Virtual reality exposure therapy for claustrophobia

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Abstract

One in four people in Norway will be affected by an anxiety disorder at some point in their life. One of these prevalent anxiety disorders is claustrophobia. Facing these scenarios on their own may help or worsen the problem depending on several factors. Therefore, it needs further exploration in the right environment assisted by a licensed physician to ensure the patient has an empowering experience rather than a traumatic one. A virtual reality simulator has been developed and evaluated to help with exposure therapy for claustrophobia.

The project had 7 medical professionals volunteer as evaluators in 8 evaluation sessions. SUS scores from evaluation sessions of the latest version of this application show that 5 out of 6 evaluators give highly positive feedback on all usability counts. Testimonies from the evaluators support the claim that the simulation can trigger an anxiety attack in people with claustrophobia, even though we could not test this hypothesis on actual patients.

When asked, several evaluators said they felt like they were using an actual elevator. Being able to capture that feeling through only visuals and sounds is a significant achievement for this project.

The results from the evaluation session indicate that the elevator simulator has considerable potential for use in exposure therapy for claustrophobia.

Acknowledgements

Contents

List of Figures

Glossary

acrophobia Fear of heights. 40, 44, 48, 53

agoraphobia Fear of open places. 15, 40

anxiety disorder A mental disorders characterized by significant,excessive and uncontrollable feelings of anxiety or fear [12]. 1, 7

arachnophobia Fear of spiders. 16

camera stacking Camera Stacking allows multiple cameras to overlay each other. 33

claustrophobia An anxiety disorder that causes an intense fear of enclosed spaces [43]. 1, 7, 8, 9, 10, 11, 14, 20, 22, 39, 40, 45, 47, 48, 52, 53

exposure therapy A psychological treatment that was developed to help people confront their fears[2]. 1, 2, 8, 9, 10, 12, 13, 14, 15, 16, 19, 21, 41, 45, 52, 53

nosocomephobia Fear of hospitals. 15, 53

nyctophobia Fear of darkness. 40

Acronyms

API Application Programming Interface. 16

AR Augmented reality. 16

IDE Integrated Development Environment. 16

LTS Long Term Support. 16, 28

MRI Magnetic Resonance Imaging. 7, 8, 11, 12, 20

SRP Scriptable Render Pipeline. 33

SUS System Usability Scale. 1, 9, 10, 20, 26, 27, 36, 37, 51, 53

URP Universal Rendering Pipeline. 28, 33

VR Virtual Reality. 8, 9, 11, 12, 13, 14, 16, 21, 22, 31, 33, 34, 36, 37, 38, 40, 41, 43, 44, 45, 46, 48, 49, 52, 54

XR Extended Reality. 16, 33

Chapter 1

Introduction

1.1 Motivation

One in four people in Norway is going to be affected by an anxiety disorder at some point in their life [9]. These conditions vary in severity, but many cases are so severe that they make up serious impediments to the person's weekday. Anxiety disorder can manifest itself in all stages of life. Many of these disorders start developing in childhood and are critical to address with treatment as soon as possible.

When one finds themselves faced with an anxiety disorder, it is essential to learn how to manage it positively. Many people would rather avoid situations that may induce anxiety rather than face them[22]. Further isolating oneself reinforces the disorder's effects and limits the ways the person can participate in social engagements. They may go out of their way to avoid situations that may trigger episodes of anxiety. Sometimes the trigger scenarios are unavoidable and need to happen. Making habits of avoiding all potential trigger events can accumulate unnecessary costs and stress for the patient. As an example, people with claustrophobia may have great difficulties taking an MRI at a hospital. Currently, these cases get treated on a case-by-case basis. Many cases include several additional appointments with their physician slowly approaching the MRI machine when sedation is not an option. These additional appointments cost both money and time for the hospitals, physicians, and patients.

Another common scenario for people with claustrophobia is elevators. Elevators are a common occurrence in most public buildings and often the only practical option.

Facing these scenarios on their own may help or worsen the problem depending on several different factors. Exploring the condition in the right environment assisted by a licensed physician ensures the patient has an empowering experience rather than a traumatic one.

1.2   Origin of the thesis

This project is a cooperation between The Institute for data technology, electrical technology, and science, and Helse Vest IKT at The Children and Youth Clinic, Haukeland University Hospital[33]. The project will primarily aim at treatment for children and youths.

The assignment originated with chief physician Paul Joachim Bloch Thorsen, who will be an integral part of the team going forward. The team will include innovators in health Thomas Fiskeseth Larsen and Håkon Garfors, and physiotherapist and assistant professor at HVL Lars Peder Vatshelle Bovim. This project is part of a more significant intention to create a library of ready-to-use personalized exposure treatments in virtual reality for the most common types of anxiety and phobias[15].

1.3   Scope and limitations

Helse Vest IKT is currently gathering and creating VR simulations to aid in exposure therapy against commonly occurring phobias. Considering the scope of the task has been narrowed down, so the extent of the thesis to exclusively focus on a VR application for handling claustrophobia. Even within claustrophobia, there are many subcategories of the disease. Each subcategory has its unique triggers and problem area. The VR application of this thesis will therefore cover a scenario commonly associated with claustrophobia, taking an elevator.

The VR treatment scenario chosen for this thesis is an elevator ride because of its prevalence in public spaces and the high number of potential patients that could benefit from it. Elevators are often small, enclosed spaces without windows. These are common denominators as triggers of claustrophobic episodes in people with the disease. Actively avoiding elevators can cause unnecessary difficulty and stress upon those with claustrophobia.

An MRI scan scenario was another consideration based on the need to help alleviate the current problems when physicians require such tests to form a diagnosis. Currently, patients with severe claustrophobia must use heavy anaesthetics to perform an MRI scan. In cases where that is not possible, practice and acclimation with a therapist over several sessions is currently the only option. In the end, the plans for this scenario were removed due to time constraints. The benefits of the MRI scenario could potentially be more significant for the patient than from the elevator scenario, but the number of potential patients would be far fewer.

To summarize, the scope of the task is limited to a single VR scenario for treating claustrophobia and testing restricted to volunteering therapists. Due to limitations, the scope and testing of this thesis's goal and research question reflect this.

1.4   Goal and research questions

Despite this project being a part of a more significant ambition of creating a catalogue of ready to use VR exposure treatment for the therapists at Helse

Vest, the goal and success of this project will be evaluated separately from the rest of the catalogue.

This thesis aims to create a virtual reality application for treating claustrophobia in patients to overcome specific real-life scenarios they usually have problems with due to their diagnosis. It will be used in exposure therapy on children and youths by a psychologist. This application aims to be utilized in medical treatment. Therefore, medical guidelines and advisement from doctors were adhered to in its design.

This thesis aims to develop a VR application that therapists can use as a tool in the therapy of patients with claustrophobia and fear of elevators. The design of the application aims to be convenient and uncomplicated to operate to make it usable with children for the interests of the collaborators of this thesis The Children and Youth Clinic, Haukeland University Hospital[33].

This research question this thesis will be answering :

> What is the feasibility of developing a VR tool for therapists to use in treatment for claustrophobia?

1.5   Research method

As a result of the short time frame, the application will not be evaluated using actual patients. The need for lengthy approval processes and subject approval for all software used in medical treatment makes this unobtainable. Instead, testing will be done voluntarily by doctors with both standardised System Usability Scale (SUS)[18] and a more customised question sheet for interviews afterwards to gather their opinions on the application.

The volunteers with medical insight will be able to determine the effectiveness of the application by exposing them to relevant situations that can trigger an anxiety episode. The patient needs to be in these uncomfortable scenarios willingly for the exposure therapy to work, but not too extreme as that may traumatise the patient. The application needs to find itself on that fine line to be effective and appropriate for medical use. After each session, the volunteers will have an interview that follows a list of questions concerning all parts of the application. These questions will be standardised for all the participants and will adhere to guidelines for testing software used in medical treatments[6] and testing of virtual reality applications in general[35].

In quantitative research methodology, the results are obtained from data analysis, either statistical, mathematical, or numerical. Qualitative research methodology handles non-numerical data to understand opinions, experiences, or concepts. This master thesis uses a mixed research method since both numerical and non-numerical data will be used in the evaluation of the application[44].

1.6 Evaluation

In order to evaluate the success of the application, evaluation sessions will include evaluators (voluntary employees of Helse Vest). These sessions will consist of a testing phase followed by a questioning phase. The testing phase consists of scenarios performed by the evaluators both as the subjects and the therapists. Questioning will follow a semi-structured standardized interview format with a list of 17 questions and a System Usability Scale (SUS) form.

The evaluation sessions for this project will be carried out exclusively by the generosity of volunteers from Helse Vest and Helse Vest IKT. Giving positive reviews can be in their self-interest as they gain access to the application at the end of the project. The number of participants is also relatively low for a study case with seven participants over eight sessions.

The standardized interviews will make the results easier to compare between sessions and create an average approval rating of the application. After comparing the results, the application will be deemed either appropriate and sufficient for use in exposure therapy on young patients with claustrophobia or not.

System Usability Scale (SUS) consists of 10 statements that the test subjects rate on a scale from strongly agree (5) to strongly disagree (1). It is a fast method of ranking new systems and comparing scores with competing products. The questions have remained essentially the same since the creation of the test in 1986, with the only notable change being the proposed wording adjustment from "cumbersome" to "awkward" by Finstad[8] and Bangor[3]. The questions are formulated so that the odd-numbered questions are positively angled, and the evenly numbered questions are negatively angled. Each question gets a score from 1 to 5, with 1 strongly disagree with the statement and 5 strongly agree. The odd-numbered statements subtract 1 from the score, and the even-numbered statements subtract the score from 5. Then all the scores are added together to form the final SUS score. The SUS score is a number between 0(very poor perceived usability) and 100(excellent perceived usability)[18].

Due to the tests being conducted at The Children and Youth Clinic, with evaluators from Helse Vest, all potential conflicts and potential impacts on the evaluation results need to be disclosed.

Participants came from connections of employees of Helse Vest related to the project. Invitations to participate in the evaluation session were sent to employees of Helse Vest with experience with exposure therapy or other forms of therapy. Potential weaknesses in these kinds of evaluations can include potential bias due to personal interest in the success of the project from the participants or the choice of which participants.

Some participants may want to use a similar system later and do not want to discourage development in that sector. Previous experiences and knowledge of the evaluators in a specific area may also affect the objectivity when evaluating the application. The number of participating subjects may not be enough to show the general opinions of the intended users. The delivery and the order of the questions and the person who delivers them can indirectly influence the answers given. It is unlikely that any of these potential scenarios will have had any noticeable influence on the results.

1.7 Related work

Research for the project uncovered other products that aim to solve the same problems. Some of the most relevant products will be discussed in this section to ascertain the strengths and weaknesses of the related products. Since most of these products are commercially available and not research studies, the only information they will be judged by is the company websites or personal experience with the product.

1.7.1 Psious

Psious is an all-in-one VR platform for therapists and mental health professionals[29]. They offer subscriptions that include a VR headset, access to their VR therapy platform and a library of ready to use VR scenarios categorized into specific fears and phobias. Their library has over 70 scenarios in 25 categories[31]. In the claustrophobia category, they provide two types of elevator simulations, one large and one small. Both can stop at different floors and add the presence of others in the elevator. They also provide a cellar scenario in which the therapist can make the walls close in. The last scenario in the claustrophobia section is a waiting room and presentation of an MRI machine by a virtual doctor[28].

The texture quality of the scenes is generally high, with photo scans used for specific objects and most people in the simulations. Sound is also a strong point in Psious scenes. Scenes have several layers of background noises and add footstep sounds when the patient moves. Some scenes also include a fully voiced section for delivering information in the simulation.

Their subscriptions seem to come with a Psious branded Pico Goblin 2 (G2) VR headset[30, 26]. It is a 3 degrees of freedom (DoF) headset, which detects the pitch, yaw, and roll of the user's head. A 6 DoF headset also detects the head position of the user in the x-, y- and z-axis allowing for movement[21]. Psious also have a mobile app so that the patient's smartphone and a pair of compatible, compatible VR glasses can replace the Psious VR goggles[27]. The Pico G2 comes with a hand controller[26], but this appears not to be included in the Psious VR kit offer[30].

One of the positives with the Psious VR treatment system is that treatment can be performed remotely. Psious envision Psious headsets get sent to the patients, and the therapist can walk the patients through the treatment during an appointment over the internet.

The type of VR therapy Psious offer ranges from pure 360°video to VR scenes with some control for the therapist. All scenes where the patient moves have fully automated sections, and all patient scene interactions appear to be through aiming the headset or verbal response to the therapist. As a result, the patient is always stationary when using the VR goggles, only moving their head. As a side effect, this can potentially lead to motion sickness in the patient if they are not completely still during treatment due to the disruption between the patient's motion and motion in the scene.

The MRI scene only lets the patient be in a waiting room and the room with the

MRI machine but never allows the patient to experience using an MRI machine. For this specific experience, there is a commercially available product through the Steam platform called VRemedies - MRI Procedure Experience.

1.7.2 VRemedies

A range of commercially available products through the Steam platform from VRemedies includes an MRI Procedure Experience, Radiotherapy Procedure Experience, CT Procedure Experience and Theatre Procedure Experience[39]. The virtual reality applications are a step by step simulated medical procedure aimed at children.

The products are currently available on Steam, and the product can be used without a medical professional present but do require that at least one extra person present to supervise and respond to keyboard prompts[**mVRemediesSteam**].

MRI Procedure Experience

The most relevant scenario for this thesis provided by VRemedies is the MRI Procedure Experience. An MRI VR scenario was highly considered for this thesis early on in development. This product was available at Helse Vest for inspiration to what could have been the product of this thesis.

There is currently no way to skip the 10 min intro that goes through everything from who works with the MR machine to what noises the machine makes in the form of a children's game before the actual MR simulation.

The sound of the MRI machine was realistic but got drowned out by one of three music options the user had to choose. They played for the duration of the MRI scan simulation. All the sounds also disappear when the robots are giving instructions or encouragement during the procedure.

VRemedies responded to one of their reviews concerning the lack of an option to skip the demonstration part of the simulation. They respond with news of the development of version 2 of the application, which will include such features[38].

The MR simulation itself was decent, but the simplified models broke the immersion when I tried it. The lack of detail and shading inside the MRI model removed all references of being in an MR machine with the screen going completely white.

1.7.3 Efficacy of virtual reality exposure therapy for treatment of dental phobia: a randomized control trial

A study on the efficacy of VR exposure therapy on patients with dental phobia was proposed in 2015[32] and was realized in 2018 [11]. In this trial, the participants were chosen randomly among adult outpatients who had not visited the dentist in the last 12 months or reported avoiding dental procedures due to anxiety.

The scenarios had five increasingly intense steps starting with the user surrounded by dental tolls and a dentist standing beside them. They continued with the dentist inspecting the mouth of the patient, followed by an injection.

Lastly, the dentist performs some drilling first without and then with the sound of the drill. The patient's anxiety level was recorded every 35 seconds during the simulation[11].

The trial results were positive, with a significant proportion of the participants that, after six months, no longer fulfilled the requirements for a dental phobia diagnosis. They speculate that the success of the trials is partly attributed to the level of realism in the VR scenario and the prolonged and controlled confrontation of the patients feared stimuli[11].

1.7.4 OTR Customer-Engaging Virtual Reality Elevator Simulator

OTR is an independent end-to-end IT company with more than two thousand employees. They provide AR development, VR development, RPA services, and custom software[25]. The product of interest to this thesis is the Customer-Engaging Virtual Reality Elevator Simulator[24].

Customer-Engaging Virtual Reality Elevator Simulator is a virtual reality project developed in Unity as a VR simulation of an Elevator. It is designed to allow the manufacturer to showcase different elevators to potential customers. The system facilitates real-time changes to size, colours, materials, button configurations, and more. The outside environment can also be changed to better match the intended destination of the elevator. The application supports VR headsets and controllers with 6 DoF (Degrees of Freedom)[24].

The project does not seem to be available to the public but is open to business inquiries through their website. The project is not designed with a separate options screen and gives all the options to the VR controllers. This control would need to be given to the therapist if it were to be used in exposure therapy.

1.7.5 A Randomised Controlled Feasibility Trial of Immersive Virtual Reality Treatment with Cognitive Behaviour Therapy for Specific Phobias in Young People with Autism Spectrum Disorder

This trial assesses the feasibility of using VR treatment with cognitive behaviour therapy in young people with an autism spectrum disorder. The trial had thirty-two participants who underwent five sessions, one ordinary cognitive behaviour therapy session and four sessions in a virtual environment[20].

One-third of the test participants showed improvements with their real-life phobias after six months of managing activities and situations they were not able to manage before the trials. By contrast, none of the participants in the control group showed improvements with their phobias. Additionally, five of the control group participants showed regression with the handling of their phobias, with only one form the VR group experiencing the same[20].

This trial shows that it is possible to obtain positive results in treating phobias using VR exposure therapy.

1.8   Innovation

The VR claustrophobia exposure therapy application will include a customizable elevator connected to a building so the patient can move from one environment to another. The patient controls the movement between the building and the elevator using a handheld VR controller. The different environments will have distinct differences in ambient sound to reinforce the patients feeling of traversing between environments. The elevator can be expanded and decreased in length, width, and height to adjust the intensity of the sessions. The gap between the elevator and the building can also be altered. The elevator has a panel with buttons for the patient to push, making the elevator go up, down, stop, start, and turn off the alarm if needed.

The therapist administering the therapy will be able to watch what the patient sees from a separate screen. They will also be able to make all the changes available in the scenes before and during treatment. The therapist is responsible for preparing the scenes suitable for the patient and giving the patient the required controls over the scene for that particular treatment. Offering the therapist the option to give the patient control over the scene or taking that control away is part of the idea that the sessions must be progressive with increasing intensity to make progress.

The application will differ from related products by being a fully functional elevator simulator with several customization options, including size control of the elevator. It is designed as a tool to be used during exposure therapy. Physicians requested all the features and helped develop a list of scenarios to be used in conjunction with the simulation to increase the intensity of the sessions incrementally. These scenarios ensure an increase in the patient's exposure tolerance and avoid stagnation in the treatment progression.

Chapter 2

Background

2.1 Phobias

A phobia is an excessive and irrational fear reaction[45]. Environments, situations, or objects can trigger this reaction. The severity of the reactions varies by type of phobia and on a case-by-case basis. Severe phobias may limit the person's ability to participate in daily activities. They may also cause the person severe anxiety and depression[23]. Certain types of phobias are more likely to cause these symptoms. People who fear open spaces (agoraphobia) may be confined to their house in severe cases as wandering outside may incur a panic attack. For those with nosocomephobia (fear of hospitals), easily treated medical conditions can suddenly become far more severe as the affected people will avoid seeking treatment.

2.2 Exposure therapy

Modern exposure therapy is based on emotional processing theory[19]. Emotional processing theory suggests that fear represented as a memory structure can be explained as a program for escape and avoidance[34]. The theory states that since fear can be represented as memories, it can be modified through emotional processing and therefore modify or remove the fear itself. By exposing the patient to perceived dangerous situations, they could eventually re-educate their associations for similar situations by removing or reducing the feeling of fear.

Many people view exposure therapy as unethical, poses an unacceptably high risk of harm to the patients and is stressful and potentially harmful to the therapist[7]. The type of exposure therapy that will be the primary use case for the application in this paper is a form of therapy that gradually increases the severity of the sessions. This way, the stress put on the patient, while necessary, can be controlled to some extent to avoid any severe trauma to befall the patient. While the patient has to face their fears in exposure therapy, they also need to disassociate the situation from fear and instead associate it with other positive feelings like mastery or control over the situation.

2.3 Virtual reality

Virtual reality (VR) is a way to experience a simulated environment using specially made goggles with computer screens for lenses. Military use of VR goggles for training in the 1970s with the term "virtual reality" first used in the mid-1980s. Today there are multiple high-quality devices accessible to the public on the market[16].

2.4 Medical utilization of virtual reality

Knowledge of the potential for using VR for training and education in medicine goes far back. Especially training for use in surgery has made significant progress. In a 2002 study on the improvements of operating room performance by medical residents using VR training, the results showed an increase in dissection speed and a mean error six times lower in a gall bladder dissection[36]. Over time the proven effectiveness of utilizing VR has inspired its use in other areas of medicine, such as exposure therapy.

In a paper from 2017 discussing the effectiveness of using VR to treat anxiety and other psychiatric disorders, they found that in two studies on flight phobia, the patients demonstrated symptom reduction and behavioural change in that the subjects were more likely to fly on an aeroplane after treatment. Following up on the subjects showed that the effects of the treatment remained after 1- and 3-years post treatment[19].

A paper in 2011 reviewing the possibility of treating children with phobias using VR had positive results on children with school phobia and arachnophobia (fear of spider). They go on to explain that although the results were promising, there is still a need for large, randomized control trials with control conditions and long-term follow-up to reach firm conclusions of its effectiveness[4].

2.5 Game engine

The software used to create this virtual reality elevator simulator is Unity. Unity is a game engine and IDE (Integrated Development Environment) with a publicly available free version. It comes with complete documentation for its API. Examples for most use cases are available in its documentation. Unity is prevalent and, therefore, has very active online forums that have accumulated the most questions and answers a new user is likely to encounter. The version used is 2019.4.11f1 LTS (Long Term Support). This version includes XR integration. XR is the combination of VR (Virtual Reality) and AR. Developing XR integration makes it easy to create VR applications that work on all currently available types of VR Headsets. The Unity Editor is user friendly with its intuitive drag-and-drop system for adding elements to a scene[5].

Chapter 3

Design

3.1   High level design
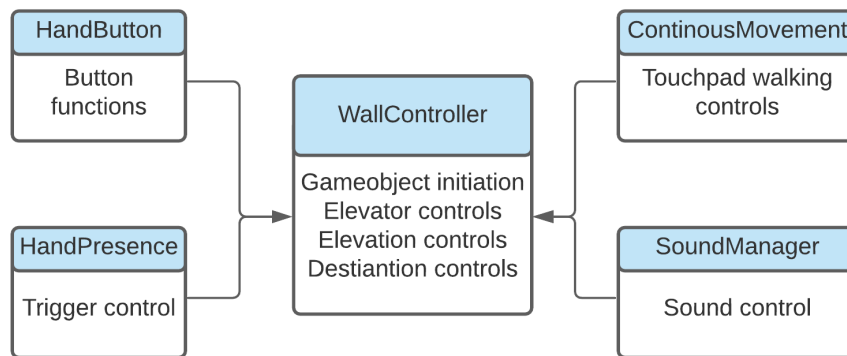
Figure 3.1: High Level Design of the application

The VR application consists of five classes: WallController, HandPresence, SoundManager, HandButton, and ContinousMovement as seen in figure 3.1.

The class HandPresence handles the input from the VR controllers. This class had a much more significant role in earlier builds. All the options now available on the therapist's screen were initially made for the VR controllers during early features testing. Part of the original plan was to give the patient many of the same options the therapist has to give them a feeling of control over the situation. This approach was later changed because the controller's touchpad menus got too complicated and diminished immersion, which conflicted with the project's intent of simplifying all patient interactions to increase immersion. All that remain of the class is the trigger functions that can be switched on using the therapist's screen to let the patient alter the size of the elevator.

SoundManager is the class that controls all the sounds in the application. This class controls all audio, from the background noise to the sound of elevator doors. This class was added to version 3 of the application. Before that, there was no sound. All the different audio clips have their individual function so that they can be called separately. The class allows all the sound functions to run parallel with each other and other functions to ensure no audio malfunctions occur.

HandButton is the class that handles the required logic of interactions with the buttons. This class allows any game object to become a tactile button that reacts to touch. When the spherical trigger zone of the VR controllers intersects with the hitbox of the game object, the game object moves with the controller in the allowed direction. If the game object travels far enough, it triggers a function to run. Due to the mechanics of all buttons being the same, this class can be used for all of them with only different functions called when pressed.

ContinousMovement is the movement system of the application. It allows for more movement in the simulation than is possible by moving in the physical play area. The system is linked to the left VR controller's touchpad. The choice of using the left touchpad and not the right one is because almost all current console video games use controllers that use the left thumb to move around with. By doing this, the patients already familiar with console video games will not suffer any disadvantages while not making it more complicated for those without preconceptions. Moving forward in the movement system is linked to the VR headset and will always be the head direction of the patient.

The largest class by far is WallController. All game logic not previously mentioned in the other classes is handled by it. The Start function involves initiating the elevator parts, assigning starting values to the variables, and creating eventlisteners to the interactable elements on the therapist's screen. StoryInitiate initiates the necessary parts of the building. This function was used to initiate the whole building when the building could change size. Due to the removal of this feature and baked lighting problems, only the south wall (wall facing the elevator) and doors still employ this function. The Update function is called every frame and modifies all variables that change over time. This function also checks if any requirements are fulfilled and changes the appropriate variables or calls the proper function. Elevation of the elevator is calculated in the function ElevationChange. The elevation of the next destination and the current elevation is compared, and changes to the current elevation are made accordingly if the elevator is moving. All upcoming elevator destinations are added to and sorted based on the current floor and order in which they were added.

3.2   Methodology
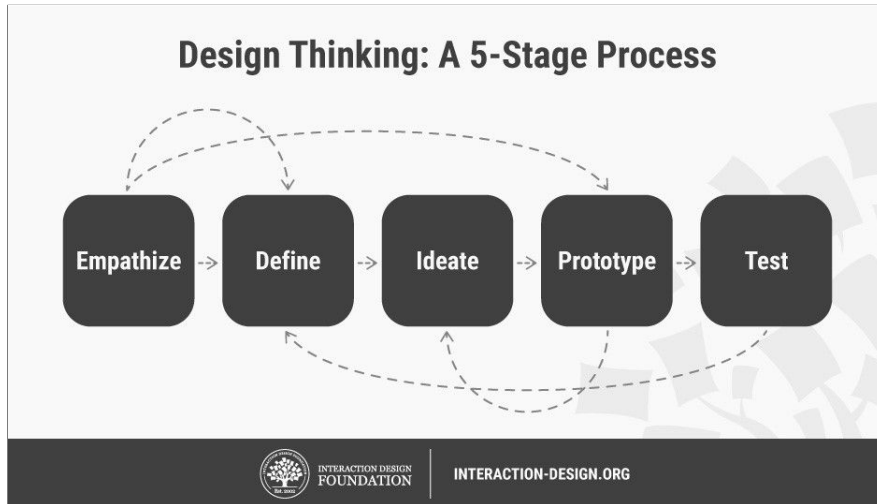
Figure 3.2: Design Thinking Methodology (Source: Design Thinking by Interaction Design Foundation[14])

The design methodology used in this thesis is based on Design Thinking but has some notable differences. Design Thinking is a design methodology that provides a solution-based approach to solving problems[10]. It consists of five phases: Empathize, Define, Ideate, Prototype, and Test as seen in figure 3.3. The methodology is non-linear, and some phases can go back to previous ones.

The methodology custom-built for this project has renamed the different phases to reflect the process better. As seen in figure 3.2, the model consists of four phases named: Specify assignment, Define requirements, Develop the product, and Evaluate the product.
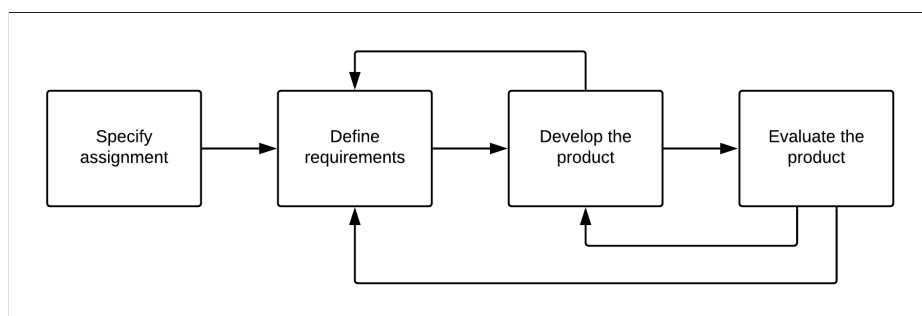
Figure 3.3: Design Methodology for this project

This project started as an assignment proposal from Helse Vest as a possible master project. The proposal was "Exposure therapy for phobias/anxiety". Because Helse Vest did not have any specific phobias in mind, the wording was deliberately vague to include the master student in outlining the project. This project is to help fill out the growing digital library of ready to use VR scenarios,

and all suitable scenarios not already included was therefore available for this project. In the first phase of the method: Specify assignment, claustrophobia was chosen for the project. The scenario to trigger this phobia was an elevator ride. Possibilities of creating an additional scenario if the first one was completed early were also discussed. This additional scenario would have been an MRI scan.

In phase two: Define requirements, a list of all essential and non-essential features was made. The essential list focused on what was needed to make a minimum viable product. On the list were: the elevator itself, sound, an alarm button, an area in front of the elevator, and the option for changing the settings from a separate screen. The elevator had to work and look like an actual elevator with sound for the immersion and realism needed to trigger anxiety in the patient. An alarm button was also needed since it is a common cause of stress and adds realism. The area in front of the elevator allows for the transition into a claustrophobic space. According to chief physician Paul Joachim Bloch Thorsen, letting the patient cross the threshold is an integral part of the experience.

On the non-essential but nice to have list, we had customizability of lighting and textures, size altering of the elevator, a walking system, a gap between the elevator doors, and a panic button. The size altering of the elevator, walking system, and door gap controls were added. By being able to alter the size of the elevator, the difficulty can be increased between sessions to build up the patient's tolerance. The walking system would allow for more freedom of movement while being restricted to the finite real-world play area. Control over the individual doors allows for more scenarios customized for the patient's needs.

The third phase: Develop the product, involve creating the application with the beforementioned features. The result of this project is not a prototype but rather an application that can be developed further by Helse Vest IKT. That is the reason for the change of wording in the new model. Every other week during the project development, there was communication with the client to find the best solutions and ensure progress. Separate technical meetings with Thomas Fiskeseth Larsen and Håkon Garfors from Helse Vest IKT were held to solve problems during the development process.

For the last phase: Evaluate the product, seven evaluators participated in eight evaluation sessions. With the System Usability Scale (SUS) and a custom-made questionnaire with 17 questions, we gained insight into the application's usability and assumed effectiveness. All the evaluators were employees at Haukeland Sykehus, and the sessions took place at Haukeland Sykehus Barne- og ungdomsklinikk's VR-room. Several excellent suggestions for improvements came from these sessions. One of these suggestions was that the area connected to the elevator needed to be opened up. No matter how large the area was, it required windows and a door to get all the benefits of an open area. This discovery was so crucial that it was added to the essentials list after the first two sessions.

3.3 Sessions
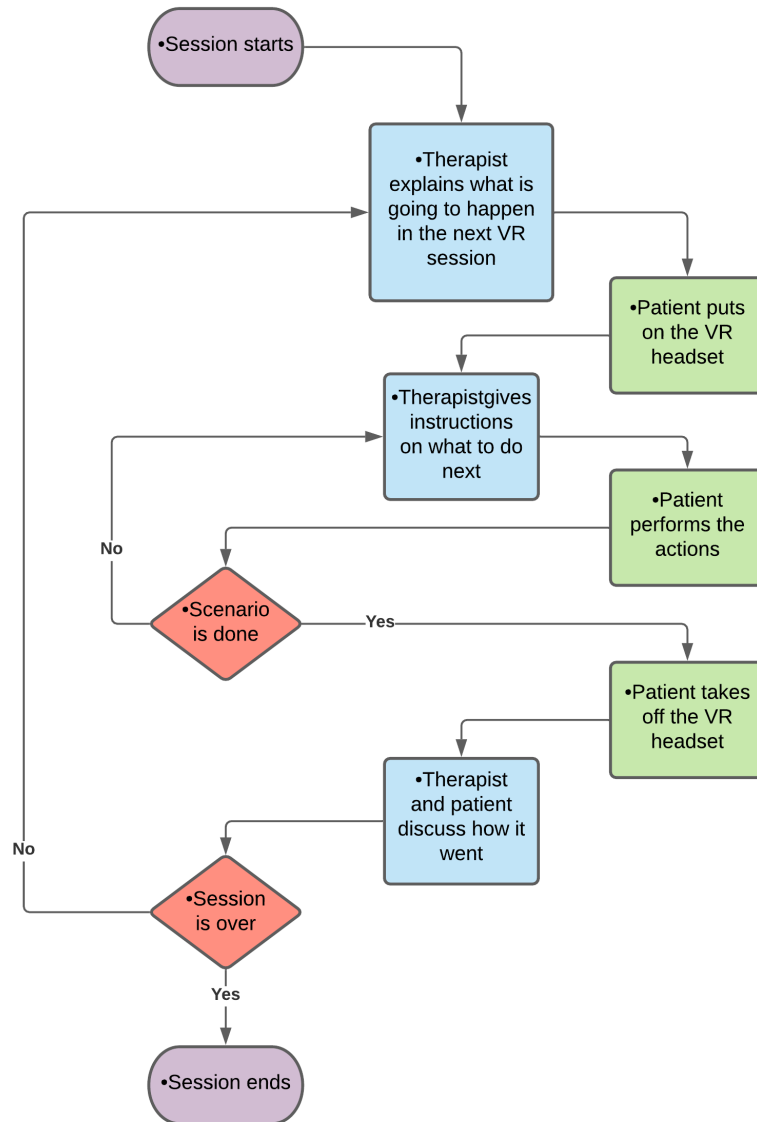
Figure 3.4: Proposed therapy session flow diagram

The session layout is developed in cooperation with employees at Helse Vest to mimic the practices generally used when performing exposure therapy against phobias. As seen in figure 3.4 the therapist and the patient talk over what is going to occur when the patient enters VR. A VR headset and controllers are then put on the patient and adjusted to fit. The therapist then instructs the patient on what to do based on what scenario performed. The session continues until the entire scenario is over or the therapist deems it enough. The patient

then takes off the VR headset and controllers and sits down to talk with the therapist about what just happened. If the therapist deems it necessary to perform another scenario or the same scenario again, it will follow the same procedure.

3.3.1 Scenarios

The session scenarios were created in cooperation with a psychiatrist with a speciality in child and youth psychology. The scenarios differ in complexity and severity to have options ready for the most likely use cases. They are sorted by increasing severity and can be considered guidelines for what scenarios to use if the patient masters a previous scenario.

The scenarios list is the beginning of a potential treatment protocol to be used with the application. For the scenarios list to be considered a treatment protocol, it would have to undergo several tests performed on patients with claustrophobia.

Scenario 1: The patient stands outside the elevator with the elevator door open. The patient can look inside the elevator or go inside the elevator, but everything is stationary. (figure 3.5)

Scenario 2: The patient stands outside the elevator, and the elevator doors are closed. There is an audio indication, and the elevator doors open. After a while, they close. This action repeats with irregular intervals. The patient does not need to go inside the elevator, but the elevator does not move if they choose to. (figure 3.6)
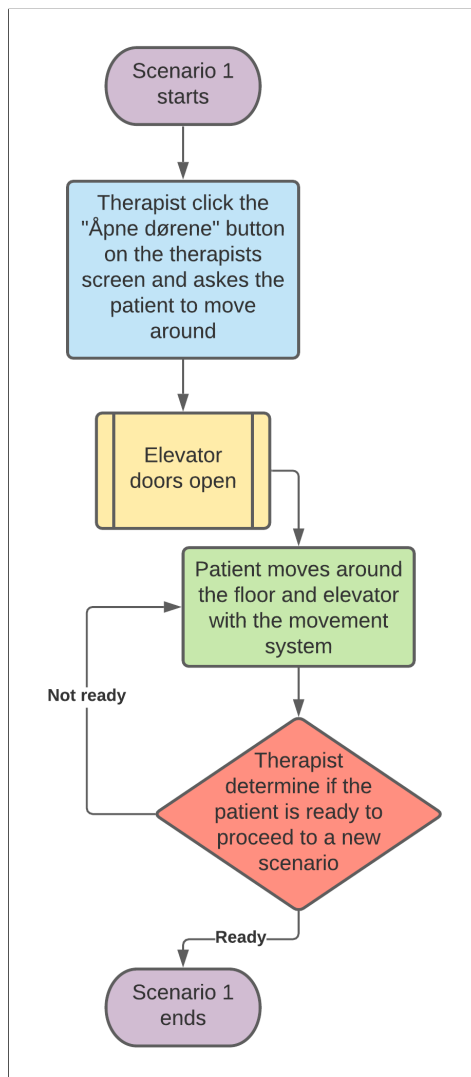
Figure 3.5: Scenario 1 flow diagram
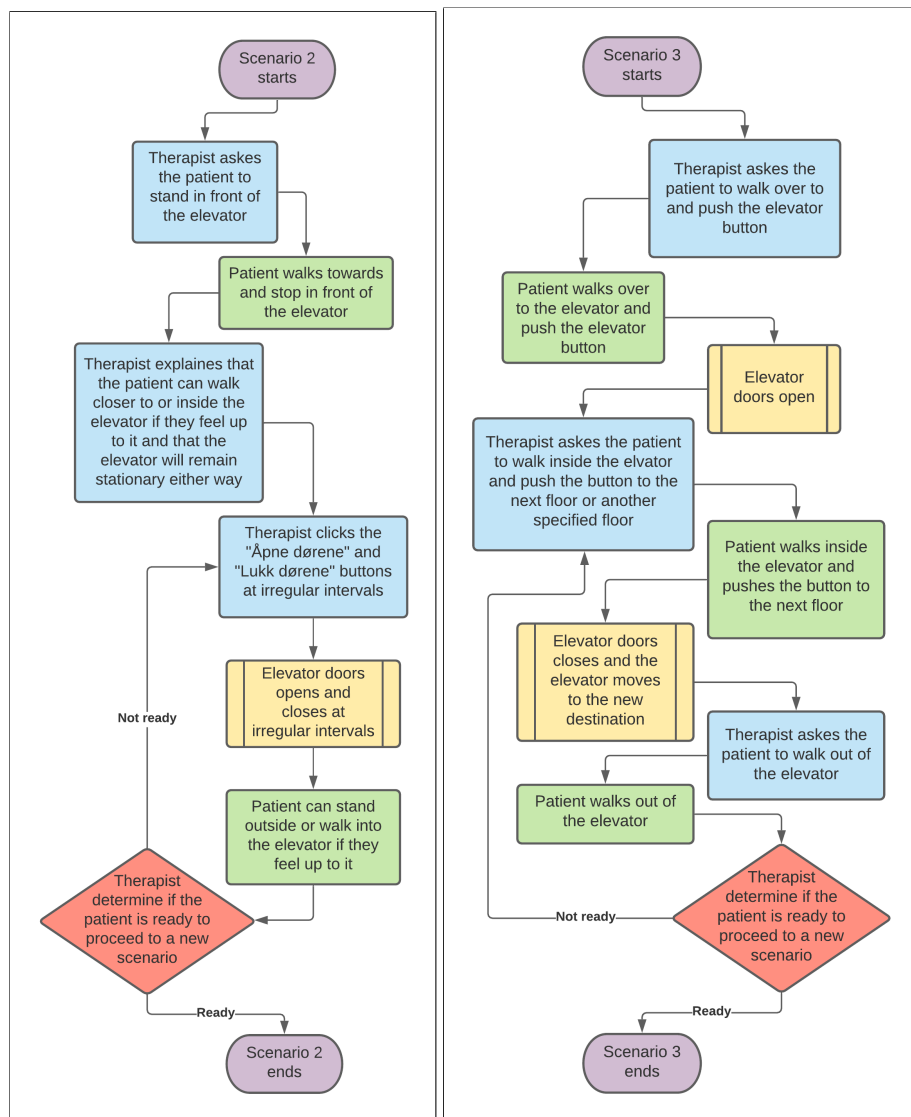
Figure 3.6: Scenario 2 and 3 flow diagram

Scenario 3: The patient is going to use the elevator as usual. They press the call elevator button, go inside the elevator and select a floor. They then stand in the elevator while moving and exit the elevator when it arrives at the destination. (figure 3.6)

Scenario 4: The patient is going to use the elevator as usual. They press the call elevator button, go inside the elevator and select a floor, but the elevator will stop at every floor between the current floor and the destination floor. (figure 3.7)
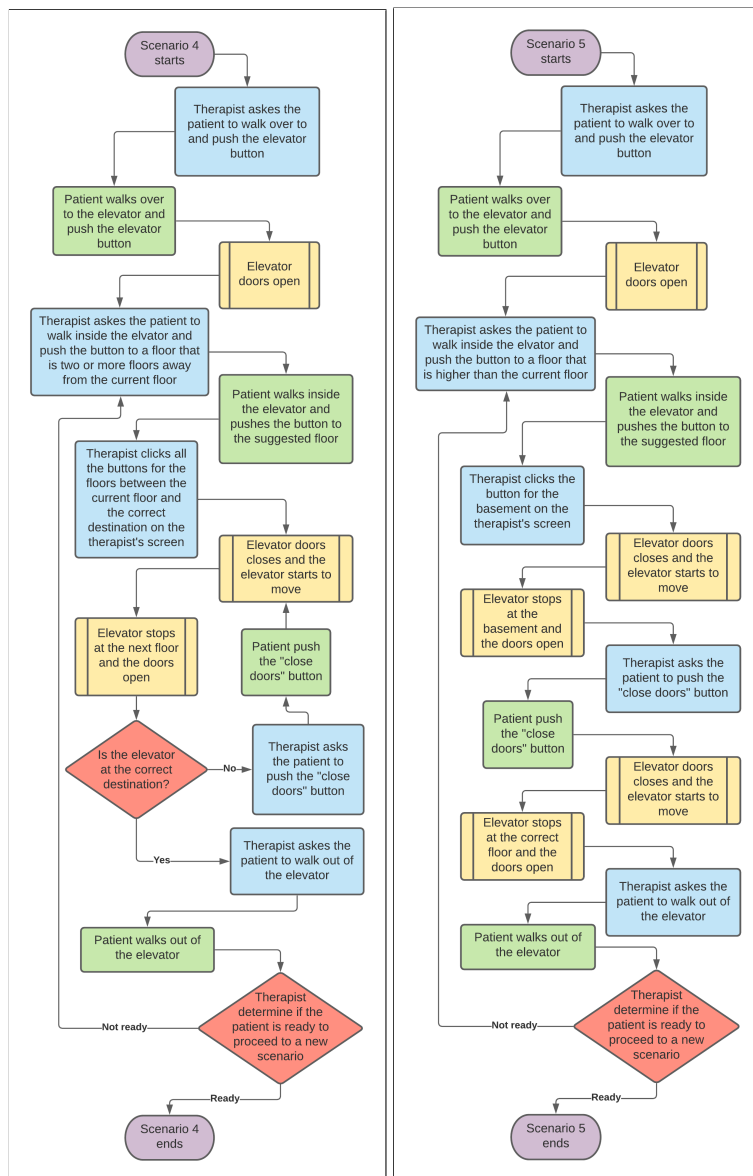
Figure 3.7: Scenario 4 and 5 flow diagram

Scenario 5: The patient is going to use the elevator as usual. They press the call elevator button, go inside the elevator and select a floor, but this time the elevator goes in the opposite direction to the chosen destination. If the chosen destination is on a higher floor, the elevator will go all the way down to the basement. If the chosen destination is on a lower floor, the elevator will go to the top floor. After pushing the close doors button, the doors will close, and then the elevator will go to the chosen destination. (figure 3.7)

Scenario 6: The patient approach the elevator and press the call elevator button. The doors open partially. Afterwards, the patient walks into the elevator and presses the button for the chosen floor. The elevator begins to move, but the doors do not close all the way. No matter what destination gets chosen, the elevator goes down into the basement. After pushing the close doors button, the elevator continues to the chosen destination but suddenly stops between floors. The patient has to use the alarm button to make the elevator move again. When the alarm button is pushed, the elevator goes to the chosen floor, stops and open the doors. (figure 3.8)
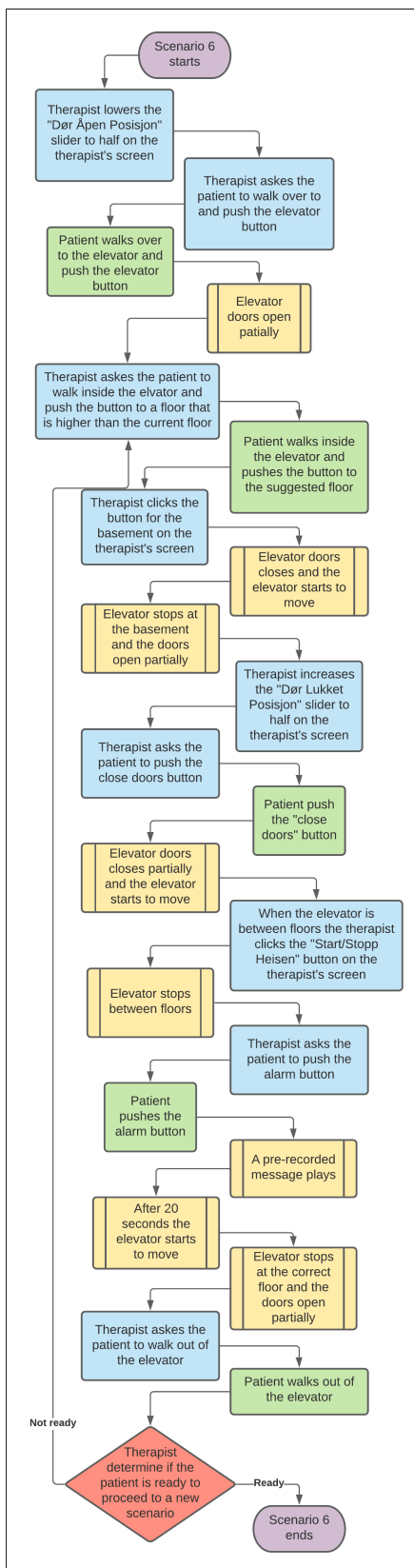
Figure 3.8: Scenario 6 flow diagram

3.3.2 Questionnaire

The questionnaire intends to uncover the perceived ease of use and usefulness based on findings in the Extended Technology Acceptance Model[42].

The questioning took the form of a semi-structured interview as in the book Successful Qualitative Health Research[13]. By performing the interview in this way, we can get answers to questions by listening to the evaluator talking while using the application. This method was used in the first two sessions as intended, and the questions crossed out after the evaluator answered one of the questions indirectly. Changes to this approach were included in later sessions to a more formal questioning due to lack of elaboration on some partially answered questions or answers that conflicted with direct answers to other questions. The questions need not follow any particulate order. However, all the questions would be asked at the end of the session to get all relevant information.

Questionnaire for application evaluation sessions:

1. What is your overall impression of the elevator simulator?
2. What do you think of the visual quality?
3. Did you experience any performance issues?
4. How user friendly was the patient's point of view and the therapist's point of view?
5. How immersed were you when using the simulator from the patient's point of view?
6. Do you feel some of the tasks to be superfluous?
7. Do you think some of the tasks were too difficult for the intended users?
8. How would you describe the scaling of difficulty of the tasks?
9. Were some of the tasks difficult to understand or execute?
10. How was the feedback of your actions from the patient's point of view and the therapist's point of view?
11. Was the task instructions unclear or confusing?
12. How did you find using the therapist screen?
13. How was using the VR-headset and controllers?
14. What utility value does the application provide as it stands today?
15. What needs to be changed or added before clinical use?
16. How is the application as a foundation for further development?
17. What other areas could be potential use cases for the application?

3.3.3 System Usability Scale

The System Usability Scale (SUS)[18] is a tool to be able to determine the usability of a system quantitatively. SUS makes it easy to compare the usability

between different systems with similar functions or makes it easy to compare different versions of the same system. Changes or additions to a system can then be determined if they positively affect its usability. In this thesis, the SUS will only be used to compare different versions of this application. All similar products that have been found during research for this project do not have publicly available SUS data of their products.

Number	Statement	Strongly Disagree 1	2	3	4	Strongly Agree 5
1	I think that I would like to use this system frequently.	O	O	O	O	O
2	I found the system unnecessarily complex.	O	O	O	O	O
3	I thought the system was easy to use.	O	O	O	O	O
4	I think that I would need the support of a technical person to be able to use this system.	O	O	O	O	O
5	I found the various functions in this system were well integrated.	O	O	O	O	O
6	I thought there was too much inconsistency in this system.	O	O	O	O	O
7	I would imagine that most people would learn to use this system very quickly.	O	O	O	O	O
8	I found the system very awkward to use.	O	O	O	O	O
9	I felt very confident using the system.	O	O	O	O	O
10	I needed to learn a lot of things before I could get going with this system.	O	O	O	O	O

Chapter 4

Development

4.1 Tools

The project uses Unity version 2019.4 LTS (Long Term Support) to ensure long term stability without problems possibly occurring due to an update to Unity. Unity LTS versions are stable builds of the software that receive only the most necessary updates to increase the system's stability. Long term support builds get bi-weekly updates for the first two years and monthly updates for the third year before it stops receiving updates[40]. This project started using the Universal Render Pipeline template in Unity Hub. The Universal Render Pipeline (URP) adjust the Project settings to optimise performance and broad platform support.

4.1.1 Models, textures and sounds

The elevator and the main building are made up of simple shapes to facilitate the size change mechanics. Various models, props, and sounds were added to create a realistic office environment with a surrounding city landscape.

The office interior models come from the Unity Asset Store under the name Stylized Interior Props Vol2[1]. An open landscape office layout with a cleared path on the ground floor from the door to the elevator was created by using the models(fig 4.1). The models make the room more realistic and give the user lots of space to move around and familiarize themselves with the controls. The higher floor has the same layout with the addition of a central meeting table. The basement is different in that the room is empty, except for a few servers.

Surrounding the traversable central building are several high story buildings(fig 4.2). These buildings come from the Unity Asset Store under the name of Modular City Buildings[37]. The buildings were positioned in a semi-random pattern around the central structure to prevent most visibility beyond. Several details like balconies and antennas were on the buildings, but some of these details had very noticeable graphical errors. The transparent part of the antenna texture was filled in with the default unity white colour on the antenna, making them look unnatural. Additionally, removing unnecessary vertices for performance

Figure 4.1: Picture of one of the desk model groups.

optimization and a problem that stopped the models from moving resulted in the removal of some of the models.

The problem that stopped the details from moving affected all the interior props since everything needed to move except the elevator. The building model details were removed, and the interior was all put in a separate game object prefab. Why this worked is unknown, as it was later discovered that the problem was hidden static tags nested deep inside the prop prefabs. This problem is not uncommon with cheaper models and was easy to fix. To fix this, turn the prefab tag to static with the nested children and then back to dynamic. This fix was later applied to ensure no further problems, but the complicated prefab grouping of the interior stayed due to the late discovery of the problem.

All the sounds in the application is acquired from the website FreeSound[41] or self-recorded. During development, several sound recordings were taken from public elevators in shopping malls in Bergen. Still, these recordings were not used due to the background noise and the amount of work needed to make them loop naturally. Audio clips were added to button presses, opening and closing the elevator doors, elevator movement, background noise in the building, and heavy fan noises in the basement. The alarm button has a different sound when pushed and then plays a voice recording.

4.2 Elevator

The entire elevator is constructed from basic geometric 3D shapes in Unity to fully control the virtual play area. The width, length and height are all customizable both before and during a session.

The elevator and story floor doors connecting the two are segmented to mimic real elevator doors. I could not find any official elevator door speed, only that according to regulations, the speed of the doors are linked to the mass and
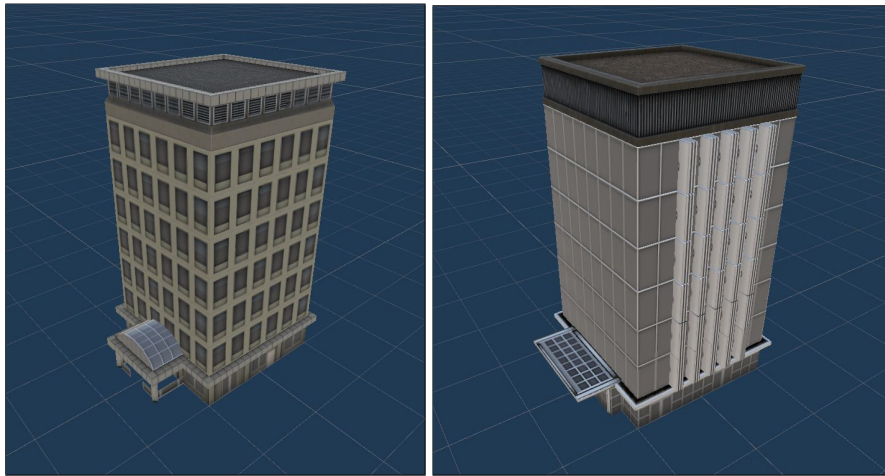
Figure 4.2: Picture of two of the surrounding buildings.

must not amount to more than 135N of force when opening and closing[17]. The implemented speed of opening and closing the doors will be 2.2 m/s after timing the doors of several elevator recordings. How far the elevator doors can open and close is customizable in the therapist's screen. This functionality was added at the client's request to show the elevator movement when inside. The doors can be opened and closed using the buttons inside and outside the elevator but will not change during elevator movement. The therapist's screen can open, close, pause, and change the limits of the door at all times.

4.3 Building

The building is constructed similarly to the elevator. In the first versions of the application, the size of the building and elevator were linked. There were additional sliders for customizing the dimensions of the building, but these were found unnecessary during the first two sessions. Changing the size of both the elevator and the building simultaneously made the users feel like they were shrinking and not the room getting larger. In the later versions, the building no longer changes size. The wall connected to the elevator consists of three segments that change the size to fill the gap between the changing elevator and the building floor height and width boundaries.

4.4 Buttons

The button panel in the elevator control the destination of the elevator, the doors, and calling for help with the alarm button. The buttons are physical objects in the application that the patient must press with their hands to activate. When the controller's hitbox intersects with the button's physics object, the button's horizontal position translates from the controller within predefined limits. If the position of the button shifts with half its length towards the button frame, it will trigger a function.

The elevator button panel have eight red buttons numbered floor 0 - 7(fig 4.3). Under the red buttons are a green button for opening the elevator doors and a blue button for closing them. At the bottom of the panel is a red button with the word "ALARM" on it. Pressing this button will play a unique button sound, followed by a voice recording stating that the alarm is registered and help is on the way. After a 20 second pause, the distinct alarm button sound will play once more, and the elevator will continue moving towards the next destination if it had stopped between floors when pushed.
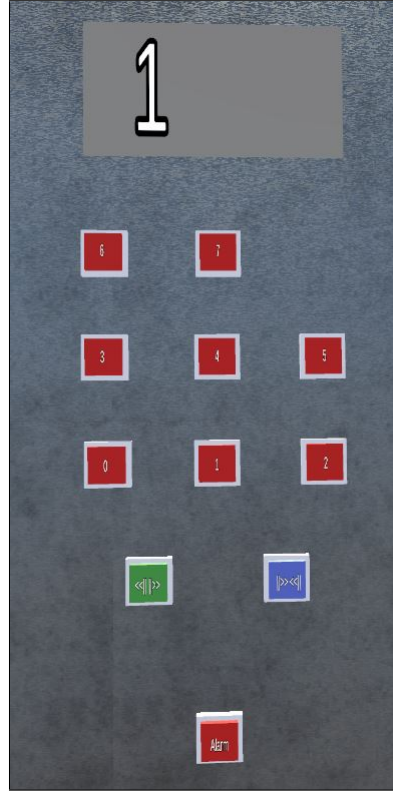
Figure 4.3: Elevator button panel

4.5 Walking system

The physical play area in the real world is limited and too small for what is required in the simulation. To get around these limitations, an additional movement was added to the application. The system allows the patient to move using the touchpad on the hand controller. The use of the touchpad will move the entire VR rig in-game. To avoid unrealistic movement, the headset position with the distance from the floor create a capsule that will be the patient's hitbox, disallowing walking through walls and doors. The patient can still walk through the wall if they physically move inside the physical play area.
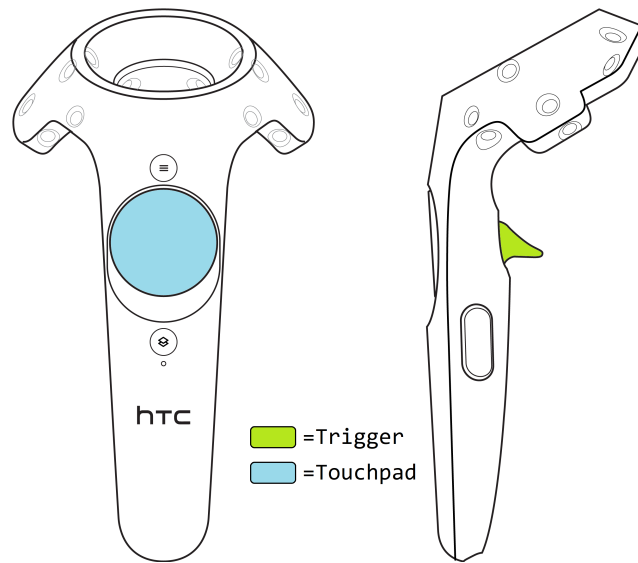
Figure 4.4: The touchpad on the left controller controls the walking system. The therapist can allow the user to change the size of the elevator using the triggers of both controllers.

4.6 Elevation Change

Both the movement of the elevator and elevator doors "transform SetPosition" is used. The requirement for the type of movement is smooth, even motion and no problems with rigid body colliders while moving. The latter requirement was no longer a problem by having the story building move and not the elevator. There are several ways to change the position of a game object in Unity, and they all have advantages and disadvantages. AddForce, MovePosition, and SetVelocity require rigid bodies and interact well with other rigid body game objects. Transform Translate and transform SetPosition does not require rigid body game objects.

AddForce makes the game object accelerate, which conflicts with the need for smooth, even motion. The only rigid body collider is on the player model inside the elevator when the story building is moving. Also, making game objects rigid body require some CPU usage to calculate the physics. Therefore, the need for the elevator to be a rigid body game object disappears, and there is no need for AddForce and MovePosition.

Transform Translate has many of the same strengths and weaknesses as transform SetPosition. They both move at a consistent speed when combined with Time.deltaTime. They both have some issues when colliding with other game objects but behaves as expected when not moving.

4.7 Therapist's screen

The therapist's screen is a separate monitor from the VR headset where the therapist can see what the user is seeing and make adjustments with the tools provided on the screen(fig 4.5).

The therapist's screen was the projects most time-consuming part to get working.

Based on previous experiences of team members, the therapist's screen was expected to be a simple addition. What became apparent early on was that using Unity's new scriptable render pipeline (SRP) would lead to many problems integrating this feature.

An additional screen for the therapist had been included in Unity's built-in 3D render engine to assign both the camera from the VR headset and the camera with the option menu-overlay to Display 1. Difficulties with the new SRP occur due to the VR headset camera overriding the overlay camera options.

Figure 4.5: Left picture shows what the therapist sees. Right picture shows what the user sees.

Among the first experiments to solve this was trying out a feature introduced with Universal Render Pipeline (URP), camera stacking. Camera stacking allows multiple cameras to overlay each other. The problem with this approach is that only one camera can be treated as a standard camera and allowing for screen designation. All the other cameras must be labelled as Overlay, restricting many configuration options. As a result, the overlay menu would be visible for both the VR headset and the therapist's screen if enabled.

Another attempt to solve the problem was making a new camera as a child of the VR camera. It inherits the position and rotation of the VR camera and then has the new camera show on the therapist's screen. This approach conflicted with Unity's XR system used for the application's VR headset and controller interactions, making both the therapist's screen and the VR headset not work.

The next attempt had the same goal as the previous but circumvented Unity's XR system. By writing a script to copy the rotation and position of the VR camera, the new camera does not rely on Unity's editor options. Problems with this solution were interference with the image refresh rate between all cameras resulting in delays between the right and left eye in the VR headset.

The solution implemented included setting the render mode of the therapist's screen canvas to Screen Space - Overlay. The options overlay would only be visible to the therapist and not the user of the VR headset. This solution has its problems, and warnings are visible in the console while using this solution(fig 4.6). The additional rendering cost in the console warnings seems to be minimal and does not seem to affect the frame rate of the application much.
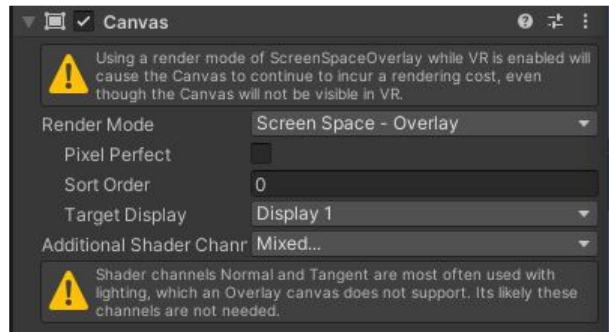
Figure 4.6: Unity Inspector of the canvas overlay

The therapist's screen has three main functions: controlling the size of the elevator, controlling the doors of the elevator, and controlling the movement of the elevator(fig 4.7).

The size controls in the upper left corner of the therapist's screen are divided into overall size, length, height, width and user control. Changing the overall size of all three axes without altering the ratio between them is done by using the elevator size slider. The length, height and width sliders will only change their respective axis. The last feature in size control is the ability to give the user control over the overall size by using the triggers on the VR hand controllers(fig 4.4).

Control over the elevator doors are located on the top right and include the open doors button, close doors button, open door position slider, closed-door position slider and the start/stop door button. The open doors and close door buttons do as they suggest. Using the open- and closed-door position slider will change how far the doors can open and how much they can close. To start or stop the movement of the doors, one can use the start/stop doors button on the therapist's screen. When clicking this button, the doors will stop moving and will continue moving when pressed again. Using these functions, the therapist can make the doors stutter or make changes to the open and closed positions without input from the user.

The last section of the therapist's screen is the elevator movement section on the lower right side of the screen. Here you will find a similar button panel as in the elevator with buttons of all the floors from 0(the basement) to 7. Three displays on the therapist's screen show what floor the user is currently on, the elevator destination list and a prioritized elevator destination list. The elevator destination list is a sorted list of all the floor buttons the user has pressed. When a floor button is pressed in the elevator, then that floor would become the next destination. All subsequent floor button presses are sorted in ascending or descending order based on whether the elevator moves up or down. If the therapist chooses a new floor, then it will be added to the prioritized destination
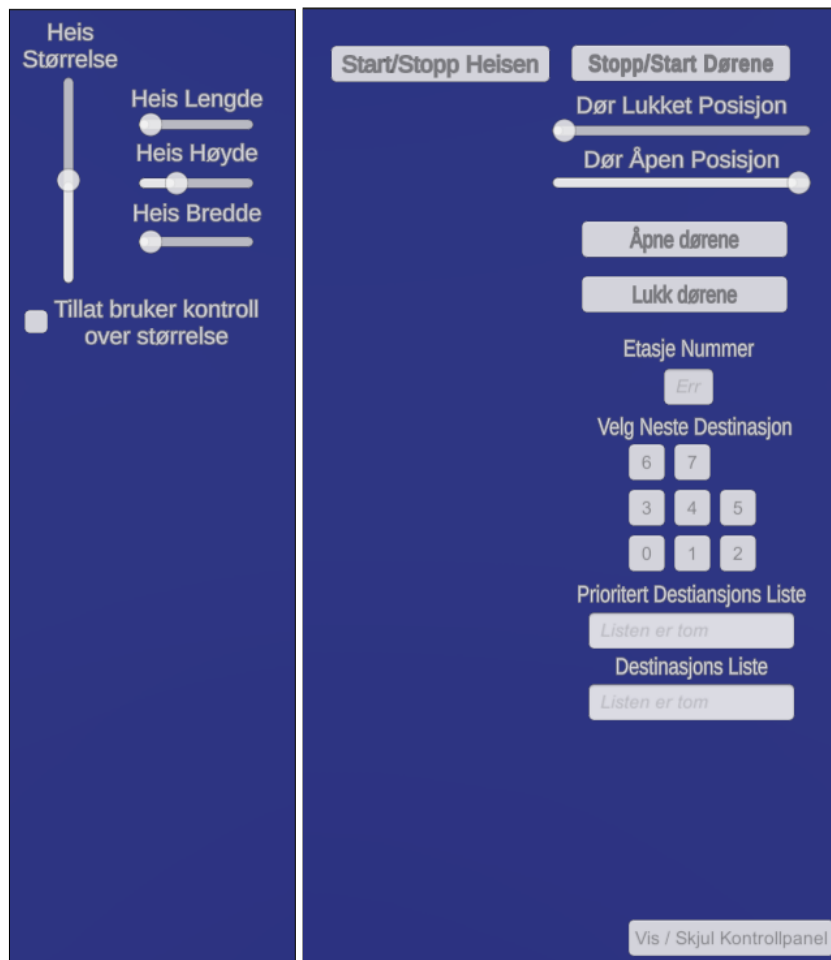
Figure 4.7: Left and right part of the options overlay on the therapist's screen

list. The prioritized destination list is a separate list for the therapist's selected floors and will always be chosen over the user's destination list. This list is not sorted and will proceed as an ordinary queue.

Chapter 5

Analysis and Assessment

This thesis uses a mixed research method with semi-structured interviews to assess the application, as explained in chapter 1. Recordings of all sessions were made with permission from the participants. First, the evaluators gave information about their professional qualifications and their experience using Virtual Reality equipment. Then followed a guided session through all the scenarios with increasing difficulty. If the evaluator's comments matched with the questionnaire, those questions would not need to be asked at the end of the test. After the test, the remaining questions on the questionnaire were asked to the participants, followed by a SUS (System Usability Scale) form filled out by the participants. The sessions were held in the VR lab of The Children and Youth Clinic, HaukelandUniversity Hospital. The VR headset used in the testing was a pair of HTC VIVE Cosmos with VIVE hand controllers.

5.1 Evaluation

Session one was performed on 21st June 2021. An unexpected error in the application occurred the day before and was not discovered before the session. A function called ChangeSizeRatio had been added to the Update function by mistake. As a result, all changes to the elevator ratio would reset to the default settings along with the door positions every update. The ratio sliders on the therapist's screen would not move, and the building and elevator would stutter between the default position and the new position several times a second.

In preparation for session two, the ChangeSizeRatio function was removed from the update function. Two additional fixes prevented the elevator from moving unless the patient was inside the elevator and prevented door opening during elevator movement.

Session two was performed on 1st July 2021 and concluded without any unforeseen problems. The session started with a quick overview of the different goals of the session, proceeding with the evaluator putting on the VR headset. All feasible scenarios were performed in order by the evaluator from the patient's point of view. Afterwards, the evaluator tried using the therapist's screen. The evaluator was shown the different options on the therapist's screen and tested

them. Later, the evaluator was interviewed using the questionnaire and filled out the SUS form.

After the first two sessions, the application went through several significant changes to its visuals and audio. The building will no longer change size when the elevator changes. The starting position of the elevator changed from floor 0 to 1. As a result, the building got an underground basement in alignment with scenarios 5 and 6. The building got glass walls, and the ground with surrounding structures was constructed to give visual references of height. The buttons were numbered and given symbols to differentiate them, and a display that shows movement and the current floor was added to the elevator. With these changes, the application worked as intended in the Unity Editor. The application did not build correctly after this, and all subsequent sessions after session two were therefore performed in editor mode.

After the last session, all the significant issues that occurred during or before session three were solved. One issue was the inability to build the application properly. This issue had no meaningful impact on the results of the sessions but resulted in all sessions after session two having to be run in the unity editor. The solution to the issue was removing and then adding the elevator scene back into the build settings. It was discovered that the issue first occurred after changing the scene's name.
An issue that has persisted since the inclusion of the movement system is the touchpad-slider issue. When a slider on the therapist's screen has been selected, the patient can move the slider by moving sideways with the movement system. This was fixed by enabling a setting in the VR controllers.
Another issue that was discovered during session four was a problem with the destination list. If the therapist and the patient both pressed the same floor button, then the floor would not be removed from the list after the floor was visited. This was solved right after the session by adding an if-case to the destination list function.

Dates of all sessions:

1. 21st June 2021

2. 1st July 2021

3. 19th August 2021

4. 19th August 2021

5. 30th August 2021

6. 31st August 2021

7. 1st September 2021

8. 3rd September 2021

5.1.1   Evaluation session participants

All evaluators taking part in this project are employees at Haukeland University Hospital, and the sessions took place at Haukeland Sykehus Barne- og ungdomsklinikk's VR-room. There were two evaluators in session one, but only one

evaluator was present to get each evaluator's full opinion in all subsequent sessions.

List of evaluators:

- Evaluator A is a psychiatric nurse
- Evaluator B is an environmental therapist
- Evaluator C is a psychologist
- Evaluator D is a clinical child welfare educator
- Evaluator E is a psychiatrist
- Evaluator F is a psychologist
- Evaluator G is a psychologist

5.2   Information about session summaries

The following session summaries are based on notes and voice recordings from the interviews at the end of the sessions. Answers were given in Norwegian language and have later on been translated. The order of the content in the summaries does not necessarily follow the same order as the questionnaire. Some of the answers were given out of context during the testing phase.

5.3   Session 1

Session one includes Evaluator A, a psychiatric nurse specializing in sports therapy and Evaluator B, an environmental therapist. They both have extensive VR experience and have experience using VR in therapy.

The elevator was a good proof of concept and a good foundation for further development, but not an application they would use as is. The textures were not convincing. It did not look like real life. The room was without anything to rest the eyes upon, and there was no way to distinguish between floors and no way to know what floor you were on. The lighting was way too dark inside the elevator.

The evaluators reported discomfort from using the VR headset when the size of the elevator was changed. The sliders for size ratio and door gap would flicker and reset to their original position when changing them. Moving the elevator using the therapist's screen with the patient outside the elevator caused the patient to either fall through the floor or fly through the ceiling. If the elevator was moving or the patient was on another floor than the elevator, the door buttons still worked. It would open the doors between floors.

The walking controls were easy to use, but a bit confusing since the direction you were moving would change if you turned your head. It was un-intuitive to push the hand at the buttons, but it was not a problem after being informed. They expected to be able to point with controllers and pull the trigger at the

button. The text on the therapist's screen was confusing. The evaluators did not know what the different sliders did before being told. The blue tint on the therapist's screen while in settings mode was hard to look through and unnecessary.

Feelings of being in an elevator were had, but no perception of the elevator moving was registered. It was like being in a metal box. The textures got scaled with the walls, so it just felt like you (the patient) were getting smaller when the room got larger.

Scenario six could not be tested because the alarm button had not yet been implemented. The evaluators got to read all the proposed scenarios at the end, including scenario six. They reacted to scenario six because it would be a form of flawed practice. The elevator does not suddenly start to work when the alarm button is pressed in the real world. Instead, a pre-recorded message should be played before a short waiting time before the elevator starts to move. The wording of the scenarios was clear and easy to understand with no difficulty following instructions. The evaluators consider non of the scenarios excessive and that the scaling of the scenarios were good. Still, it would be on a case by case basis of what scenarios would be used in each treatment session.

The evaluators did not report any problems pushing the elevator buttons with the controller. Still, they did say that it was impossible to tell if the elevator was moving after the doors closed or not. The therapist's screen was mostly responsive when used. However, the size slider, ratio sliders, story addition sliders, minimum door gap slider, and maximum door gap slider were non-responsive due to an error in the application.

The evaluators found the naming of the different sliders and buttons to be confusing and unintuitive. An example of such naming was the X-Ratio slider replaced with Elevator Depth and Y-Ratio with Elevator Height. They also commented on using English for the therapist screen and would like to have Norwegian naming as an option as it could be a hindrance for some of the older therapists.

The application as it stands in the session is only beneficial as an instant claustrophobia experience. This would not be part of standard treatment procedure as it stands now and would only be used if the therapist wanted to push the patient straight into a claustrophobic space without the build-up.

"Sånn som det står nå (programmet) så starter du rett inn i en klaustrofobisk situasjon med ingen synlige måter å komme seg vekk." -Evaluator A
("As it stands now (the application) you start directly in a claustrophobic situation with no visual ways of escape.")

The first opinion the evaluators shared when starting the session was the room was fully enclosed. No matter how big the room was, the fact that it is fully enclosed means that the patient starts in a claustrophobic environment taking away the transition from a non-enclosed space to an enclosed space. The entire building would need glass walls or big windows to the outside world to change

this aspect. It would also need a door to give the patient an illusion of how they got in the building.

The subject stated that the application provided a promising foundation to build upon and expressed an interest in attending further sessions.

The application version used at the session would not be of much value outside of claustrophobia and elevator fear. Still, after fixing the problems discussed, it could also potentially be used to treat agoraphobia, acrophobia, or nyctophobia.

5.4   Session 2

The evaluator in this session is Evaluator C, a psychologist with moderate experience using VR.

The overall impression of the application is very good. It would be better if it were more apparent when the buttons have been pushed and if they did something. Make it more obvious that the door is closing. Everything that can add to the immersion that you are in an actual elevator would be good. The experience of walking into the elevator can be pretty anxiety-inducing for many.

This version of the application is a quite good starting point for further development. More elements to make the experience more lifelike would be nice. It could be made to look like an office landscape or other spaces that often have elevators. Feelings of being inside the virtual world were experienced, but feelings of being in an elevator would require some additional elements. The process of walking to the elevator felt immersive.

The VR headset was a bit out of focus or cloudy. They suggested using colours with more contrast to allow the eyes somewhere to rest. They did not know if they were able to press the buttons in the elevator. The lack of feedback meant that the evaluator did not receive any confirmation when events occurred, be that pushing a button or the elevator moving.

Using the application from the patient's point of view went fine. The therapist's screen had too many choices. It would be better to take away some of them and make some of the options more standardized. I have concerns regarding the required technical competence to use it is too high. It would be beneficial if the technical requirements were lowered by simplifying the therapist's screen even more.

Very nice start with scenarios one and two to get to familiarize the patient with the environment. It also lets the patient get familiar with the controls before having to focus in more stressed settings. The scenarios will most likely be manageable by most patients, but the therapists would not put a patient in a situation they could not handle. The patients are supposed to feel the anxiety during sessions so having more challenging scenarios is good. The scaling of the scenarios is fine, but the way therapists work today, the sessions do not have to follow a strict gradient scaling and can jump between difficulties.

Some of the last scenarios could be difficult to understand what is happening from the patients perspective. Without sound in the application, the only way the patient knows something is happening is if the therapist tells them what is happening. They would like to have more responses in the form of sound and the buttons lighting up after being pushed by the patient.

They had some problems finding the proper function on the therapist screen when given verbal directions. The text on the therapist screen was hard to read and was not self-explanatory. The text size was too small, and the wording was too technical for people without an intimate knowledge of the application to understand.

The application provides value in that it allows easy access to exposure therapy for patients too encumbered to use actual elevators. Make changes to the environment visually, add sound and make it evident for the patient that the elevator is moving. It could be an office landscape or a hotel.

It would be nice to see an application version that does not rely upon having a therapist present. The system could be more automated with a version that can be run on a standalone VR headset without the need for a PC screen. The evaluator thinks that the application is too specific to be used in other areas without significant changes.

5.5 Session 3

The evaluator for this session is Evaluator D, a clinical child welfare educator specialising in the mental health of children and youths with some experience with VR.

The application seems like a good tool for exposure therapy on the fear of elevators, and the evaluator did not experience any technical problems during the session.

It felt like taking an elevator, but the sound of the elevator moving should change when coming to a stop instead of just stopping. It is difficult for the patient to know if the elevator is moving in the wrong direction without looking at the display. The windows were so transparent that you couldn't see the window. Adding people to the scene would help reinforce the anxiety in the patients. A part of the fear of being stuck in an elevator can be that other people could come at any moment. The gap between the elevator and the building was too wide.

"Jeg synes det (teraputskjermen) var veldig bra, veldig lett og oversiktlig..."
- Evaluator D
("I think it (the therapist's screen) was very good, very easy (to use) and clear...")

The therapist's screen was good, but it could be made easier to navigate quickly.

Grouping together similar options and colour-coding them could be an option. Some of the sliders should be simplified with fewer options for ease of use. In addition, the text on the therapist screen could be a more contrasting colour to the environment. The colour of the text on the buttons is grey and should probably be black. The patient's movement was quite uncomfortable, and Evaluator D had closed eyes while moving in small increments. The possibility of other modes of movement could help some people. They would prefer teleporting rather than continuous movement.

The element that broke some of the immersion was the first scenario with the doors wide open. This is because elevators usually do not just stay still with open doors for long periods. Scenarios one and two are similar enough that scenario one could be considered excessive.

None of the instructions were difficult to understand, and the instructions were easy to understand. The scaling of the scenarios felt natural. When dealing with youths, instructions should be precise and no longer than two sentences. It was a bit difficult at first with the buttons because the test subject moved forward simultaneously when pushing the button. Moving the hand to the buttons was unnatural at first. Evaluator D also wanted to pull the triggers on the controllers when pushing the buttons.

The sound feedback for pushing the buttons in the elevator was good. Evaluator D wanted more ways to notify the patient when something was happening.

The application has some utility value in that the patient can be exposed to challenging situations. With the help of a therapist, the patient would get continuous help and instructions on how to handle those situations. As a standalone application without a therapist present, it would have less utility value. The application is a tool and is only a part of the therapy and can't replace it.

Before use in actual therapy, the previously discussed changes to the therapist's screen should be addressed. A more in debt protocol on how to introduce the application to the patients should also be made. The evaluator is positive to the notion of having the application developed further with suggestions for adding NPC (Non-Player Character) characters in the scene to include social anxiety and maybe reinforce the claustrophobic experiences in the simulation.

5.6   Session 4

The evaluator in this session is Evaluator C, a psychologist, and the same evaluator as in the second session since the improvements done to the application between these sessions are substantial.

The evaluator had a good overall impression of the application and seemed optimistic about the changes made after the second session. They did feel a bit unwell at times from the movement function in the simulation when asked. A difference between the expected and actual speed of the moving system is most likely to cause discomfort. The speed at which the evaluator moves with the

joystick is relatively slow to avoid motion sickness, but it may be the reason for it in this case. Similar to the second session, everything was a bit unclear when wearing the VR headset. One possible cause could be the poorly calibrated distance between the lenses in the VR headset.

According to Evaluator C, the realism of the visuals is satisfactory for producing anxiety, but the size and positioning of the buttons in the elevator are points for improvement. The buttons were too low to the ground and required people of average height to bend over to reach the lower buttons. Having to move both in the real world and using the movement system in the simulation makes it unnatural to move all the way over to the buttons to press them. The distance to the button panel felt unnatural and required closer than expected positioning to reach the buttons. Requests for some way to stand further away and still be able to push the buttons were made. The doors opening without the evaluator knowing due to the close positioning beside the button panel is a problem.

When trying out the application in the session, both a known issue and a new one occurred. The known fault in the application was the joystick and slider issue where the slider can change values when the joystick is moved left or right after the slider have been selected on the therapist's screen. The new problem was an oversight in the interaction between the prioritized destination queue and the regular destination queue. Suppose the first element of the priority queue and the first element of the destination queue are the same. In that case, the application will remove the priority queue element when the floor is reached but not remove the destination queue element. In the case of the priority queue containing no other elements, the application will try to go to the first element of the destination queue. The elevator will now not move unless a new different floor is added to the priority queue.

The evaluator's opinions regarding the six scenarios remained unchanged since session 2. Evaluator C stated being positive of the gradual introduction in the first and second scenarios. That scaling of the scenarios were irrelevant as in proper therapy. The therapist will pick and choose the right scenarios based on several factors for each individual treatment.

The evaluator felt that the instructions should be even more specific with where to walk, look, and which buttons to push. The evaluator could not remember hearing the beeping sound when pressing the buttons and explained that the background noise in the application was barely audible. This could be solved by increasing the volume.

The therapist's screen could be too advanced for some of the intended users. The naming of the two different queues (priority destination list and destination list) was confusing. The destination list could be renamed to patient destination list.

"Sånn som det står nå så får du ubehaget fram og det er jo det som er poenget..." -Evaluator C
("As it stands now (the application) you get the (intended) discomfort, and that is the point...")

As the application stands today, it has utility value in that it can induce the intended discomfort. Before it is used clinically, the evaluator thinks that more testing of the moving system in the problem to see if other evaluators have the same motion sickness problems as they had and make changes to the movement speed accordingly. Another option for movement like teleporting would be too diverging from reality. Evaluator C wants to walk in real life and the simulation simultaneously without the need for other movement solutions. Space constraints make it challenging to move beyond the elevator by moving in real life.

The application was deemed a good foundation for further development and is getting close to a usable product when referring to session two in which Evaluator C participated. The usability of the therapist's screen was still a bit too in debt, and they would wish to see more ready-made options, e.g., instead of a slider for the size of the elevator, have three options: small, medium, and large. About other potential use cases for the application, Evaluator C suggested maybe acrophobia but conveyed that the application is made for a very particular use case, and changes would have to be made if the application should be used differently. This suggested use case could be achieved by making parts of the elevator out of glass.

5.7 Session 5

The evaluator in session five is Evaluator E, a psychiatrist with a speciality in child and youth psychology. This evaluator has been actively involved in the application's design but has not used it before this session. The evaluator has much experience using VR.

The overall impression of the application was positive. It was described as intuitive, elegant, and motivating in the sense that Evaluator E wants to explore all the different levels of exposure with patients and push the patients comfort zone even further. The degree of customization lends itself to customization and explorations with patients, with everything from altering the size of the elevator to taking the elevator with the doors always being open. Evaluator E went on to say that it was easy to immerse oneself in the simulation with it feeling like being inside an actual elevator.

When first using the VR headset with the application, the evaluator was surprised that the hand could push straight through the wall when trying to press the buttons. Evaluator E commented feeling slightly motion sick when moving using the movement system with the joystick and walking in the real world simultaneously. Turning and using the motion system led to the evaluator feeling nauseous due to the movement turning with the user's head.

The known fault in the application with the joystick and slider issue appeared during the session. The doors open position slider changed values when the joystick was moved left and right after the slider had been selected on the therapist's screen.

Time to learn the VR controls were short, and the ease of use was quite good, with the joystick on the left controller being the only interactable element on the controllers. The rest is intuitive enough that the patient should be able to use it without practice. The therapist's screen is sufficiently self-explanatory, and Evaluator E had nothing to comment on the ease of use after a quick rundown of the features before trying it out.

Evaluator E was involved in the making of the scenarios list. The scenarios work well when tested in the session and have logical progression in the level of severity. During an actual therapy session, only one or two scenarios would be performed each session, not all in a row as has been done in these sessions. Each new scenario level brings a new element that was challenging or potentially challenging. Evaluator E expressed confidence in following the list of instructions to perform each scenario without further training required.

The feedback when using the VR controllers could be improved by introducing elements like vibration in the controllers. Still, it was usable when accustomed to the application and would rather listen for the beeping sound than look at the button for confirmation on it being pressed. The instructions for the tasks in the different scenarios were neither unclear, confusing, or difficult to understand.

When asked about the therapist screen, the evaluator responded that it surpassed their expectations. Evaluator E has been involved with the project since the beginning and commented that it was easy to use and with more functionality, than expected. The current utility value of the application is being able to perform a good exposure therapy session using the application as it stands now.

"Jeg tror at dette kan være en veldig god støtte og et godt verktøy for å jobbe med eksponeringstrening for heis og klaustrofobi." -Evaluator E
("I think that this (application) can be of great support and a good tool for working with exposure therapy for elevators and claustrophobia.")

There are possibilities for improvement with the lights being far too bright, giving it an unnatural sterile look. The sounds in the application are only audible for the patient using the VR goggles, with only the louder sudden sounds such as the beeping of the buttons being audible to the therapist through the VR headset. When altering the size of the elevator, the sliders for doors closed position and doors open position gets affected, leading to odd door configurations that the therapist must fix. Changing the elevator's speed would be a welcome addition as the elevator can be relatively slow, especially when going from the basement to floor seven. When stopping the elevator to have the patient push the alarm button, it is possible to press the start/stop elevator button on the therapist's screen, making the elevator stop when it should start. Disabling this and giving the therapist's screen a way of knowing where the elevator is currently and if the elevator is moving combined with further training in using the application prior to sessions would help with that problem. Last on the list of possible improvements is being able to remove destinations from the destination lists on the therapist's screen.

The application could be used in therapy as it stands now, but the evaluator would also want the application to be useable remotely in treatment. The patient can be at home during therapy sessions with the therapist communicating and controlling the application remotely. The evaluator also wanted a way to customize the environment to simulate specific places. Doing this can prepare the patient for specific situations. The application is a very good foundation for further development with possibilities for including other phobias such as fear of lightning, heights, the dark and social anxiety by having other people in the building and elevator.

5.8 Session 6

The evaluator in session six is Evaluator F, a psychologist. Prior VR experiences are limited to 360° movies. The application achieved its goal well and could be used in therapy.
The evaluator reported that everything was a bit blurry when using the VR headset. At the beginning of the session, quite a lot of time was used to adjust the focus of the lenses in the VR headset, but the problem was not fully solved. Visually the game was sufficiently realistic, but the environment felt too sterile without any other people in the scene.

"Jeg følte jo at jeg var i en heis, men det er veldig viktig det at du faktisk kan få gå inn i heisen selv. At du ikke bare er plassert i heisen fra starten av. Da tror jeg det kunne føltes litt mer ut som et rom." -Evaluator F
("I did feel that I was in an elevator, but it is really important that you can walk into the elevator by yourself, not just placed in the elevator from the start. Then I think it could feel more like a room.")

The movement in the simulation is essential for the immersion and the illusion of the elevator. Having to walk through the elevator door made it feel more familiar and helped the association between the simulation and an elevator. The elevator was too large at the beginning of the session, which made it feel more like a room with a big door instead of an elevator.
The VR controls and the therapist's screen were easy to use with some instructional information at the beginning. The therapist's screen had a simple layout, and the amount of customization could be helpful to personalize the therapy to specific users.

Some of the scenarios can seem redundant for someone without a fear of elevators, but all the scenarios are appropriate for actual therapy. The instructions were clear, but when asked to walk over to the buttons or the elevator, the evaluator had problems deciding whether to walk in real life or the simulation. At several times Evaluator F started walking and then realized they had to use the movement system in the simulation once they hit the outer bounds of the VR play area. Evaluator F would like more precise instructions on what type of movement and when to use which one. This could be helped by spending more time on the first and second scenarios and asking the patient to walk around the office space to familiarize them with the controls. Moving and pushing the

buttons simultaneously, resulted in an unexpected plunge forward towards the buttons.

Regarding the therapist's screen, the evaluator commented that the text was too small and was confused about the priority destination list element. It was unclear to Evaluator F if they could fill in the numbers using a keyboard. A noticeable delay was also registered when pushing the number buttons on the screen. This led to uncertainty about having the enter button pressed to confirm the choice. After using it for a while, the evaluator learned how to use it. The therapist's screen is easy to use if you plan what you will do in the therapy session beforehand.

The sound in the simulation is essential for the immersion of the patient. The sound was reportedly too low and difficult to hear. They also suggested the use of even more sound effects for all the different parts of the scene. The immediate opening of the doors and departure when the doors closed broke some of the immersion. One possible suggestion is to have a slight delay between the different parts to simulate real-life better. The delay could also be an additional concern for the patient when using the elevator to not know if the doors will open even after going to the correct floor. Adding people to the scene would make it more realistic and could impact the effectiveness of the simulation.

In the current state of the application, it can already provide value in treating patients with fear of elevators and claustrophobia. It is a good option for easing in patients in a controlled and safe environment. The application could prepare patients for further therapy using real elevators. Before clinical use, the application should implement solutions for the previously mentioned problems.

5.9   Session 7

The evaluator in session seven is Evaluator A, a psychiatric nurse specializing in sports therapy. This is the same evaluator as in session one.

Using session one as a point of reference Evaluator A deem that this application has improved significantly and is ready for use in therapy. The comments from the first session focused on the need for the patient to start in an open environment. These problems have been solved in this version of the application. The volume was a little low at the start of the session but was increased at the request of Evaluator A.

Visually the game is more impressive and more realistic than in the first session. The wall-length windows were too transparent and made it feel like there were no walls, and the patient could fall off if they walked to the edge. Making the glass darker or more dirty would help. Putting in support columns or adding small wall segments to break up the glass would also help with the realism as it is unlikely that the four pillars in the corners could hold up the building in real life.

The simulation made Evaluator A feel like they were in an actual elevator connected to a building. Movement felt fine, and when discussing different options

for movement, Evaluator A concluded that there were no other apparent options for handling movement without compromising on the immersion.

The scenarios were approved with compliments from the evaluator on the number of different scenario difficulties. Regarding the scaling and difficulty of the scenarios, Evaluator A explained that no scenario could be too difficult as it is the therapist's responsibility to ensure the patient can handle the scenarios chosen. The variety of scenarios are good, but Evaluator A would not necessarily follow the scenarios in the given order.

Most of the door controls were deemed unnecessary on the therapist's screen, and everything you need to perform the scenarios can be achieved with the Start/stop doors button, the close doors button, and the open doors button. All the other sliders are just more clutter. Using the VR headset was easy to learn, and the controls were intuitive. The only action that did not come naturally was pushing the buttons with the controller. The evaluator pulled the controller's trigger every time a button was pressed out of habit from playing other VR games. However, Evaluator A said that it would probably be easy to become accustomed to the button interaction with some practice.

The application could be put into practice today, but if something is going to be improved upon, it would be the visuals and audio. Adding options for lighting could make the application applicable in other areas like fear of darkness and making the back of the elevator out of glass would make it usable for therapy for acrophobia. Doing this would close the gap between virtual and reality. In the evaluator's opinion, the application should only be an intermediary to prepare the patient for therapy using an actual elevator. No matter how good the simulation gets, it cannot replace the experience of using a real elevator.

5.10   Session 8

The evaluator in session eight is Evaluator G, a psychologist that has previous experience with therapy regarding fear of elevators and claustrophobia. The evaluator has not used a VR headset and controllers before but has seen some 360°movies utilising a smartphone and a head-mounted phone holder.

Evaluator G felt immersed, and the simulation felt well put together, but having to operate the buttons broke the immersion because the evaluator had to focus on the specific task at hand. The buttons were too low to the ground, and the numbers on them were hard to read. It was again commented on the transparency of the glass walls with suggestions to have actual walls with smaller windows. The absence of a floor indicator in the building made it difficult to know which floor the patient was on without going back into the elevator.

The VR controls felt natural but took a while to get used to. Evaluator G commented that the peripheral vision was a bit out of focus, but this may be due to the design of the VR headset. The movement speed felt too slow, and the simulation made the evaluator want to run around, not walk.

"... lyd er en sensorisk modul som kan øke stressnivået." -Evaluator G
("... sound is a sensory module that can increase the levels of stress.")

The sound design of the simulation was good, but the volume was a little bit low and was kept low to be able to communicate during the session. The evaluator would like to see even more sounds to hint at the patient that something is happening. Elevator music could also be included to give the patient something to focus on, making it more apparent when the elevator is moving.

The scenarios were well received with the number of options available to the therapist, and there were more than Evaluator G expected. More time should be spent on scenario one to familiarise the patient with the controls and their environment. The difficulty of the scenarios is impossible to say as a general as the previous experiences of the patient will affect how they handle them.

The application is a good intermediary before treatment using an actual elevator. It can bring forth anxiety in patients and give them a feeling of mastering the fear. Adding other people to the simulation would further improve upon the experience. This application has great potential for allowing treatment to be performed remotely with the therapist at an office and the patient in their own home should development continue in that direction.

5.11 Summary

The first two sessions with the earlier application versions were optimistic regarding further development but not very positive when using that version. The visuals, such as graphics and models, were purely practical. The applied textures got stretched and appeared with large pixels when looking at it in person with the VR headset. The building connected to the elevator was completely boxed in with no windows and was poorly lit. Poor lighting was the result of prebaked lighting on game objects that got instantiated later. The closed space and poor lighting were something the evaluators in session one felt strongly about. They gave good examples of how to improve the application by opening the building with large windows. Doing so would alleviate the sudden claustrophobic experience the user would get when entering the simulation. In addition, these alterations would help reinforce the feeling of a transition between open space and a claustrophobic space in the user. Also, the size-changing that changed both the building and the elevator simultaneously and rate made it seem that the user was shrinking instead of the room getting larger. The therapist's screen part of the application got some complaints about the language being too difficult to understand and way too many options. Some technical problems impacted the user experience. The most severe issues got solved before the second session.

The feedback from the remaining sessions were overall much more positive when compared with the first two. The opening up of the building with windows, the addition of sounds and the addition of room interior were all received as positive additions. Some evaluators commented on the transparency and size of the windows, saying that they felt there was nothing to stop them from going over

the edge of the building. The therapist's screen was simplified, and the language changed to Norwegian because older therapists could potentially have problems using it. The changes to the therapist's screen were all positive. The only comments were that further simplifications and removal of features was necessary. 4/5 evaluators that tested version 3 gave very positive feedback. Most of them agreed that the application has utility value for use in treatment as it stands today.

5.12 Results from the System Usability Scale

5.12.1 SUS Question results

Each question is scored from 1 - 5 (0 - 4 points).
1 = Strongly Disagree. 5 = Strongly Agree.
The odd-numbered questions are positively worded, and the even-numbered ones are negatively worded. The even-numbered questions decrease the overall score with its points, and a low score is therefore preferred on these questions.

Evaluators \ Questions	1	2	3	4	5	6	7	8	9	10
Version 1										
Evaluator A (Session 1, 21.06.21)	1	4	4	3	1	3	4	1	2	2
Evaluator B (Session 1, 21.06.21)	2	3	2	3	2	4	3	3	2	4
Version 2										
Evaluator C (Session 2, 01.07.21)	3	4	3	2	3	3	4	2	3	3
Version 3										
Evaluator D (Session 3, 19.08.21)	5	1	4	2	4	1	5	1	4	1
Evaluator C (Session 4, 19.08.21)	4	4	2	5	4	3	3	3	2	5
Evaluator E (Session 5, 30.08.21)	5	1	5	2	5	1	4	2	5	1
Evaluator F (Session 6, 31.08.21)	5	1	5	4	5	1	4	1	4	2
Evaluator A (Session 7, 01.09.21)	4	1	5	1	4	1	5	1	5	1
Evaluator G (Session 8, 03.09.21)	5	1	5	2	4	1	3	2	4	1

Table 5.1: SUS question results

By observing table 5.1, a pattern starts to emerge. In version 3 of the application, the evaluators score reliably higher on the odd-numbered (grey) questions and lower on the even-numbered (red) questions compared to the earlier versions. This means that most of the earlier weaknesses have been improved in version 3.

5.12.2 SUS total score

To get the total score you have to add together all the question scores. Because half of the questions are negatively worded so the scores of the evenly numbered questions has to be inverted as shown: $1 \rightarrow 5$, $2 \rightarrow 4$, $3 \rightarrow 3$, $4 \rightarrow 2$, $5 \rightarrow 1$. Take the total and subtract 10. This will will give a total score between 0 and 40. Then you multiply this total score with 2.5 to get a final score between 0 and 100.
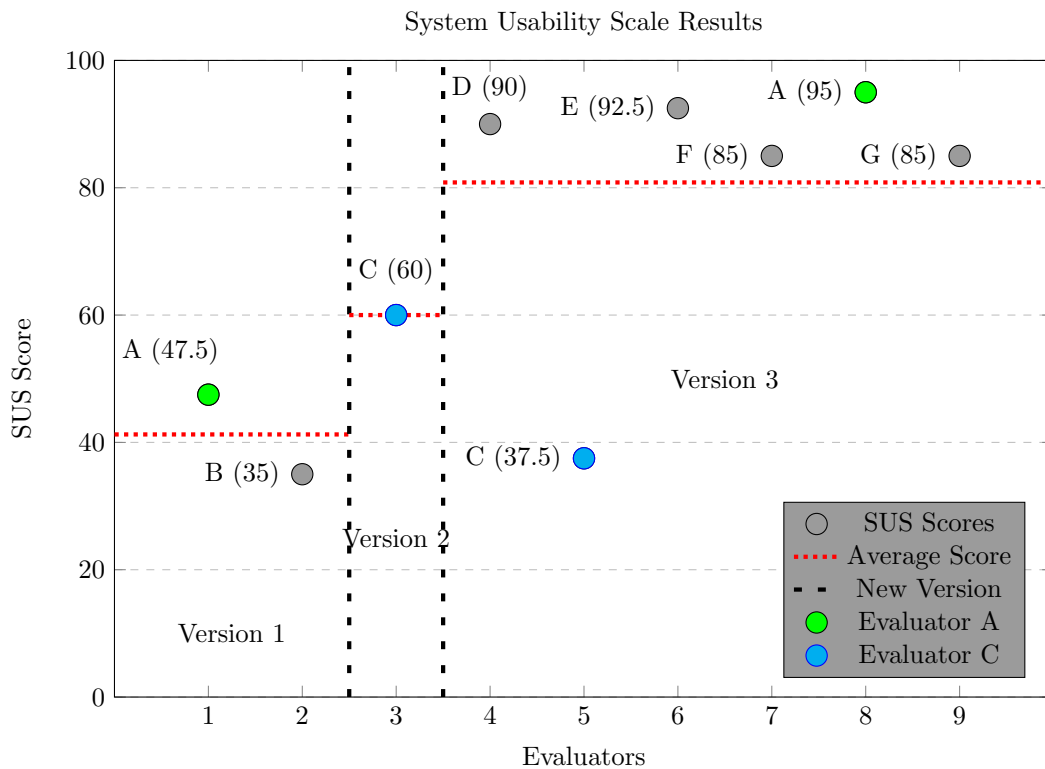
The final SUS score graph shows a noticeable increase in user satisfaction in version 3 of the application. Evaluator A came back and tested version 3 of the application as well. Most of the problems Evaluator A had during the first session were improved upon. After session 7, Evaluator A gave the highest final SUS score of the entire trial with a 95/100. The only other evaluator to try out the application more than once was Evaluator C that participated in both sessions 2 and 4. Despite the improvements and additions of version 3 of the application, Evaluator C gave a lower final SUS score in session 4 than in session 2, with 37.5/100, down from 60/100. All other SUS evaluations of version 3 gave final scores of 85/100 or above.

Chapter 6

Results, Discussion and Conclusion

6.1 Expected Results

Research question: What is the feasibility of developing a VR tool for therapists to use in treatment for claustrophobia?

VR technology is on the rise and seems to be well suited for use in the medical field. Exposure therapy for claustrophobia is an area in which VR could be beneficial.

The simulation is expected to be able to induce a claustrophobic response in the patient. Realism is dependent on the quality of commercially available in-game models and textures. The sound design will be made from actual recordings of elevators to encapsulate the experience.

It is expected that the simulation can trigger an anxiety attack in people with claustrophobia. The anticipated element of the system to be most challenging to implement without breaking the immersion is the movement system. Feelings of movement are expected to occur when the patient is taking the elevator. These feelings of moving will come from both visual and audio.

6.2 Discussion and Conclusion

Research question: What is the feasibility of developing a VR tool for therapists to use in treatment for claustrophobia?

The expectations that the simulation could trigger an anxiety attack in people with claustrophobia seems to hold. Testimonies from the evaluators support this claim, even though we cannot test this hypothesis on actual patients. After a couple of minutes of using the movement system, the evaluators said it was awkward at times but did not ruin the experience. The feeling of movement when taking the elevator did not occur until version 3 of the application. The lack of sound in the first versions made the feeling of movement non-existing. In

the third version of the application, the evaluators all said that they felt like the elevator was moving. The audio in the elevator cemented the feeling of being in an actual elevator. Improvements regarding textures and models between versions 1 and 3 directly impacted the response of the evaluators in a positive manner.

When asked in the SUS if they would want to use the application frequently, answers started in the range of Strongly Disagree to Neutral, but in version 3 ended up in Agree to Strongly Agree for all evaluators. The statement of unnecessary complexity of the application had a similarly polarizing change between versions. It started with responses that Agreed or was Neutral but ended with only Strongly Disagree in version 3 except Evaluator C, which gave the same answer after both sessions. The rest of the statements in the SUS followed a similar pattern where 5 out of 6 evaluators using version 3 gave highly positive feedback on that version.

Several of the evaluators said when asked that they felt like they were using an actual elevator. Being able to capture that feeling through only visuals and sounds was one of the most significant concerns when starting the project. The evaluation sessions' results showed that this application could be helpful as a tool in exposure therapy for claustrophobia. The evaluators said they would like to see some changes to the therapist's screen and make the glass walls more visible before trying out the application on actual patients. Most of the evaluators who used version 3 said they would like to try the application in future exposure therapy sessions.

The results from the evaluation session indicate that the elevator simulator has considerable potential for use in exposure therapy for claustrophobia.

6.3   Further work

Should development continue on this application, a few things could be done to improve the application.

One of the recurring points for improvement suggested by most evaluators was even further simplification of the therapist's screen. It has been challenging to find the right amount of control to give the therapist without making the therapist's screen needlessly complicated. Several previously implemented options, such as altering the dimensions and the size of the building, were removed during development. Based on the feedback from the evaluation sessions, further removal of unused functions, reduced slider steps, and more automated options for the scenarios are needed.

The current application contains only a single environment with buildings surrounding it. Making it easier to change the interior and exterior could make the application applicable to a broader collection of use-cases. As suggested in an evaluation session, making the elevator out of transparent glass could make it usable for the treatment of acrophobia. Making the interior look like a hospital could help with nosocomephobia(fear of hospitals). There are endless possibilities, and making these implementation types as effortless as possible would add much value to the application.

One of the appeals of utilizing VR is that the treatment is not necessarily reliant on the environment. The current application is custom-made to work in Haukelands University Hospitals VR-lab with a therapist present. All customization options for personalizing the scene are located on a separate screen from the VR goggles. This means the application needs to be played on a VR headset connected to a monitor for all functionality to be available. Creating a way to change these options using the VR controllers would allow for use alone. This is not the application's current use case but would be a natural progression.

To further build upon the idea of letting patients treat themselves at home, one of the suggestions after the evaluation session is to make an online version. By letting therapists perform the sessions remotely, the simulation would benefit by allowing at-home treatment with proper oversight to ensure progression. This concept is not new and previously mentioned Psious[29] are using a similar concept for their treatment products.

6.4 Observations

During the development process, many observations have been made on what works and why. With these new experiences, a few things would have been done differently if the project were to start over. One of these things would be a remake of the high-level design.

The current setup has few classes(figure 6.1), with uneven distribution of functions. This makes it difficult to make changes to the application without an intimate knowledge of the classes and how they interact.
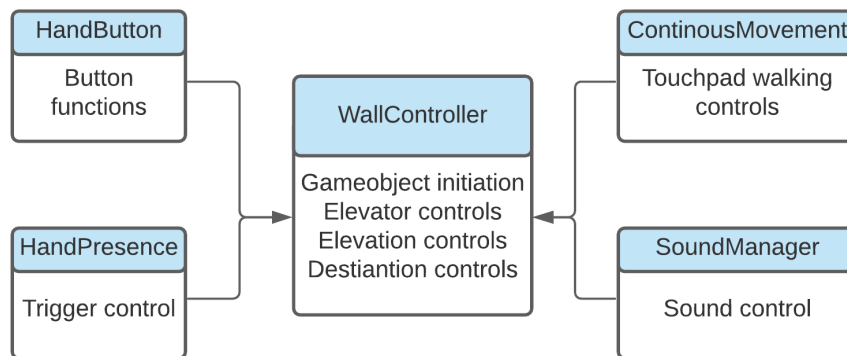

Figure 6.1: Current High Level Design of the application

A separation of responsibilities approach would have been better with clear boundaries and connections. This new model would include more suitable class names and relevant functions. The new model could look something like figure 6.2.
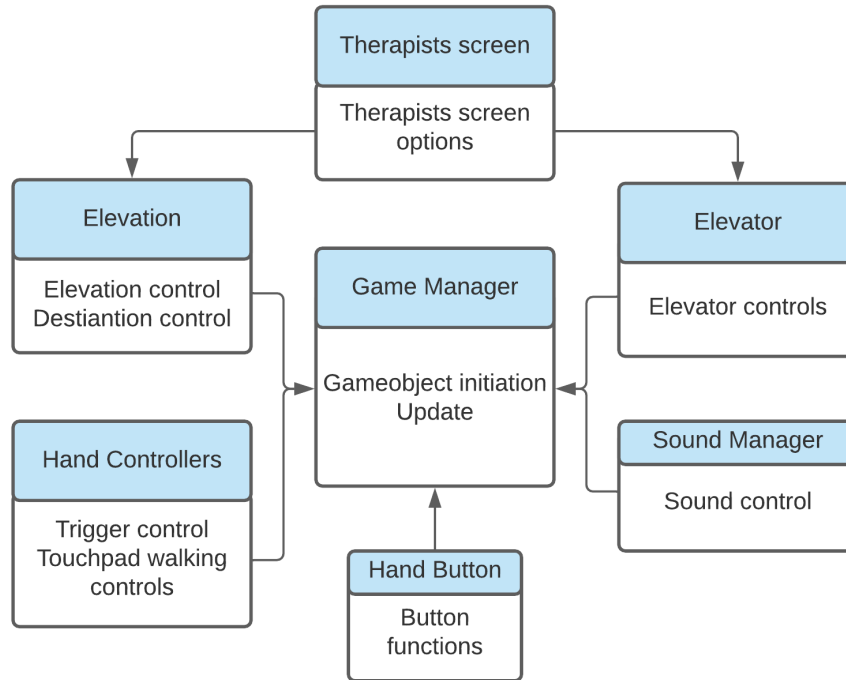
Figure 6.2: Proposed High Level Design of the application

In this proposed alternative model, the therapist's screen, elevator, elevation, hand controllers, hand button, and sound manager have their own classes with a central game manager.

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