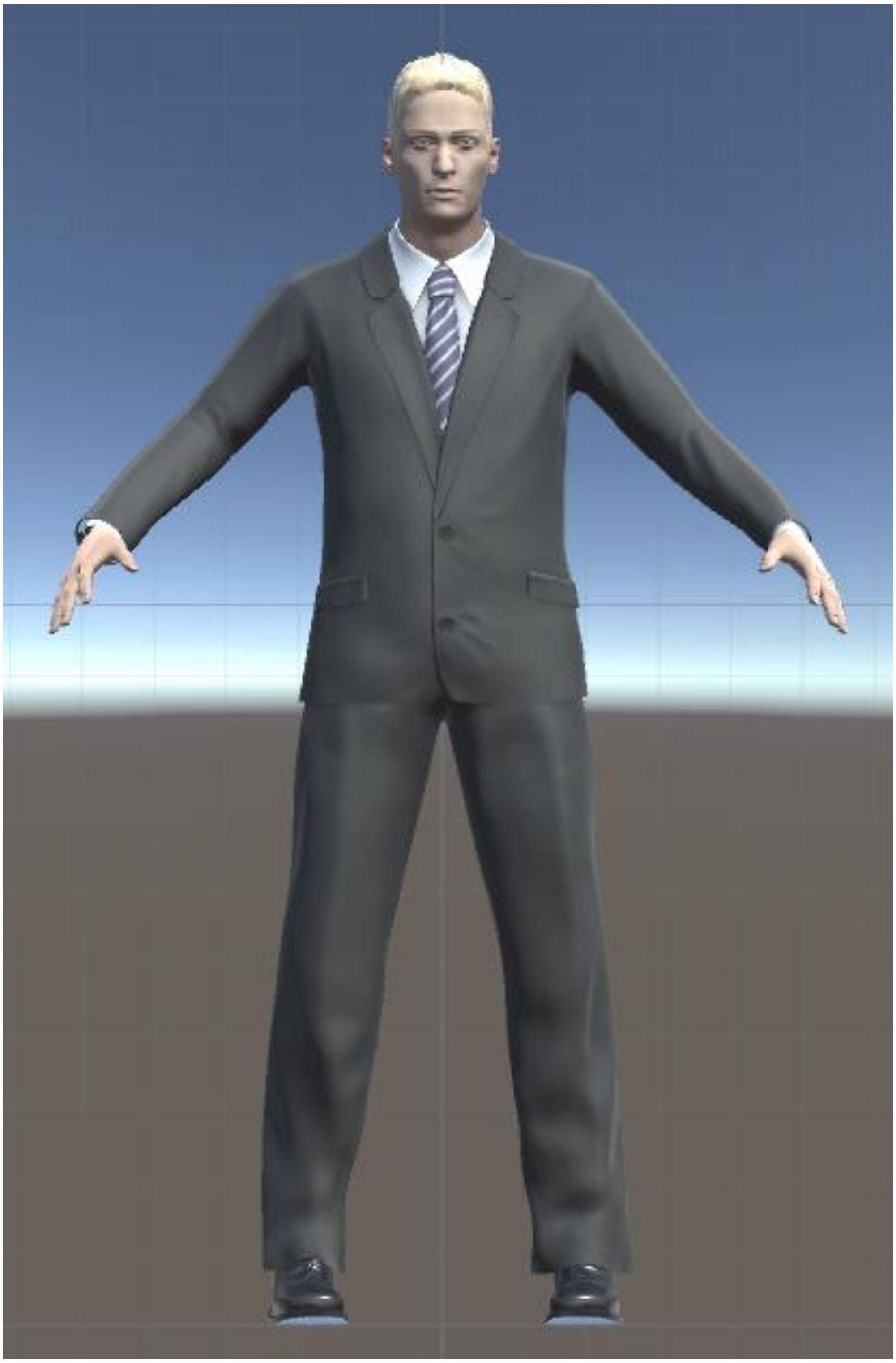


**Figure 4-2 Male Model**

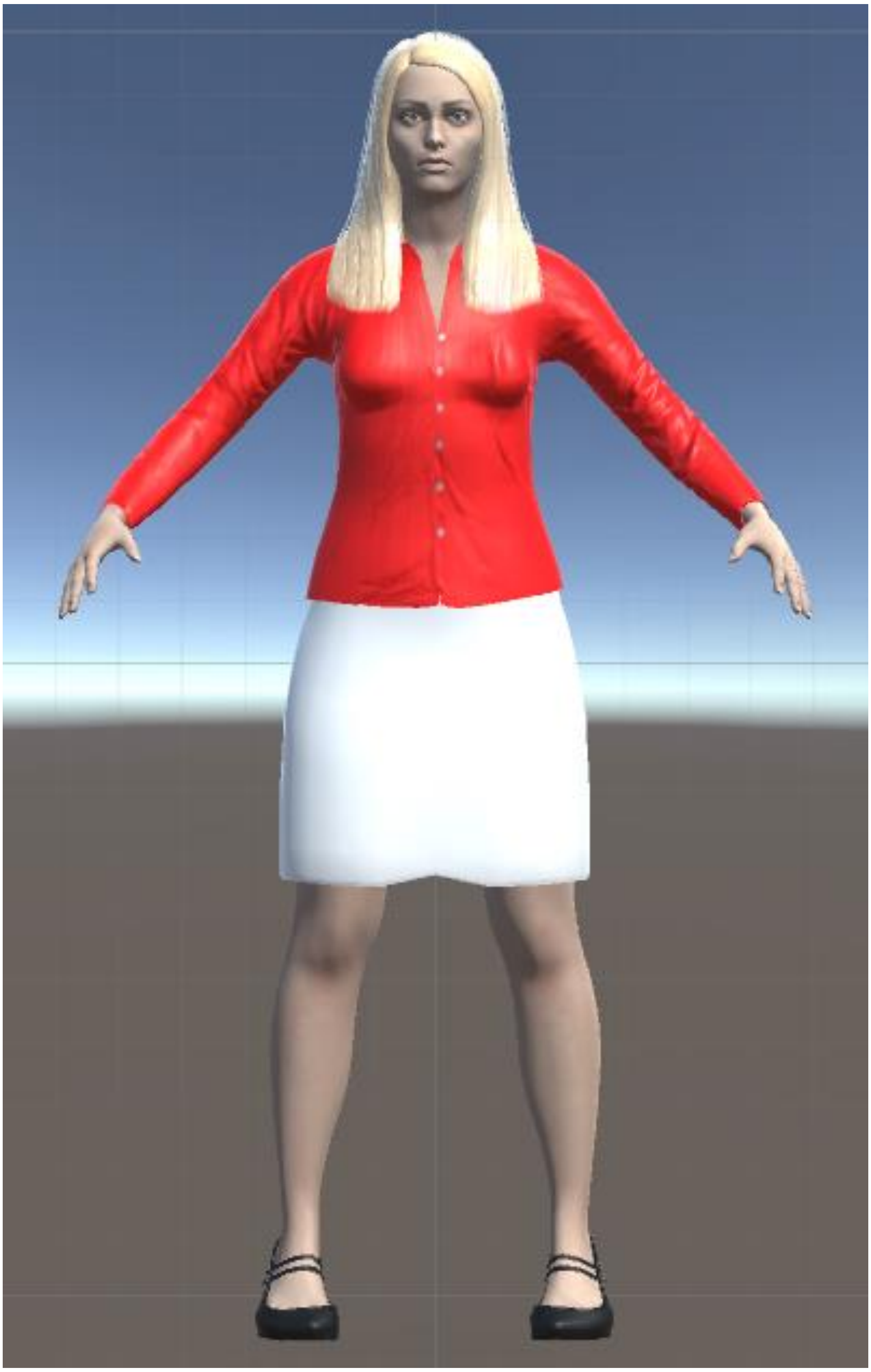


**Figure 4-3 Female Model**

The models were imported to Blender where they were animated. The 3D environments for each scene were also modelled in Blender, along with an assortment of other models, such as furniture, to be used as environmental elements in those scenes.

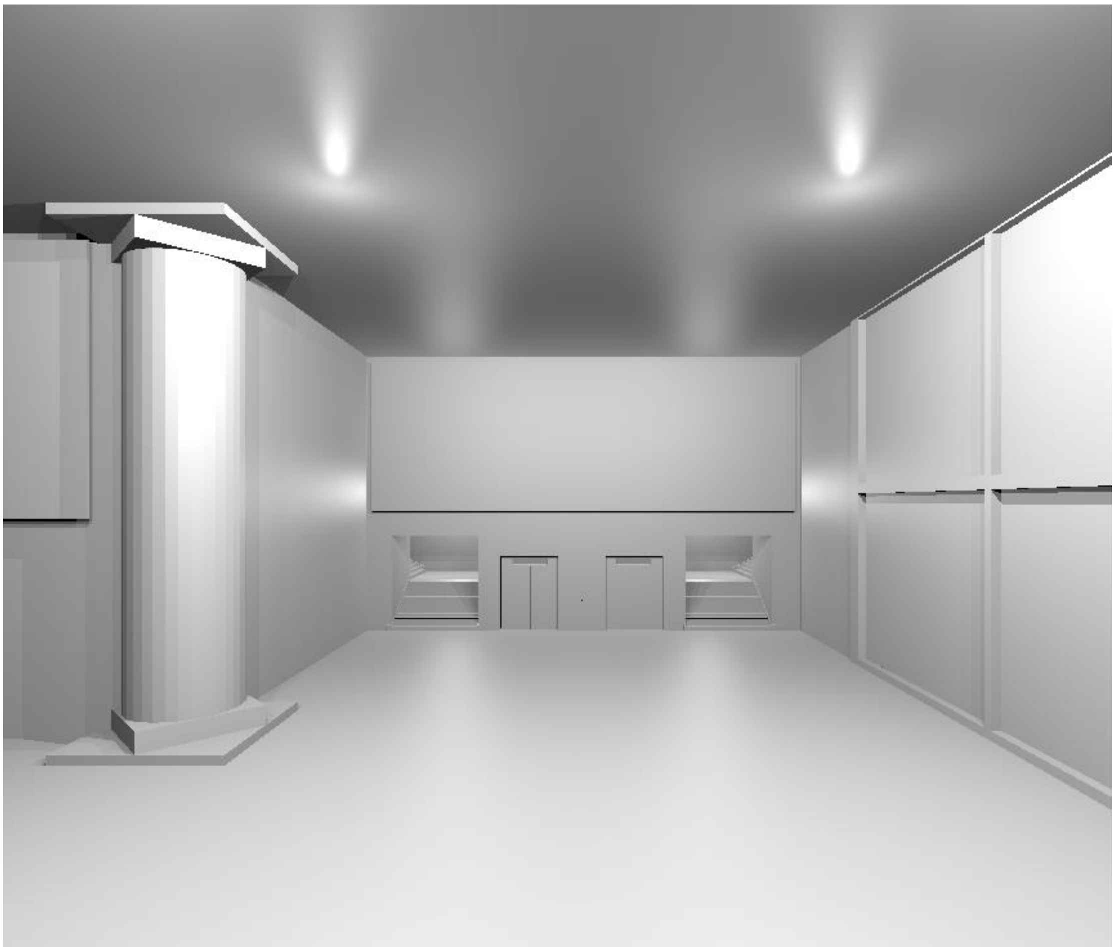


**Figure 4-4 New Building Model**

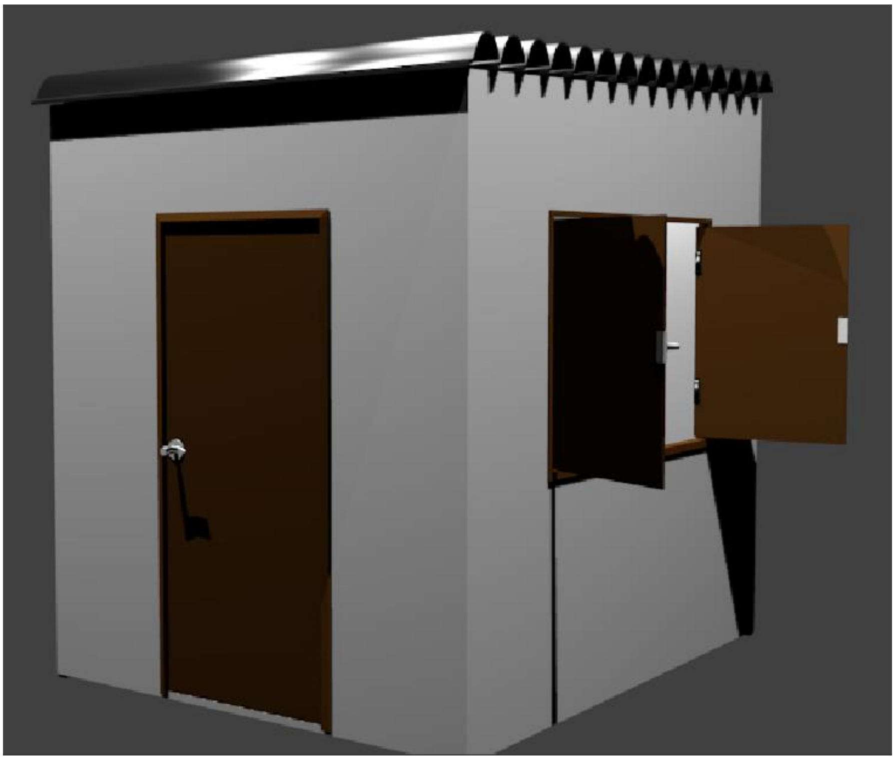


**Figure 4-5 Storage Room Model**

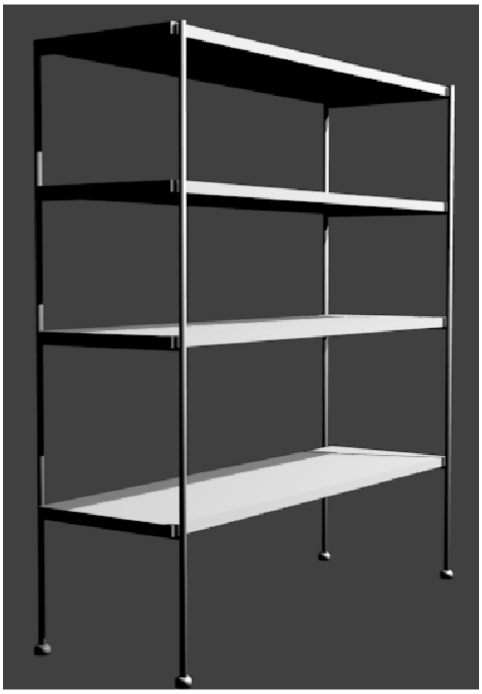


**Figure 4-6 Shelves Model**

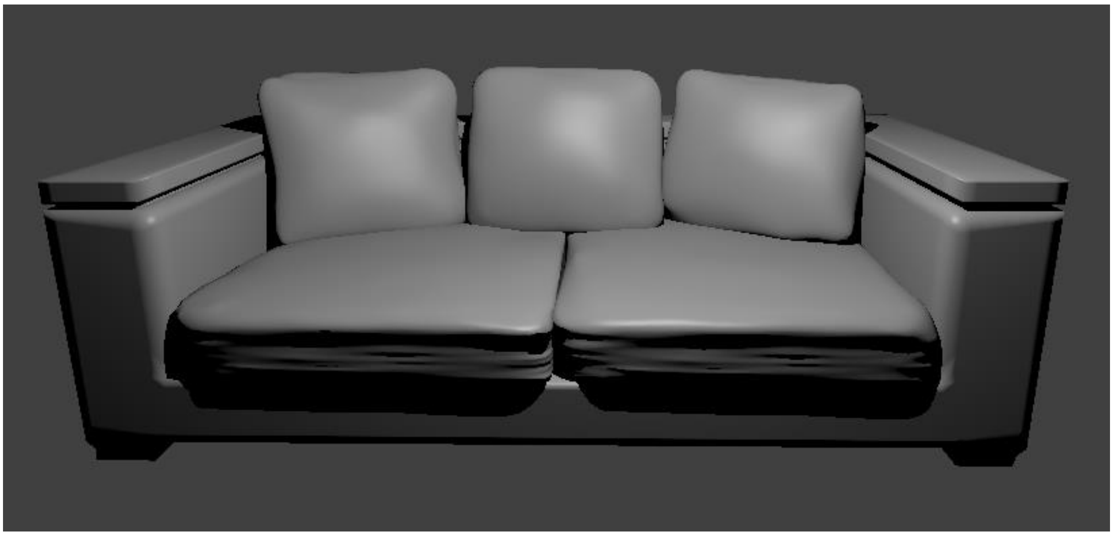


**Figure 4-7 Couch Model**

The texture diffuse maps were created from royalty-free pictures, edited with the image manipulation software GIMP when they needed to be fitted to specific UV Layouts.

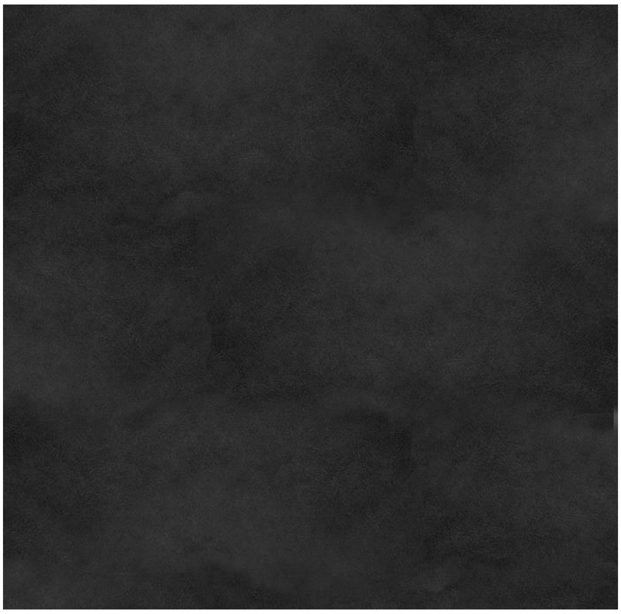


**Figure 4-8 Black Leather Diffuse Map**

When additional maps were needed, these maps were then imported into AwesomeBump to generate Normal and Specular maps.

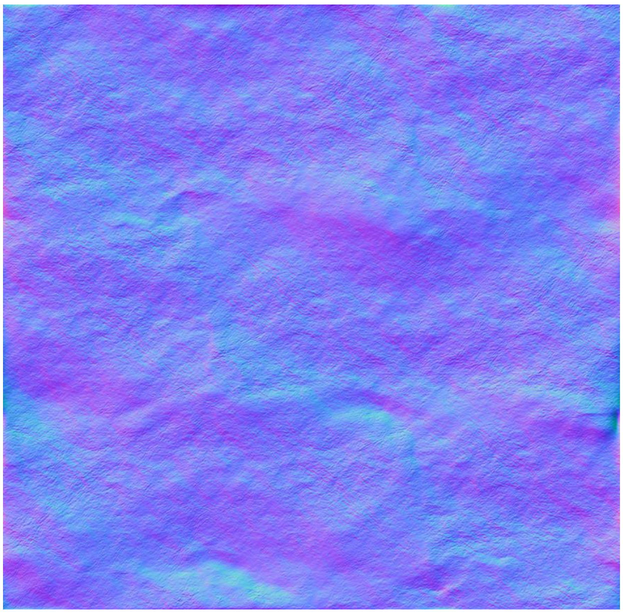


**Figure 4-9 Black Leather Normal Map**

The project makes use of various sounds, for example the music playing during the main User Interface, the elevator music, the MRI machine noise etc. Royalty free sound-clips were used, edited when needed with Audacity.

All of the created assets (3D models, maps and sound-clips) were imported into Unity where they were combined to create the different environments.

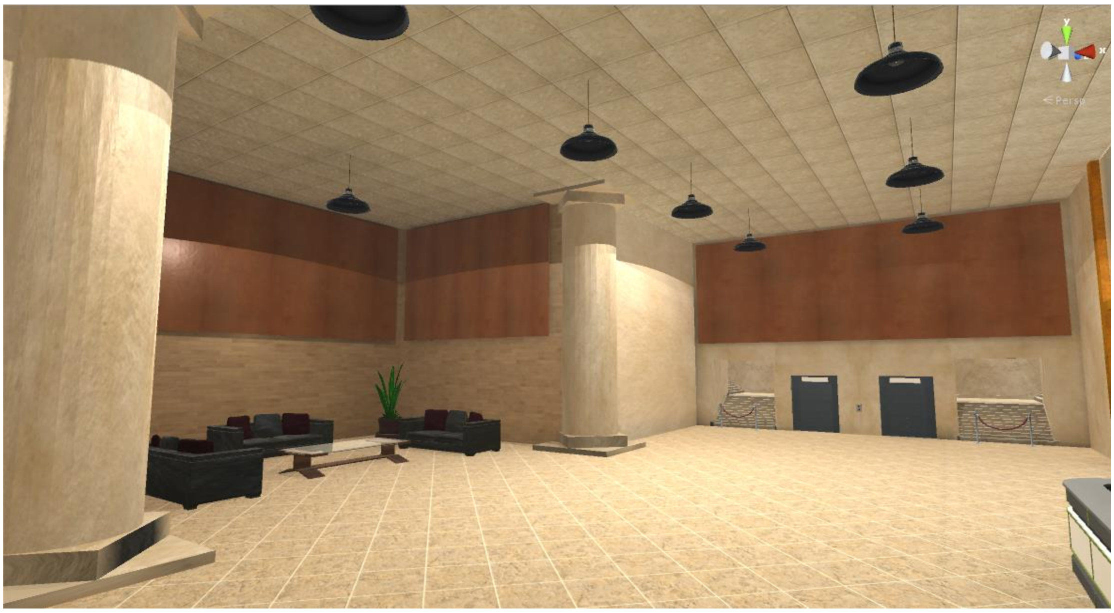


**Figure 4-10 New Building Scene in Unity**

The UI and all GameObject behaviors were coded in C#, on the MonoDevelop IDE, using Unity, System and Oculus SDK libraries.

## Graphical User Interface

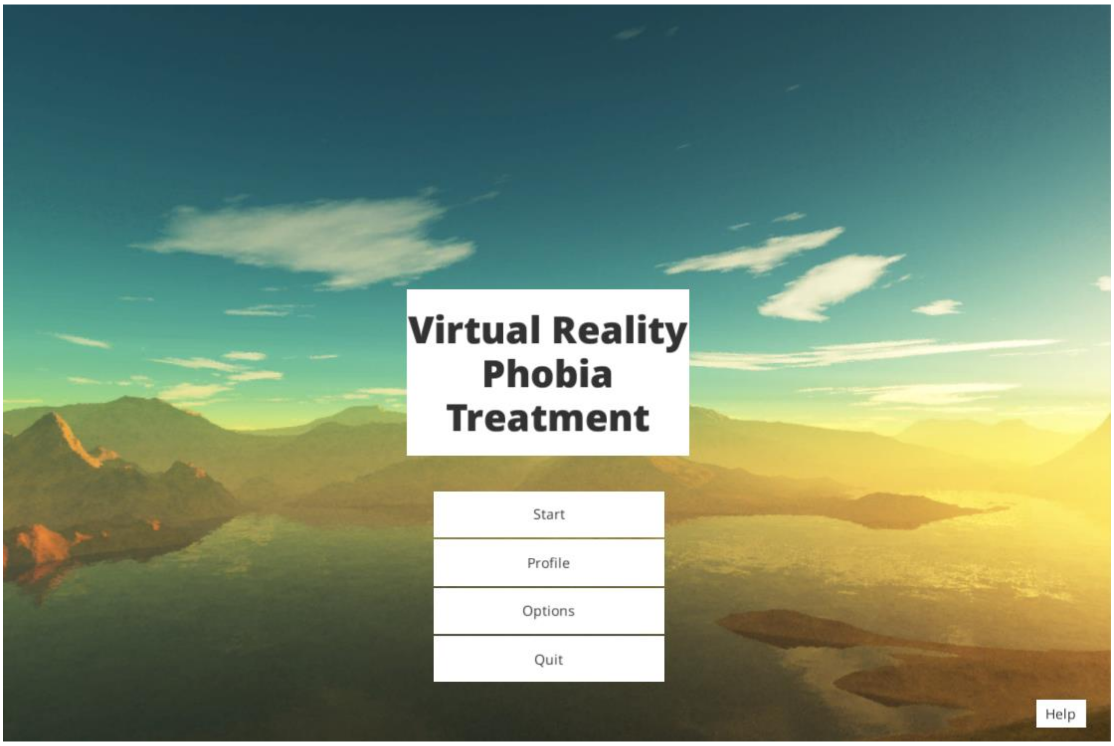
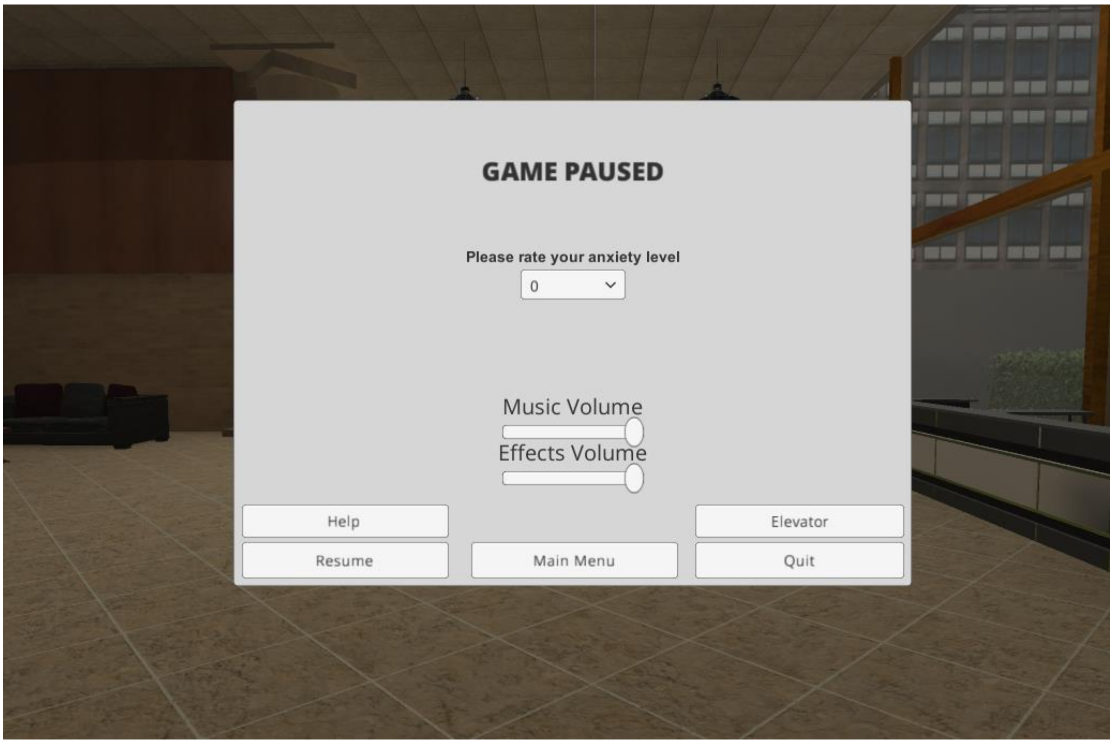


**Figure 4-11 Main Menu User Interface**

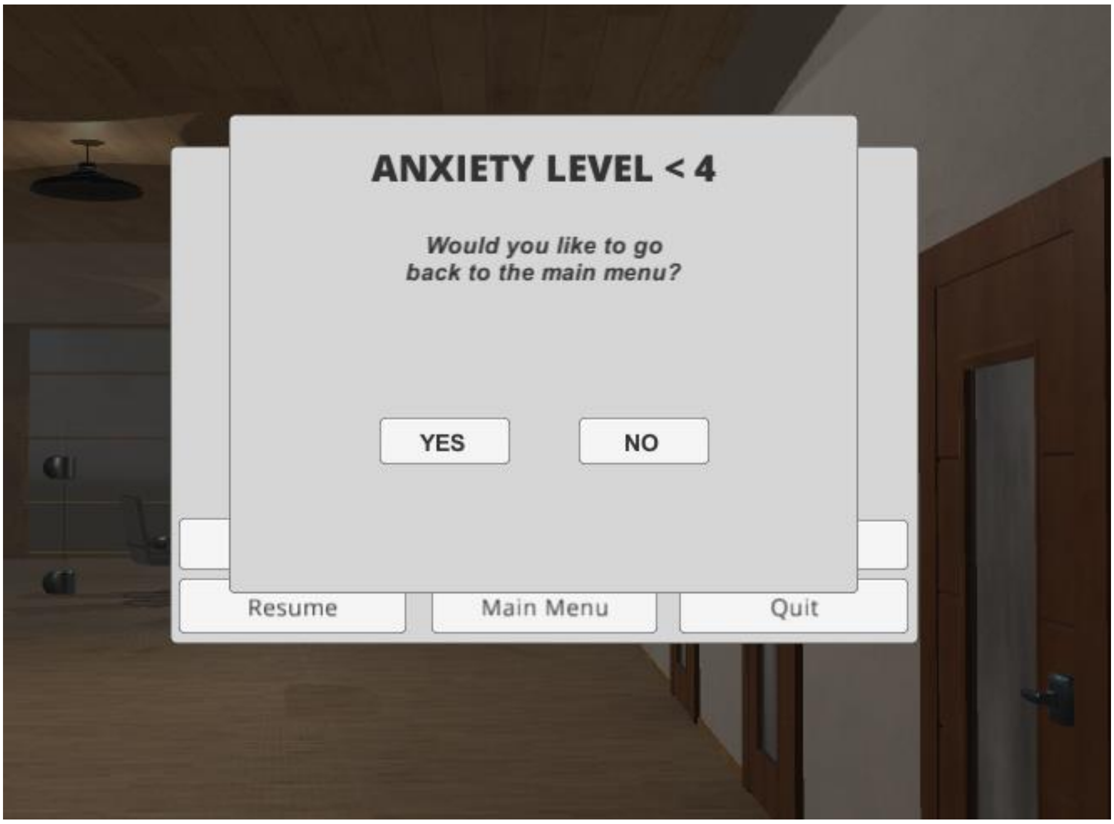
The Main Menu User Interface was created on a separate scene with its own skybox, rendered on a 2D canvas on the main camera. This approach makes it visible to the normal display, but invisible in the VR Device. If the initial tests show that this software can be used as a self-help tool, the UI will be redesigned as 3D objects instead.



GAME PAUSED

Please rate your anxiety level: 0

**Figure 4-12 Pause Panel**



ANXIETY LEVEL < 4

*Would you like to go back to the main menu?*

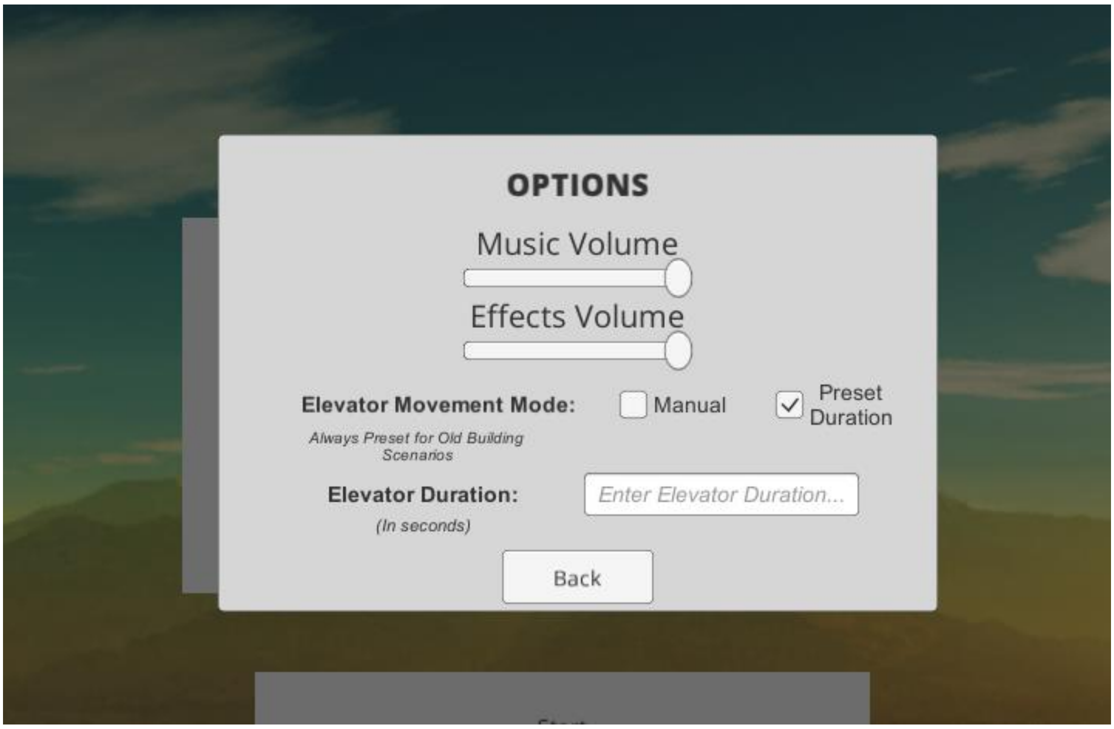
**Figure 4-13 Question Popup for Low Anxiety**

The in-game UI is enabled upon pressing the Escape key and pausing the game. It is again made on a 2D canvas, and as such, invisible in the VR Device.

The GUI system is based on the Game Jam Menu Template, offered by Unity freely on the Asset Store, but greatly expanded. It is composed of 10 different panels, each one with its own utility and functions, all attached to a single GameObject that persists between scenes.

**Table 3 User Interface Panels**

| | |
|---|---|
| *MenuPanel* | Contains the Title and Buttons visible in the Main Menu Scene |
| *PausePanel* | Becomes enabled when the game is paused |
| *OptionsPanel* | Provides game options such as audio control, and elevator mode |
| *ScenePanel* | Scene selection when starting a new scenario |
| *ProfilePanel* | Allows profile creation and selection |
| *QuestionPopUp* | Panel that shows up when the player rates his anxiety below 4 |
| *WarningPanel* | Error message that shows up when the player is attempting to start a scenario without first selecting a profile |
| *EndScenarioPanel* | End message when the player finishes a scenario |
| *StartScenarioPanel* | Panel that shows up at the start of a scene, if some required options have not been set |
| *HelpPanel* | Panel with helpful information, such as key binds |



Music Volume

Effects Volume

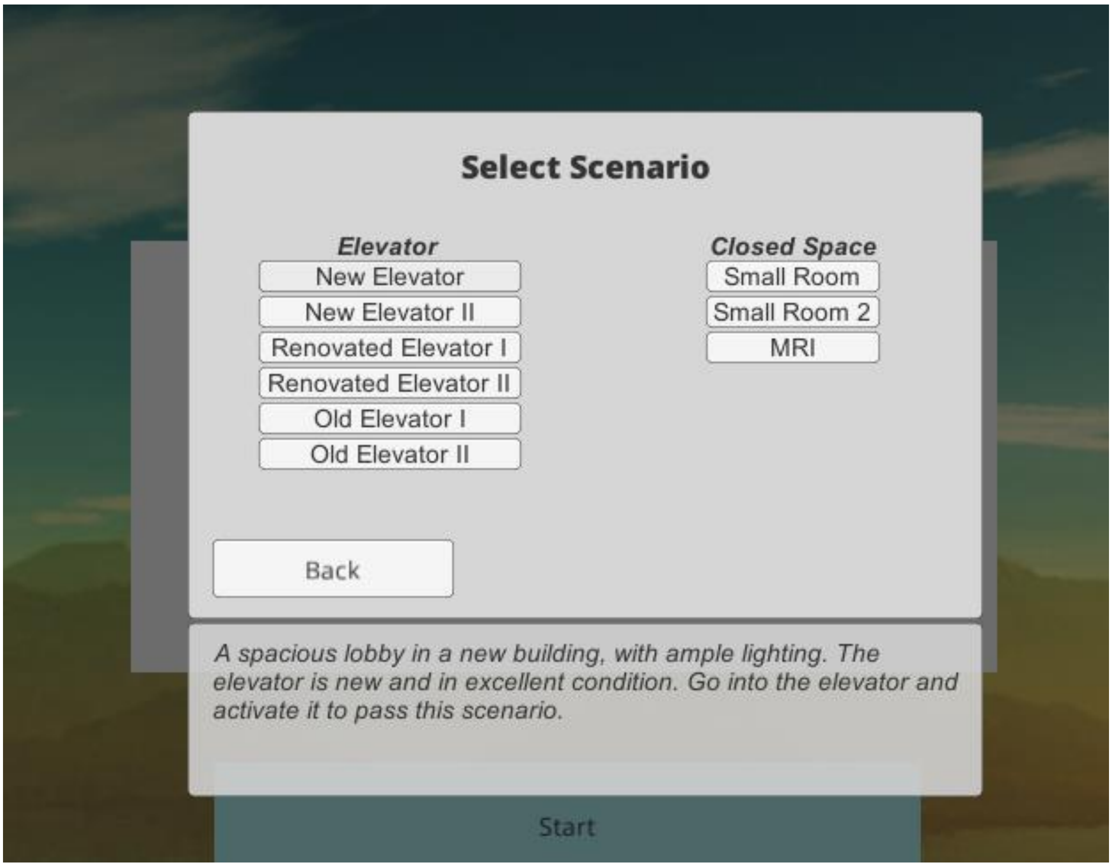
Elevator Movement Mode: □ Manual ☑ Preset Duration

*Always Preset for Old Building Scenarios*

Elevator Duration: *Enter Elevator Duration...*

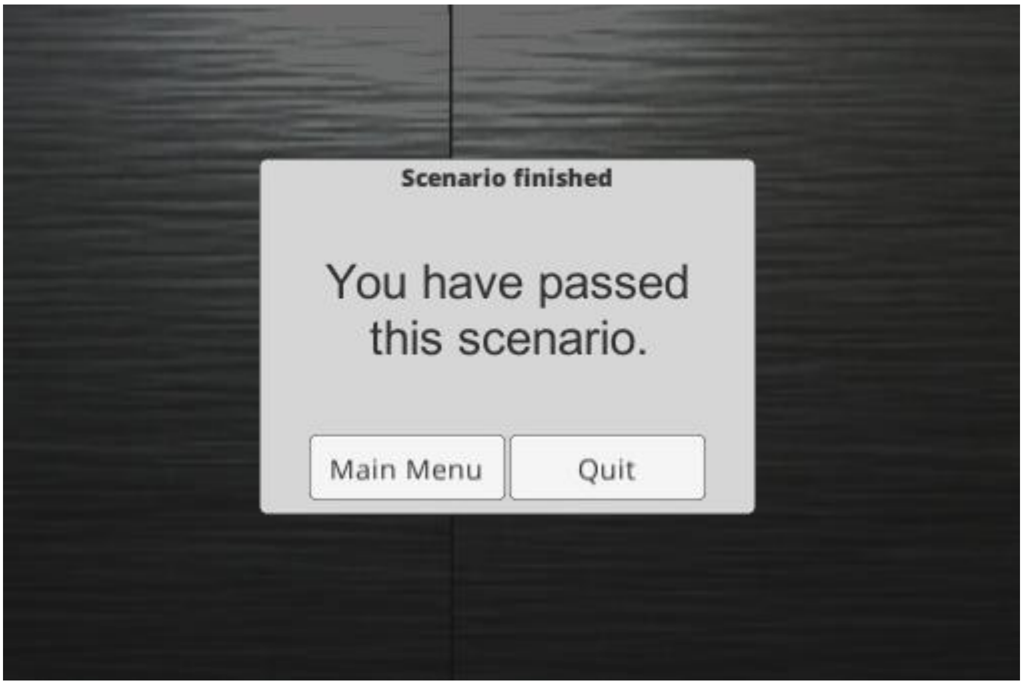
*(In seconds)*

*Figure 4-14 Options Panel*



*A spacious lobby in a new building, with ample lighting. The elevator is new and in excellent condition. Go into the elevator and activate it to pass this scenario.*

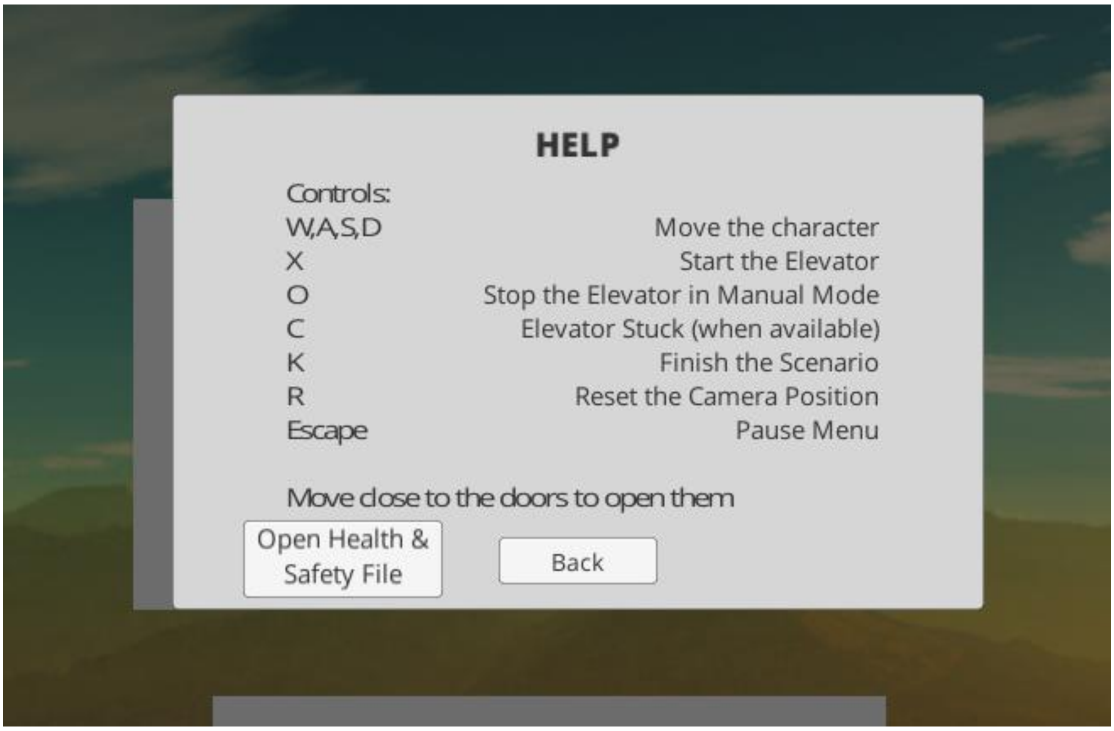
**Figure 4-15 Select Scene Panel**



Scenario finished

You have passed this scenario.

**Figure 4-16 End Scenario Panel**



HELP

Controls:

|  |  |
|---|---|
| W,A,S,D | Move the character |
| X | Start the Elevator |
| O | Stop the Elevator in Manual Mode |
| C | Elevator Stuck (when available) |
| K | Finish the Scenario |
| R | Reset the Camera Position |
| Escape | Pause Menu |

Move close to the doors to open them

**Figure 4-17 Help Panel**

The parent GameObject has scripts attached that provide functionality, such as the ‘Show Panels’ script, that handles enabling and disabling the different panels, the ‘Start Options’ script, that covers all the actions needed to load and initialize a new scene, and the ‘Timer and End Logic’ and ‘End Scenario’ scripts that handle the scenarios’ goal tracking.

## Profile System

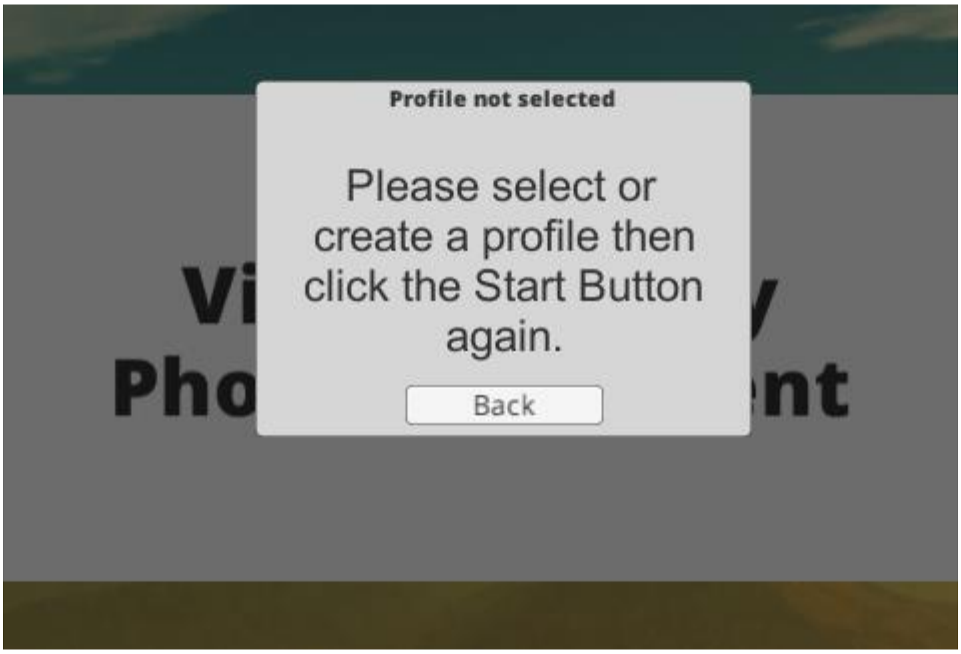
The user profiles are stored in XML format and are retrieved and created during runtime. The data structure is described in the following XML Schema:

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">
    <xs:element name="patients">
        <xs:complexType>
            <xs:sequence>
                <xs:element name="patient" maxOccurs="unbounded">
                    <xs:complexType>
                        <xs:sequence>
                            <xs:element name="gender" type="xs:string"></xs:element>
                            <xs:element name="age" type="xs:int"></xs:element>
                          </xs:sequence>
                        <xs:attribute name="name" type="xs:string"></xs:attribute>
                      </xs:complexType>
                  </xs:element>
              </xs:sequence>
          </xs:complexType>
      </xs:element>
  </xs:schema>
```

**Figure 4-18 Profile XML Schema**

```
<?xml version="1.0" encoding="UTF-8"?>
<patients>
  <patient name="TestPatient1">
    <gender>Male</gender>
    <age>25</age>
  </patient>
  <patient name="TestPatient2">
    <gender>Female</gender>
    <age>30</age>
  </patient>
</patients>
```

**Figure 4-19 XML Profile File Example**

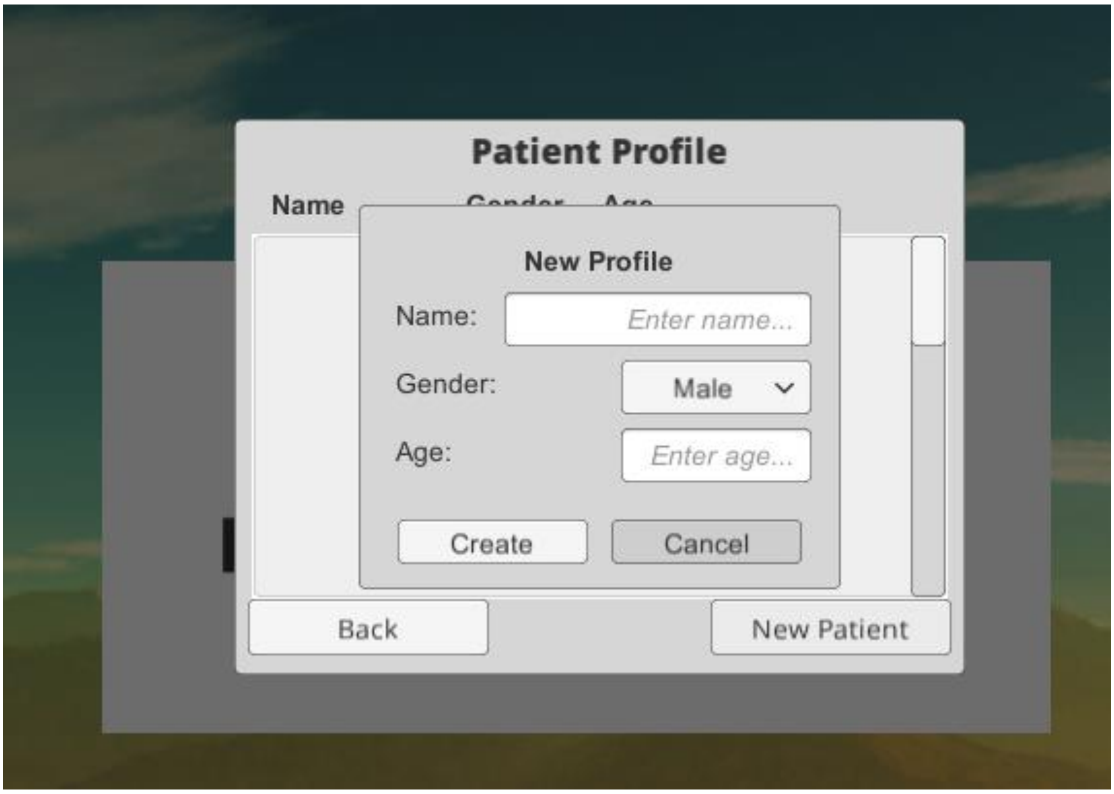


Profile not selected

Please select or create a profile then click the Start Button again.

**Figure 4-20 Warning Panel**

Through the Profile Panel of the GUI, the user can create new profiles as new elements in the XML, or select one of the existing ones.



Patient Profile

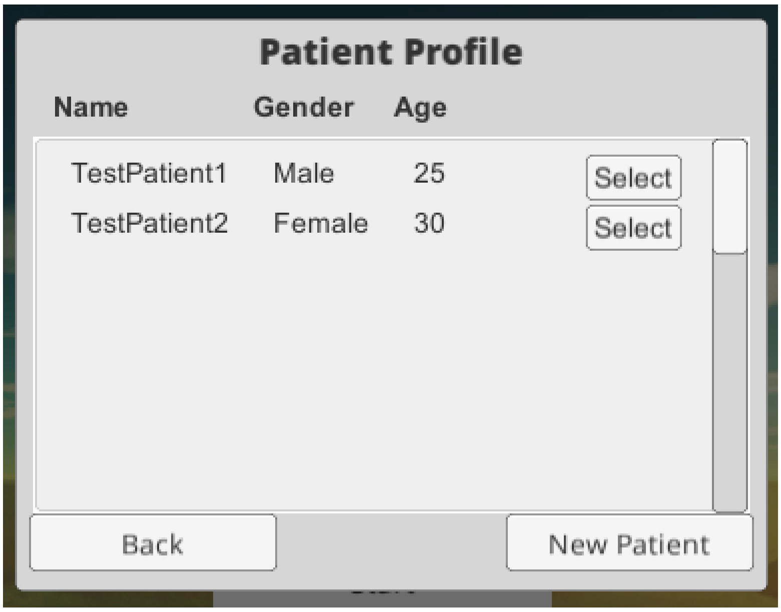
New Profile

Name: Enter name...

Gender: Male

Age: Enter age...

**Figure 4-21 Profile Creation**



Patient Profile

| Name | Gender | Age |
|---|---|---|
| TestPatient1 | Male | 25 |
| TestPatient2 | Female | 30 |

**Figure 4-22 Profile Selection Panel**

Selecting a profile allows the user to go into the scenarios, and affects whether the player avatar will be male or female. It also controls where the Patient Log text file will be saved.

## Patient Log System

The software is first and foremost a tool to help psychologists. To that end, it is imperative that a log is kept with information regarding the player/patient's performance. More specifically, the log keeps track of the date, in MM/DD/YYY format, and time, in HH:MM:SS format, that the player finishes a scenario or quits it prematurely, along with how long it took. Additionally, in the Pause Panel, the player can rate his anxiety level from 1 to 10, and that rating is stored in the log, accompanied by date, time and scenario id.

```
Patient 0-TestPatient1 completed Scenario_2 at 6/27/2016 7:11:09 PM. It took 18.78456 seconds.
Patient 0-TestPatient1_Scenario_8___6/27/2016 7:11:33 PM___Anxiety Level: 8 |
Patient 0-TestPatient1 completed Scenario_8 at 6/27/2016 7:11:56 PM. It took 45.34679 seconds.
```

**Figure 4-23 Patient Log File Example**

The file is stored on the software executable location, in a folder following the naming convention of "Patient[Profile name]", for example "PatientTestPatient1". This folder is automatically created.

## Animations

As previously mentioned, the character animations, both player avatar and NPC, were created in Blender. They were then imported into unity in the form of FBX files. Other animations, for example elevators ascending/descending and doors opening/closing were created inside Unity. All animations are managed with Unity Mecanim animation controller using State Machines.

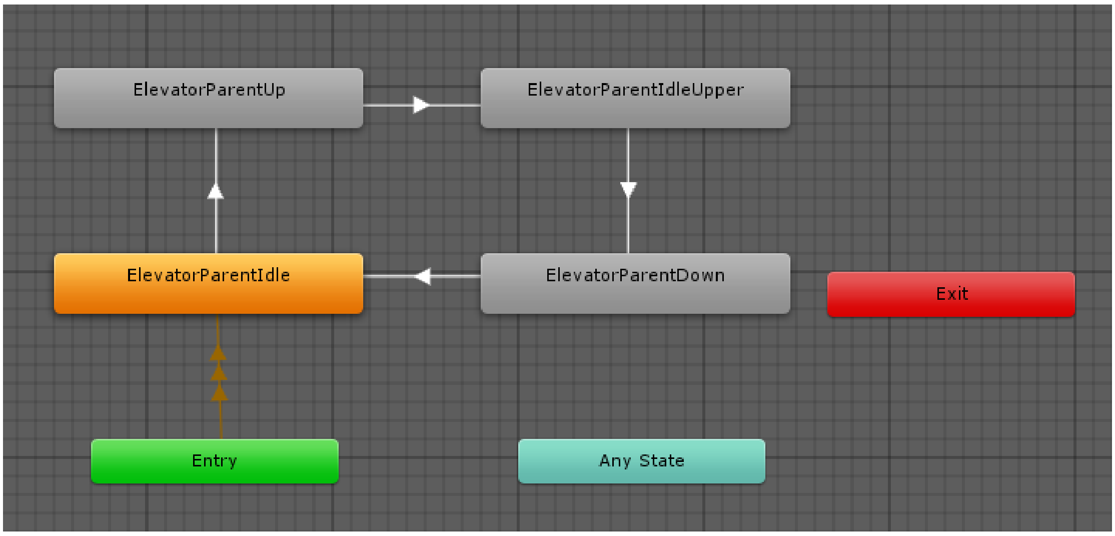


**Figure 4-24 Elevator State Machine**

The State Machine flow is dependent on external variables, for example, a Boolean "isMoving" or a float "speed", and the animations' exit time.

## Additional Behaviors

In order to cover the requirements of the treatment plan and to create a more realistic, immersive experience, some additional behaviors needed to be programmed in some of the game elements. For example, on the scenarios that feature an old elevator, it was requested that the elevator would shake and even stop between floors, and in some cases the elevator light would flicker. The code snippet below shows how the shaking effect was handled.

```
if (elapsed < duration) {
            elapsed += Time.deltaTime;
               float percentComplete = elapsed / duration;
               float damper = 1.0f - Mathf.Clamp (4.0f * percentComplete - 3.0f, 0.0f, 1.0f);
               float x = AxisX ? (originalPos.x + ((Random.value * 2.0f - 1.0f) * magnitude *
damper)) : target.transform.position.x;
               float z = AxisZ ? (originalPos.z + ((Random.value * 2.0f - 1.0f) * magnitude * d
amper)) : target.transform.position.z;
               Vector3 newPos = new Vector3 (x, target.transform.position.y, z);
               target.transform.position = newPos;
           } else {
               elapsed = 0.0f;
               isShaking = false;
               this.gameObject.SetActive (false);
```

**Figure 4-25 Part of the ShakeObject script**

This code moves the target object on the X and Z axes every frame by a randomized value that is however decreased the longer the object has been shaking, until it has been shaking for the predetermined duration. This makes for a smooth shaking effect that gradually slows down.

## Game elements

### *Goals*

The main goal of the game is mostly abstract and it can best described as “overcoming the fear”. The player has to go into the individual scenarios and successfully complete the given objective. In the first scenario, the player just has to get into the elevator and indicate that he is ready to use it. In the rest of them, the objective is to stay in the scenario for a set of time decided by the treating psychologist.

When the scenario Goal is achieved, the End Scenario panel of the UI appears to notify the player that he has finished the scenario, his progress is recorded in the Patient Log file, and he is returned to the Main Menu.

### *Obstacles*

The obstacles that hinder the player’s progress are in the form of real-life situations that would trigger the player’s phobia. These include the design of the environment, whether the elevator room is big or small, the lighting condition, whether the atmosphere feels smothering, and the behaviors of specific objects, such as the elevator shaking while it moves, the light flickering, the MRI machine making loud noises etc.

Due to the nature of these obstacles, they are of course applicable only to phobia patients, and a player not suffering from phobias would not be hindered by them.

## Adjusting for VR

Once the choice was made to use Unity to develop an Oculus Rift application, the implementation of VR was straightforward, as Unity has built-in support for stereoscopic rendering and head tracking. More specifically, once the option for VR support is enabled, a new double-camera rig, with each camera corresponding to each eye, is positioned at the Main Camera Object's position and orientation. This VR Camera's local transformation is controlled by the head-tracker on the Rift, and it outputs to the Rift's displays. The original camera follows the local transformations of the VR Camera, but it outputs a single image to the computer display.

While implementing VR in Unity is straightforward, the challenge lies in the design of a VR application, and despite designing from the very start with VR in mind, once testing with the actual device commenced it was observed that certain adjustments were needed.

### *Controller*

As it was mentioned earlier, it is important to remember that the VR Device completely hides the real-life environment to the player. It is therefore optimal to allow the player to use a familiar or easy to grasp controller, such as a gamepad. As the prototype is intended to be used in the company of a treating psychologist, most controls, such as using the interface, activating the elevator etc. are available via keyboard keys to the psychologist, with movement available to the player via the gamepad joystick.

The controller setup had to also be changed, compared to a conventional first-person game. In those, the mouse is used to rotate the character's view and body, while the horizontal axis input is used for side-stepping. In real life, side-stepping is not very common in everyday situations, and the head can rotate independently of the body. It was then made so that the head-tracking input would rotate the view and avatar head and the horizontal axis input would rotate the body instead of moving it.

### *Camera Position*

When VR Support enabled and the new VR Camera rig is created, it is positioned in a way that matches the original camera's position to the left eye of the player. Through live testing, the original camera position was adjusted so that the VR Camera would align with the player's expected view.

It is also crucial that the player can have a freedom of movement that does not massively break the immersion, by placing the view through his own avatar's body or through a wall. To remedy the former, the camera had to be placed in a set distance from the avatar that both seemed natural to the player and ensured that there would be no near-view clipping with the avatar model, under normal circumstances.  In the case of the latter, clipping through the environment, the environment colliders are set to a size that does not allow the avatar to get too close. It is still possible, through unintended player behavior, to move the camera separately and through those colliders, but that is an ongoing, currently unsolved issue with VR applications. It is simply expected to not be abused by players.

In live-testing it was also noticed that the VR Camera object could, in some cases, escape its normal local position and become disembodied. An additional control button was added to counter that, which resets the camera position and is available to both the psychologist through a keyboard button and the user through a button on his controller.

### *Character Movement Speed*

In conventional first-person games, players are accustomed to an unrealistic movement speed of their character. In a Virtual Reality environment however, large accelerations and higher-than-normal speeds can contribute to Simulator Sickness, especially when the player is standing still while the avatar is moving. Through live-testing a comfortable speed was found, and the animation and footstep audio-clip were adjusted to match it.

### *Health and Safety*

A button was added in the Help panel that loads the Health and Safety Warnings PDF file, provided by and for Oculus Rift.

### *In-Game Samples*

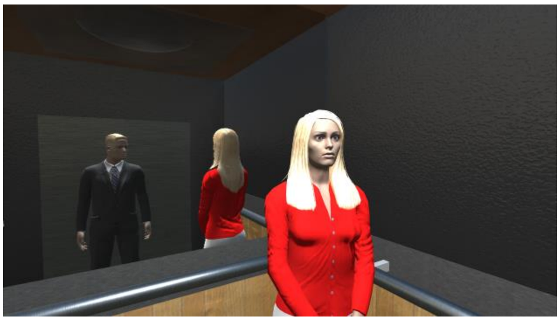


Figure 4-26 Elevator with NPC Inside

In the second elevator scenario, the player can see another person in the elevator with him. It is programmed to show a woman if the player is male and a man if the player is female.

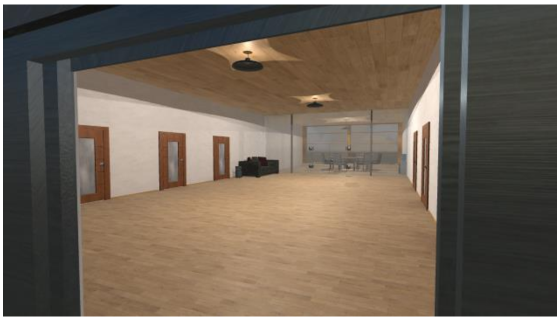


Figure 4-27 New Building Top Floor

Reaching the top floor, the player can see a new environment, so it becomes more believable that he has moved locations.

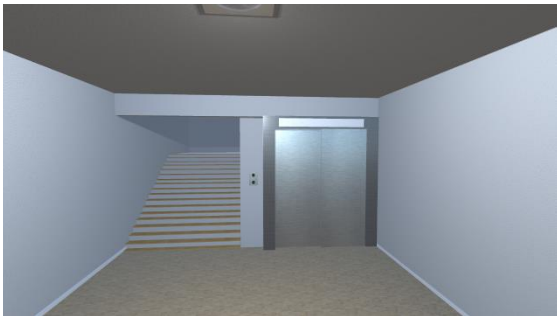


Figure 4-28 Renovated House

A slightly old-fashioned but renovated building with an elevator. The building design is simple but clean and the elevator looks brand new, from the outside.

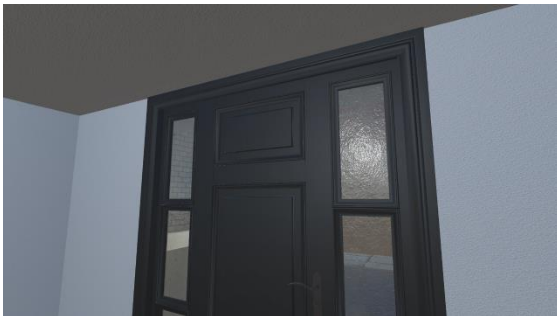


Figure 4-29 Renovated House Door Detail

Through the door, the player can see the street outside and parts of the neighboring buildings. This can help in giving a sense of location.

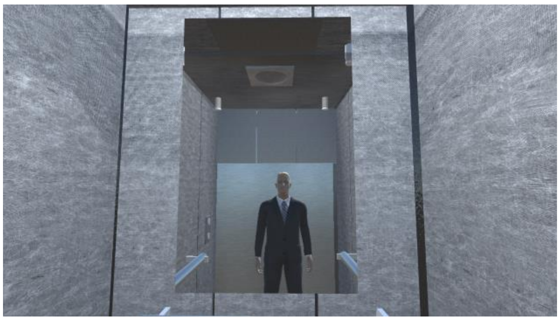


Figure 4-30 Renovated House Elevator

The elevator from inside seems to be in a good enough condition, although not as new as it looked like from the outside.

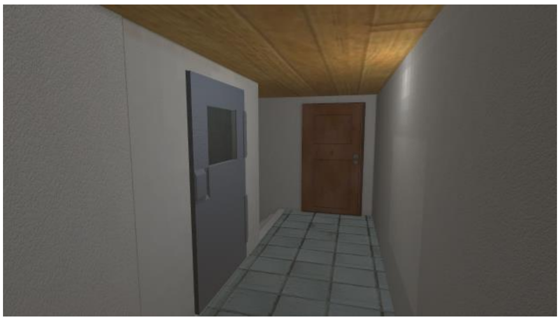


Figure 4-31 Old Apartment Building

The third and fourth elevator scenarios take place in an old apartment building. The corridors between apartment doors are narrow and the building materials give it an older feeling, with old floor tiles, concrete and rough wood planks.

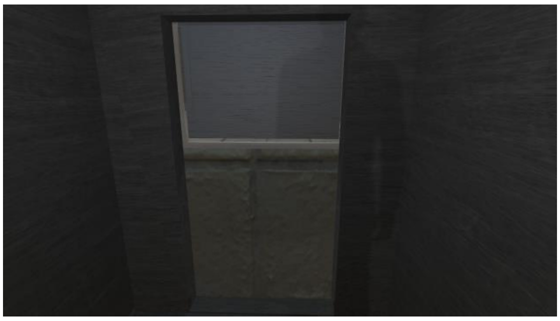


Figure 4-32 Moving Old Elevator - View between Floors

This elevator is not secured with a protective inside-door or frame. The player can see the wall between the floors as the elevator moves.

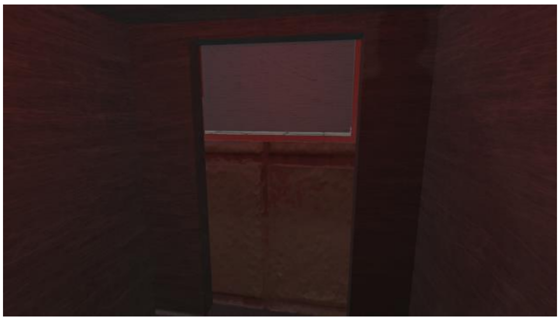


Figure 4-33 Old Elevator Stuck

The old elevator is not only shaky and unsecured, it can also unexpectedly get temporarily stuck between floors, in which case a red alarm light will start blinking until the elevator moves again.

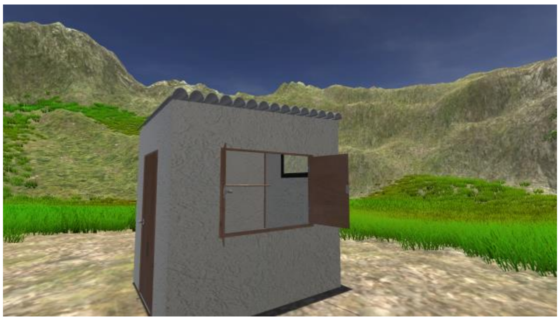


Figure 4-34 Small Storage Room

Located in an open countryside environment, the small storage room can be entered through the door and houses some boxes. This is meant to be an easy experience for the player as the window makes the room feel bigger.

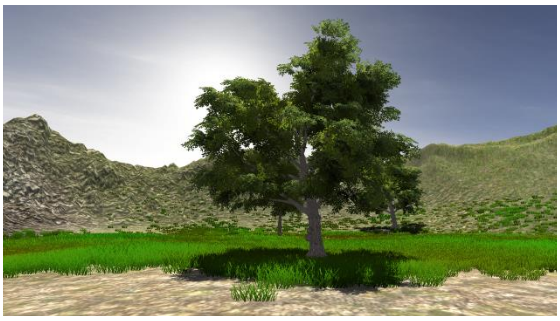


*Figure 4-35 Small Storage Room Environment*

Trees, grass, hills and a bright blue sky can be observed in this scenario.

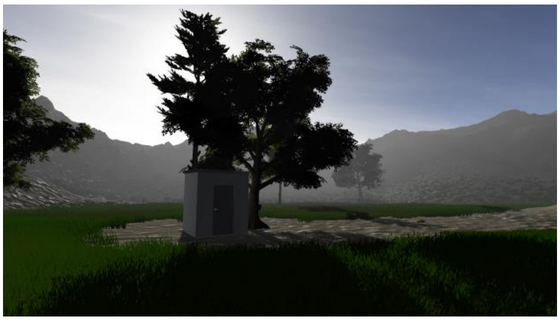


*Figure 4-36 Small Storage Room Evening*

With just a few changes, the small storage room scenario turns scarier. The lighting is lower with long shadows cast from the trees.

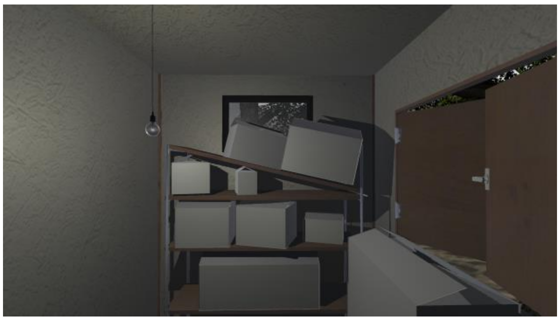


*Figure 4-37 Small Storage Room Evening Interior*

The room is now packed with boxes. A broken shelf on one wall block the small window, while the tree just outside the shack block the bigger window from opening. The flickering hanging lamp provides little lighting.

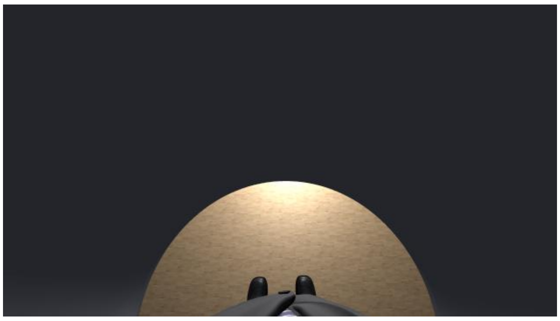


*Figure 4-38 View from Inside the MRI*

The picture does not do justice to the feeling the player can get lying down and seeing his (avatar’s) body inside the narrow tube that is the MRI machine.

# Chapter 5 - **Conclusion**

### *Summary*

During the writing of this dissertation it was researched how Virtual Reality could be applied to develop a tool that can assist psychologists with the treatment of phobia patients. As Virtual Reality Exposure Therapy has been shown to have positive results in treating phobia patients, a VR application that takes advantage of the new technologies was devised, that combines the benefits of other approaches while attempting to avoid the drawbacks. The available VR devices' specifications were compared in order to choose the one best suited for the task. A prototype application was then developed in Unity Game Engine for Oculus Rift, intended to be used by phobia patients and their treating psychologists.

The application is structured as a game, with goals and obstacles, but follows a treatment plan devised by a consulting psychologist. The prototype contains a plan for Claustrophobia, with numerous different scenarios the patient could realistically be put into.

## Future Work

First and foremost, the application needs to be tested for its effectiveness. This testing will take place in Greece, conducted by the consulting psychologist (Kostaki, 2015). The Patient Log system can also be enhanced to store all information required.

If it is proven that this application can indeed assist with the treatment of phobias, the application can be expanded into a software platform that runs phobia modules, with multiple scenarios in each one, covering different phobias in that way. This would make the product easier to commercialize as the consumers, both psychologists and phobic users, could purchase the base standalone software and only those phobia modules that are needed. Additionally, there is a number of technologies that could be implemented to further improve the immersion of the player, the most affecting ones being Kinect by Microsoft, as another means of character controller, the Virtuix Omni, for moving the player character in a more realistic way, and the – as of writing this still in development – Gloveone, to give tactile feedback to the player.

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# Appendix

## Why Oculus Rift

It was early on in the research process understood that most of the Virtual Devices on the market would not be suitable for this project. Mobile VR solutions were suggested, such as the Google Cardboard or Samsung VR, but were dismissed for the following reasons:

- Even highest end phone GPUs are dwarfed by desktop GPUs, and VR is a very GPU heavy process.
- Acceptable latency is <20ms, Cardboard latency is about 75ms or higher. Noticeable latency causes motion-sickness.
- Impossible to run heavy software on phone, and streaming the content through a computer would require HDMI or USB 3.1 at full speed. No such phones released yet.
- Maximum resolution 1024*768@30Hz, through streaming that pushes latency over 100ms. In comparison, Oculus Rift CV1 does 2160*1200@90Hz over HDMI at 0 transference latency and <20ms tracker latency.
- Visual experience on Oculus much better as it uses optics designed with VR in mind. Phone visualization still pixelated due to magnification.
- Cardboard FoV (Field of View) is 70 degrees. Other VR solutions range between 90 and 110 degrees. Losing on immersion.

The decision finally came down to three candidates, Oculus Rift, HTC Vive and Razer OSVR. The OSVR's specifications are below the other two devices, and the table below shows the comparison between the Rift and the Vive.

**Table 4 Rift and Vive Comparison Table**

| | **Oculus Rift** | **HTC Vive** |
|---|---|---|
| **Resolution** | 2160x1200 (total) | 2160x1200 (total) |
| **Display** | OLED | OLED |
| **Refresh Rate** | 90Hz | 90Hz |
| **FoV** | 110 degrees | 110 degrees |
| **Tracking Area** | 5x11 feet | 15x15 feet |

| | | |
|---|---|---|
| **Built-in-Audio** | Yes | Yes |
| **Sensors** | Accelerometer, gyroscope, magnetometer, 360-degree positional tracking | Accelerometer, gyroscope, laser position sensor, front-facing camera |
| **Connection** | HDMI, USB 2.0, USB 3.0 | HDMI, USB 2.0, USB 3.0 |
| **Price** | $600 | $800 |
| **Pros** | Rift devices were available in Mektory for testing.<br>Cheaper. | Device can be tracked in a larger space.<br>Front-facing camera allows view of real-life environment to avoid obstacles. |
| **Cons** | Positional tracking limited. | More expensive. |

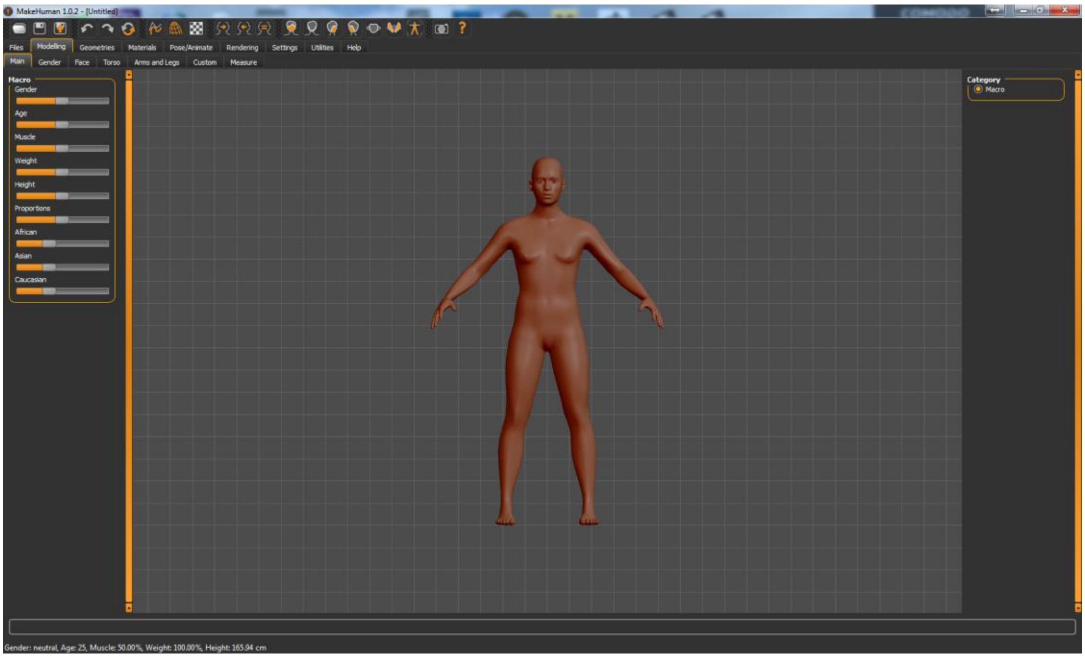
While the HTC Vive offers more than the Oculus Rift, there was no access to a device for testing and its price made it unaffordable, thus the Oculus Rift was chosen.

## Tools Used

### *MakeHuman*

MakeHuman is a free and open source software to create realistic 3d humans for:

- Illustrations
- Animations
- Games
- Zbrush/Mudbox sculpting



Gender: neutral, Age: 25, Muscle: 50.00%, Weight: 100.00%, Height: 165.94 cm

**Figure Appendix-0-1 MakeHuman**

## *Blender 3D*

### The organization

Blender Foundation is a Dutch public-benefit corporation, established to support and facilitate the projects on blender.org.

### The software

Blender is the free and open source 3D creation suite. It supports the entirety of the 3D pipeline—modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation. Advanced users employ Blender’s API for Python scripting to customize the application and write specialized tools; often these are included in Blender’s future releases. Blender is well suited to individuals and small studios who benefit from its unified pipeline and responsive development process.

Blender is cross-platform and runs equally well on Linux, Windows and Macintosh computers. Its interface uses OpenGL to provide a consistent experience.

As a community-driven project under the GNU General Public License (GPL), the public is empowered to make small and large changes to the code base, which leads to new features, responsive bug fixes, and better usability. Blender has no price tag, but you can invest, participate, and help to advance a powerful collaborative tool: Blender is your own 3D software.

### Why Blender?

Blender was chosen as the 3D modeling and animation tool for this thesis because of its robustness, as it can accomplish everything that was needed and more, and its licensing. Blender being under the GNU GPL, users are free to use it for any purpose, including commercially or for education.

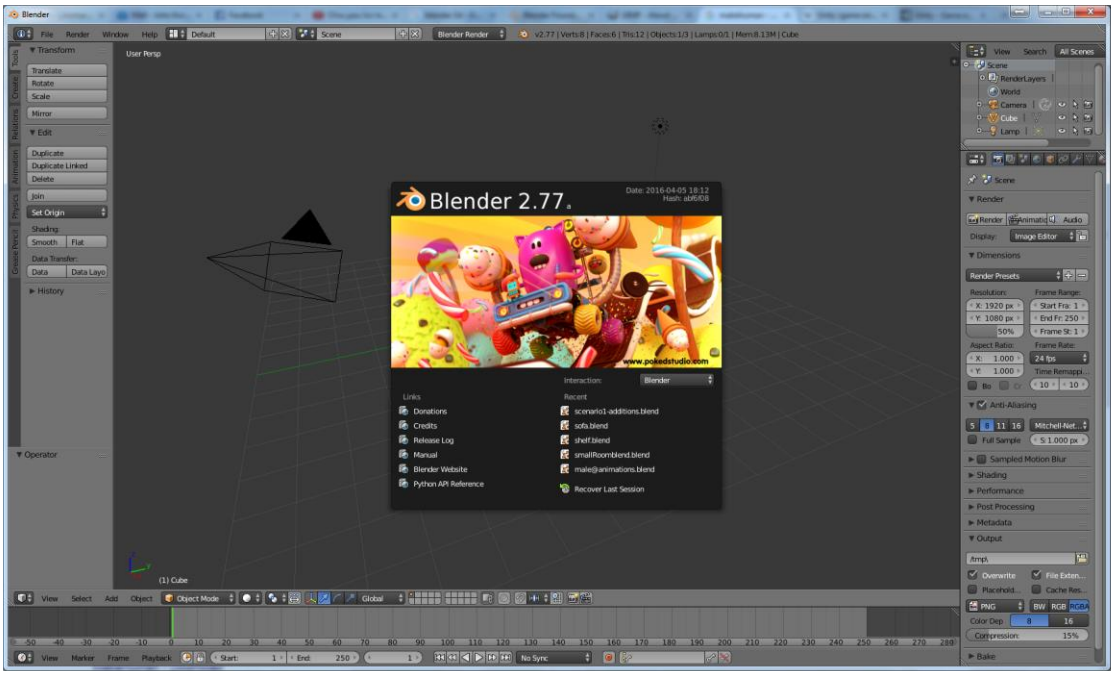


**Figure Appendix-0-2 Blender**

## *GIMP*

### Overview

GIMP (GNU Image Manipulation Program) is a cross-platform image editor available for GNU/Linux, OS X, Windows and more operating systems. It is a freely distributed program for such tasks as photo retouching, image composition and image authoring. The terms of usage and rules about copying are clearly listed in the GNU General Public License.

### Why GIMP?

Despite the author having no previous experience with GIMP, the tasks that it was needed for were basic enough that the lack of experience was deemed inconsequential, and GIMP was chosen due to its licensing, that allows it to be used for commercial and educational purposes freely.

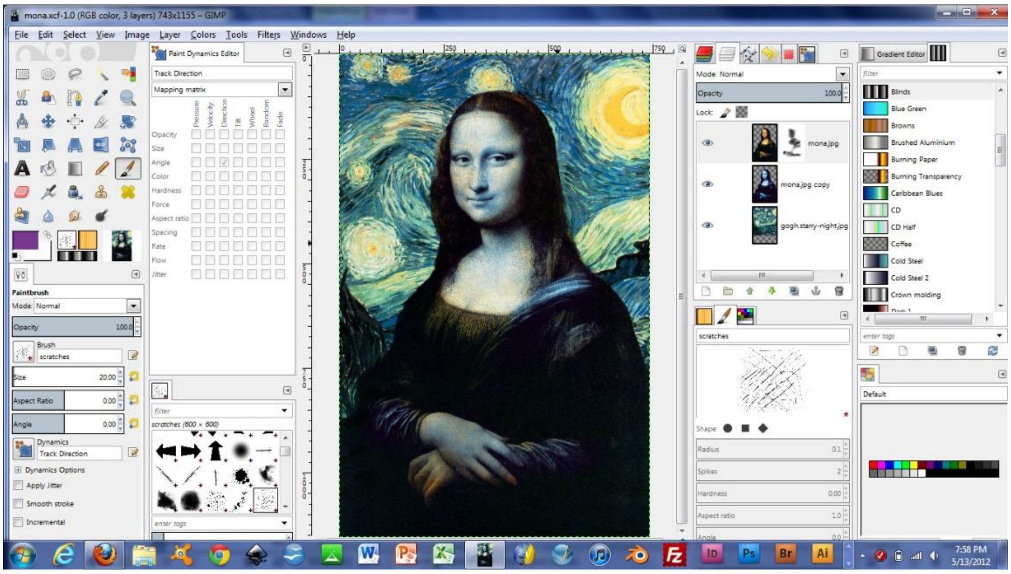


**Figure Appendix-0-3 GIMP**

### *AwesomeBump*

AwesomeBump is a free program written using Qt library designed to generate normal, height, specular or ambient occlusion textures from a single image. Since the image processing is done in 99% on GPU the program runs very fast and all the parameters can be changed in real time.

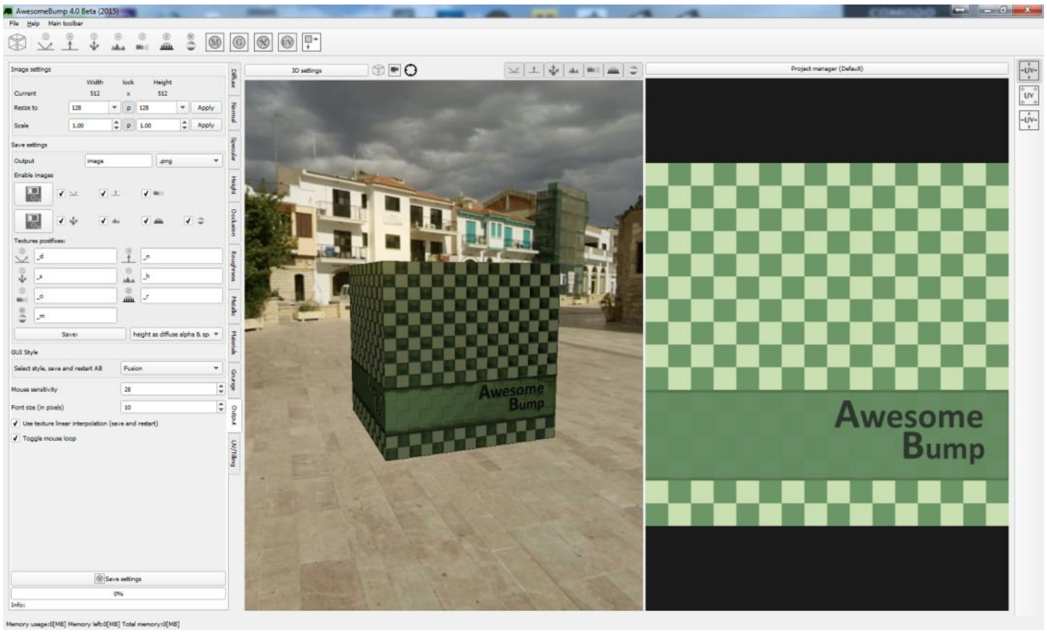

AwesomeBump 4.0 Beta (2015)
File Help Main toolbar
Image settings
Save settings
GUI Style
3D settings
Project manager (Default)
Awesome Bump
Memory usage:0[MB] Memory left:0[MB] Total memory:0[MB]

**Figure Appendix-0-4 AwesomeBump**

### *Audacity*

Audacity® is free, open source, cross-platform audio software for multi-track recording and editing, available for Windows®, Mac®, GNU/Linux® and other operating systems.

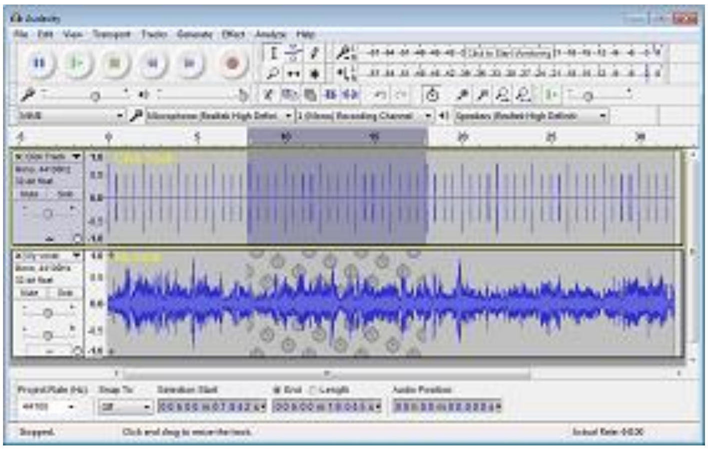

Audacity
File Edit View Transport Tracks Generate Effect Analyze Help
Project Rate (Hz)
Snap To
Selection Start
End
Length
Audio Position
Stopped.
Click and drag to resize the track.

**Figure Appendix-0-5 Audacity**

### *Unity 5*

Unity is a cross-platform game engine developed by Unity Technologies and used to develop video games for PC, consoles, mobile devices and websites.

#### Unity Supported Platforms

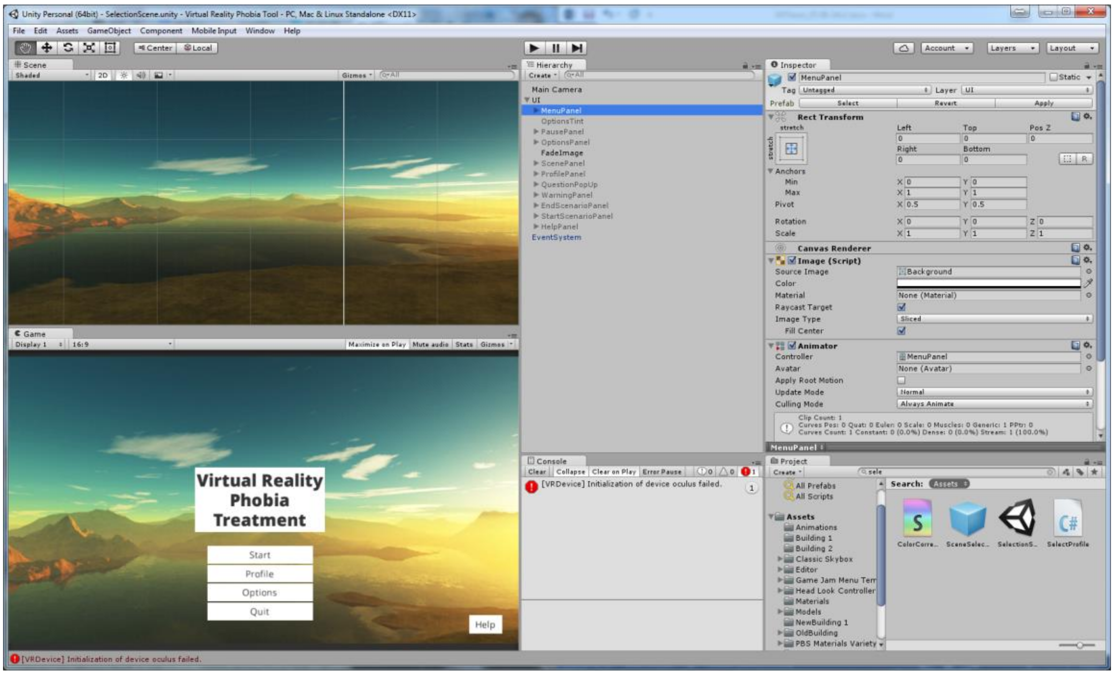
Renowned throughout the industry as the multiplatform game engine, Unity allows you to target more devices more easily. With Unity, you get one-click deployment to the full range of mobile, VR, desktop, Web, Console and TV platforms.

**Table 5 Unity Supported Platforms**

| | | | | | | |
|---|---|---|---|---|---|---|
| Platforms supported in Unity | iOS | Android | Windows Phone | PlayStation Vita | Windows | Windows Store Apps |
| | Mac | Linux / Steam OS | Oculus Rift | PlayStation 4 | Tizen | Xbox One |
| | Xbox 360 | Wii U | Nintendo 3DS | PlayStation VR | Google Cardboard | Steam VR |
| | Web GL | Gear VR | Microsoft Hololens | Android TV | Samsung Smart TV | tvOS |

### Why Unity?

Aside from the author having extensive previous experience with development in Unity, this game engine was chosen for its built in support of all currently available VR devices, ease of prototyping content, and licensing plan, that allows loyalty free commercialization until a threshold of income from sales is reached.



Unity Personal (64bit) - SelectionScene.unity - Virtual Reality Phobia Tool - PC, Mac & Linux Standalone <DX11>

Hierarchy:

```
Main Camera
▼ UI
  ▶ MenuPanel
    OptionsTint
  ▶ PausePanel
  ▶ OptionsPanel
    FadeImage
  ▶ ScenePanel
  ▶ ProfilePanel
  ▶ QuestionPopUp
  ▶ WarningPanel
  ▶ EndScenarioPanel
  ▶ StartScenarioPanel
  ▶ HelpPanel
EventSystem
```

Inspector:

```
☑ MenuPanel                                □ Static
Tag  Untagged                 Layer  UI
Prefab   Select   Revert   Apply
Rect Transform
stretch        Left      Top       Pos Z
               0         0         0
               Right     Bottom
               0         0
Anchors
  Min          X 0       Y 0
  Max          X 1       Y 1
Pivot          X 0.5     Y 0.5
Rotation       X 0       Y 0       Z 0
Scale          X 1       Y 1       Z 1
Canvas Renderer
☑ Image (Script)
Source Image       Background
Color
Material           None (Material)
Raycast Target     ☑
Image Type         Sliced
  Fill Center      ☑
☑ Animator
Controller         MenuPanel
Avatar             None (Avatar)
Apply Root Motion  □
Update Mode        Normal
Culling Mode       Always Animate
Clip Count: 1
Curves Pos: 0 Quat: 0 Euler: 0 Scale: 0 Muscles: 0 Generic: 1 PPtr: 0
Curves Count: 1 Constant: 0 (0.0%) Dense: 0 (0.0%) Stream: 1 (100.0%)
```

Console:

```
[VRDevice] Initialization of device oculus failed.    1
```

Project:

```
All Prefabs
All Scripts
▼ Assets
    Animations
    Building 1
    Building 2
  ▶ Classic Skybox
  ▶ Editor
  ▶ Game Jam Menu Tem
  ▶ Head Look Controller
    Materials
  ▶ Models
    NewBuilding 1
  ▶ OldBuilding
  ▶ PBS Materials Variety
```

Figure Appendix-0-6 Unity