

# VR supported self-help treatment for adolescents with psychosis

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## Abstract

*Psychosis* is a severe psychological condition that affects some people, including adolescents. Unfortunately, treating psychosis and psychotic disorders takes a long time. Cognitive Behavioral Therapy (CBT) and CBT for treating psychosis (CBTp) promise the most effective treatment; however, it is too long, considerably affects patients' individual lives, and involves high individual costs. Using Virtual Reality (VR) technology, behavioral experiments in CBTp can be carried out during therapy sessions by exposing the patient to simulated social scenarios that they find challenging. This CBT-supported process promises improvements in increased patients' experiences and allows patient gains in their regular lives.

This report illustrates the development based on a VR-assisted treatment protocol currently being developed and clinically tested at the Department of Child and Adolescent Psychiatry at Haukeland University Hospital, Bergen, Norway, and the possibilities of a VR self-help application as a supplement to clinical sessions. Furthermore, patients will be able to perform different social-training exercises in familiar home conditions using the therapists' defined guidelines prepared beforehand.

This project's application uses VR technology and speech recognition to reach this goal of self-help treatment. With the help of speech recognition, the VR application can understand what the patient is saying, provide appropriate feedback, and assure a flow in the conversation through the different scenarios.

An iterative mixed method, including system usability tests and follow-up interviews with clinical domain experts, was conducted to test this application's usability and feasibility. First testing iterations' System Usability Scale (SUS) results were positive and indicated concrete issues for improvement. Moreover, the final testing iteration delivered excellent results, showing the possibility of using a VR-supported self-help treatment for psychosis.

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# Acronyms

**AI** Artificial Intelligence. ii, 23, 39, 40, 66

**CBT** Cognitive Behavioral Therapy. x, 3, 4, 13–15, 54

**CBTp** Cognitive Behavioral Therapy for Psychosis. 14, 65

**CPU** Central processing unit. 81–83

**GPU** Graphics processing unit. 81–83

**HMD** Head-mounted display. iii, 3, 11, 12, 17, 18, 29, 52, 54, 63, 65, 68, 69

**HR** Heart Rate. 7

**HVL** Western Norway University of Applied Sciences. 1, 81, 82

**iVET** in Vivo Exposure Therapy. 15

**OS** Operating System. 81–83

**PC** Personal Computer. 65, 82, 83

**RAM** Random-access memory. xi, 81–83

**SAD** Social anxiety disorder. 6, 8

**STT** Speech to text. 39, 41, 42, 62, 65–69

**SUDs** Subjective Units of Distress scale. iv, 48–51, 53

**SUS** System Usability Scale. v, 26, 52, 54–56, 58–63, 65–67, 70, 74

**VR** Virtual Reality. iii, v, 1–18, 22, 26, 29, 35, 37, 52–55, 59, 63, 65, 67–69, 78, 79, 81

**VRAM** Video RAM. 82, 83

**VRET** Virtual Reality Exposure Therapy. 6, 15, 17

**XR** Extended Reality. 13

# Chapter 1

## Introduction

Clinicians at the Haukeland University Hospital had the idea to improve treatment and integrate modern treatment measures such as Virtual Reality (VR). Therefore, the specialized outpatient unit for adolescents with psychosis at the hospital collaborates with Thomas F. Larsen from Helse Vest IKT to develop a new treatment method.

The project direction resulted from the desire to move the existing development and progress forward and make a more effective treatment. This desire led to a cooperation between the Department of Computer science, Electrical engineering and Mathematical sciences master students from Western Norway University of Applied Sciences (HVL) and the Department of Child and Adolescent Psychiatry at Haukeland University Hospital, which aims to make a self-help treatment application.

Meanwhile, it is crucial to note that this project is based on a VR-assisted treatment protocol currently being developed and clinically tested at the Department of Child and Adolescent Psychiatry and Helse Vest IKT. The existing treatment protocol is an outpatient treatment, while this project focuses on an self-help treatment application that can supplement the existing treatment. This supplementary project can also be used if the patient is averse to attending the session in person or faces other practical challenges in journeying to the hospital.

VR possibilities make it easier to train real situations in a simulated environment where the therapist can be present, which is very difficult in a real situation. Furthermore, treatment data like; patient's experiences, social interactions, new associations, and other findings are discussed within the existing treatment protocol sessions with the therapist, leading to more intensive and faster treatment.

## 1.1 Motivation and problem description

*Psychosis* is a combination of symptoms resulting in an impaired relationship with reality. Psychosis is the hallmark feature of the schizophrenia spectrum and other psychotic disorders and a co-occurring aspect of many mood and substance use disorders, as described by Calabrese et al. in "*Psychosis*" [5]. Schizophrenia is the most common psychotic disorder, as argued by Grande et al. in "*Kognitiv terapi ved psykose*" [6, Ch. 2, p. 61-62].

There are many causes of psychosis, and most of them are very complex. Inheritance is a known factor, including several environmental factors identified as risk factors, including pregnancy and birth complications, low birth weight, cannabis abuse, migration, and social stress, described by Holmén in "*Hva er psykose?*" [7]. Psychosis can have greater or lesser manifestations of three symptoms:

- Positive symptoms (e.g., hallucinations, delusions, disorganization)
- Negative symptoms (e.g., social withdrawal, emotional flattening)
- Some more general symptoms (e.g., cognitive difficulties, anxiety, depression, substance abuse problems)

A patient having a psychosis disorder is most likely to have high individual costs like; loneliness and isolation, difficulties finishing education, difficulties in being at work, a long and extensive treatment, and reduced life expectancy. The life span for people with schizophrenia is as much as 15-20 years lower than the average population, according to "*Healthy Active Lives (HeAL)*

*Keeping the Body in Mind in Youth with Psychosis*” [8]. Schizophrenia costs the Norwegian society more than heart, cancer, and rheumatic diseases combined, concluded in *”Evidensgrunnlaget for medikamentfri behandling av psykose: En litteraturgjennomgang*” [9] by Moen et al.

According to most clinical guidelines, the recommended treatment entails a combination of psychological, psychosocial, and pharmacological interventions, as written in *”NICE guidelines*” [10]. Variable attendance, low activity levels, and disengagement from service are challenges in young individuals struggling with psychosis, as concluded by Boeing et al. in *”Adolescent-onset psychosis: prevalence, needs and serviceprovision*” [11]. In addition, approximately 30% of young people who experience psychosis disengage from therapy, as argued by Doyle et al. in *”First-Episode Psychosis and Disengagement From Treatment: A Systematic Review*” [12].

Virtual Reality (VR) in the last decade has been researched more frequently as a treatment of mental disorders, as concluded in *”Creating state of the art, next-generation Virtual Reality exposure therapies for anxiety disorders using consumer hardware platforms: design considerations and future directions*” by Linder et al. [13]. The advantages of the VR technology to create an illusion of something physical in an artificial world allows VR to be used more frequently in psychosis treatment. A Head-mounted display (HMD) transmits the head movement into the artificial world to create an immersive feeling. The reason that usage of VR treatment has become so popular is the effectiveness of its possibilities. Over 20 research projects with VR treatment in [13] have reported that it is equally effective as Cognitive Behavioral Therapy (CBT), [section 2.4] and comes with its advantages. When exposed to the same discomfort, patients experience the same emotional and physiological reactions in the artificial world as in the real world. VR treatment for social anxiety has proven to reduce the symptoms and build up higher mastery belief, also discussed in *”Social interactions in virtual reality exposure therapy: A proof-of-concept pilot study*” by Morina et al. [14]. Support and completion rates are significantly higher with VR than with traditional methods, *”Virtual reality in the psychological treatment for mental health*



*problems: An systematic review of recent evidence”* by Valmaggia et al. [15]. According to this study, VR can create a safe environment for the patient even in situations that discomfort them. Nevertheless, the treatment does not report simulator sickness<sup>1</sup> as a part of the VR experience that could discomfort the patient.

This project aims to use VR in making a self-help treatment application for adolescents with psychosis. The plan was to redo an existing VR-assisted CBT application for exposure-based social training. The existing application is used in an outpatient clinic and requires a therapist present. The intention is to use the self-help treatment application as a supplement in-between sessions or for those who disengage from traditional therapy. In addition, the application will use concepts of gamification [section 2.1] and Serious Game [section 2.6] to keep the patient engaged in the simulation and give them a sense of accomplishment.

## 1.2 Research question

This project will focus on developing a self-help treatment application for adolescents with psychosis.

**Research question:** How can VR be used in self-help treatment for adolescents with psychosis?

## 1.3 Expected results

Treatment should be a pleasant experience for adolescents and help them overcome the fear of facing socially discomforting situations. With a self-help application, patients will be taking the treatment home with them. Furthermore, working on the treatment in a safe environment with no one watching over them and no fear of performing pressure.

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<sup>1</sup>One problem with VR is simulator sickness, also called VR Sickness. It is an unpleasant condition that can resemble seasickness, which one can experience during or after using VR.

Thus, by close cooperation with clinical domain experts evaluating the project and based on the research question in [section 1.2], the expectation is to develop a VR game to have patients use at home as a supplement to regular treatment for psychosis. Therefore, also expect to make the application easy to understand and self-explanatory while operating it. Moreover, having the patient not distracted from the experience by technical issues.

## 1.4 Methodology

This paper is a software development research paper. Having that in mind, it will have; a research methodology and a development methodology, which will now be described in the sections below. Additionally, how the methods are thought to be applied in this research is described below.

### 1.4.1 Research

A mixed methodology will be used to answer the research question. This research question needs clinical domain experts and, hopefully<sup>2</sup>, potential patients of this treatment solution's target group to be answered and evaluate this VR self-help treatment application and comment on the experiences and potential difficulties while using the application. Therefore, semi-structured interviews will be conducted to answer the research question. The evaluators fill out a predefined questionnaire and participate in a follow-up interview to gather quantitative data and evaluate this research. For example, questions like, *"I felt that the application was unnecessary complicated and hard to use."* and *"What was the best and worst part of the application?"* will be used during the research evaluation.

### 1.4.2 Development

The iterative development methodology is planned to be applied when developing this project's application. *"Software Engineering: The Current Prac-*

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<sup>2</sup>This point is explained in the discussion section [subsection 4.2.5] as to why no patients could be present during the testing of the application.

*tice*” [16] by Vaclav Rajlich describes many iterative methods. However, this development will use the agile, iterative process, as there are two developers, making the most decisions on what to work on in a given iteration from the product backlog. Following is a description of the interpretation and execution of the iterative methodology. Initially developing the application into a particular developmental state to receive feedback and suggestions from innovators and other people/classmates who have tested the application. This information then goes into the product backlog to improve the application in the following developing iterations. Then after reaching a stable version, first tests with clinical domain experts will be conducted to gather information on how the application works in a clinical environment. After improvements in the second development iteration based on the first test’s feedback, the application will be retested with the same clinical domain experts to collect new feedback and thoughts on its new development state.

## 1.5 Related Work

*”Feasibility of virtual reality environments for adolescent social anxiety disorder”* by Parrish et al. [17] presents a study of adolescents with and without Social anxiety disorder (SAD). They are exposing them to two virtual social scenarios and two neutral ones. To see and compare reactions of people with SAD and those that feel more comfortable in social environments. After VR exposure, both parties involved had a moderate rise in distress in all scenarios but markedly more in public and party ones. Also, adolescents with a much higher spike of distress are resulted to be those with SAD, showing that VR treatment is feasible when treating medical disorders by increasing the distress level.

Another study focuses on home-based Virtual Reality Exposure Therapy (VRET), *”Home-Based Virtual Reality Exposure Therapy with Virtual Health Agent Support”* by Hartanto et al. [18]. This study explores the idea of a Virtual Health Agent, which is supposed to support and guide the patient during this VRET. However, this study concluded that only one of its pa-

tients completed all given sessions, with other patients experiencing various technical issues.

”The pilot study also revealed a number of serious technical problems. These technical problems need first to be addressed before any further studies with patients can be considered.”

This study tells us that getting multiple iterations of application testing on a group of target users is vital to getting a usable product with fewer technical problems, which are hard to anticipate as a developer.

On the other hand, Realpe et al. have a study called *”Co-designing a virtual world with young people to deliver social cognition therapy in early psychosis”* [19]. This study explores how help from the target group can help develop a virtual world. They invited a group of young people to help in development, and a part of the conclusion of this study is:

”Meaningful input from user and carer consultants needs to be part of any study. The co-design process permitted a feedback loop that continues to inform design and solve problems as they emerge in the pilot study.”

This conclusion shows that if one wants to develop any virtual environment, which specifically targets a group of people, then it is in the best interest to involve people from that target group in development, to ensure a meaningful and correctly developed solution.

A different research paper, *”A VR Environment for Anxiety Treatment of Children and Adolescents”* by Lenz et al.[20], has little in common with this project. However, the research title was interesting, having a similar title to this project while being recent from 2020. This group of researchers has focused on creating a realistic environment and studying adolescents’ experiences with the program. The study had different specific experiences and tasks with Heart Rate (HR) exercises to complete. After 20 people of varying ages, genders, and VR experiences played the ”game”; they concluded that the VR hardware is very effective and well constructed to give a spatial

presence feeling. Although the research and study wanted to make it very realistic, they could not achieve that in their research. The whole "world" created in VR is too unreal compared to real life, and the adolescents are conscious of it not being the real world, which makes it very hard to make people feel the desired reality.

An article, "*Developing an automated VR cognitive treatment for psychosis: gameChange VR therapy*" by Lambe et al. [21], focuses on researching and making an automated VR cognitive treatment. Based on Lambe's success in his previous VR research, they focused their new research project on making an automated VR treatment for patients with anxious social withdrawals, including a virtual coach to guide the patient. Their project includes several scenarios where the patient has to stay in anxiety-inducing situations to cope with them. In addition, there is a way to expose the patient to more or less distress with multiple levels within the scenarios. The levels differ by simultaneous or sequential exposure to more anxiety-inducing situations, becoming busier and noisier, with anxiety triggers appearing or becoming more prominent.

### **1.5.1 Related work differences and discussion**

Focus groups featured in related work [section 1.5] are broad and differ from this project. For example, adolescents have been a group of focus for Social anxiety disorder therapy, but the study has been taken in another direction, not focusing on psychosis treatment. Nevertheless, all of the above had VR in focus. In comparison, one focused on the feasibility [17]; another one focused on the benefits of co-designing with young people [19]; while another one explored the idea of having a virtual therapy with virtual health agent support [18]. On the other hand, Lenz et al., in their research [20] focused on the reality aspect of VR, which will help in this project, deriving from this research that the reality in VR/Serious Games is not essential since patients already feel great engagement from the whole situation.

The most similar research to this project is [21], yet there are many differences in both approaches to a similar problem. Comparably, Lambe et al.'s research and this project develop an automated VR treatment with no input from a therapist throughout the session. Furthermore, both projects use similar environments like the café and public transport. However, both projects approach these environments' treatment differently. For example, in this project's coffee shop, the patient talks in a date-like scenario with a stranger. Contrastingly, the patient in their project orders something and has to shout after a customer who accidentally left their wallet. In addition, the bus environment in their treatment focuses on trapping the patient in an anxiety-inducing situation. While in the previous work of this project's light rail, the focus is on helping a stranger recover a scarf after losing it on the ground or getting out of a crowded transport. The patient additionally has to speak and overcome the fear of possible rejection, not simply be present in such a situation and only learn to cope with it.

Regardless, the main difference in this project is the target patient group decision. This project focuses on psychosis-diagnosed adolescents, while their research focuses on all patients with anxious social withdrawals. Furthermore, this project's self-help treatment application targets adolescents' anxiety-inducing situations by recreating them according to the target group's opinions of the most discomforting situations and the inclusion of adolescent characters. It means that this project's self-help treatment suits adolescents and not necessarily all patients with anxious social withdrawals. In addition, this VR self-help treatment will have no virtual coach/therapist, at least in the early stages.

Furthermore, this project focuses on an automated treatment where the conversation is suited to the patient's dialog answers. Lambe et al.'s automation did not make this extra step to base the conversation on the patient's answers. Instead, it has pre-generated outcomes for the scenarios. Those outcomes trigger depending on the patient's behavior by listening for anomalies in speech/voice, such as shouting or, in some cases, just speaking.

Conclusively this project will develop a self-help treatment VR application to supplement the regular treatment where a physician is present in the regular treatment and will not be in the supplementary self-help one.

## 1.6 Report outline

This **chapter 1: Introduction** introduces the research problem, the motivation, and the research question while covering some past related work.

In **chapter 2: Background** important topics used in this project are described.

The design and implementation process of this project's VR application is covered in **chapter 3: Design and Implementation**.

The following **chapter 4: Results and discussion** covers this project's results and discusses them.

Finally, this whole project is concluded in **chapter 5: Conclusion**, briefly mentioning and discussing what can be further done or developed in this field of research.

Lastly, all the sources, assets and important information along with references used and researched for this project are collected and listed in **Appendix A: Assets and Bibliography**

# Chapter 2

## Background

This chapter will cover and explain different terms and concepts used throughout this paper.

### 2.1 Gamification

Gamification is the application of game-specific elements to a non-game context. This process is used in applications to engage and motivate the user. Some elements that are possible to use to achieve this are; leader-boards, badges/achievements, and statistical graphs of improvement, as Basten mentioned in "*Gamification*" [22].

### 2.2 Virtual Reality

Virtual Reality (VR) is a concept to simulate an experience. To achieve this simulation, the user wears a Head-mounted display (HMD) that can be seen on [Figure 2.1]. The user will also hold controllers in both hands to interact with the environment displayed in the HMD.

To improve the user's experience and simulation, one of the HMDs functionalities is to playback all sounds from the environment directly to the user





Figure 2.1: Oculus Quest VR HMD with two controllers [2]

that wears the HMD or gives the option to connect an external headset. This functionality improves the interaction with the simulation. In addition, it achieves a higher sense of presence which further enhances the perception of immersion, as concluded by Serafin et al. in *"Sound Design to Enhance Presence in Photorealistic Virtual Reality."* [23]. VR is not a new concept but has been developed and improved for a long time. Current technology allows users to jump into a VR experience anywhere by putting on an HMD and holding two controllers in their hands, with no extra accessories necessary, such as external cameras, rigs, or even computers. Mata's Oculus Quest enables this exact freedom and is the hardware that is currently used to develop and test the application.

## 2.3 Unity

This project uses Unity to develop the application. *Unity* is a popular cross-platform game engine used to develop over 50% of games across mobile, PC, and console, with 5 Billion downloads just in 2020, from Unity's official website [24]. The Unity game engine uses C#; thus, all scripts for development are also written in C#, making it straightforward and consistent throughout programming. Furthermore, Unity makes it easy to develop and test the application simultaneously with its built-in play mode, making game devel-

oment and debugging more straightforward and faster. This easy-to-use functionality is displayed in the [Figure 2.2] below, showing how only one button makes testing a complex scene very easy.



Figure 2.2: Unity editor in play mode

### 2.3.1 Unity VR

Unity provides its own Extended Reality (XR) interaction toolkit [25], making it possible to quickly create a VR game without implementing all the necessary scripts and logic from scratch. That makes the whole VR game development faster, and one can fully focus on developing a unique game.

## 2.4 Cognitive Behavioral Therapy

One of the methods used to treat patients with psychosis is called Cognitive Behavioral Therapy (CBT). CBT aims to strengthen the patient's ability to identify self-destructive behavior that perpetuates emotional problems and teach new skills. CBT has shown to be effective, and the results of CBT last longer than other forms of treatment. CBT also shows a significant effect when it comes to social functioning, as described in *"Evidensgrunnlaget for*

*medikamentfri behandling av psykose: En litteraturgjennomgang*” by Moen [9]. CBT makes the patient try out new methods to think about a problem with the help of training in social situations in between sessions. However, this method comes with its challenges, as the patient cannot always train in the given social situation. This challenge may occur because the patients have difficulties getting themselves up to perform the training. They would prefer not to face situations that make them uncomfortable, or the patient could forget to do the training due to the psychotic cognitive challenges. These are some of the factors that can elongate the whole treatment process.

### **2.4.1 Cognitive Behavioral Therapy for Psychosis**

Cognitive Behavioral Therapy for Psychosis (CBTp) is like CBT but strictly focused on treating psychosis. The treatment aims to enhance functioning and identify the negative symptoms, thought disturbances, or hallucinations to help patients with distressing psychotic experiences and change their beliefs about these experiences. Moreover, with an equal goal to reduce patients’ distress and disability. Therefore combining the CBT for patients with psychosis has long-lasting, cost-effective benefits by following the structured, goal-based, and time-limited treatment modality of CBTp. Also, Further studies have *”clinically validated the CBTp intervention for psychosis, with research indicating a [...] 50-65% of patients displaying reduced symptomology when treated with CBTp.”*, mentioned by Landa in *”Cognitive Behavioral Therapy for Psychosis (CBTp) | An Introductory Manual for Clinicians”* [26].

### **2.4.2 Virtual Reality Cognitive Behavioral Therapy**

A study, *”Virtual-reality-based cognitive behavioral therapy versus waiting list control for paranoid ideation and social avoidance in patients with psychotic disorders”*, carried out by Pot-Kolder et al. [27], researched whether VR-CBT does help patients to strongly reduce their safety behavior in real-life situations that further lead to gathering more social information and developing new associations. Furthermore, this study concluded with no

differences between VR-CBT and the waiting list control, indicating that VR can be used to supplement CBT with no setbacks.

## 2.5 Virtual Reality Exposure Therapy

Virtual Reality Exposure Therapy (VRET) is the appliance of VR in therapies such as CBT. There are multiple pieces of research done on this topic. Some of them are; "*Exposure to virtual social interactions in the treatment of social anxiety disorder: A randomized controlled trial*" by Kampmann et al. [28], "*Virtual reality compared with in vivo exposure in the treatment of social anxiety disorder: a three-arm randomised controlled trial*" by Bouchard et al. [29] and "*Virtual Reality Therapy in Social Anxiety Disorder*" by Emmelkamp et al. [30].

These articles conclude that VRET is as effective as in Vivo Exposure Therapy (iVET). Bouchard et al. concluded that "VR was significantly more practical for therapists than in vivo exposure" due to its simplicity in recreating traumatic situations. It is also important to mention that only [30] of these three examples concluded research where VRET was not combined with regular CBT, giving a more insightful comparison of VRET and CBT. Emmelkamp et al. concluded that there were no differences in efficacy between CBT and VRET, including that there is a clear need for more studies that focus on VRET as a stand-alone treatment without mixing it with CBT.

## 2.6 Serious Games

Serious Games (computerized interventions that utilize gaming for serious purposes) are widely used to adopt games in training and education. One method to apply this is to use gamification [section 2.1] in educational or training games. Furthermore, to engage users and motivate them to play the game even more, thus benefit from education/training, which is the primary purpose of these games. Mentioning here that it is a game, but in reality and from the common definition used in "*Juegos serios para el tratamiento o la*

*prevención de la depresión: una revisión sistemática*” by Fleming et al. [31], the adoption of word gaming is often overused. VR can offer simulations and experiences close to real life for training, treatment, or rehabilitation purposes. A proposition from mentioned article to VR interventions is that VR interventions are not completely inherently games unless they include significant features of gaming f.ex.: rules, goals, and objectives mentioned in *”Digital Natives, Digital Immigrants Part 1”* by M. Prensky [32].

”Serious Gaming are games with a purpose beyond entertainment, including but not limited to games for learning, games for health, and games for policy and social change.” in *”Serious Games: Mechanisms and Effects”* by Ritterfeld et al.[33, Ch. 10, p. 146]

”We found that most definitions [of Serious Games] encountered either in research or industry agree that serious games include entertainment dimension [...] This can be in different contexts such as education, training, health, or interpersonal communication.” in *”An Overview of Serious Games”* by Laamarti et al. in [34]

Both quotes from [33] and [34] mention in respective articles that serious games include entertainment and at the same time are used for, but not limited to, exercises like education, training, and health. Serious Games, with its power, enhances regular versions of these exercises.

### **2.6.1 Serious Games in Healthcare**

This project uses concepts of Serious Games in its healthcare application. Previously described in the [section 2.6], Serious Games, with their positives, can help make games fun and engaging for patients, encouraging them to play more. It simultaneously positively affects patients in treatment psychosis behavior, as stated by Grendel Games in *”Serious games for healthcare | seriously entertaining”* [35]. Serious Games in healthcare can reduce the workload by independently having multiple patients play and exercise with Serious Games. After patients finish playing, all the data gathered from their

session will be available for the therapists, allowing for independent follow-up, as argued by Grendel Games in [35]. Grendel Games also describes that this leads to a better patient outcome, with cheaper and faster treatment overall.

## 2.7 Speech Recognition

Speech recognition is a service used to translate/recognize users' input by speech into text. The program then interprets this text input and decides on how to respond. Many companies, such as Google and Microsoft, use this service for their virtual assistant service, Google Assistant and Cortana.

”Speech-to-text, also known as speech recognition, enables real-time transcription of audio streams into text. Your applications, tools, or devices can consume, display, and take action on this text as command input. This service is powered by the same recognition technology that Microsoft uses for Cortana and Office products.”

As written on Microsoft's documentation site for Speech-to-text service, *”What is speech-to-text?”* [36]. Summarily, speech recognition is a service that translates an audio clip into text.

## 2.8 Previous Work

The base of this project is the previous work developed by Helse Vest IKT. They developed a treatment application such that a therapist is in the same room with the patient who wears a VR-HMD. The therapist guides the patient through the exposure session, making the application a VRET application. The therapist continuously helps the patient through the experience and training session, simultaneously giving the patient a sense of assurance by being at their side all the time.

Based on the therapist's traditional therapy session with the patient, the therapist chooses a scenario. The patient then starts their training session by putting on the HMD. While going through the chosen scenario, there are moments where the patient has to say something and interact with the simulation. When the patient has said something, the therapist chooses a reasonable answer based on the patient's response to challenge the patient further or make them more comfortable. After the therapist's choice, the scenario will continue to play out with more or no more interactions from the patient until the scenario finishes.

The following subsections will describe the scenarios available in the application developed by Helse Vest IKT, where three different environments exist, and to which the VR treatment is applied. Different yet common everyday situations that psychosis-diagnosed adolescents find very unpleasant are simulated as different scenarios within the three environments. When the question arose of why they chose those particular environments and scenarios, the answer was as follows. The clinical domain expert at Haukeland University Hospital concluded a questionnaire research with psychosis-diagnosed adolescents. Three particular situations and environments mentioned below were the most anxiety-inducing for adolescents. Thus, giving the most benefit to adolescents from exposure therapy by exposing them to scenarios that they find discomforting.

### 2.8.1 Meeting a stranger of equal age at a coffee shop

In this environment, the patient walks through several options, difficulty levels in treatment, and degree of discomfort. This environment mimics a regular coffee shop where people are chatting, and there are coffee shop noises from real life in the background. The patient has then a task to successfully walk through one of the sub-scenarios in a coffee shop; Sit and wait until a stranger arrives, but in the meantime, a waitress approaches to ask the patient if they want something to drink. The design of this environment strives to make it more uncomfortable and train patients to accept that such a situation is not scary.

Furthermore, the coffee shop includes several similar scenarios that gradually become more difficult for a patient with psychosis to overcome. For example, the next difficulty level requires the patient to talk openly with a stranger sitting at the same table. Small talk or complimenting an aggressive or kind stranger are some scenarios that patients can practice with the therapist.



Figure 2.3: Coffee Shop. Neutral situation showing waitress and the stranger.



## 2.8.2 Going to and speaking with a group of known adolescents

With the same concept of making different difficulties of a scenario, the place differs from the previous coffee shop. It is a schoolyard with a group of adolescents talking while others are just sitting on a bench to relax. It is a very typical situation for every kid or adolescent, but it can be very challenging for a patient with a psychosis background.

This environment, therefore, exposes the patient to a group or makes them approach the group. Another few examples that patients can practice in this environment are approaching and asking a group of adolescents or approaching and answering a question. Further discomfort varies when the therapist chooses an outcome where the group totally ignores the patient or partially ignores them after, for example, asking the question.



Figure 2.4: Group of adolescents at a schoolyard, Neutral situation at a schoolyard with four friends.

### 2.8.3 Approach a stranger

The patient is on a light rail in Bergen city in this environment. Compared to the other environments, this is a day-to-day route to school or a job in real life in a bigger city, with many people around and noise that discomforts the patient with psychosis. In the same way as the other environments, audio plays in the background, simulating being present in the current situation.

One of the scenarios that a patient will face in this environment is, approaching a stranger and asking him to move aside while leaving the light rail after it has stopped at their destination. A very typical situation in day-to-day life, but for adolescents with psychosis, it can be a very stressful and challenging experience to ask a stranger in a public place. The discomfort level in this scenario is mainly affected by the behavior of this given stranger, where the therapist can choose, for the stranger, to be either aggressive, neutral, or apologetic to the patient's question.



Figure 2.5: Showing the stranger and people the patient encounters and interacts with on the light rail.

## Chapter 3

# Design and Implementation

Three different environments exist within the current application and the treatment process developed by VR domain experts at Helse Vest IKT. Treatment of psychosis and surpassing the fear of speaking with people or asking for help is the focus of all those environments. This project explores the idea of converting such a treatment process into a self-help treatment application that allows for treatment without a therapist and a VR expert during the VR experience. The focus and project origin is to enhance the current treatment and not include new environments, such that this chapter will describe the explored in-depth idea of self-help treatment. The development of the self-help treatment application happens through close collaboration and discussion of the treatment model with a clinical domain expert.

Giving the patient an option to choose environments and scenarios is essential in a self-help treatment application. Therefore, a tablet that the patient can interact with by touching the tablet's touchscreen was included. This tablet is in a break room, where the patient can feel safe and know that there are no threats around. It is a place where the patient can relax to some background music and throw around some available stress balls. The tablet can be picked up and held in hand, just like in real life. After the patient chooses their preferred scenario, a short fade-out indicates that scenes are changing and the patient is about to start the self-help treatment.

Another vital part of this application requires having an active conversation between the patient and the application without anyone else involved. This conversation helps move the whole treatment forward and makes the patient's interaction with the application more realistic and immersive. Different solutions were tested and explored to achieve this, resulting in a final decision to use Microsoft's speech-recognition service, "*Microsoft Azure speech-recognition*" [36] along with Mata's Wit.ai intent recognition service "*Wit.ai*" [37]. This solution helps capture patients' speech and transcribe it into text, which gets sent to Wit.ai, which sends the intent back to the application and decides how it responds. To train the intent recognition AI according to adolescents' possible replies, twenty helpful adolescents answered a quick questionnaire asking what they would reply if they were in such a situation from the application.

This project uses an iterative development method to develop all these functionalities and use them in the self-help treatment application, as mentioned before in [subsection 1.4.2]. It consists of first developing a functional and working prototype for evaluation with clinical domain experts. Later, after tests and feedback, improve the solution and retest with the same evaluators. However, improvements were also made based on interpretations and observations from testing, adding new functionalities to create a better solution.

Furthermore, the rest of this chapter discusses and explains the solutions developed, used tactics, and software to make this application a self-help treatment application.

## 3.1 Application demonstration videos

The first and the final stage of the application and how the application works can be seen in published YouTube demonstration videos below:

1. **VR self-help application Master Thesis<sup>1</sup>**

[https://www.youtube.com/embed/9Li-qF0dYeU?cc\\_load\\_policy=1](https://www.youtube.com/embed/9Li-qF0dYeU?cc_load_policy=1)

2. **VR self-help application Master Thesis Final**

<https://www.youtube.com/embed/0oW-bSCKPpQ>

## 3.2 Software

First, let us list some of the more important software used while developing this solution.

- Unity - Version 2021.2.2f1
- Facebook - Access to Wit.ai and Oculus
- Azure DevOps - Code repository
- Wit.ai - For intent recognition
- Microsoft Azure Speech Service - For speech recognition
- Oculus Link

## 3.3 Methodology

The methodology chosen and applied when developing this project's application was an iterative design process, with a perspective towards design science, "*Design science cycles*" [3] written by Hevner and illustrated on [Figure 3.2]. Separately illustrated on [Figure 3.1], the derived iterative process in this development strategy can be seen.

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<sup>1</sup>Closed captions need to be turned on

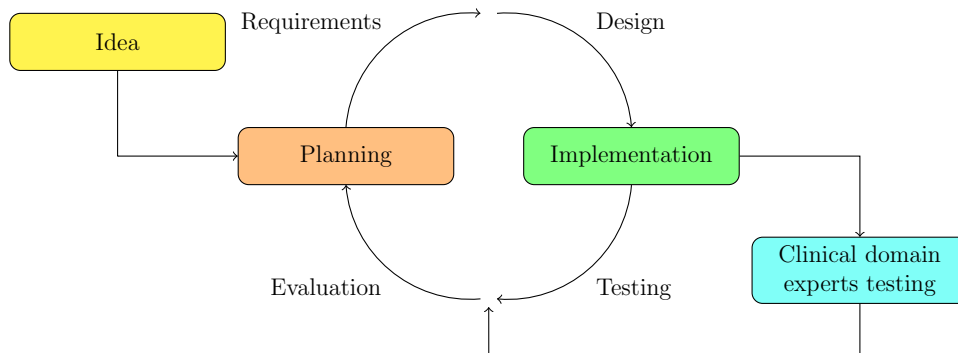


Figure 3.1: The iterative design process applied in the development of this project’s application.

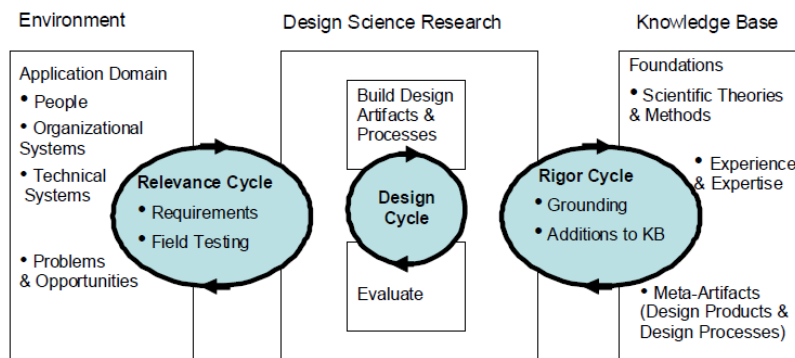


Figure 3.2: Design science cycles by Hevner [3]

Before starting the application’s development, there was an initial idea of the final application. Then problems and opportunities were discussed, resulting in the application domain, requirements, design, and the desired target group. During the implementation, numerous tests were carried out by various testers and other students, resulting in valuable feedback and comments on how the application could be further improved.

Initially, a work plan in TeamGantt [38] was created to plan out the time used for the development and time to write the report. In the initially drawn plan on [Figure D.1], one can see the division between report work (blue bars) and development work (purple bars). Such a plan helped greatly organize the workload and focus points in a given period. Meanwhile, on [Figure D.2], one

can see the final plan, which illustrates when each thought-out section started and ended. Comparably to the first plan, the final duration of different project parts differentiate slightly, but the general idea was held very closely. For example, the application had two short SUS tests instead of one long and was slightly behind schedule compared to the first plan. This delay led to an extra month with improvements, second tests, and more writing in the design and implementation section. Therefore, the result took more time than anticipated beforehand. Additionally, the development did not start until half a month later due to technical issues when including master students in the code repository and Helse Vest IKT systems, further described below. All circumstances ultimately resulted in a delayed plan and a more intensive month towards the end but having such a plan to follow when working with an iterative process was invaluable in keeping the schedule intact.

The iterative process included constant availability to communicate and follow up with the clinical social worker, a clinical domain expert, and the innovator, a VR domain expert. This process consisted of biweekly meetings. As the application was constantly in a development state, every meeting included an agenda to present new functions to evaluate the current state of the application. In addition, all feedback after the meetings/testings was evaluated to plan further improvements. Moreover, a presentation was made to showcase changes since the last meeting and show a plan for the following two weeks before attending the next meeting, resulting in all parties constantly being well informed.

Then after reaching a functional version of the application, semi-structured tests were conducted with clinical domain experts, who will likely use this application in their future treatment model. Results and feedback obtained from these tests were further used to improve the application. Finally, after reaching a new and improved version, the second iteration of semi-structured tests was conducted with the same clinical domain experts. Testing with the same evaluators made it possible to compare the usability of two separate versions and observe the possibility of such a self-help treatment application.

Continuously working in a close domain expert collaboration meant a lot while developing the previous work constantly under development. As a result, this projects branches out to add a new self-help functionality. Meanwhile, the constant development of the previous work adds more environments and does not influence this project. The project required an in-depth walkthrough of the application's stage at that point to understand the concept and how to approach further development in another direction with a suitable plan. The modules and complex scripts from the professional innovators were coded with high standards, making the intense interpretation process less cumbersome than assumed beforehand. Cooperating with such a big company and group of innovators required multiple prerequisites.

Getting involved in a project of this size indirectly required acquiring access to their systems, allowing access to the code repository. Security stands at high priority within Helse Vest IKT. Therefore a security course had to be taken to comply with these standards before accessing the confidential work. Moreover, signing a non-disclosure agreement was one of the significant steps when finally approaching the code. Correspondingly a second non-disclosure agreement needed to be signed, considering that all information seen and heard at the hospital could not be shared with any third party. Every meeting and gathering with the domain experts at the hospital was a potential breach of patient information if a patient was seen at the place.

The development could finally start after settling all the formalities and accessing the repository. However, as previously mentioned, understanding the code and how to develop it further took considerable time in the beginning. Thus programming started somewhat later than initially thought.

GitHub's project solution was used to create an overview of the different tasks at hand and better organize the time used to complete them. The project board consisted of five columns; an application backlog column, a thesis backlog column, a todo column, an in-progress column, and a done column. This helped differentiate between tasks and their priority levels. Once a task was planned to be implemented, it was added to the backlog.



Then, when the day started, tasks that should be finished were pulled to the todo column. When work began on a task, it was moved to the in-progress column and finally to the done column after reaching the acceptance level, helping with tracking the progress at any time.

In order to work more effectively, the concept of pair programming was applied to the development strategy. With pair programming, the development phase was more effective by instantly reviewing the code, discussing the different possible approaches, and deciding on the best method. These are some of the extreme programming principles explained by Beck in "*Extreme programming explained : embrace change*" [39].

Pair programming also opened for collective code ownership, and no one felt left out of the programming and had their contribution in the coding direction. For the code to be less complex and more scaleable with no duplicate code snippets, functions were split into smaller pieces of code, also called refactoring. For example, each scenario has a timeline in the application. Thus having a method to play each timeline accordingly is necessary. Nevertheless, each scenario ends precisely the same way, displaying a notification informing what to do next to progress to the following scenario. One solution for this is to write precisely the same code for each scenario, or on the other hand, write one function controlling the ending of scenarios and call it from each scenario when it ends. As a result, the code will have fewer duplicates in the second option, and the functions will be specific to their tasks.

## 3.4 Break Room

The first objective was to make a break room, a room where one could take a breath, relax, and know that they are in a "safe" place.

The first iteration of the break room includes a typical school environment. School furniture and the principal office is the main focus and place, but with some background music to calm the atmosphere. One can move freely around the room and interact with two objects; play with balls, or pick up the "remote control" tablet [section 3.5] from the desk to initiate the self-treatment process.



Figure 3.3: The main room of the break room, where the self-help treatment application starts.



Figure 3.4: The second room of the break room that one can walk into and relax within the stress balls area.

The break room encourages patients to take a break and prepare for further training. All "threats" such as something unexpected happening or unexpected interactions are extracted to ensure relaxation and readiness for training. Similar to other VR games, there is also a possibility to take the Head-mounted display off. Being in the break room ensures that one will not miss anything from the treatment; e.g., no notifications or dialogues will appear.

Following, let us look at how the break room changed and improved after the second development iteration from the first testing iteration comments.



Figure 3.5: The main room of the break room after the second development iteration, where the self-help treatment application starts.



Figure 3.6: The second room of the break room after the second development iteration, where one can walk into and relax within the stress balls area.

The above figures illustrate changes made to the break room after comments from clinical domain experts who tested the application. The most noticeable and frequent comment was that the break room looked too formal and was not very friendly. The specific comments were about the furniture used in the break room and that they resembled a courtroom. As a result of observations during the first tests, the decision was made to shorten the second room of the break room, as the room was too big and made it more complicated to comprehend its entirety. Other changes to make the break room more friendly were to change the furniture, which means removing all chairs and tables, placing a sofa and a beanbag, and rotating the bench in the main room.



Figure 3.7: One can use stress balls to relax within the break room's stress balls area.

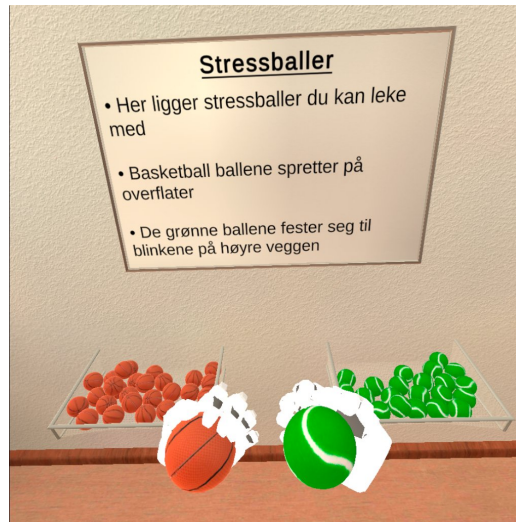


Figure 3.8: An improved version after the second development iteration of the stress balls area.

**Text from the figure in English:** Stress balls

- Here are stress balls you can play with
- Basketball balls bounce on surfaces
- The green balls attach to the flashes on the right wall

Stress balls were difficult to reach, especially the balls placed on the lower part of the rack [Figure 3.7], so a decision was made to change the whole idea of how the stress balls were placed. Baskets holding the balls replaced the rack and were placed next to each other instead of on top. The textures used for the balls were also changed to resemble better the balls found in real life. A basketball texture was used for the bouncy ball, and a texture resembling a velcro ball for the sticky ball, making the balls more intuitive. Targets to throw the balls at were also added to add a challenge and take one's mind off the treatment process. Different sounds were also added for a greater feeling of achievement when hitting the bigger or smaller target.

On [Figure 3.9] below, the entire break room scene can be seen from the outside, showing just how small the break room is while at the same time being complex and offering many experiences.



Figure 3.9: The entire break room seen from outside in Unity Editor.

### 3.5 Tablet

In the first tablet prototype, a regular white cube was used that acted as an interactable object in Unity. The cube was stretched out and thinned out to form a flat surface. An additional gray canvas was added on the front side of the cube to imitate a tablet screen. This screen was used to showcase the different option buttons for the self-help treatment such that the scenarios could be started.



Figure 3.10: The first implementation of the tablet

The canvas was gray and had no clear distinction between its purpose and the white cube. The purpose was to imitate a screen and make the tablet look more realistic while consisting of multiple components. Further, a discussion emerged among the master students to decide what background color or image to use as the suitable tablet screen for this "remote control". With exploring different options of landscape images or relaxing colors, the solution ended up being a mixture of multiple colors with deeper reasoning and meaning after reading "*12 Color Meanings - The Power and Symbolism of Colors (Infographics)*" [40]. The color mixture consists of three colors; orange, blue, and brown. The encouraging color that provides emotional strength and encourages social communication is orange. The blue color symbolizes trustworthiness and is calming and relaxing while making one feel confident and secure. Finally, the brown color was used to make one feel

protected and supported while comforting and inspiring to appreciate the simple things in life. Conclusively, the deeper meanings of those three colors were the final solution chosen as the screen background for the tablet and can be seen displayed on [Figure 3.11].

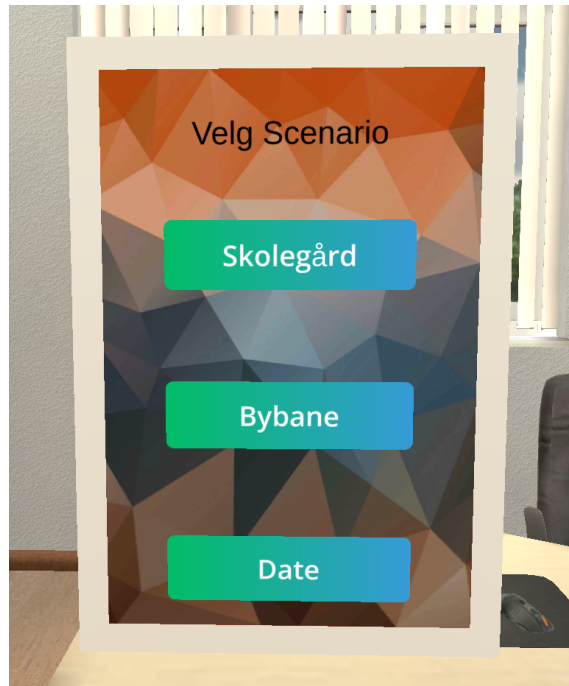


Figure 3.11: The background implementation for the tablet screen.

Nevertheless, this solution did not look like or illustrate a modern and regular real-life tablet or iPad. Meaning that this solution did not satisfy the need to make the tablet feel natural and intuitive. Hence, different options from multiple websites that offer free 3D models were explored. Finally, the solution resulted in downloading and implementing a free *"iPad tablet"* [41] version made by Walery Nowak. This model suited perfectly for the required purpose of intuitiveness and simultaneously fulfilled the need of a natural look.

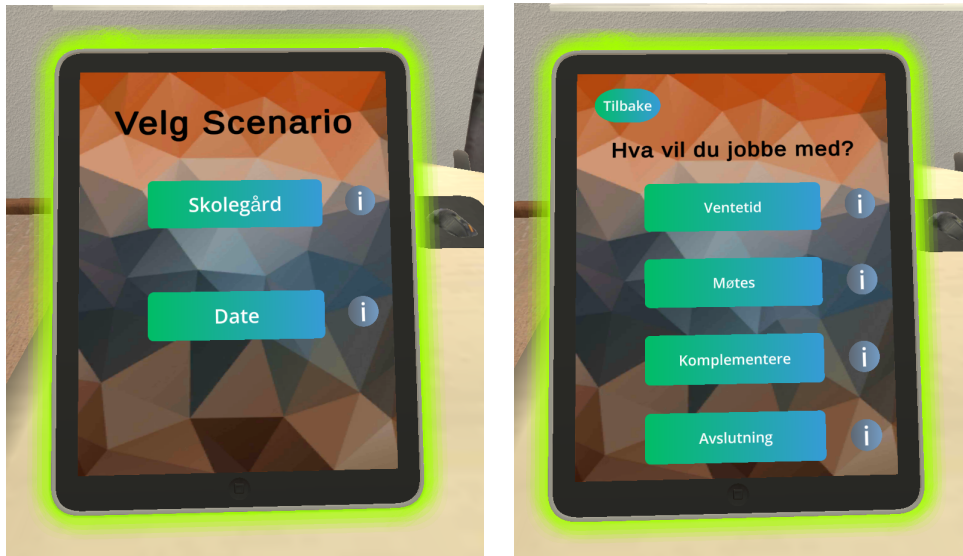


Figure 3.12: The final implementation of the tablet.

Additional functionality was implemented besides the built-in controllers and select functions from Oculus Quest to achieve realness and intuitiveness. The "remote control" is a tablet, and the intuitive usage is to touch the screen with a finger to navigate between available options. Thus, the additional functionality includes adding individual colliders to the screen buttons that trigger on finger collision. The collision works equally to the built-in select function from VR controllers, but giving the possibility of variation is beneficial considering an interactable tablet and how it would be used in real-life.

Large amounts of new functionalities come with benefits and challenges. For example, after implementing the touchscreen feel, it was found that the colliders were not always working as initially wanted. Concludingly, resulting in many failures, tests, and different solution discussions before realizing the vision.

The final solution was to spread the buttons on the tablet screen further away to avoid unintentionally triggering the wrong collider and clicking the wrong option. The fast object changing and displaying in Unity caused new unpredicted actions when using the touchscreen, actions such as choosing



options from the second screen displayed after successfully navigating past the main screen. Accordingly, a slight delay had to be added after clicking any button, but not just a delay without any feedback. Thus a loading screen is visible for the delay duration before showing the new screen and activating new button colliders.

Finally, to make the interaction and navigation between screens and scenario options more intuitive, a "Back" button was added. Any wrongly pressed buttons should not impact the experience, and it should be possible to change one's mind on what scenario to exercise.



Figure 3.13: Tablet with touchscreen functionality when picked up.

Noticeably, a highlighting glow was added around the tablet shown in [Figure 3.12] and [Figure 3.13]. Reasoning concluded from stress testing the application and testers not finding the "remote control". Thus a need to attract one's attention to it with a highlight that pulses and lights through walls such that it can not be left unseen.

## 3.6 Guidance

After the first test run by close cooperators and developers, they pointed out that it should be straightforward to understand and use the VR game because this application intends to be self-help with no third-party guidance. Therefore, when patients are using the controllers and multiple buttons from the controller interacting with the game, it was decided to add a poster on the nearest wall, in the break room. The poster includes a small guide to how these controllers operate and how they are used in the application. Additionally, some instructions to guide patients in exploring and playing the different scenarios were added on the poster beside.

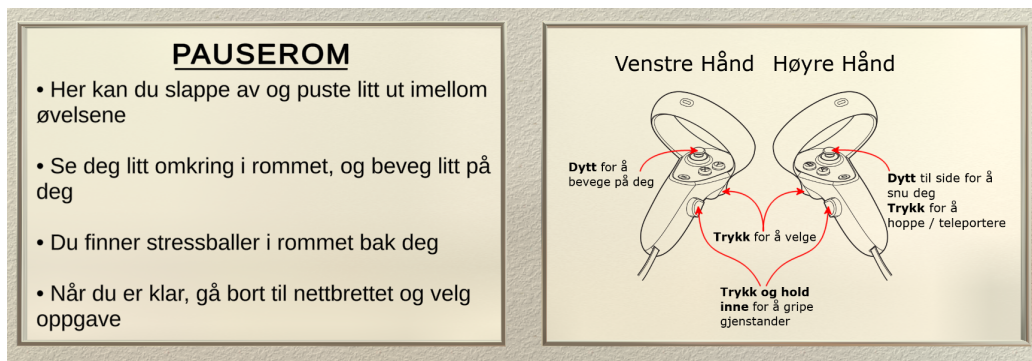


Figure 3.14: Posters with information and guidance in the break room.

**Text from figures in English:** Break room

- Here, you can relax and breathe a little in between exercises
- Look around the room and move around a bit
- You will find stress balls in the room behind you
- When you are ready, go to the tablet and select a task

Further, after testing and discussing with cooperators and domain experts from Helse Vest IKT and Haukeland University Hospital, it was concluded that adding information screens about the different scenarios on the tablet supplements very well for operating inside the application on patient's conditions and without interventions from the therapist. The information screens are small sentences that give the patient enough information about what will happen and what the exercise expects from them in a given scenario. These

information sentences are from the clinical domain expert cooperators, who already use the same information in their medical treatment. The implemented information screens work as a pop-up notification on the tablet when the patient clicks the information button next to the scenario buttons. The notification pops up with the information in the middle of the tablet screen, as showcased on [Figure 3.15].



Figure 3.15: Tablet with information screen about the school scenario. Figure 3.16: The final version of the school scenario information screen.  
**Text from figures in English:** Talk in a group of peers in a schoolyard

[Figure 3.15] and [Figure 3.16] differentiate the slight change made to the notification pop-up after comments from the first testing iteration. The noticeable change is the smaller notification area to focus one's attention on the text while not covering up the entire screen. In addition, the dot that resembled a list was removed, and the text was aligned centrally, reasoned by its quick and direct information, and to emphasize the intent of the notification by making the text stand out.

## 3.7 Speech Recognition

First, implementing a simple input configuration script to recognize if the patient was speaking to a standard microphone allowed a flow in conversations happening through the different scenarios. However, that did not work when multiple answers and responses were available to the patient's answer. Hence, a random selection from predefined responses when given a specific scenario was the first considered solution. Nevertheless, after talking to innovators from Helse Vest IKT, a conclusion was drawn that this naive and straightforward solution would not provide a feeling of a real conversation and that it would probably only work in short conversations.

After discussing with innovators, the final decision became a complete integration of a speech recognition service. The Azure Speech Service [36] from Microsoft was chosen and used to achieve this desirable goal, given that the innovators from Helse Vest IKT recommended this speech recognition service. It made the decision between multiple options available easier. This Microsoft speech recognition service is used to understand what the patient is saying. An additional intent recognition service, Wit.ai [37] provided by Meta, is used to recognize the intent of the sentence received from Azure Speech to text (STT). Later the obtained intent from the Meta service is used to respond with the correct and wanted reply in context to the patient's sentence and intent. This solution with two external services achieves the desired goal of a continuous flow/conversation between the patient and the application. Choosing Wit.ai was based on the ease of implementing this service into the application and its ability to recognize intents in Norwegian sentences. The Microsoft Azure speech recognition service can also recognize intents in sentences, but it does not yet provide this function for Norwegian sentences.

Wit.ai uses Artificial Intelligence (AI) to recognize intents from sentences. Therefore, some initial sentences had to be provided to this service to train the AI to recognize intents. When training the AI, each phrase in each sentence had to be manually selected and connected to particular intents.

Next, the response and application's reaction are based on the intent received. Therefore when training the AI with more samples of different words, phrases, or even sentences and binding them to a given intent, Wit.ai will return the correct intent with higher confidence when the application requires it. The application will require the intent from Wit.ai when the patient has spoken in a scenario, and it has to continue the conversation based on the intent.

Providing many samples<sup>2</sup> of possible answers from the patient to the AI is essential and what takes the most time. The amount is not the solution by itself, but the training and how well the responses fit into the situations are crucial. A thoughtful process and many conversations with the clinical domain expert provided enough samples to try and fail when developing the application. Nevertheless, classmates' also helped test the AI within the scenarios, thus providing samples for broader use. They answered with some of the already existing and thought beforehand replies yet provided more possible answers, which helped with further AI training.

A subsequent approach that slightly differs from the previous one is when adolescent friends and family members were asked to fill out the training AI form [C.1]. The idea derived from the previously researched study "*Co-designing a virtual world with young people to deliver social cognition therapy in early psychosis*" by Realpe et al. [19]. The study concluded that if one wants to develop any virtual environment that specifically targets a group of people, it is in the best interest to involve people from that target group in development. Thus, they were asked to fill out the form with their most accurate answers as if they were hypothetically placed in this self-help treatment application's scenarios [Table 3.1].

The answer samples were later included in the training process of AI and significantly helped this application correctly find the intent from answers provided by the targeted group of people, which are adolescents.

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<sup>2</sup>Samples: Answers that patient replies.

### 3.8 Architecture

This section shows how the implemented Speech to text (STT) works and communicates with this application to correctly make a self-help treatment application as a supplement to regular treatment. Considering that the focus and solution for making such an application required complete integration of STT, its description is the only part of this application’s architecture.

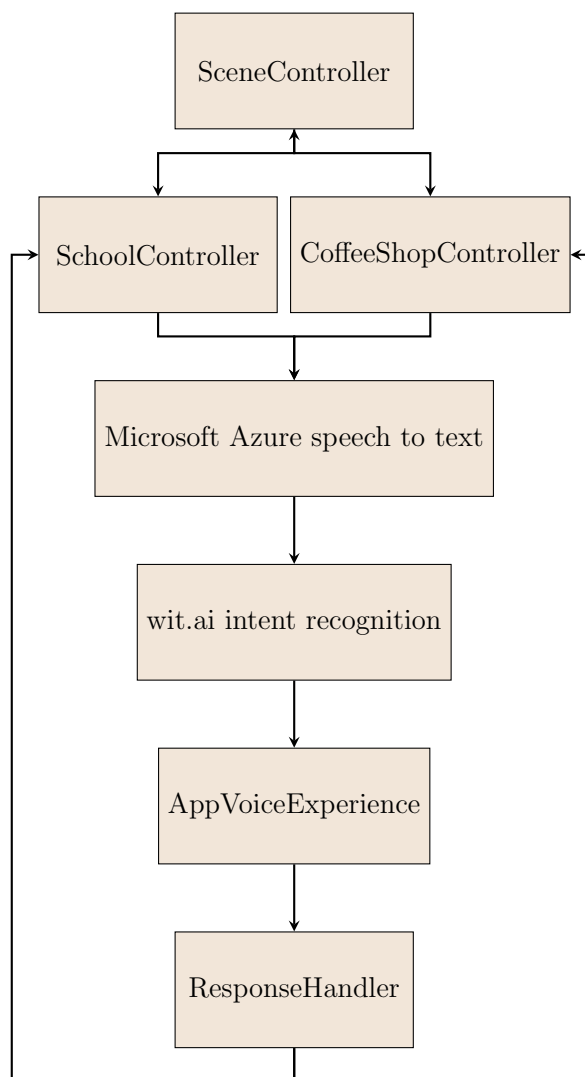


Figure 3.17: Architecture showing how the application obtains intents from users speech

There are three different Unity [2.3] scenes in the implementation. Each represents the environment for the implemented treatment scenarios, CoffeeShop [2.8.1] and School [2.8.2]. The last scene is the Break Room [3.4], where the patient is encouraged to relax.

When the patient first opens the application and starts the self-help treatment, they will be located in the break room scene with different options available. When using the implemented "remote control" [3.5], the SceneController will be invoked. Then, based on the patient's choice, this controller will use the appropriate environment controller, either SchoolController or CoffeeShopController, to perform the correct tasks according to the patient's decision.

[Figure 3.17] illustrates the architecture of the STT communication and how it works, as mentioned in [section 3.7]. Firstly, when in a specific environment, the patient will speak to the VR headset microphone, and this audio is then sent over to Azure STT [36] service to transcribe the audio to text. The later stage includes the Wit.ai intent recognition [37] service, receiving the transcribed text, and returning the correct intent to the application. Finally, the AppVoiceExperience in the application accepts the intent and performs the correct action based on the ResponseHandler that the intent invoked. This action then triggers a process within the correct environment controller.

### **3.9 Converting scenarios into self-help**

This section will describe the first objective of converting each scenario from a manual treatment application that includes a therapist, as described in [section 2.8], into a more autonomous and patient-driven self-help treatment application.

Most of the time was used to implement a working and scalable version that is useable through different scenarios and environments, making it essential to understand how the scenarios play out based on the patient's and therapist's

interference. Then, with that knowledge and the source code from previous work, it was most helpful to make a few flow charts to understand the scenarios better, further helping develop the self-help treatment application and making the working process easier.

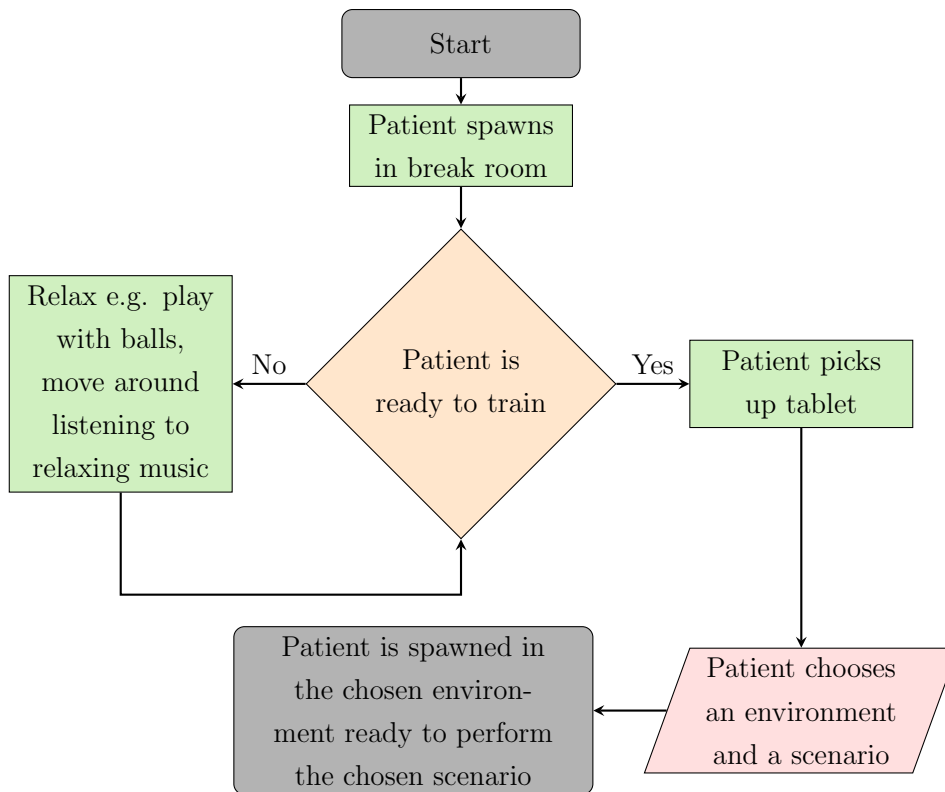


Figure 3.18: Application flowchart, Showing the flow of the application after startup

The flowchart on [Figure 3.18] shows the thought-out process and how the application will flow from the startup until the patient chooses a scenario to exercise. When the application starts, the patient is placed in the break room [section 3.4], where there are multiple activities to perform. First, the patient can relax before choosing a scenario and starting the exercise process. There are numerous possibilities for the patient to relax, one of them is relaxing music playing in the background. The patient can also play with a couple of balls by throwing them around. After relaxing, the main



focus for the patient in the break room is to begin a scenario by selecting it from the tablet [section 3.5]. Lastly, after choosing the scenario to exercise, the patient is relocated from the break room to that scenario.

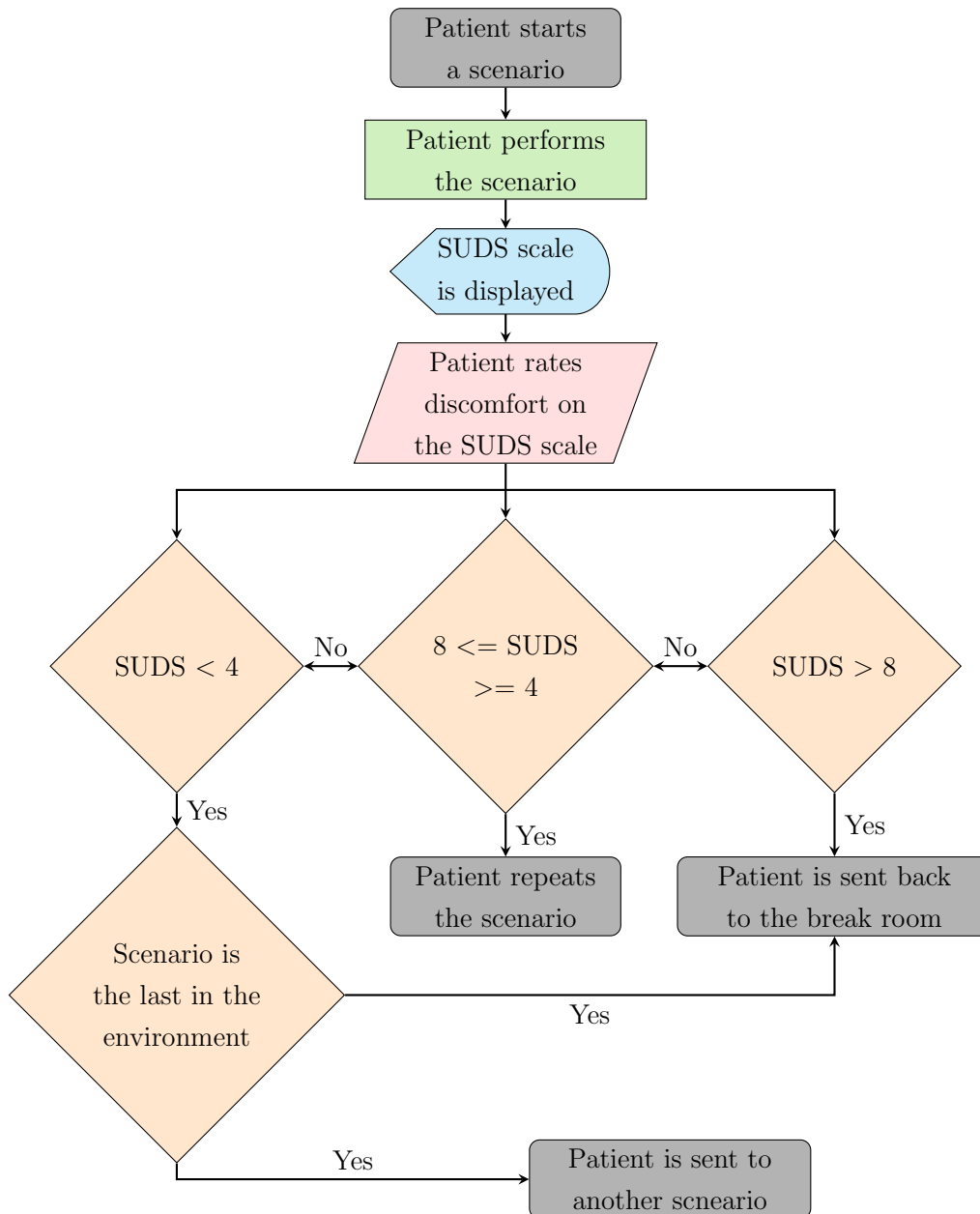


Figure 3.19: Scenario flowchart, shows the flow of the application during a scenario.

The scenario flowchart on [Figure 3.19] shows how the different scenarios and the break room are connected based on the process after performing a scenario. In addition, this flowchart illustrates how the exercise process includes the patient’s experienced discomfort. It will later be discussed in [section 3.10] how this is implemented and applied in the application. In short, the patient performs a simple scenario and gets congratulated after every scenario but, based on a scale from 0-10, chooses the discomfort they feel after completing it. If the discomfort is too high, a notification pops up with information to relax and relocates the patient back to the break room. If the discomfort is medium, the patient gets a notification that the scenario will repeat for repetitive training. Finally, the patient will be notified to train on the following scenario if the discomfort is minimal.

Table 3.1: Scenario choice shows the different scenarios within each environment.

<b>Date</b>	<b>Speak with a group</b>	<b>Talk with a stranger</b>
Walking	Approach	Ask for place
Meet	Answer a question	Help the stranger
Compliment	Ask a question	Ask to move
Ending		

The [Table 3.1] shows all implemented scenarios in the manual previous work treatment available to practice within all three environments. Furthermore, all scenarios from the "Date" and "Speak with a group" environments are converted into this project’s self-help treatment application, but none from the "Talk with a stranger" environment.

Date environment is a coffee shop and includes four different scenarios that the patient can choose from and practice either once or repetitively. The first scenario, "Waiting", makes the patient sit at a coffee shop table and wait until the waitress approaches. The scenarios gradually get more complicated and expose the patient to more discomfort. Thus the second scenario re-

quires the patient to meet a stranger of equal age and small talk with them about eating something. Suppose the patient has a low enough discomfort level from the less complicated scenario. Then, they will be automatically exposed to a more difficult scenario while staying in the same environment. Complimenting the stranger the patient has met before is more challenging for adolescents with psychosis. Hence the stranger comes with a compliment about the patient first, and the patient has to compliment them back. When the patient compliments, the scenario will end. Lastly, in the last scenario within the coffee shop, "Ending", asks the patient to end a conversation and say bye to the stranger without the stranger initiating any first words. However, the stranger is very thankful and compliments the patient on the way out of the coffee shop, avoiding any further discomfort escalation.

Speaking with a group is environment number two and is located in a schoolyard. This environment consists of three scenarios that are, equally as in the "Date" scenario, gradually getting more challenging and discomforts the patient more. The first scenario available in this environment is approaching a group, where the patient has to come close to the group as they make space. Another scenario is to answer a question where the patient gets asked if they could recommend a TV show, and the group reacts based on the patient's reply. The third and last scenario available in this environment is to ask the group a question. The patient has to ask the group what they are going to do during the weekend, and the group will respond.

The third environment is a light rail environment and includes three scenarios with increasing discomfort in each successive scenario. The first scenario focuses on the patient asking for a place on the light rail, where the difficulty in this scenario and discomfort come from the stranger's behavior. Another scenario is helping a stranger, where the patient can see a scarf on the floor that may belong to the woman beside it. The response in this scenario is either that the scarf belongs to the woman or not. In the third scenario, the patient has to ask a stranger to move aside to get off the light rail. The stranger can respond by being aggressive or apologetic.

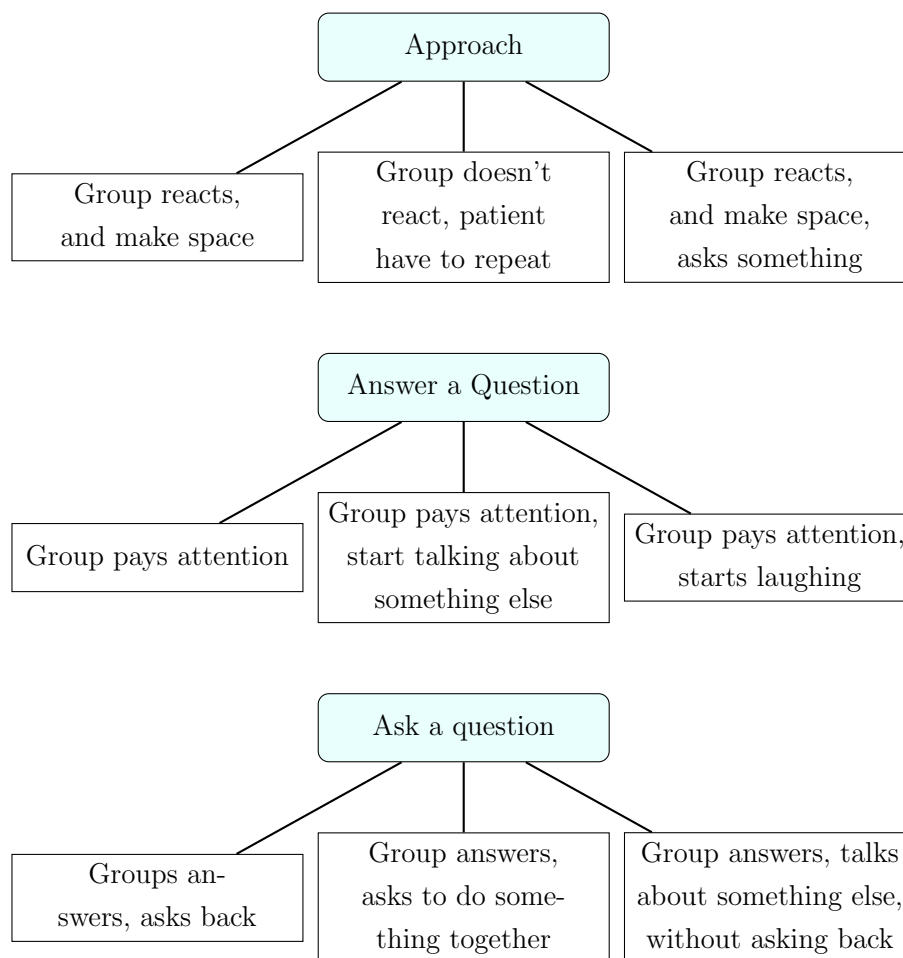


Figure 3.20: Different difficulties/responses from the application in the school environment

In [Figure 3.20], the chart shows the three different scenarios in the school environment. Each of these scenarios has the possibility of three different difficulty levels/different responses from the group. For example, when approaching the group in the first scenario, three different responses classify into difficulty levels. The least discomfoting response is when the group reacts and makes space for the patient. A slightly more discomfoting response is when the group does not react, and the patient must repeat. Moreover, the most challenging response is when the group reacts by making space and asking the patient a question.

In the second scenario, where the patient answers a question, the various responses from the group are; Starting from the least discomfoting when the group pays attention to the patient’s reply. After that, a more discomfoting response is when the group pays attention to what the patient is answering but starts talking about something completely different. Lastly, the most discomfoting response is when the group pays attention to the patient but starts laughing.

In the last scenario, where the patient has to ask a question, the different responses are when the group answers while also asking the patient back. Another response is classified as a medium difficulty response when the group answers and asks to do something together. The third and last response is when the group answers but starts talking about something else without asking back, which ranks as the most discomfoting scenario option.

### 3.10 Subjective units of Distress scale

Subjective Units of Distress scale (SUDs) is a scale where the patients rates their distress on a scale between 0 and 100, as explained by Stripada et al. in *“Between-session and within-session habituation in Prolonged Exposure Therapy for posttraumatic stress disorder: A hierarchical linear modeling approach”* [42]. In Stripada et al.’s study, there has been a significant conclusion based on 12 participants and over 300 SUDs measurements. With that much information, the study concludes that participants who had a reduction of at least 50% on CAPs<sup>3</sup> were qualified as high responders, and a reduction below 50% within participants qualified them as low responders. The study used SUDs, and it concluded that high responders had a significantly higher SUDs decrease than low responders in between sessions. High responders needed a break before their SUDs decreased. In-session SUDs scale results showed that low responders had a higher decrease in SUDs rating than high responders. With this information, the conclusion is that low responders had a better

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<sup>3</sup>Clinician-Administered Post Traumatic Stress Disorder from Blake et al. *“The Development of a Clinician-Administered PTSD scale”* [43]

outcome from sessions to reduce their SUDs scale rating without in-between session breaks than high responders who needed an in-between session break.

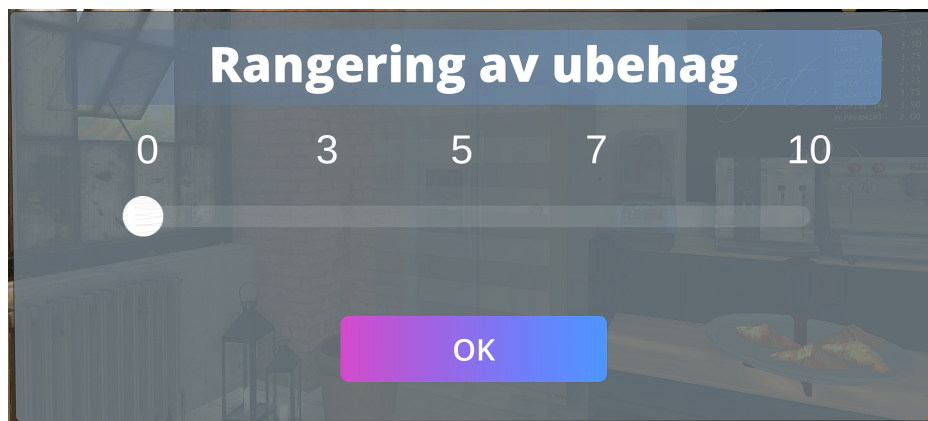


Figure 3.21: SUDs scale in the coffee shop.

**Text from the figure in English:** Discomfort ranking

Based on the study [42] and after discussing with a clinical domain expert from Haukeland University Hospital, the conclusion was to include a scale from 0 to 10 as the best approach in this project's application, where the patient rates their discomfort immediately after each scenario. The rating determines what decision the application makes; either leave the scenario and go back to the break room, this will happen if the distress level is too high (8-10). Another option, based on distress levels between 4 to 8, is where the patient has to repeat the same scenario. Claimed based on the study [42] that this distress range is where patients are most prone to treatment. Nevertheless, suppose the distress level is below 4. Then, the patient is comfortable with the situation and will not improve from further repeats of the same scenario. Thus the application will take the patient into the following scenario in the same environment or back into the break room if the scenario is the last in this environment.

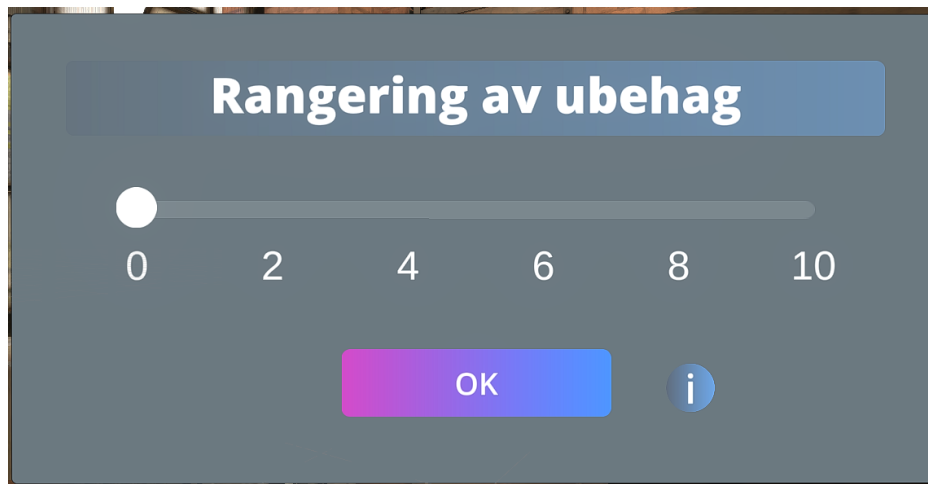


Figure 3.22: An improved version of the SUDs scale in the coffee shop, after comments from evaluators.

**Text from the figure in English:** Discomfort ranking

Conclusively, after conducting the first testing, most evaluators struggled to use the SUDs properly. This evolved into a more significant issue and needed further improvement to complement the self-help treatment with no help from the therapist. The white dot is not intuitive and does not resemble a slider, which led to it not being used, and the numbers were clicked instead. The numbers also did not complement anything and had no justification, thus had to be more clearly evaluated and decided on which numbers to display. Followingly, an information button was added to inform its functionality and easier guidance. The numbers displayed after the improvement have an increment of 2 and greater complement the logic behind its functionality, allowing to choose the right numbers for correct progression in the treatment. Additionally, the improvements changed the numbers' location and allowed clicking them when choosing the discomfort level without using the slider exclusively.

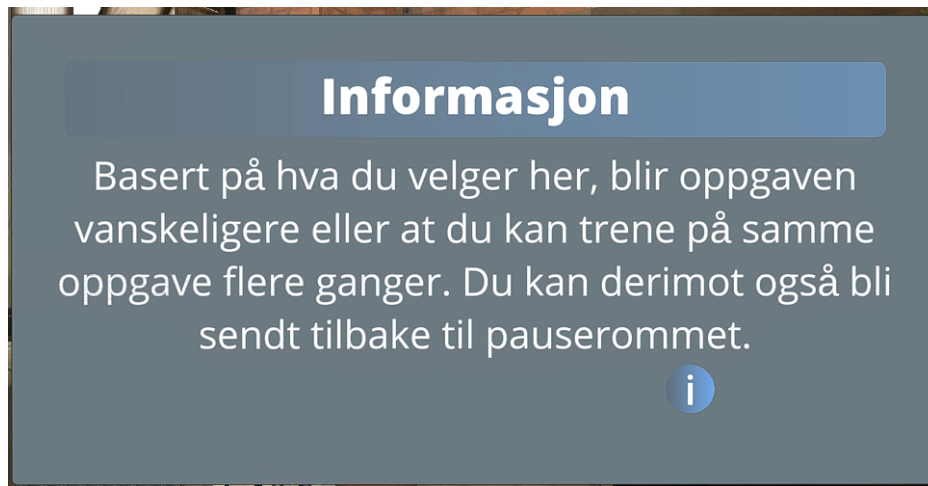


Figure 3.23: Information about the SUDs scale.

**Text from the figure in English:** Information

Based on what you choose here, the task becomes more difficult or you can train on the same task several times. However, you can also be sent back to the break room.

Above [Figure 3.23] shows an improvement in the guidance in the application after the first testing iteration. An observation was made that the evaluators needed guidance to understand how this part of the application worked. Therefore, a decision was made to include its information in the application. Discussions were held with a domain expert about what to include in this information screen as this part of the application is crucial, and one should not exploit it by knowing what happens in the background. The importance lies in that one should not be able to skip a scenario or leave the scenario intentionally without going through the recommended treatment. The displayed information is about the possible outcomes of the answer supplied in the SUDs but not precise values or other details.



# Chapter 4

## Results and discussion

This chapter will cover findings and discuss the results from tests conducted using a mixed-method consisting of a System Usability Scale (SUS) questionnaire that evaluates the application's usability and follow-up interviews to find improvement potential.

Clinical domain experts from Haukeland University Hospital were asked to evaluate the application. For the first tests, the number of evaluators was seven. After getting the necessary information about the test and the application, each evaluator got the VR Head-mounted display (HMD) and explored different scenarios and the break room. The necessary information was about the application, what to expect, and the testing itself.

Firstly, the evaluators were told to take a reasonable amount of time and explore the VR controllers within the break room and move around the "safe area". Using VR controllers to move around was the second option of movement besides simply walking in real life and was explained to the evaluators. After all, the evaluators were to test the application. The evaluators were assigned two scenarios within two environments, which they had to try out while evaluating the application. In order to not interfere when the evaluators explore the application, they were informed where to find all information inside the application and in the break room if any unclarity arose or they

wanted to find more scenario-specific information. Lastly, SUDs, explained and described in [section 3.10], play a big part in the progression and learning process solution. Thus the evaluators had to be informed about navigating it correctly, using the implementation of SUDs when finishing the assigned scenarios. They could repeat the assigned scenarios if desired, but only twice.

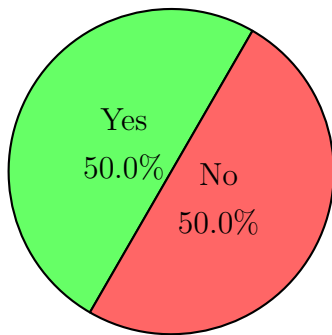


Figure 4.1: Have you been informed/have information about the application from before?

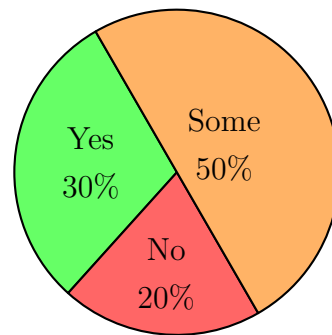


Figure 4.2: Do you have experience with VR and VR games?

Before the test, the evaluators filled out a [Pre-testing form, B.1] with questions that later were used to establish the baseline of evaluators' experience with VR shown on [Figure 4.2] and their knowledge of this application shown on [Figure 4.1] to better understand and discuss the results. After the VR experience and test, the evaluators filled out a [Post-testing form, B.2] to answer the questions with fresh thoughts after the experience. The answers from this form are the basis of the results that will further be discussed. Evaluators also answered multiple [Follow-up interview, B.3] questions about what they thought was best and worst about the application. To analyze these results in detail, evaluators received an anonymous number that they entered in both forms, making it possible to identify and combine them without writing down the evaluators' names. This way, the evaluators' identities remained anonymous. With answers to the follow-up interview, further improvements to the application were planned before conducting the subsequent test.

Followingly, the second iteration could be conducted after further improvements described in depth in [chapter 3] based on results and follow-up interviews from the first testing iteration. Due to only evaluating the application based on the improvements, only evaluators who had tested the application in the first iteration participated in the subsequent iteration, with only four available for the second iteration. Therefore, there was no need for a pre-testing questionnaire and no need to explain the application. Instead, evaluators were handed the VR Head-mounted display (HMD) and the controllers and told to explore everything, including every scenario. After a finished testing session, they filled out the same [Post-testing form, B.2] as in the first testing and elaborated with comments about the improvements made to the application from the first iteration.

## 4.1 Results

On [Figure 4.3] test results are illustrated, showing the scores from individual evaluators, both from the first and the second testing iteration. While [Figure 4.4] is showing the average score of all participating evaluators.

One evaluator gave markedly lower results than others, scoring 65<sup>1</sup> with a C grade on Sauro's [44] SUS curve from the first testing iteration. The pre-testing form helped to understand the skewness of this result. This<sup>2</sup> evaluator had no experience with VR but had information about the VR-CBT self-help treatment application. This evaluator's answers to the post-testing questionnaire indicate that they needed to learn a lot before using the application and needed guidance during the testing session. From the follow-up interview, it can be concluded that this evaluator experienced discomfort from using and learning VR technology itself and not the application per se. Further opening for discussion about VR knowledge as a prerequisite, described in more detail in [subsection 5.1.3].

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<sup>1</sup>Light red point on [Figure 4.3], Worst first test result

<sup>2</sup>Evaluator four on [Table 4.3], E4

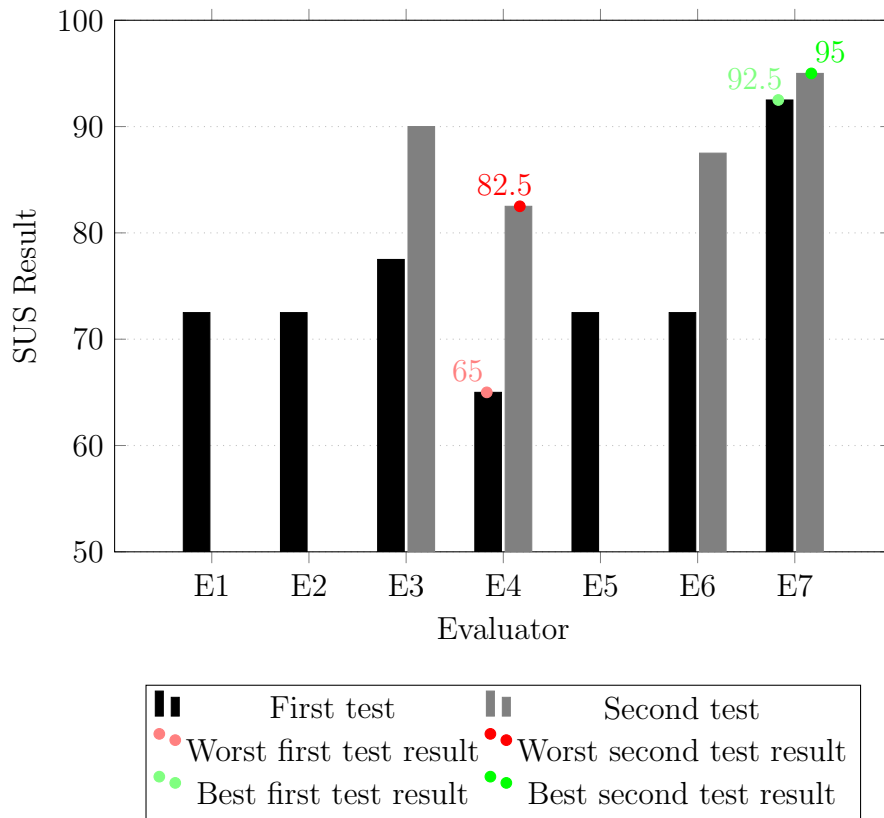


Figure 4.3: SUS Results from testing

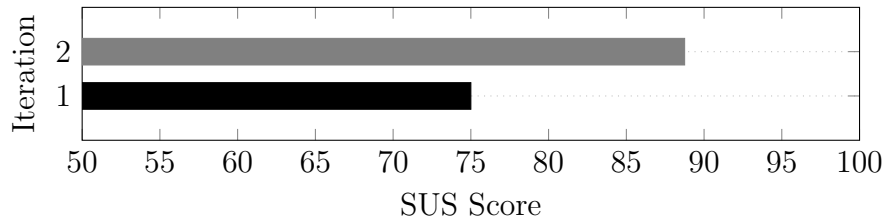


Figure 4.4: The average SUS result from both testing iteration

On the other hand, another evaluator’s answers to the questionnaire after the first testing iteration resulted in a SUS score of 92.5<sup>3</sup>. This evaluator’s pre-testing form answers<sup>4</sup> explain that this project was not fresh news for them. Also, this evaluator had some VR experience. The questions that asked if the application understood their answers and if they needed guidance while

<sup>3</sup>Light green point on [Figure 4.3], Best first test result

<sup>4</sup>Evaluator seven on [Table 4.2], E7

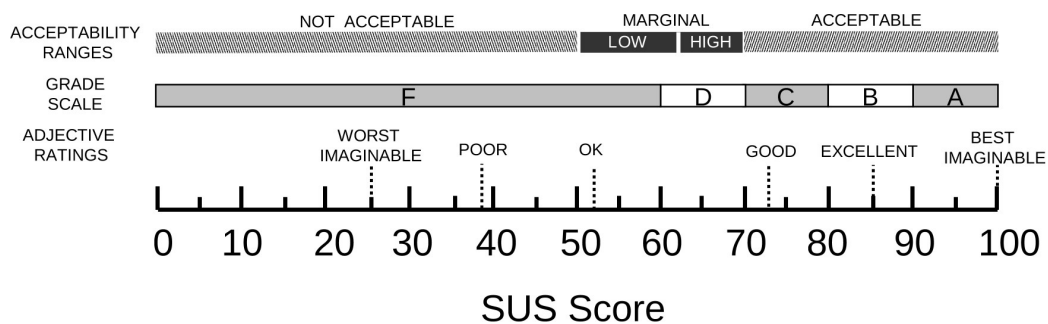


Figure 4.5: System Usability Scale (SUS) score from [4]

using the application are only the ones this evaluator did not give a full score. These results gave the application an A+ grade on Sauro’s SUS curve [Figure 4.3].

The [Figure 4.3] also shows results obtained from the second testing iteration. Results from the second testing iteration are illustrated with gray bars on the [Figure 4.3]. Evaluators without a gray bar were not available to test the application during the second iteration. However, the evaluators who scored the best and worst during the first iteration were available. A clear improvement can be seen in the results from Evaluator 4, scoring a SUS score of 82.5 in the second iteration, compared to 65 from the first iteration. Also, the best scoring evaluator scored better in the second iteration, showing that some improvements were achieved. Nevertheless, all evaluators who tested during the second iteration gave a higher SUS score than the first iteration, leaving the worst scoring evaluator from the first iteration being the worst scoring evaluator in the second iteration. Moreover, an improvement can be seen from a good application on the SUS score on the [Figure 4.5] scoring 75 from the first tests to an excellent application on the SUS score, scoring 88.75 in the second testing iteration.

The [Table 4.1] illustrates how the SUS score is calculated. With questions alternating between positively and negatively charged, odd number questions being positively charged, and even number questions being negatively charged. Before calculating the SUS score, one point was subtracted from the odd-numbered question-answer. Then the even-numbered question-answer

point was subtracted from five resulting in equally weighted answer scores between zero and four.

$$Q_i = \begin{cases} A_i - 1, & \text{if } n \bmod 2 = 1 \\ 5 - A_i, & \text{if } n \bmod 2 = 0 \end{cases} \quad n \in (1..10)$$

Finally, all answers' points were summed up and multiplied by 2.5, producing a scoring range of 0 to 100.

$$(\sum_{i=1}^{n=10} Q_i) * 2.5$$

Table 4.1: Evaluator 1 SUS score Calculation

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
<b>Answer</b>	4	4	5	3	5	1	4	4	4	1
<b>Calculation</b>	A - 1	5 - A	A - 1	5 - A	A - 1	5 - A	A - 1	5 - A	A - 1	5 - A
<b>SUS score</b>	3	1	4	2	4	4	3	1	3	4

Each evaluator's calculated scores with the calculations explained in [Table 4.1] can be seen on [Table 4.2]. In addition, additional colors were added to illustrate how each evaluator answered and how each question scored, from best to worst; green, yellow, orange, and red. One can, in particular, notice that the fourth question had the worst scoring while the tenth question had the best scores. These observations are further discussed in the following [section 4.2].

Table 4.2: SUS scores of individual evaluators from the first testing iteration

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS
E1	3	1	4	2	4	4	3	1	3	4	72.5
E2	3	4	3	1	2	4	3	2	4	3	72.5
E3	4	1	3	2	3	4	4	2	4	4	77.5
E4	3	2	3	1	2	3	4	1	3	4	65
E5	4	3	2	3	1	4	3	3	2	4	72.5
E6	4	4	1	2	3	3	3	2	3	4	72.5
E7	4	4	4	3	2	4	4	4	4	4	92.5

The following [Table 4.3] shows similarly to [Table 4.2] the individual evaluators' scores obtained from the second testing iteration. Considering the second testing iteration only had evaluators that participated in the first one, the number of evaluators differed when evaluators 1, 2, and 5 could not attend and participate due to scheduling collisions. Since only the same evaluators tested the application, the evaluator numbers are retained in both tables. For example, E4 in [Table 4.2] is the same evaluator as E4 in [Table 4.3].

Table 4.3: SUS scores of individual evaluators from the second testing iteration

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS
E3	4	3	3	4	3	4	4	3	4	4	90
E4	3	3	3	3	2	4	4	3	4	4	82.5
E6	4	3	3	3	3	4	4	3	4	4	87.5
E7	4	4	4	4	4	2	4	4	4	4	95

## 4.2 Discussion

This section will discuss the obtained test results that have been unwrapped in [section 4.1] and reflect on the mixed method used to obtain these results. Furthermore, mention possible uncertainties by modifying a standardized questionnaire form instead of using it how it is predefined.

### 4.2.1 First iteration of tests

The System Usability Scale (SUS) results from the first testing iteration show that this is an acceptable application. Still, there is room for improvement, as explained by Sauro in "*Measuring Usability with the System Usability Scale (SUS)*" [44]. As Sauro explained and shows on the curve in [44], a SUS score of 75, the first testing iterations score, is above average and has a B- grade. If a score is below 50, the testing would conclude that the system tested is not usable. In this case, the first results show that the application is good yet has room for improvement and requires preparation before the second testing iteration.

Additionally, concluding from the first testing iteration, the best scoring evaluator's answers show that some VR experience with information about the application's usage and background is enough to understand and use the application. Simultaneously, the worst scoring evaluator shows that the application needs further improvements to be entirely usable as a self-help treatment application and improve the health care process while emphasizing the conclusion about the need for VR knowledge.

Furthermore, concluded from the [Follow-up interview, B.3], they complement results from the SUS scale and that there are multiple aspects of the application that require investigation and improvement.

#### 4.2.2 Second iteration of tests

The second testing iteration's scores significantly improved compared to the first tests in the overall usability, scoring 88.75 compared to 75. Still, the best scoring evaluator from the first test scored the highest in the second iteration with an improvement. At the same time, the worst scoring evaluator from the first test scored the worst but markedly higher than in the first iteration.

From the individual evaluator answers [Table 4.3], an observation can be made that the best scoring evaluator<sup>5</sup> felt an improvement in the need for guidance and that the application recognized their speech and intent well. However, the evaluator felt that the application responded with more unexpected responses than during the first testing while recognizing their intent better, which could indicate a misunderstanding of the question asked. Simultaneously, the worst scoring evaluator<sup>6</sup> showed an improvement in the application's complexity and that the application did not answer with unexpected responses. A more significant improvement in this evaluator's perceived usability was in their need for guidance and the need to learn new things.

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<sup>5</sup>Evaluator seven on [Table 4.3], E7

<sup>6</sup>Evaluator four on [Table 4.3], E4



From the individual question answers, one can see an improvement in the need for guidance (Question 4 on Post-testing form, B.2) and the need to learn new things (Question 8 on Post-testing form, B.2). This shows a positive tendency in the development and usability of the application. Nevertheless, these scores could also be higher because the evaluators are already familiar with the application. Therefore not feel the need for as much guidance and learning as during the first tests. The other questions also had a positive shift, but neither had an equally drastic shift.

### 4.2.3 Reflection on System Usability Scale

Although the System Usability Scale (SUS) evaluation is simple and easy to use, it also comes with challenges and considerations to be made when using it in testing the usability of a system. Orn describes some of the positives and challenges in "*The Pros and Cons of the System Usability Scale (SUS)*" [45]. It is a short questionnaire that does not require many resources, thus an excellent method to get reliable information fast. Additionally, a template form with standard questions already exists, making the research and designing process a quick and easy tweaking process instead to better target own study system.

Orn also mentions that SUS should not be used as the only testing method and that SUS is not a diagnostic tool. As SUS can give a score for a system, it will not tell what is wrong or good about it. However, the SUS score can give a general idea of evaluators' perceived usability of a system while not saying anything about what can be improved upon to get a better score. Having that in mind, the follow-up interviews added on top of the SUS questionnaire in this research provided the missing information, which allowed distinguishing what was good and bad.

As explained in "*Why You Only Need to Test with 5 Users*" [46], the satisfying amount of evaluators needed to get good results is five and to have an iterative design with multiple small tests. The number of evaluators in this application's testing iterations was sufficient to get a proper and reliable un-

derstanding of the usability. However, more testing iterations would provide better and more reliable results. Considering that multiple small tests are needed with a few evaluators, and this project only conducted two iterations, there is room for improvements by conducting more tests.

#### **4.2.4 Modified SUS questions for this application**

SUS questionnaire consists of ten standard questions that ultimately represent the user's experience after testing a system. However, the questions used in this project were slightly modified and directed toward this project's application. For instance, the standard questions differ because the ordering is different, but the question's positively and negatively charged identities are still the same, which means that the scoring is unaffected. In addition, three questions are also completely revamped and written to target this application's usability and challenges.

The first question in the standard form asks if the user would like to use the system frequently. Considering that the application is developed and made for adolescents with psychosis in rehabilitation but tested by clinical domain experts, the question was indirectly modified to ask the evaluator if they would recommend this application for use by the target group.

At the same time, the third question would ask the user if the system was easy to use but was alternatively modified to ask the evaluator if the interaction with the application was intuitive. That resulted in a question from another angle that required the evaluator perhaps to think more than in the standard question form.

Following question four differentiates similarly to the third by a slight change in the formulation towards the present time. On top of that, instead of asking about necessary technical support while using the application. It instead asked if the evaluator needed guidance to understand the application, resulting in a different question that could give an error in the score compared to using the standard one.

Question five was revamped entirely and targeted the uniqueness of this application when asking the evaluator about the STT implementation and how well the intent was recognized.

Question number six from the standard form was moved down and changed to be a positively charged question, asking for consistency instead of inconsistency in the application. By moving the question, a new one was added targeting the unique aspect of STT implementation. This time the question was negatively charged and asked the evaluator if the application responded with an unexpected response several times.

Question number ten from the standard form was moved up by two places, meaning that no changes were made and the question was still negatively charged. Similarly, question number nine was moved down by two places, retaining the positively charged identity.

Question ten on the post-testing form, equally to questions five and six, was revamped yet retained its identity. Instead of the standardized question, the question asked if the scenarios and tasks in the application were difficult to understand.

Considering that nearly all the questions have been modified in this project compared to the standard SUS questionnaire, the results may differ if standard questions were used. For example, some questions have vague meanings and are hard to understand, which could explain the different scoring between the evaluators on the same questions. Additionally, some questions could be better formulated to convey the intended message better. For example, question five on the [Post-testing form, B.2] asked *"I feel that the application recognized the meaning of what I said well."*, but rewriting it to *"I feel that the application reacted well to what I said."* would better convey the message. Furthermore, question nine on the same form should alternatively specify that most *adolescents* would manage to learn the application quickly instead of asking if most *people* would manage to learn the application quickly.

Concludingly, if another SUS testing were to be conducted, some of the questions would be redefined, or all questions used would instead be from the standard questionnaire form.

#### **4.2.5 Testing without patients**

The VR-supported self-help treatment is developed for adolescents diagnosed with psychosis. Therefore, this study should conduct the testing with the desired target patient group, but that is not the case. The main reason for not including patients in this study is this project's scope which does not include patient effect study testing. This project's application is meant to supplement regular clinical treatment protocol. However, there are other reasons to not include patients in tests at such an early development stage, such as how vulnerable and exposed they already are when diagnosed. In addition, testing an application without a guarantee that it is excellent can harm these patients, making them lose their mastery feeling while increasing their psychosis symptoms.

Another reason why this study did not include patients was due to ethical issues concerning VR. The Meta [47] company that issues the VR product Oculus Quest collects a tremendous amount of data from the device. For example, using VR-HMD from such a company comes with challenges in the medical environment due to privacy reasons. Such data collected includes all motion and sound recorded, and additionally, before using the VR-HMD, one must log on with a private account to their systems. This account again includes private information that conflicts with the medical environment privacy. Trying to avoid these problems by making one account for all patients and making each anonymous by not binding a patient to an individual account is also disallowed by Meta guidelines [48]. A therapist cannot encourage to break those. The last point to identify is the production issue of such a VR-HMD. Having full consent and using Oculus Quest in the medical environment forces the hospital to explore and analyze how these products are made and where they come from to find potential clinical research breaches.

Instead of testing with the target patient group, the tests were conducted with clinical domain experts from the Department of Child and Adolescent Psychiatry at Huakeland University Hospital. However, the clinical domain expert and the innovator involved in the development stage were not participating in testing. Because of their involvement, their results could be positively biased and not give a clear understanding of how well a self-help application is usable and easy to understand with little to no prior knowledge.

# Chapter 5

## Conclusion

This chapter concludes with steps on the study progress and explores possibilities for further work within this field of research.

This project aimed to develop a VR self-help treatment application for adolescents with psychosis and identify how VR can be used in such treatment. The application aims to supplement regular CBTp treatment and help make the treatment faster and more intensive yet easy to use. This project achieves this by giving an option to expose psychosis-diagnosed adolescents to discomforting scenarios without having to find such situations in real life or even leaving the house. After concluding a mixed qualitative evaluation method with clinical domain experts consisting of a SUS questionnaire and [follow-up Interviews, B], the final results are positive and display an acceptance and ease of using the application. To use VR in self-help treatment for adolescents with psychosis, one possibility chosen and developed in this project was to make a VR application that uses STT to realize the self-help treatment idea.

This project explored using VR to make a self-help treatment application that can be used on a standalone VR-Head-mounted display (HMD) without needing an additional PC. Furthermore, this project did not start the application's development completely from scratch. Thus the development

focused on converting the existing solution into a standalone method without the need of a physician or the innovator being available during treatment. An STT service from Microsoft and an intent recognition service from Meta were used to make such an application. During development, one of the main focus points was the need for guidance and information available within the application during the experience without a third party available for explanation.

As mentioned previously, the development focus for this project was the implementation of STT to make the conversation flow naturally with no disturbance in the treatment. The final solution was to use and implement recognition of Norwegian speech and its intent. Furthermore, teaching the intent recognition AI and properly assigning intents became the biggest challenge. To achieve the desired result and train the intent recognition, AI needed multiple samples of the possible answers. Therefore, adolescents were asked to provide their possible responses in the conversations if they were in the scenarios. This showed to be an excellent idea and provided a great amount of crucial data to train the AI.

Sending the audio clip to be understood, analyzed, and derive the correct intent from it by third-party services makes this application's only concern to respond to the received intent correctly. The responses from the application were thoroughly discussed and evaluated with the clinical domain expert not to discomfort the adolescents while using the application unnecessarily.

Once the necessary guidance in the application was implemented and the needed STT and intent recognition services properly set up, two evaluation iterations were conducted with clinical domain experts. The first iteration included seven evaluators, while the second iteration only included four of the same evaluators. The evaluators answered a SUS questionnaire tailored for this project. Additionally, they answered follow-up interview questions to provide answers that the SUS questionnaire could not provide about what could be improved. After the first testing iteration, further improvements were implemented, and the second iteration was conducted.

The second testing iteration aimed to result in a better SUS score and delivered a final result with an uprise in score by 13,75 compared to the first iteration and jumping to an excellent from a good application based on [Figure 4.5] adjective ratings. After reliable usability tests, the final score are positive and display that VR can be used together with STT to realize an application that can avoid the additional involvement of a physician and innovator.

### **Research Question:**

*"How can VR be used in self-help treatment for adolescents with psychosis?"*

To answer the research question, the solution explored in this project using third-party services like STT and intent recognition can create a standalone method that adolescents could use in self-help treatment to supplement the regular treatment protocol. According to the obtained results, the clinical domain experts perceive the current implementation as acceptable, and from the follow-up interviews recommend that adolescents with psychosis should try this application.

## **5.1 Further Work**

Following is a discussion and suggestions on where this project could further be expanded and what could further be explored as solutions for this self-help treatment application. Including thoughts and explanations for why further work in this direction can be beneficial.

### **5.1.1 Further testing**

To further test the application's usability and maybe efficiency, the application should be tested with adolescents and subsequently with psychosis-diagnosed adolescents. This should be conducted by clinical domain experts and follow all necessary policies for such tests, which is out of scope for this project. For example conducting a case-control study comparing two groups, one of which experienced the VR self-help supplementary treatment while



the other did not, to analyze how or if such supplementary application can enhance psychosis treatment for adolescents. Nevertheless, such tests are out of scope for this project's study and have to be clinically performed over a more extended period.

Furthermore, usability and Speech to text (STT) can constantly be improved such that more extensive testing methods should be performed, including the target group. Additional features that help the usability and understanding can be included in the application to improve the experience and create a better self-help treatment. However, understanding and usability are not the only focus such that more treatment environments and scenarios should find a place in further development.

### **5.1.2 Game interaction without VR hand controllers**

One feature idea during usability discussions was to get rid of controllers completely, thus the need to learn what every button does. Instead, use the Oculus' hand tracking feature, allowing patients to interact with the game only using hand gestures. This feature would make the interactions easier and perhaps more intuitive and allow for a more immersive experience. While simultaneously making the application more available to use with less hardware, thus more manageable for the hospital to lend the VR-HMD to their patients. Regardless, a controller-less experience would still require the patient to learn all hand gestures instead of buttons.

### **5.1.3 VR tutorial room**

While a controller-less feature would perhaps make the following feature less needed, another feature that could further be explored is the inclusion of a VR tutorial room. Many evaluators did not have experience with VR beforehand. Thus, the adaptation to such control was somewhat difficult for them, and an appropriate tutorial room would greatly help in such cases. The tutorial room would take the patient through different sections to familiarize themselves with the controllers and their required usage to grab objects,

select items from the tablet menu, or walk around the break room. This could make the usability better when they are in the actual treatment by focusing on the task at hand rather than thinking about the controllers or how to use the required equipment correctly, further enhancing the treatment to focus on the experience instead of VR technology entirely.

#### **5.1.4 Therapist inclusion in the application**

Another feature discussed during the iterative development meetings and seen in related work was the inclusion of a therapist inside the break room VR environment. This feature could enhance the self-help treatment experience and lower the patient's discomfort level by constantly having an assurance of the therapist's presence and finding help when necessary. Such a therapist can be a hologram or a 3D model to assure the patient's relaxation and feeling safe in the therapist's company. The therapist in this situation could additionally provide guidance and have a voice to answer the patient's questions without exiting the application. The answers would be short and precise and could generally be predefined and prerecorded to help the patient immediately.

On the other hand, the 3D model can be a second VR-HMD connected to the same environment and act as a multiplayer game where the patient and the therapist are playing together, but possibly from two different places in real life. Thus, making the self-help treatment possible to carry out from the home environment and have the possibility to consult the therapist. The therapist does not have to be present at all times, making the 3D model only visual when the patient "calls" for help or reaches a high enough discomfort level. The patient could call for the 3D model or multiplayer mode by saying it aloud and STT reacting accordingly or clicking a button on the VR controller.

### **5.1.5 More scenarios/environments**

Adding more environments or scenarios may seem trivial and should also be the first expanding point of this project. There already exists another light-rail environment in the previous work developed by Helse Vest IKT but was not included in this project scope due to the environment not being complete during the start-up phase. Expanding the application to include more scenarios and environments would broaden the reached audience and help more psychosis-diagnosed adolescents. Furthermore, creating and implementing more scenarios and environments that the clinical domain expert concludes to be the most discomforting to adolescents would be the next step in this expansion direction. For example, a grocery shop environment where the patient buys an item and has to interact with a cashier could be a possible scenario. Making the cashier react more aggressively or friendly could be different difficulties.

### **5.1.6 Data collection**

Data collection is a high focus in the medical environment and treatment. Thus, connecting a database to save and collect the patient's discomfort level chosen when ending a scenario can be beneficial to analyzing the self-help treatment experience in later stages. Alternatively, discuss the experience after using the supplemental application in the regular treatment session. This further step in development requires an exact decision as to what and how much data should be collected. Otherwise, the implementation is a simple step to create a database and connect the SUS variable used in the current implementation to the database. However, it is essential to mention that all the data would need a direct or indirect connection with the patient to distinguish between different patients, resulting in a challenging approach considering the clinical environment. Any other data that is not for medical help, like location or speech, or movement, would not require to be tracked and thus not collected.

# Appendix A

## Assets

Following are the assets and plugins that were used in the process of developing this application.

### A.1 Additional assets

- Ipad
- Phone Stand 3D model
- Tennis Ball texture (for sticky ball)

### A.2 Unity Assets

- Auto Hand - VR Physics Interaction
- Timelines
- Highlight Plus (to direct patient's attention onto the tablet in break room)
- Beautify 2 - Advanced Post Processing
- TextMeshPro

- School Scene
- ArchVizPRO Interior Vol.2
- ArchVizPRO Interior Vol.5
- ArchVizPRO Interior Vol.6
- 3D Scifi Kit Vol 2
- Alloy Detail Texture Mega Pack
- Coffee Machine set ( Cafe props )
- Croissants Pack
- Dance MoCap Collection
- Everyday MoCap 01
- ScreenShot Class
- Clean & Minimalist GUI Pack
- Hexart - Complete UI
- Free Laptop
- Conversations - Mocap Animation Pack
- MOBILITY: Conversations Mocap Animations
- Movement MoCap
- Screen Fade (VR support)
- Free Smartphone
- Coffee House Kit
- Suburb Neighborhood House Pack (Modular)
- Tea Kettle

- Character Creator & iClone
- LipSync Pro
- Magic Light Probes
- Mesh Combine Studio 2
- Modern UI Pack
- Oculus Integration (for intent recognition)
- UFPS: Ultimate FPS (for ball targets in break room)
- DOTween Pro
- More Effective Coroutines [PRO]
- Real Materials Complete
- Sitting MoCap 02
- Soft Snow
- Speech SDK (for speech recognition)
- VR UIKit - Bootstrap Your VR App with Ease!

# Appendix B

## Interviews

In testing for System Usability Scale (SUS), two forms with questions that can be found below, were used. These forms were originally in Norwegian, and are translated for this rappers appendix.

### B.1 Pre-testing form

0. Participant number \_\_\_\_\_

1. Do you have experience with VR and VR games? 

yes	some	no
-----	------	----

2. Have you been informed/have information about the application from before? 

yes	no
-----	----

## B.2 Post-testing form

0. Participant number	_____					
	<b>Strongly Disagree</b> <b>Strongly Agree</b>					
1. I would recommend this application for use by adolescents with psychosis in rehabilitation.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
2. I feel that the application was unnecessarily complicated and difficult to use.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
3. I feel that the interaction in the application was intuitive.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
4. I feel that I needed guidance several times to understand the application.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
5. I feel that the application recognized the meaning of what I said well.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
6. The application responded with unexpected response several times.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
7. I feel that the execution of the application was consistent.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
8. I had to learn several new things before I could get started and use the application.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
9. Would most people manage to learn the application quickly (2 attempts)?	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		
10. I felt that it was difficult to understand what the different scenarios and tasks were about.	<table border="1"><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr></table>	1	2	3	4	5
1	2	3	4	5		



## B.3 Follow-up interview

- What do you think was best about the application?
- What do you think was worst about the application?
- Would an adolescent be able to use the application on their own?
- What would you say the usefulness of this application is?

# Appendix C

## Training AI form

### **C.1 Form for training Speech to Text AI with answers from adolescents**

This form was used to gather answers from adolescents, which is the targeted group for this application. This data was then used to teach the intent recognition service, wit.ai, to better recognize intents of the answers provided from the application.

Hi,

we are master students who will make a VR game for adolescents with social anxiety (adolescents who are not confident in social situations, or experience such situations as very uncomfortable).

On this occasion, we want to ask YOU to answer these questions as realistically as possible (remember that these do not have to be long answers, and you do not have to state anything personal that you do not want to).

This will help us in the development of the application. Such that it understands and can better respond to what adolescents say while using this application.

All answers are anonymous and can be answered several times.

Thank you very much for all the answers and all the help in advance :)

---

1. Age \_\_\_\_\_

### **Coffee Shop**

You're sitting at a coffee shop and are going to meet a friend.

2. The waitress asks you: Do you want to \_\_\_\_\_  
order something to drink?
3. The friend arrives and asks: Have you \_\_\_\_\_  
been waiting for a long time?
4. The friend sits at the table and asks: Are \_\_\_\_\_  
you going to eat?
5. The friend compliments you. How do you \_\_\_\_\_  
respond?
6. You must end the meeting. What do you \_\_\_\_\_  
say?

### **Schoolyard**

You are going to talk to a group of school friends

7. The group talks about needing a new series \_\_\_\_\_  
to watch, they ask you: Do you have a  
good series?
8. You approach the group and ask what they \_\_\_\_\_  
are going to do this weekend: What do you  
say?

# Appendix D

## Project Plan

In [Figure D.1], the project plan as of September 2021 is displayed. This diagram shows the work plan for this project, both the thesis and the VR application. It also shows the expected duration, start, and end for every task. [Figure D.2] on the other hand, it illustrates the final and completed plan on how each task's schedule ended when the project came to an end. One can see differences between the estimated plan and the final plan, mainly in the development schedule of the VR application. Similarly, the thesis finalization did not go as planned, and there was still much work at the end of the period.

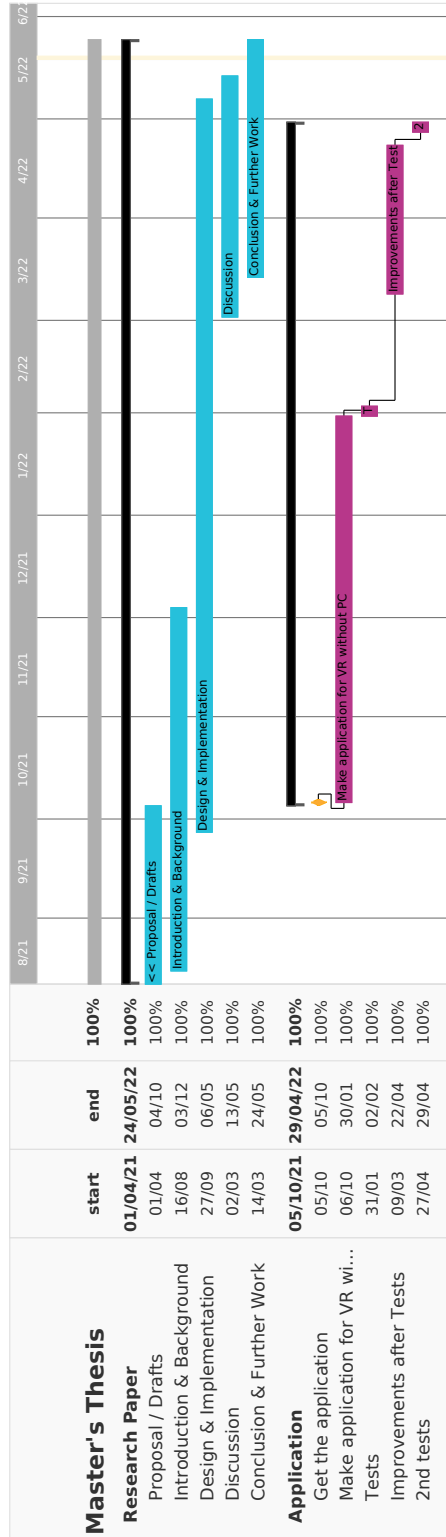
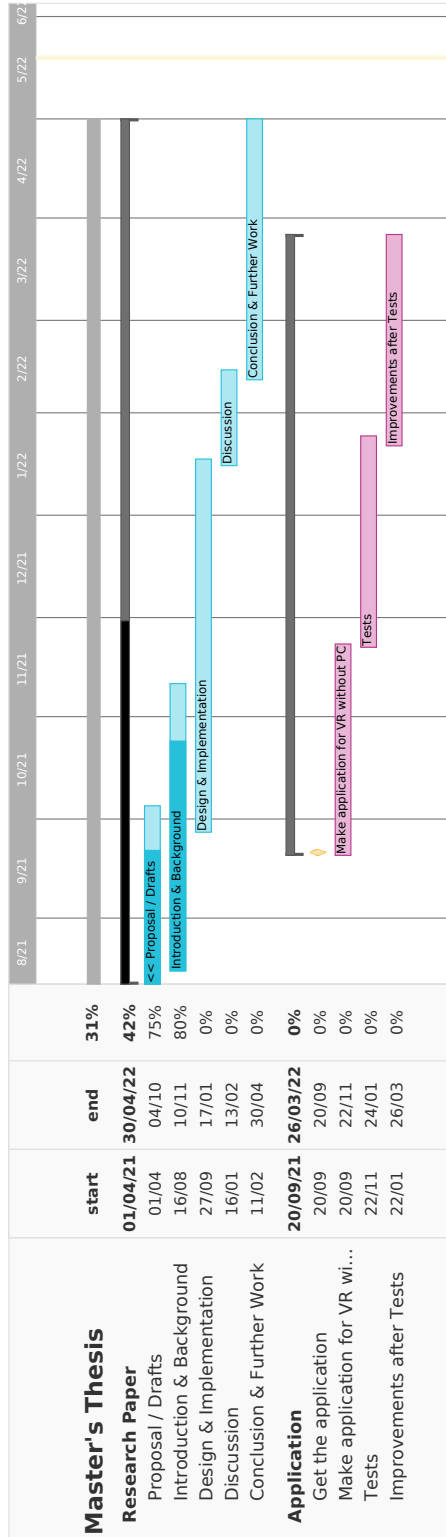


Figure D.1: Initial Gantt work plan (as of, September 2021)

Figure D.2: Final Gantt work plan (as of, May 2022)

# Appendix E

## Hardware

The following is the specs of hardware used to develop the VR application for this project.

### E.1 Virtual Reality Head Mounted Display

#### Oculus Quest from HVL

<b>Display</b>	Dual OLED 1600x1440
<b>Audio</b>	Integrated, in-strap
<b>CPU</b>	Qualcomm® Snapdragon 835 @ 2.3GHz, 3-cores
<b>GPU</b>	Qualcomm® Adreno™ 540
<b>RAM</b>	4.0 GB
<b>OS</b>	Android-based Operating System

**Specification reference:** "*Oculus Device Specifications | Oculus Developers*" [49].

## E.2 Desktop PC's

### Jaroslav's Komplette desktop PC from HVL

<b>GPU</b>	NVIDIA GeForce 1080 TI
<b>VRAM</b>	11.0 GB GDDR5X
<b>CPU</b>	Intel(R) Core(TM) i7-7700K @ 4.20 GHz, 8 cores
<b>RAM</b>	32.0 GB
<b>OS</b>	64-bit Operating System, x64 based processor, Windows 10 Home

### Wojciech's Komplette desktop PC from HVL

<b>GPU</b>	NVIDIA GeForce 1080
<b>VRAM</b>	8.0GB GDDR5X
<b>CPU</b>	Intel(R) Core(TM) i7-7700K CPU @ 4.20GHz, 8-cores
<b>RAM</b>	32.0 GB
<b>OS</b>	64-bit Operating System, x64-based processor, Windows 10 Home

### Jaroslav's Komplette home desktop PC

<b>GPU</b>	NVIDIA GeForce 1060
<b>VRAM</b>	6.0GB GDDR5
<b>CPU</b>	Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz, 4-cores
<b>RAM</b>	16.0 GB
<b>OS</b>	64-bit Operating System, x64-based processor, Windows 10 Pro

### Wojciech's Komplet home desktop PC

<b>GPU</b>	NVIDIA GeForce 1060
<b>VRAM</b>	6.0GB GDDR5
<b>CPU</b>	Intel(R) Core(TM) i7-8700 CPU @ 3.20GHz, 6-cores
<b>RAM</b>	16.0 GB
<b>OS</b>	64-bit Operating System, x64-based processor, Windows 10 Pro



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