Imperial College London

BEng Individual Project

Department of Computing

Imperial College of Science, Technology and Medicine

A Virtual Reality Platform for Administering Self-Attachment Therapy

Author:

Yue Shin Koh

Supervisor:

Prof. Abbas Edalat

Prof. Berc Rustem

Second Marker:

Prof. Duncan Giles

June 24, 2018

Abstract

In 2014, one in six people in the UK aged 16 and over exhibited symptoms of depression.[35] It is projected that, by 2030, mental health problems, particularly depression, will be the leading cause of mortality and morbidity globally.[35] Self-Attachment Therapy (SAT) is a self-administrable intervention for chronic depression.[15] It seeks to encourage the long term self-management of depression symptoms by facilitating successful emotional regulation and present an alternative treatment method that reduces growing pressure on mental health services. It is based on ideas proposed in Bowlby's Attachment Theory that suggest failure in childhood to form secure attachments to parental figures results in a diminished capacity for emotional regulation that can create vulnerability to mental illness.[19]

A key barrier to the successful administration of Self-Attachment Therapy is the inability of patients to imagine an inner child with which they must interact to practice the therapy's protocols. The administration of SAT using Virtual Reality (VR) was proposed as a solution, such that patients could perform the therapy in VR with a virtual inner child, removing the need for imagination. This work explores the application of VR to the administration of SAT, by building a comprehensive platform for its delivery. The platform allows users to perform all protocols in all four stages of SAT as well as providing step by step guidance through their execution in VR. It demonstrates that the interactions required for successful SAT can be made VR compatible and that VR can, as it has in its applications to exposure therapy, add value to the therapy by enhancing the level of immersion patients experience. This is especially significant for SAT because as an imagination-based therapy centered on the quality of the bond created between the patient and inner child, any additional realism achieved can improve its effectiveness.

Acknowledgements

I would like to thank my supervisor **Professor Abbas Edalat** for his guidance, support and contagious enthusiasm throughout this project. I extend my hopes for his well-being and eventual release.

I would also like to thank my supervisor **Professor Berc Rustem** for his guidance and support in light of extenuating circumstances.

I would also like to express my gratitude to:

Ibrahim Ghaznavi and **Usman Jehanzeb** for their ongoing support, advice and good laughs. Without them my platform would have 50 rooms and a talking dinosaur.

Nana Asiedu, Summer Jones and **Jay Munnangi** for bringing the best of groupwork to this 'individual' project.

Henry Davies for his witty proof-reading and constant supply of phD wisdom in the writing of this report.

My friends **Jamaica Eisner** and **Jordan Cubbin** to whom I owe my sanity.

My brother **Alasdair** for all the hugs I could ever want and

My parents for their unconditional love and support (a.k.a my tuition fees).

Contents

List of Figures

1 Introduction

Virtual Reality (VR) has many existing applications in psychotherapy. It is an enhanced method of delivering the stimulus required for different psychotherapy techniques. The psychological effects of VR experiences has proved to be worth further examination. It has, in its deception of human senses, shone new light on the psychology of self, identity and body. It has the potential to revolutionize the way that psychotherapy is performed and provide therapists with a measure of control and understanding of their patients that could not previously be achieved. In the use of VR in psychotherapy, VR has opened up exploration in the study of the neurobiology of VR experiences, how it relates to the neurobiology of psychotherapy and whether brain chemistry is distinguishable when experiencing VR or real life.

Self Attachment Therapy (SAT) is a self administered form of psychotherapy aimed at correcting the insecure attachment of individuals whose primary caregivers during their childhood development exhibited behaviours that prevented the individual from forming secure attachments. Thus, resulting in a variety of compensatory characteristics. The adverse impacts of early attachment insecurity is a reduced capacity to self-regulate emotion. This has been shown to have a lasting influence on the psychological condition of the individual, making them susceptible to psychological disorders and mental illnesses.[15] In SAT, by working with an inner child that symbolises their childhood psychological profile, patients, as their adult self, seek to provide to their childhood self the necessary compassion to facilitate the formation of a secure attachment. This secure attachment of the patient's inner child to the patient's adult self then helps the patient gradually improve their ability to regulate emotion as though they really had secure attachment in their childhood.

1.1 Motivation

In 2014, one in six people in the UK aged 16 and over showed symptoms of anxiety or depression.[35] With the destigmatisation of mental illness, demand for mental health treatment has increased significantly. In recent years, the percentage of people with health problems seeking help increasing from 23.1% in 2000 to 24.4% in 2007 and 37.3% in 2014.[35] This increased demand has seen access to mental health services limited by a shortage of mental health professionals, resulting in long waiting times. Even with the introduction of new waiting time standards in April 2016 set out in the government's policy paper Achieving Better Access to Mental Health Services by 2020[44], 75% of those suffering from common mental disorders will only receive treatment within 6 weeks and 95% within 18 weeks.

One way the health industry is attempting to reduce the pressure on mental health services is by encouraging self-management and peer support.[14] As a self-administrable intervention for chronic anxiety and depression[16], SAT presents a structured method that patients can use to self-manage. By building a cohesive platform that patients can use to guide them through the therapy, a SAT platform could be a powerful contributor to the movement towards making mental health services more accessible.

SAT addresses an attachment formed during childhood, in the pre-verbal years when visual senses are more influential. Thus, it makes significant use of visualisation and imagery techniques. [8] It requires users to imagine interactions with an inner child and attempt to form an affectional bond with them. While the protocols designed to help patients conceptualise the inner child are highly structured and have proven effective, the feedback received often highlighted the difficulty of this visualisation. This makes it an ideal candidate for mapping onto a Virtual Reality (VR) platform, a technological medium which allows for the substitution of our real visual and auditory sense inputs with computer generated, 'virtual' input data. In this way, VR has the capability to replace the imaginary visualisation practiced within the SAT protocols with virtual visualisations.

By introducing patients to Self-Attachment Therapy through a virtual inner child, the aim is to help patients more easily transition to practicing the protocols with an imaginary inner child. In addition, given the sense of presence and embodiment created by a virtual scene, a VR platform for SAT could also enhance the process of bonding with an inner child by increasing the realism of the experience. This is especially valuable as the quality of the adult-child relationship is central to the success of SAT.

Therefore, this work is motivated by the desire to increase the rate of participation in Self-Attachment Therapy by using VR to provide a method of administering it where difficulty visualising an inner child is not a barrier to access.

1.2 Objectives

The goal of this project is to build, using the Unity game engine, a platform for administering SAT using the Oculus Rift virtual reality system. It represents a proof of concept for the viability of administering SAT in VR, and an exploration of whether such a platform can successfully address the shortcomings of imagined SAT. As such, the development of this platform has the following key objectives:

- **Overcome Barriers to Accessing SAT** The primary reason for considering the use of VR for administering SAT was because it could help users who could not sufficiently imagine their inner child to visualise the inner child and therefore undertake SAT. How this platform tackles this problem is detailed in 3.1.1 Incorporating the VR Inner Child and evaluated for success in 6.1.3h Overcoming Barriers to Access.
- **Ensure Accessibility** As a platform used to administer a medical intervention, it is important it is accessible to those with special needs and disabilities. How this was achieved is detailed in 4.1.3 Designing for Accessibility and evaluated for success in 6.3.1 Accessibility.
- **Integrate Speech Recognition and Motion Detection** This platform's development seeks to demonstrate that in VR motion detection and speech recognition are viable alternative methods of collecting user input. How this was integrated into the platform is detailed in 5.3.3. Speech Recognition and 5.6. Building the Mirroring Experience. Its success is evaluated in 6.3.1 Accessibility.

1.3 Challenges

In the design and development of this platform, the key challenges are:

- **Developing for VR with Oculus Rift** Virtual reality technology has only recently become affordable and commercially available. As such, design and development practices have not been standardised and documentation can be varied. In any exploration of new technologies and its capabilities, it is expected that the development process will experience unexpected difficulties, changes in direction and setbacks due to technological limitations.
- **Developing for Medical Purposes** Developing a VR platform for medical purposes requires a higher level of rigour and has a lower tolerance for error compared to VR game

development. As a VR implementation of a clinically tested therapy method, it is important that its conversion into VR does not take too many creative liberties or deviate significantly from its original specifications. Maintaining this balance between technological innovation and the rigidity of medical practice will be a key design challenge.

- **Building Physical Interactions in VR** Some protocols of SAT involve physical interactions with the inner child which present a challenge in VR because, while the child has a physical body in the virtual environment, it is not physical present in the real world. This need to design convert tactile interactions for VR, is a key design challenge in the development of this platform.

1.4 Contributions

The key contributions of this project are:

- **Mapping Self-Attachment Protocols to Virtual Reality** Adapting the protocols of Self-Attachment therapy for use with Virtual Reality technology. Interactions with the imaginary inner child are redesigned for use with a virtual inner child. (3.1 Mapping Self Attachment Protocols to Virtual Reality) Instruction sets were adapted from the technical specification of the SAT protocols[16] to make the platform a better instructive guide through SAT. (3.2 Designing the Instruction Sets)
- **Design and Development for Virtual Reality** Proposing best practices for virtual reality development and strategies for simulating physical interactions with the inner child in VR. (4.2 Designing Physical Interactions with the Inner Child)
- **Usability Testing** Collecting and analysing user feedback about the platform's performance. Key points for evaluation include ease of use (6.3 Usability), success of the VR interpretation of SAT (6.1 Therapeutic Effectiveness) and user response to interactions VR inner child (6.2 Mapping Protocols to VR). This helps identify target areas for the future development of a VR platform for administering SAT.
- **Integrating Patient Progress Tracking** The integration of the Patient Health Questionnaire into the intended user journey through the SAT in VR. This makes the VR platform a more comprehensive tool for treating and monitoring depression. (3.4 Tracking Progress with Patient Health Questionnaire-9)

1.5 Outline

This report is organised into the following six chapters:

- **Chapter 2** provides the necessary background required to understand the theoretical justifications behind using virtual reality to administer self-attachment therapy. It covers key concepts in psychotherapy, attachment theory and virtual reality research.
- **Chapter 3** describes the thought processes behind how the platform was designed. It breaks down how every protocol of SAT was redesigned to be executable using the Oculus Rift. It also details the main contributions this work gives to how SAT should be administered through a cohesive platform.
- **Chapter 4** presents the design challenges specific to developing for virtual reality. It details the main contributions this work provides to existing literature on how platforms should be built in virtual reality. It outlines design decisions behind the interface, physical, voice and onboarding interactions.

- **Chapter 5** covers the implementation details of the platform. It details the design of the code base, the key development practices used in developing for Oculus with Unity, as well as what technical challenges were identified and how they were addressed.
- **Chapter 6** evaluates the success of the platform in terms of its effectiveness as a therapeutic intervention, its mapping of SAT protocols for VR and its usability.
- **Chapter 7** summarises the key outcomes of this project and outlines areas for future development.

2 Background

2.1 Key Concepts in Psychotherapy

Psychotherapy is a broad term that encompasses a wide range of treatment techniques that aim to treat a medical condition through psychological means. It is often employed in treating mental illnesses and behavioural disorders.[21] This project aims to map the structured protocols of Self-Attachment Therapy (SAT) into a Virtual Reality (VR) environment with the intention of improving treatment outcomes. Thus, an overview of the key elements and theories of psychotherapy on which the efficacy of our approach lies is detailed below.

2.1.1 Neurobiology of Psychotherapy

The field of psychotherapy has often been criticised for being too subjective and largely qualitative in nature.[28] Despite being a common treatment for a variety of mental illnesses, little is known about its biological mechanisms.[17] However, with the advancement of brain imaging technology, the successful outcomes of psychotherapy have been linked to quantitative data about changes in neurobiology. In particular, in comparison with psychiatry and pharmacotherapy, some studies have found that psychotherapy achieved a similar normalisation of the functional abnormalities in brain circuits that create symptoms.[17]

Neuroplasticity is central to understanding therapeutic change and how psychotherapy can affect neurobiology.[23] It posits that the formation of the brain does not end, instead there is a continuous re-mapping of cortical networks according to individual life experience. Neuroplasticity is necessary for the efficacy of psychotherapy. It facilitates the restructuring of neural networks, in particular those in the subcortical-limbic system responsible for unconscious emotional motivations and dispositions, thus creating enduring change.[23]

The idea that psychotherapy could induce long term physiological changes in the brain is supported at a lower level by long-term potentiation (LTP). It is a form of activity dependent plasticity which results in a persistent enhancement of synaptic transmission. [3] It represents an enduring change in synaptic strength, induced by specific patterns of synaptic activity. Numerous studies, across brain regions and animal species have demonstrated that chemical synapses have a reliable capacity to undergo lasting changes in efficacy in response to various induction protocols. [3] Thus, it provides psychotherapy with neurobiological markers for the quantitative evaluations of progress and success. As such, psychotherapy is a powerful intervention that directly affects and changes the brain. [33]

Therefore, the effects of psychotherapy should be visible as long term changes in pathophysiological patterns of the brain. These can be studied through brain imaging technologies like Functional Magnetic Resonance Imaging (FMRI) and Position Emission Tomography (PET) scans. [23] Studies utilising this technology to quantitatively compare the outcomes of psychotherapy with psychiatric treatments have given positive indications that psychotherapy is capable of creating enduring changes in brain activity similar to that which is achieved through medication.

In a study by Baxter et al.[2] comparing outcomes of psychotherapy with psychiatric treatment for obsessive-compulsive patients. Cognitive Behaviour Therapy (CBT) and treatment using Imipramime both reduced the over-activation of the rostral caudate neucleus[2], thus indicating that psychotherapy can affect cerebral metabolic rates.[33] In the study of depressive patients by Brody et al.[6] and Martin et al.[37], pre-frontal lobe activity was found to have decreased following both interpersonal psychotherapy and antidepressant medication. Viinamaki et al. [67] had two patients with decreased serotonin uptake in the prefrontal cortex and thalamus, an indicator of depression[11], compared to a healthy control group. One patient was treated with dynamic psychotherapy for a year and afterward was found to have normal serotonin uptake. These findings suggest that dynamic psychotherapy can affect serotonin metabolism.[33] Thus, it represents a viable treatment intervention for Major Depressive Disorder (MDD) and an alternative to antidepressants such as tricyclic antidepressants (TCAs) and selective serotonin reuptake inhibitors(SSRI's).[11]

These studies support that psychotherapy is able to functionally 'rewire' the brain [23] due to long-term potentiation and neuroplasticity. Through procedural learning it should be expected to influence the structure and functions of the brain by altering synaptic plasticity.[23] Thus, validating its ability to treat the neurological impairments in cognition, emotional regulation, memory, motoric function, motivation and neurovegetative symptoms of mental illnesses like depression.[11] In particular, with respect to the neurobiological causes and indicators which have been identified.

2.1.2 Role Play

Role playing is an established psychotherapy. It is an imaginative process, in which the patient acts out a situation as if it were real.[9] It allows therapist to observe how the patient operates in real life situations and permits the individual to consider their actions in a neutral situation and engage in self reflection.

The value of therapeutic role-play depends on three factors.[38]

1. Simultaneity - the simultaneous consideration of how the participant thinks, feels and acts in a situation. It makes role play a holistic technique compared to other therapeutic approaches which may only consider one aspect at a time.

2. Spontaneity - participants in role play must act and react spontaneously

3. Veridicality - how closely the role-play resembles subjective reality

The achievement of these factors enhances the effectiveness of roleplay in creating an "imaginary reality" which objectifies experience, opening it to evaluation. It is an important technique in psychotherapy, it's uses include: (1) diagnosis, (2) modeling and practicing ideal behaviour, (3) achieving catharsis from painful experiences, (4) gaining insight into individual behaviour and (5) as an alternative method of therapy for patients resistant to openly talking about their problems.[9]

The interactions in Self-Attachment resemble role-playing in that the individual role plays with their inner child with the aim of creating secure attachment. It differs slightly because the individual is simultaneously playing both the role of the child and the adult self.[15] However, the basic principles of imagination and the revisiting, re-enactment and evaluation of past traumas remain the same.

2.1.3 Bodily Self Consciousness

Bodily Self Consciousness (BSC) is a combination of the sense of body ownership and psychological sense of self. It is the concept that body representation plays a central role in structuring cognition and self identity.[53] An individual's internal body representation has been shown over a variety of experiments to be highly malleable.[60]

A famous experiment demonstrating the ability to manipulate bodily self consciousness is the Rubber Hand Illusion (RHI).[5] The subjects are seated at a table, where their left hand and arm is hidden. A rubber hand placed in view in an anatomically plausible position.[60] The rubber hand and the subject's hidden hand are synchronously stroked with paintbrushes, in the same place for each hand. Subjects experienced an illusion where they seemed to feel the touch of the viewed brush rather than that of the actual brush, as though the rubber hand had sensed the touch.[5]

Before experiencing the illusion, subjects were asked to point to their hidden hand under the table. After experiencing the illusion, repeated this procedure and the difference between the measured distances was called proprioceptive drift. It served as a behavioural measure of the illusion, where greater values indicated the participants pointed more towards the rubber hand after the illusion than before.[60] It was found that the magnitude of drift varied proportionally to the duration of the illusion. In addition, members of the control group where brushes were stroked asynchronously did not display any drift.[5] A later study showed that subjects also respond physiologically to a threat to the rubber hand the proposed that internal body representation is updated constantly based on the stimulus contingencies received.[60]

Fundamentally, this illusion demonstrates that it is possible to develop strong feelings of ownership for an object that is known not to constitute part of the human body. It gives weight to the view that experience of bodily self is the result of a multi-modal simulation. Specifically, bodily awareness is derived through exteroceptive signals arising from outside the body (i.e. vision, touch) and through proprioceptive (i.e. skeletal, muscles) and interoceptive (e.g. heart rate) signals from inside the body. Therefore, while bodily representations are usually produced and modulated by sensory inputs, they can exist in the absence of any input signals (i.e. phantom limb syndrome).[53] Thus, the human perceptual system can be seen to incorporate an emulator, isomorphic to the human body. It uses body-schematic knowledge derived from the observer's representation of their own body to constantly re-evaluate its current definition of self and body.[71]

Since the initial RHI experiment, the study of BSC has found that it can be modified in three different ways.[53]

1. Mindful Embodiment - restructuring BSC through focus and reorganisation of its contents.
2. Augmented Embodiment - augmenting BSC to achieve enhanced and extended experiences by altering/extending its boundaries. Mapping the contents of a sensory channel to a different one (i.e. vision to touch as in RHI) increasing sensitivity or replacing impaired channels.
3. Synthetic Embodiment - replacing the contents of BSC with synthetic ones. This is the method that VR is most inherently suited for, replacing sensory information with that from a VR to create embodiment in a virtual body. This is discussed further in 2.3.3 Embodiment in VR.

Understanding BSC and its role in creating embodied, transformative experiences conducive to affecting personal change is central to its effective use in psychotherapy. Its relevance to developing VR solutions is evident through its influence on the feeling of presence experienced in VR. These elements of identity, embodiment and their growing influence on the treatment and understanding of neurological and psychiatric disorders open new opportunities for VR treatment solutions that take advantage of the virtual embodiment that can be created.

2.1.4 Cognitive Behavioural Therapy

Cognitive Behavioral Therapy (CBT) is a psychotherapeutic approach that addresses unhelpful cognitions and behaviours that result in distress. It has shown effectiveness in managing anxiety disorders and depression amongst other mental illnesses.[7] CBT is a collaborative approach between patient and therapist which aims to help patients identify dysfunctional thinking and behavioural patterns and replace them with more adaptive ones. It takes the view that early life experiences shape our core beliefs about ourselves, the world and the future. CBT aims to identify

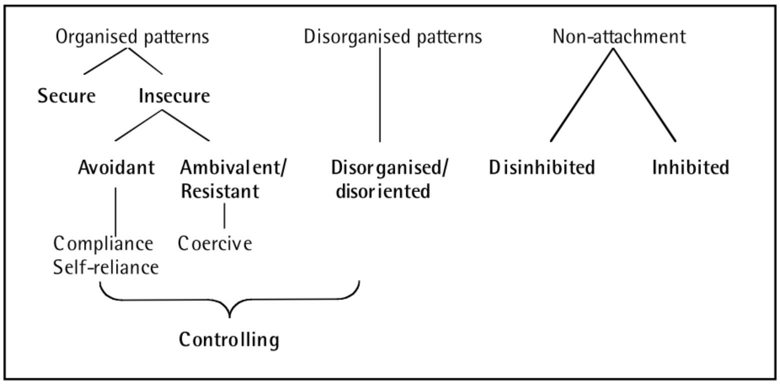


Figure 2.1: Patterns of Attachment

in core beliefs cognitive distortions and negative automatic thoughts and replace them with more adaptive realistic thoughts. [7]

CBT can be used with or without complementary pharmacological intervention. However, its effectiveness as a treatment technique can be difficult to measure quantitatively. Questionnaires and exercise sheets such as the Hospital Anxiety and Depression Scale (HADS), Patient Health Questionnaire 9 (PHQ9), Society Phobia Inventory (SPIN), anxiety ladder and behavioural experiment sheets etc. can be useful during the course of CBT as diagnostic, monitoring and measuring tools.[7]

Exposure Therapy

Exposure therapy is a type of CBT intervention primarily used for treating anxiety disorders. It involves graded exposure to anxiety evoking situations, with the aim of helping the patient realise that the feared consequences are unrealistic and statistically unlikely.[7] Thus, the goal of intervention is to activate and modify existing fear structures by presenting incompatible information and facilitating emotion processing.[36] It represents a clinical analog of extinction learning, whereby repeated presentations of a specific fear eliciting object or situation, in the absence of the aversive consequences with which it was previously paired, extinguishes conditioned fear responses.[69]

Exposure can occur through various modalities. In vivo is real life exposure, for example for treating a fear of flying, an in vivo exposure may involve taking a real flight. Thus, in the treatment of specific phobias such exposures can be difficult to arrange due to safety, cost or feasibility concerns. Alternatively imaginal exposures are dependent on patients being able to effectively imagine specific feared stimuli. [36]

2.2 Attachment Theory

First developed in the 1950s by John Bowlby following exploration of the link between separation and psychopathy. Attachment Theory provides a framework for understanding child development, especially in forming early relationships. It classifies four types of attachment, secure attachment and three types of insecure attachment: avoidant, ambivalent/resistant and disorganised/disoriented. [19]

As a child develops, it undergoes a process of attachment with its caregivers. To increased the possibility of carer reponsiveness when the child is in need, organised patterns of behaviour develop. The pattern they adopt depends on the nature of care they receive.

Secure Attachment Sensitive responsive caregiving Child feels: **Trust in self** **Trust in others** 'I am good, you are good'	**Ambivalent Attachment** Inconsistent, caregiving Child feels: **Distress in self** **Needy of others** 'You will attend to me, but I fear abandonment'
Avoidant Attachment Rejecting caregiving Child feels: **Trust in self** **Distrust towards others** 'I will do it by myself, I fear closeness'	**Disorganized Attachment** Frightening caregiving Child feels: **Frightened of self** **Frightened of others** 'I am powerful, I am scared, I fear'

Figure 2.2: Attachment types described through child's response to self and others

In the case of secure attachment, the relationship they form with their carer is one in which they experience contingent communication, psycho-biological attunement and feelings of safety. The child uses the adult as a secure base from which to explore the world around them. Continued experience of sensitive and responsive care-giving aids the child in developing a capacity for the self-regulation of emotion. In addition, the carer, by reflecting on their own and the child's emotional state, helps the child develop a strong capacity for mentalisation, further developing the child's ability to regulate emotion.[19] With successful fostering of secure attachment, the ability to self regulate emotions is mapped into the child's developing brain. Thus, the emotional availability, and attentiveness of the caregiver is a significant factor in the child's development, proving central to promoting growth, both emotional and neurobiological.[15]

Insecure attachment develops as a result of insensitive, neglectful or rejecting behaviour from carers. The different types of insecure attachment derive from differing behaviours from caregivers. Avoidant attachment is the result of rejecting carers. Passive and withdrawn behaviour with reluctant displays of emotional distress are the expression of the child's minimisation of attachment behaviour. Alternatively, the child may maximise attachment through demanding and clingy behaviours to elicit care from inconsistent carers. The resultant extreme emotional distress and resistance to comforting form ambivalent/resistant attachment. Disorganised attachment develop in response to frightened or frightening carers. Unable to organise their behaviour relative to their carer due to their unpredictability and contradictory position as source of fear and safety, self-reliance and control are the emergent behaviours.

The development and classification of attachment cannot be discretely quantised. Insecure attachment, attachment difficulty and attachment disorder describe a range of problems in attachment (see Figure 2.3) whose variety is due to differences in each child's experience.

2.2.1 Self Attachment

Insecure attachment in childhood can result in a failure to develop a strong capacity for the self-regulation of emotion. As adults, this can result in vulnerability to psychological disorders and mental illness. The idea of self attachment therapy arises from the goal of correcting insecure attachment in adulthood by taking advantage of neuroplasticity and long-term potentiation.[15] Based on an understanding of the neurobiology of secure attachment, the therapy aims to stimulate the release of oxytocin and dopamine, promoting plasticity in key regions of the brain related to developing attachment. The goal of this therapy would be for the individual to enhance their abilities to self-regulate emotion due to the creation of a secure attachment.[8]

Self Attachment is based on the creation of an affectional bond between an inner child and an adult self. The Inner Child represents the emotional self, rooted in the right brain and limbic system. The Adult Self corresponds to the logical self, rooted in the left brain and prefrontal cortex. In

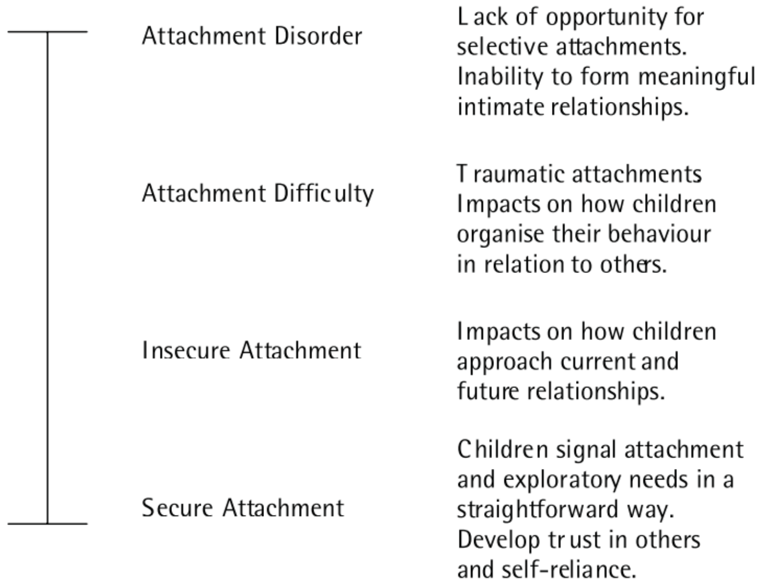


Figure 2.3: Problems in Attachment:

situations of stress, the inner child becomes dominant, while in the absence of stress the adult self is dominant.[15] The goal of the therapy is for the adult self to develop an affectionate bond with the inner child, taking on the role of primary carer who provides the inner child with the sensitive care and attention required to develop secure attachment, and thus the ability to self-regulate emotion. As the adult self gradually becomes a secure attachment object for the inner child, the aim is for the inner child to be correspondingly raised in emotional maturity. In addition, in line with existing studies on romantic and maternal love, the development and maintenance of the bond between inner child and adult self aims to be a point of incentivisation and source of joy by activating the dopaminergic reward pathways of the brain, inducing hormones and neurotransmitters.[15]

2.2.2 Self Attachment Therapy

Self attachment therapy (SAT) is a form of self-therapy which aims to simulate a relationship between the patient's adult self and their insecure attached child, such that the adult self represents a good enough care giver. It aims in four stages to help the patient acquire the consistent and unconditional love and attention they had been deprived of in childhood. [16]

1. Introduction to secure self-attachment therapy: The patient should study and understand the scientific hypothesis at the basis of secure self-attachment therapy.

2. Connection with the inner child: The patient's adult self should establish a visual and psychological connection with the inner child in as compassionate a manner as possible.

3. Falling in love with the inner child: The patient's adult self establishes an imaginary but passionate relationship with the inner child and then imaginatively adopts the inner child in an emotional ceremony as their own real child.

4. Developmental training and re-parenting the inner child: The patient's adult self exercises regular training sessions in interaction with the inner child so as to regulate its arousal level, minimise its negative affects and maximise its positive affects.

A detailed breakdown of each stage and its various protocols as it should be administered in a non-VR setting, is outlined below. The exact mapping of the Self Attachment Protocols to VR is outlined later (see 3.0.1 Mapping Self Attachment Protocols to Virtual Reality).

Stage I: Introduction to Self-Attachment

As a self-help therapy, it is important the patient become as familiar as possible with the concepts of attachment theory and the scientific basis of the self-attachment technique. This is because the nature of self-attachment protocols it prescribes can initially seem strange and childish. [16]. The patient must see validity in the effectiveness of the therapy for positive outcomes to be possible. Generally, it requires an acceptance of the fundamental hypothesis of attachment theory, that the root cause of chronic anxiety and depression is emotional problems similar to those faced by the patient as a child.

Self-attachment aims to consolidate improvements based on the long term potentiation of optimal neural circuits. Therefore, it is important the patient understands that such change is gradual and dependent on consistent and daily repetition of the protocols. Thus, Stage I of Self - Attachment therapy requires that patients gain a thorough understanding of the aims and techniques of self-attachment therapy and build realistic expectations of what to expect and the level of commitment required from them.

Stage II: Connecting with the Inner Child

The primary goal of Stage II is to build a basic psychological portrait of the inner child, such that there is a clear distinction between adult self (representing cognitive and reasoning capacity dominant when calm) and inner child (representing emotions and affects dominant under stress and crisis). This separation allows the patient, as their adult self, to build a warm and compassionate attitude towards the inner child and their emotional problems.[16] In addition, the patient should actively observe instances of the warm relationship between parent and child that they encounter in their daily lives. These observations should form the basis of the cognitive model of good parenting they seek to emulate as part of the therapy.

The protocols of Stage II are centered around two contrasting childhood photos. One should evoke happy childhood memories, while the other negative, or unhappy memories. With closed eyes in a quiet place, the patient should first imagine the happy photo and reflect on the relevant positive affects and then imagine the unhappy photo and reflect on the relevant negative affects. They should then imagine their inner child, in a happy or unhappy state, is sitting or standing beside them. The aim should be for the adult self to take on the role of a good parent, offering the inner child physical and verbal compassion.

Stage III: Falling in Love with the Inner Child

The primary goal of Stage III is to establish an imaginary, but passionate loving relationship with the inner child, subjectively experienced as falling in love with the child. This experience is hypothesised to induce dopamine secretion, activate the brain's reward system and induce oxytocin and vasopressin. Thus, the aim in Stage III is to engage the the patient in therapeutic activities that activate positive changes in brain chemistry and form the initial stages of the long term potentiation. The patient should begin the process of habituating the protocols into their daily life by making several copies of the photos, carrying them on their person and placing them in different areas of their home and work. The patient should also select one or two happy love songs that we have always favoured and choose one or two exciting phrases from them. With these foundations in place, the following exercises can be performed.[16]

- While looking at the happy photo, the patient should quietly utter and later loudly recite the selected happy love songs. In this way, they should imagine they are establishing a deep affective bond with their inner child.
- While looking at the happy photo, the patient should loudly recite the selected happy love song and gradually incorporate whole body movements i.e. shaking the head, shoulders and hands, moving eyes and eyebrows etc. In this way, they should imagine they are engaging in

a loving dialogue and dancing with the inner child, thus deepening their affective bond with the inner child.

- While looking at the unhappy photo, attune to the negative emotions associated with the photo. Then, the previous exercises should be performed.
- To remember the loving relationship between our adult self and inner child:
  - Choose a short phrase expressing love and compassion, and repeatedly utter it while looking at the happy and unhappy photos. Aim to become habituated to saying the phrase.
  - Recite the chosen happy love song loudly and repeatedly, incorporating the whole body, with the aim of habituating this behaviour. The result should be that the patient is constantly aware of their relationship with the inner child.
  - When habituation is successfully consolidated, the patient should engage in reciting these songs even when depressed or anxious. It should be an activity that can alleviate pain and remind them of the loving relationship they have with the inner child.
- After falling in love with the inner child, the patient's adult self should imaginatively adopt the inner child as their own child. In a carefully organised and memorable ceremony, the patient should pledge their love to the inner child. The adult self should vow to be a devoted and loving parent, attending to the child's health and emotional growth at any time and place.

Stage IV: Development exercises for the Inner Child

Stage IV protocols are intended to be practiced consistently over a long period of time and eventually integrated into the individual's every day life. This aims to induce long term potentiation and neuroplasticity such that the patient acquires new neural pathways to regulate their emotions in stressful circumstances. [16] It is through these processes that Self-Attachment Therapy aims to generate long term results.

A **Sessions for Processing Painful Past**
With closed eyes, the patient should recall a painful scene from their childhood, associating it with the selected unhappy photo. They should recall the associated emotions, i.e. terror, helplessness, humiliation and rage. They should then imagine that they, as the adult self, approaches the child offering compassion by cuddling and reassuring them. The aim is to behave as a good parent would when they see their children in distress. The patient should offer support, verbally and physically. A self face massage can be used to symbolise cuddling the inner child. These exercises should be repeated for all different types of traumatic patterns and scenes so that they are effectively processed emotionally and new neural patterns can be experienced in relation to them. [16]

B **Sessions to Process Current Negative Emotions**
Intended to help contain current negative emotions in relation to the patient's daily life, the patient should project their negative emotions onto an unhappy inner child, focusing on the unhappy photo. The adult self, who has vowed to support the child, should then attend to the needs of the inner child, reassuring and cuddling the child. This should continue until negative emotions are contained and the patient switches from focusing on the unhappy photo to the happy photo. It is recommended that in the first few months, exercises of Type A and B should be carried out twice a day.[16]

C **Creating Zest for Life**
This protocol aims to counteract the muscle rigidity often experienced by patients suffering chronic depression and anxiety. Looking in a mirror, the patient should imagine their image to be that of the inner child. They should then loudly recite their chosen happy love songs, and using their whole body engage in shaking their head, shoulders and moving eyes, hands and arms. This singing and dancing should be repeated as often as possible in different

circumstances until it is integrated into their life style. It represents a systemic engagement in playing, dancing, laughing and having fun with the inner child. The exercises should help maintain high baselines levels of dopamine, oxytocin and seratonin, helping the patient remain hopeful, motivated and energised with zest for life and a desire to support the inner child. [16]

D **Getting Over Negative Emotions**
This protocol aims to encourage positive interpretation and breaking out of negative patterns of thought. By relying on the positive powerful strong patterns of love with the inner child built using previous exercises, negative patterns can be broken by spontaneously singing the happy song and focusing the pattern of love with the inner child. This duality of interpretation can be visualised by the Gestalt vase, which can be interpreted as a dark black vase of negativity or two white faces looking at each other representing the bond between adult self and inner child. [16]

E **Socialising Protocols for the Inner Child**
Consistent repetition of Stage IV protocols of Type A, B, C, D aims to reduce negative emotions and increase positive affects. The Type E subprotocol asks the patient to carry out the protocols with their eyes open, integrating them into their daily life. They should extend the compassion they have for the inner child to other people, building an awareness of any narcissistic tendencies and anti-social feelings associated with the inner child. As a good parent, the adult self should help contain these feelings and discourage the inner child through an internal dialogue. Throughout this process, it is important to maintain an affectionate relationship with the inner child. [16]

F **Creating a more Optimal Internal Working Model**
Through the previous protocols, having reduced negative emotions and increased positive affects, the patient should gradually realise that some of the inner child's negative schemes of thoughts and feelings are either directly stemmed from our parents or have developed in interaction with them. Thus, when practicing Type B protocols, the patient should try and find the roots of the emotions they are experiencing in their family background and childhood relationships. This should help them build an awareness of their nature and internal working model. [16] As the patient progresses with therapy and gains emotional maturity, they should aim to understand they need not see themselves as a prisoner of early relationships and the feelings and emotions that originate from them. Thus, it is possible to build a more optimal internal working model for interpreting and managing relationships. [15]

2.3 Virtual Reality

2.3.1 Current State of Technology

Virtual Reality (VR) technology replaces real sense perceptions with computer generated ones. Sensory perceptions are effectively substituted such that the brain has no choice but to infer its perceptual model from the sensory data it is receiving from the VR. [60] While the concept has existed for over 50 years, in recent years, the emergence of VR technology as affordable consumer products has increased accessibility and experimentation with VR solutions. [22]

The key to creating VR is the head mounted display (HMD). A HMD displays images, one for each eye, creating a stereo scene. To mimic the natural function of human eyesight, each image is computed and rendered separately relative to the positon of each eye. This achieves the mathematically correct perspective calculated with respect to the 3D virtual scene. [22] Information about the position and orientation of the user's head is continuously tracked to derive gaze direction. Thus, as the user's head moves, turns, or looks up and down the images are recomputed to represent the correct field of view. [60] This creates the point of view that gives users the illusion that they are immersed in the VR environment.

With the decreasing costs in the computational power required to power VR technology many companies have developed commercial VR products of varying technical specifications. At the low end, smartphones have been used, in combination with a magnifying lens and a mounting frame to make HMDs. At its cheapest, Google Cardboard [26], is a mounting frame made of cardboard, designed for use with smartphones. More robust mid-range alternatives include GearVR[55], LG 360 VR[31] and Zeiss VR One[73]. These mid-range headsets are powered by the smartphone, containing extra tracking sensors, built in controls, mounting straps and sometimes their own screens. They are designed for better comfort, more intuitive input formats and longer periods of use compared to Cardboard VR.

High End VR requires more computational power than a smartphone provides, requiring computers or games consoles with high technical specifications, in particular for graphics card, processor and RAM requirements. Currently, the main competitors in high end VR products are the Oculus Rift[43], HTC Vive[68] and Playstation VR[49]. These are High End HMDs that provide sophisticated motion and position tracking, high resolution output and superior graphics. However, the tracking systems of these HMDs restrict the portability of the VR. For example, Oculus VR uses external camera sensors to track the user wearing the HMD[43], while the Vive uses laser sensors[68]. These sensors need to be calibrated for use in a given space and thus are not as mobile as smartphone based VR. In addition, these HMDs are physically tethered to the computer reducing ease of mobility. However, wireless high end HMDs are imminent, with the 2018 release of the HTC Vive Pro and Oculus Rift Go headsets offering wireless capabilities.

2.3.2 Presence

The term "presence" first emerged in 1992, when a new journal studying VR systems was released, entitled Presence, Teleoperators and Virtual Environments.[54] In its first issue, Sheridan describes presence as an experience elicited by technology use, whether it be "telepresence", feeling present in a remote site of operation or "virtual presence", feeling present in a computer generated environment.[59] He proposes three determinants of presence:

1 Extent of sensory information - the amount of information being transmmitted to the appropriate senses of the observer.

2 Control of position relative to sensors in environment - the ability of the observer to modify their viewpoint

3 Ability to modify physical environment - the extent of motor control available and ability to change objects in the environment.

Sheridan theorises that these determinants can vary independently, but must all be present to induce a sense of presence. However, he emphasises the new nature of the concept and the lack of existing work that explore it. Further research has since studied presence, which given the rise in Virtual Reality is especially relevant.

In 2000, The International Society of Presence Research [20] defined presence as a "psychological state in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individuals' perception fails to accurately acknowledge the role of the technology in the experience." It suggests that presence is produced by the disappearance of the medium (the facilitating technology) from the conscious attention of the subject.[54] This is particularly interesting for VR, because while a sense of presence can be generated by technologies other than VR, it seems intuitive that the feeling is experienced with varying strengths. However, this definition does not account for this variety nor does it present any plausible causes.

A 2012 book[54] on the applications of VR presented a cognitive theory of presence from recent work in the cognitive sciences. They sought to better understand the psychological processes behind the sense of presence, its purpose and role in our daily experience. It focused on three emergent research outcomes and explored how they applied to presence.

1 Cognitive processes are either rational or intuitive:

2 Skills become intuitive when our brain can simulate their outcome.

3 Space is perceived in terms of the actions we could take towards them.

Based on these outcomes, Riva and Mantovani summarised the feeling of presence as "the product of an intuitive experience-based metacognitive judgment related to the enactment of our intentions. "We are present in an environment - real and/or synthetic, when we are able, inside it, to intuitively transform our intentions into actions."[54] Therefore, the extent to which presence is achieved is dependent on the ability of the medium to satisfy the necessary conditions. The extent to which the experiences facilitate the required capabilities and interactions necessary to create a sense of presence is determined by the authenticity and intuitiveness of the user's interactions.

2.3.3 Embodiment in VR

In the discussion of virtual environments, embodiment is often defined in relation to presence as the sensation of feeling 'inside' the virtual body. In particular, the possession of a virtual body for HMD based VR has proved to be a critical contributor to the sense of presence in a virtual location.[29] In the cognitive sciences, embodiment represents the concept of reciprocity between body and mind, that bodily variables are just as significant as psychological variables in the psychotherapy process[65] However, use of the term in the context of VR differs slightly in definition. Instead, it refers to the bi-directionality of real and virtual bodies, wherein mental state remains constant to the individual participating in the virtual scene. Specifically, the sense of embodiment towards a body is the "sense that emerges when the body's properties are processed as if they were the properties of one's own biological body".[29] This is a sensation created by the Rubber Hand Illusion (RHI) discussed prior in relation to Bodily Self Consciousness.

To understand how embodiment can be manipulated with VR to facilitate psychotherapy, it is first necessary to define the properties creating embodiment within one's biological body. There are three properties: (1) sense of self-location, (2) sense of agency and (3) sense of body ownership.[29]

The sense of self-location refers to the spatial experience of being inside a body. This differs from presence in that it is specifically the relationship between one's self and one's body, rather than one's self and the environment. It is possible to feel a sense of presence without self-location, i.e. when one's self is located in a physical or virtual room without an avatar to provide a body representation.

The sense of agency refers to the feeling of having global motor control, which includes the ability to experience action subjectively, be in control, have intention, motor selection and conscious experience of will. When the predicted and actual consequences of an action match, feeling agent to those actions derives from the presence of synchronous visuomotor correlations due to active movement.

The sense of body ownership refers to one's self attribution of a body. The strength of body ownership depends on the level of similarity between human biology and the external object to be incorporated. In the example of the RHI, the rubber hand must look like a human hand and its placement must be plausible for the sense of body ownership to alter itself to incorporate it.

In any virtual embodiment, these three properties are achieved with varying levels of success. There is no concrete evidence that all three must be present for embodiment to be achieved. However, they provide important markers in the development of VR solutions for psychotherapy that aim to utilise embodiment to affect therapeutic change. In particular, some studies have indicated a likelihood that a change in body ownership can have an effect on perceptions, attitudes, behaviours and self-identity.[46] For example: virtual embodiment of participants into a black avatar has seen success in reducing implicit racial bias[48][10]; embodiment of an adult into a small body[10] has led to an overestimation of object sizes, in psychotherapeutic applications; embodiment with the illusion of agency over speaking[1] has resulted in a temporary increase in the frequency of the participants' real voices; exchanging body ownership with a virtual Sigmund Freud as part

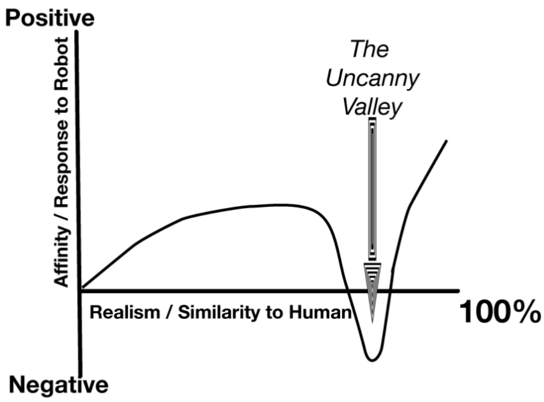


Figure 2.4: The hypothesised relationship between human affinity and realism demonstrates the 'valley' to which the theory's name refers.

of a self-counseling protocol[46] led to an improvement in mood. This represents a significant step in establishing VR embodiment a key facilitator of cognitive and behavioural adjustment in psychotherapy.

The use of virtual embodiment to manipulate Bodily Self-Consciousness is a natural extension of the base concepts behind the RHI. The use of HMDs in VR allow for the creation of a full body ownership illusion. Studies using VR to create these illusions have already replicated the results of the RHI. During a full body variation of the RHI, where a full body illusion was achieved using VR, electrical brain response to an attack to the virtual hand corresponded with the expected response for when a real hand is attacked.[25] The phenomenon of proprioceptive drift was also observed when using VR to manipulate Bodily Self-Consciousness and create an out-of-body experience.[30]

The psychological effects of embodiment and BSC form the basis for the success of VR interventions in psychotherapy. Without the sense of presence they aid in inducing, VR would not provide the enhanced sensory illusions necessary to enhance the process of achieving therapeutic change.

2.3.4 Uncanny Valley

The Uncanny Valley theory describes how complex human-like replicas (i.e. robots or computer generated animations) evoke strong feelings of eeriness if they contain a high level of realism but still have subtle imperfections.[61] This relationship is illustrated in Figure 2.4. The cause of this aversion has been the subject of numerous studies whose theories include attributions to pathogen avoidance, mortality salience or the fear of psychopathic individuals.[61] Initially proposed in 1970 by Dr Masahiro Mori, Professor of Engineering at Tokyo Institute of Technology, the relevance of the Uncanny Valley has since grown due to improvements in computer graphics and robotics, making greater realism increasingly attainable. [50]

This effect is particularly relevant in VR development because VR applications aim to manipulate sensory perceptions to create an immersive experience that is as realistic as possible. To encourage the adoption of the technology and ensure users feel comfortable in the virtual environment, it is important that the effects of the Uncanny Valley are acknowledged and addressed. Regardless of the cause, humans have shown an inherent ability to recognise computer generated representations of humans. Filmmakers and animators have found that hyper-realism have deterred audiences rather than winning their affinity. Instead, stylised animations have proved more successful at winning audiences affections as they can empathise without suffering the effects of the Uncanny Valley.[50] Thus, in the development of a VR therapeutic tool, it is important to take into account the achievement of embodiment and presence to maximise efficacy. However, while initially counter-intuitive, the achievement of this through increased realism may prove detrimental to the aim of ensuring users feel safe and comfortable in the virtual environment.

In particular, with applications to Self-Attachment therapy, a level of realism in the child avatar, i.e. resembling the user's childhood likeness, may enhance the therapy by reducing the reliance on imaginative visualisation and potentially aiding the bonding process. However, taking into consideration the effect of the Uncanny Valley, it may be advisable to balance the level of realism provided, such that it still has a positive effect. For example, users may be more comfortable with a cartoonised or caricaturised likeness of themselves created from childhood photographs they provide, rather than a hyper-realistic reconstruction.

2.3.5 Advantages of VR in Psychotherapy

VR has vast applications and has reached many industries, including medicine, entertainment and the military. It is typically described as an advanced system of interactive 3D visualisation. It achieves the illusion of an immersive reality using special equipment, i.e. HMD, data gloves and controllers, as well as motion and position tracking to update the images displayed in real time relative to gaze direction.[52] However, in psychotherapy, VR can be defined as "an advanced form of human-computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion." [57]

The immersive nature of VR and its ability to simulate the real world, makes it the ultimate 'safe space' in which to experiment, whether it be for medical or military training, or in the imaginary world of a video game. Its ability to induce strong emotional responses to essentially imaginary stimulus makes it a powerful method of stimulus provision for therapy. By placing the user in an alternate reality, body, and even identity, it is a tool with significant potential to increase the likelihood of therapeutic effectiveness.[52]

Central to VR's strength as a therapeutic tool is its ability to induce a sense of presence. It is commonly regarded as a necessary element that allows real emotions to be activated by a virtual environment.[12] By feeling like they are fully present in the virtual world, patients are more amenable to the suggestion that their perception has been distorted by a maladaptive assumption.[52] This is effective because it is important that people recognise the difference between assumption and perception in order for them to be open to updating their assumptions. Assumptions constitute the frame of reference from which people view the world, and unless they are shown to be false, they are resistant to change.[52]

As a controlled environment, therapists can manipulate the virtual scene for every individuals therapy, guiding them through gradual achievement of certain progress markers in a more personalised scene. The transferal of the stimulus from imagined to virtual also provides the therapist a greater understanding and control over what the patient is interacting with, and thus perform more detailed evaluations. The level of control provided by a virtual environment allows for a versatility and diversity of therapeutic experience. For example, VR can induce emotional reactions via different routes i.e. perceptual and conceptual, to achieve different therapeutic results.[53] Thus, by providing a high level of control over exposure dose and stimulus, VR represents a powerful tool in the conduction of highly controlled clinical and experimental research. [36]

In addition, while VR applications often strive to resemble reality as closely as possible, its "virtual" nature means it provides a unique, sheltered setting for patients to explore and act without feeling threatened. This represents an important step in the broader empowerment process that therapeutic treatment aims to achieve. Safe in the knowledge that nothing that happens them in VR actually happens in real life, patients experience a freedom that bridges the gap between the safe space of therapist's office and the real world. The security of the VR environment may enable patients to express thoughts and feelings that would otherwise be too difficult to discuss. It also helps foster a positive therapeutic alliance and allow its benefits to extend into the daily life of patients such that they can overcome the challenges for which they sought therapy. [52]

2.3.6 Existing Applications of VR in Psychotherapy

Since the introduction of VR technology, the use of VR in psychotherapy has been the subject of significant research, and its efficacy well documented and demonstrated. A 2016 review of existing literature on the use of VR in different areas of behavioural health supported the potential of VR as a clinical treatment tool. [53] A subset of its findings are reproduced in Appendix A Overview of VR applications in Psychotherapy.

Treatment of Anxiety Disorders

The nature of VR as a technical interface that allows users to experience computer generated environments in a controlled setting, lends itself to applications in exposure therapy. VR provides a solution to the barriers faced by traditional exposure modalities, in vivo or imaginal. In particular, when in vivo exposures are costly or infeasible, VR can allow for a virtual reconstruction of the exposure, unlimited repetitions and a degree of control over specific aspects of the exposure environment, allowing the therapy to better match the specific patient's fear stimulus.[36] The ability to provide more graded exposures, customising pace and intensity of treatment to each patient, all within the therapist's office represents a powerful advantage for VR Exposure Therapy (VRET) given the evidence supporting its equal if not superior efficacy compared to standard exposure therapy. [51]

For example, for treating a fear of flying, an in vivo exposure involving a real flight can be quite costly, so VR represents a cheaper alternative. In addition, if the patient specifically fears landing, exposure to just a flight landing can be provided repeatedly without accumulating costs. Similarly, control of the graded anxiety generated by the exposure can also be tuned. For example, if the patient is not ready for flight exposure with turbulence, the therapist can guarantee no turbulence in the VR exposure, but not in an in vivo exposure. [36]

Currently, VR exposure is documented to have been used in the clinical treatment of specific phobias, of which most notable are fear of flying, acrophobia, agoraphobia and social phobia. A distinct characteristic of these anxiety disorders is the lack of real danger, yet individuals feel a disproportionate fear followed by avoidance of a situation or a specific object.[64]

In evaluating the effectiveness of VR in psychotherapy applications, important metrics are the drop out rate, post-treatment results and long term efficacy. In a 2012 quantitative meta analysis of randomised clinical trials [45] comparing VR Exposure Therapy (VRET) with in vivo exposure with control conditions, it was found that for anxiety disorders: (1) VRET performs far better than waitlist control; (2) post treatment results for interventions with and without virtual reality exposure components show similar efficacy; (3) VRET has significant real life impact, comparable to classical evidence based treatments; (4) VRET has good stability of results over time, similar to classical evidence based treatments; (5) there is no difference in drop out rate between VR exposure and in vivo exposure. These findings strongly support the view that VRET represents a powerful alternative or complementary treatment option for anxiety disorders.

Findings indicate that the virtual nature of VR based exposure therapy may render it more acceptable to patients than traditional approaches. In a sample of 150 patients with specific phobias, the refusal rate for VR exposure (3%) was lower than for in vivo exposure (27%). In a sample of 352 post-9/11 US soldiers, the majority reporting a willingness to use most technology-based approaches for mental health care including VR. 19% of those who reported they would not be willing to talk to a counselor in person reporting being willing to use VR to access mental health care. This suggests VR also has the potential to address some barriers to treatment. [36]

Treatment of Depression

The applications of VR in the treatment of depression are not as extensive as in the treatment of anxiety disorders. This is due to the nature of therapeutic interventions for depression being focused on cognitive behavioural therapy, which has a less direct mapping into VR than exposure therapy for anxiety disorders. However, in the consideration of self-criticism as a major psychological factor creating vulnerability and influencing the recovery and maintenance of depression, experimental procedures have sought to use VR to enable the delivery of self-compassion, a central aspect to tackling self-criticism.[18]

In particular, they seek to take advantage of the feelings of presence and embodiment created by VR to transfer body ownership. By allowing users to be embodied in a body other than their own and receive compassion from themselves, it gives self-compassion a physical interpretation rather than being solely an internal dialogue. Therefore, this exploitation of virtual embodiment aims to increase feelings of self-compassion in individuals high in self-criticism.

In a 2016 study[18] aiming to address self-criticism as a psychological factor in the incidence of depression, patients were first asked to offer compassion to a crying virtual child while embodied in a virtual adult body. They were then embodied into the child body and could experience a recording of the compassionate gestures and words they had previously delivered to the child, now being delivered to them, from the child's first personal perspective. This transferal of body ownership and successive embodiment between the adult and child body allowed users to deliver compassion to themselves.

The study found evidence of significant reductions in depression severity and self-criticism, as well as increased self-compassion. Consistent with predictions, the use of virtual embodiment in this scenario saw a significantly greater increase in self-compassion than a control condition in which participants saw the same gestures and heard the same words from a non-embodied third person perspective i.e. not from the child's perspective.[18]

This idea of embodiment for delivering self-compassion can be extended to self-counseling. In a similar 2015 study[46], users were embodied in the body of Sigmund Freud or a duplicate body in their own image when delivering compassion and then viewed the recorded actions and words from their own perspective, as though Sigmund Freud or their double was delivering the counseling. Unlike the self-compassion study[18], this study sought to investigate not only if the transferal of body ownership affected the effectiveness of self-counseling but also if the 'person' delivering it had any impact.[46]

Patient feedback in these studies indicated that patients were able to generalise knowledge learned in the virtual scenario to real-world situations. Patients explicitly reported thinking about the experience outside the immersive VR sessions and applying it to themselves when upset. Some even suggested that materials be made available to practice outside of the VR sessions, allowing them to reflect on how it made them feel, what they experiences and how their next experience could be improved. [18]

This feedback is significant for SAT, because its success is dependent on the long term integration of the therapy techniques into the patient's life. These findings suggest that administering SAT in VR will not deter patients from engaging with the therapy outside of VR. In addition, it suggests that patients will actively engage in extending the therapy outside of designated VR sessions.

3 Platform Design

3.1 Mapping Self Attachment Protocols to Virtual Reality

The conversion of SAT from protocols wherein the patient interacts with an imaginary inner child to protocols wherein the patient interacts with a 'physical' virtual inner child forms a core aspect of this project. The VR platform also aims to facilitate smooth navigation through the four stages, serving as an instructive guide through the process of administering Self-Attachment Therapy.

For an outline of the protocols contained in each stage of SAT performed without VR see 2.2.2 Self Attachment Therapy. A detailed breakdown of how each stage and its various protocols was redesigned for VR compatibility is outlined below.

3.1.1 Incorporating the VR Inner Child

In non-VR SAT, protocols involve engaging with a happy photo and a sad photo, reflecting on respective positive and negative affects, then offering the child affection in the role of a good parent. In the VR platform, the happy and sad photos are encompassed within the VR inner child who has animations to represent those emotions. The 3D model of the inner child was taken, with permission, from work done as part of a project investigating Immersive Self-Attachment Therapy through Personalised Avatar Generation.[27]

The model has animations for the basic emotions: happy, sad and scared, as well as a dancing animation for use with certain Stage III and IV protocols. These are shown in Figure 3.1. In addition, although not a requirement for this project, working in conjunction with work done in the exploration of Immersive Self-Attachment Therapy through Personalised Avatar Generation[27], it is intended that the child model be customisable based on childhood photographs, such that it can resemble the patient as a child. In the current version of the VR platform, a default child model, without facial customisation is used.

The child model is an essential part of enhancing the realism of the virtual experience. Central to SAT is the bond created between inner child and adult self. Given that the aim of administering SAT through VR is to remove the inability to engage with an imaginary inner child as a barrier to access, it is important that interactions with the child model in VR are as authentic as possible. A detailed breakdown of how these interactions were designed is covered in 4.2 Designing Physical Interactions with the Inner Child.

3.1.2 Stage I: Introduction to Self-Attachment

In this VR platform, in addition to introducing patients to self attachment, Stage I also provides onboarding for first time users of VR. For more detail on how the onboarding process was designed see 4.5 Designing the Onboarding Experience.

(a) Idle (b) Happy (c) Sad (d) Scared (e) Dancing

Figure 3.1: Child Model Animation States

Therefore, as the primary aim of Stage I is educating the user, both in SAT and in how to use the VR platform, the design and experience of the room, illustrated in Figure 3.2, is different from the other stages. Stage I centers around a screen wherein users can click through a set of slides (see B.1 Stage I) with instructions detailing how to navigate the VR platform, i.e. using controllers and speech control, as well as a brief introduction to Self-Attachment Therapy and the role of the VR Inner Child.

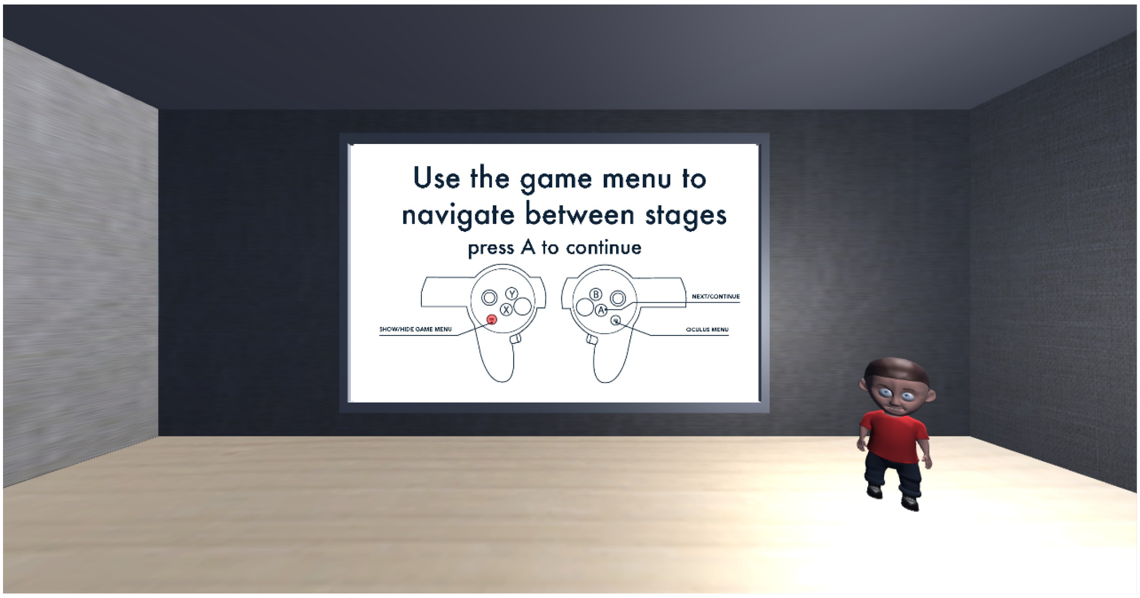


Figure 3.2: The Stage I Room: providing an introduction to to SAT in VR and the inner child

3.1.3 Stage II: Connecting with the Inner Child

In this VR platform, the menu in Stage II (see Figure 3.3) consists of three separate activities that the patient can choose between:

1 Happy Activity: Through a series of questions, the patient is invited to recall and reflect on a happy memory from their childhood, focusing on how the behaviour of their primary caregivers affected the experience. This activity does not involve any direct interaction with the VR inner child; the patient simply reflects on a series of questions presented as part of the instruction set.

2 Sad Activity: Through a series of questions, The patient is invited to recall and reflect on a sad memory from their childhood, focusing on how the behaviours of their primary caregivers affected the experience. This activity does not involve any direct interaction with the VR inner child.

3 Compassion Activity: The patient is presented with a distressed child and asked to offer it verbal and physical compassion as they would have wanted. In this activity, the patient is asked to 'cuddle' the VR inner child to offer it physical compassion.

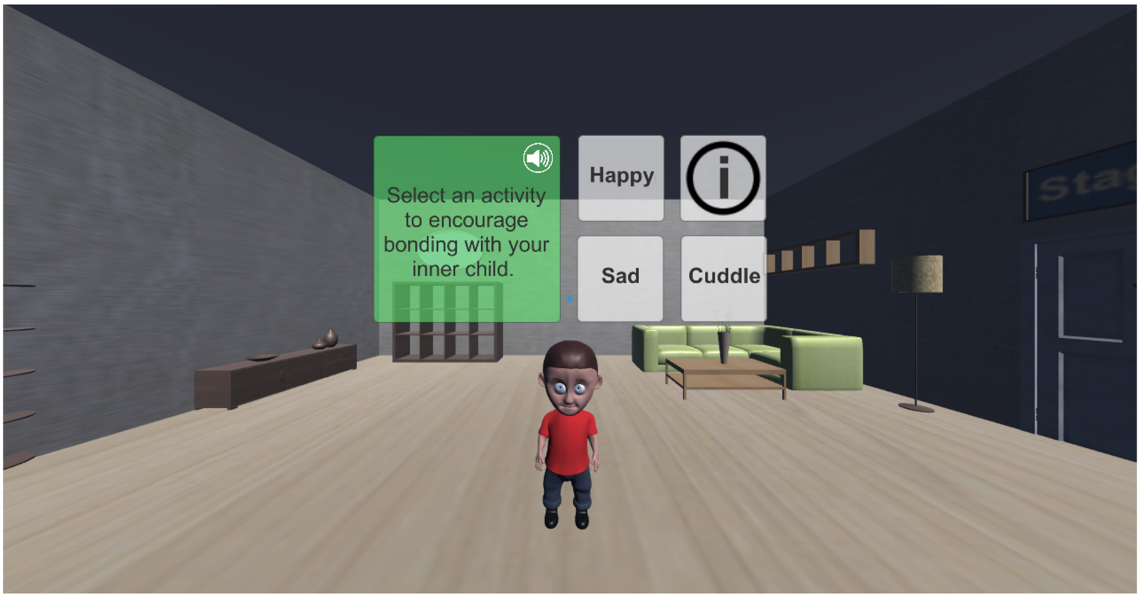


Figure 3.3: Stage II Activity Menu allowing users to choose between activities

3.1.4 Stage III: Falling in Love with the Inner Child

In these activities, there are no direct interactions with the VR inner child. The patient either reflects on a series of questions presented as part of the instruction set, or performs an action 'with' the inner child, who is given a fixed animated behaviour for each activity. The menu in Stage III (see Figure 3.4) consists of four activities the patient can choose between:

1 Happy Singing Activity: The patient is invited to imagine they are forming a deep affectionate bond with the VR inner child while singing their happy song and moving their body to the music. A pre-selected karaoke music video is shown on the screen in the VR room.

2 Sad Singing Activity: This is the same as the happy singing activity, except the patient is first asked to reflect on any negative emotions they are feeling or felt as a child. Then they perform the Happy Singing Activity.

3 Dancing Activity: The patient is invited to imagine they are engaging in a loving dialogue with the inner child and bonding while dancing along with the inner child. A pre-selected dance video is shown on the screen, giving the patient different dance moves to follow.

4 Self-Massage Activity: The patient is shown a video tutorial on how to perform self-massage. They are invited to imagine they are physically interacting with the inner child while performing the massage.

5 Pledging of Love Activity: Through a series of questions, the patient is invited to reflect on optimal parenting behaviours and vocally pledge to love and support the inner child unconditionally.

Figure 3.4: Stage III Activity Menu allowing users to choose between activities. The screen displays the self-massage, singing and dancing videos for each protocol.

3.1.5 Stage IV: Developmental training and re-parenting the inner child

In Stage IV, the patient can choose from a series of subprotocols A, B, C, D, E, F (see Figure 3.5). Protocols A - D involve either some form of physical interaction with the child, and/or a transition to a different, specially designed protocol room. Protocols E and F are stationary reflection protocols that take place in the main Stage IV menu room.

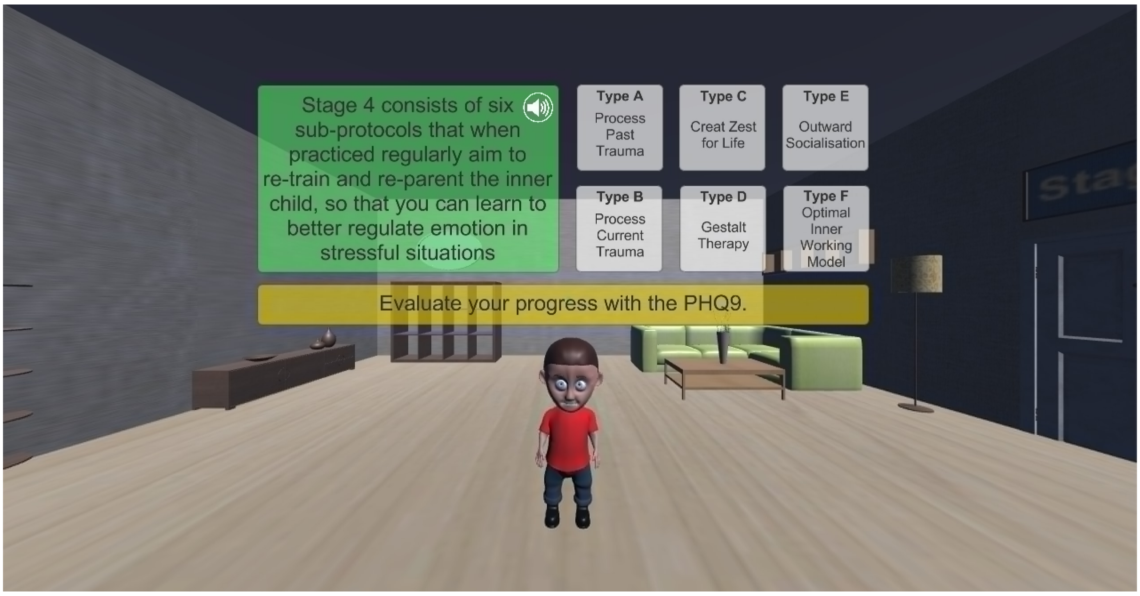


Figure 3.5: Stage IV menu allowing users to choose between subprotocols.

1 Type A - Process Past Trauma: In a blackout environment, the patient is invited to recall a traumatic past event, focusing on how they would have liked their primary caregivers to have supported them (see Figure 3.6). The patient is then presented with a distressed child and asked to offer verbal and physical compassion as they would have liked (see Figure 3.7) The patient is asked to 'cuddle' the VR inner child to offer it physical compassion. Upon

successfully consoling the child, the initially dark and bare room then opens up to a better lit, furnished room (see Figure 3.8).

2 Type B - Process Current Trauma: The patient is invited to reflect on any current negative emotions and project them onto the inner child. The patient is then presented with a distressed child and asked to offer verbal and physical compassion in their role as the adult self. The patient is asked to 'cuddle' the VR inner child to offer it physical compassion. Upon successfully consoling the child, the initially dark and bare room then opens up to a better lit, furnished room. The experience is identical to Type A (see Figures 3.6, 3.7, 3.8), except with different instructions.

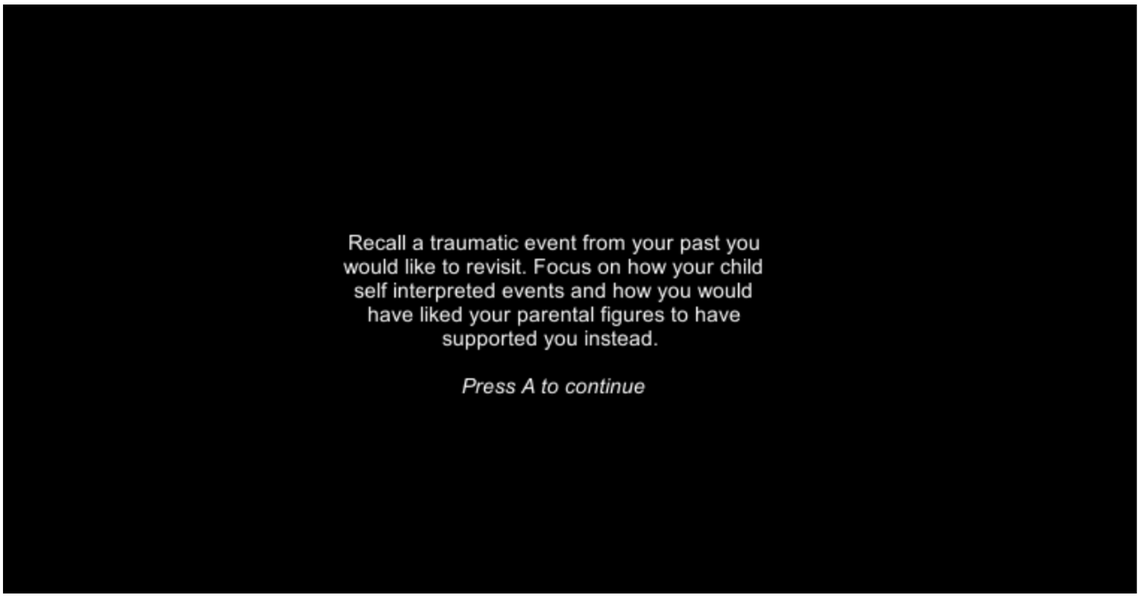


Figure 3.6: Black out environment with instruction text for Protocol Type A.

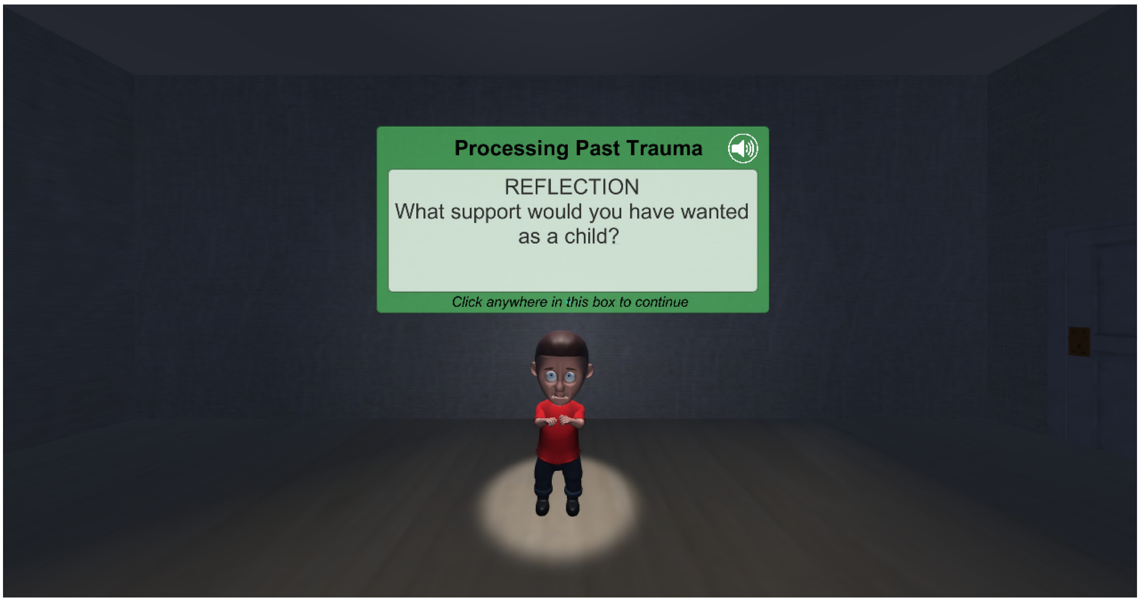


Figure 3.7: Dimly lit room where patient is asked to console a distressed child.

3 Type C - Create Zest for Life: The patient is presented with a mirror (see Figure 3.9) in which their reflection has the image of the inner child. They are asked to sing and dance in the body of the inner child; an illusion created by the VR mirror through motion detection.

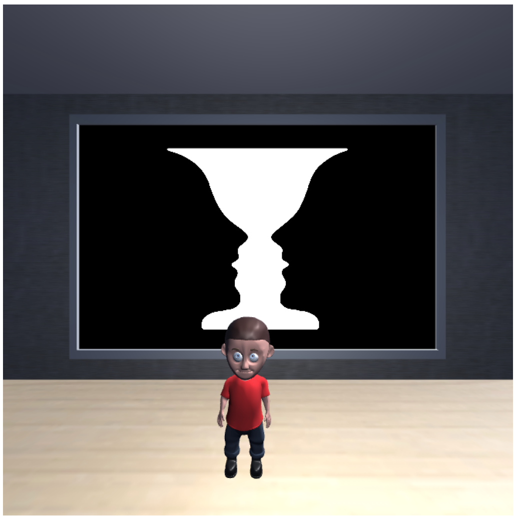
Figure 3.8: Brightly lit, furnished room emerges from behind a raised wall after the patient offers verbal and physical compassion to the inner child.

They are also asked to try and integrate singing and dancing with the child into their daily life, so as to maintain a constant relationship with the child and use it to tackle negative emotions, habits and addictions.

Figure 3.9: The patient is presented a mirror where their reflection has the image of the inner child. The child mirrors changes in position, rotation and basic actions like dancing and a raised hand.

4 Type D - Gestalt Therapy: The patient is presented with a black and white image of the gestalt vase on a screen behind the VR inner child. They are able to to invert the image colours, toggling between focusing on seeing a vase and seeing two faces (see Figure 3.10). This represents positive and negative interpretations, enhanced by a corresponding toggling of the inner child's expression between happy and sad. The patient is asked to focus on transforming negative emotions into positives by recalling the powerful pattern of love built

with the inner child. This activity does not involve any direct interaction with the VR inner child. The patient simply reflects on a series of questions presented as part of the instruction set.



(a) According Gestalt Colour Therapy, viewers are drawn to focus on darker elements of the image. Hence this colouring draws attention to the two faces interpretation of the image. This is associated with positive emotion because it can interpreted as the faces of the adult self inner child, representing their bond.

(b) Gestalt Colour Therapy suggest that viewers attentions will be drawn to the darker coloured shape of the vase. This is associated with negative emotion because it represents an endless accumulation of dark thoughts.

Figure 3.10: In Stage IV Protocol Type D, the patient is presented with images of the gestalt vase and invited to reflect on how, like the image, their negative emotions can interpreted in a more positive way.

5 Type E - Outward Socialisation: The patient is invited to try and habituate the protocols into their everyday life and extend the compassion developed for the inner child toward others. They are asked to take on the role of the good parent, continuing to display affection as well as discouraging the inner child from acting on negative emotions. This activity does not involve any direct interaction with the VR inner child. The patient simply reflects on a series of questions presented as part of the instruction set.

6 Type F - Optimise Internal Working Model: Through a series of questions, the patient is invited to reflect on how their negative schemes of thoughts and feelings stemmed from the behaviour of the primary caregivers when they were a child. They are then asked to begin practicing a modified Type B protocol, focusing on identifying the roots of any negative emotions in their family background and childhood relationships. This aims to help them understand their internal working model. This protocol relies on the long term nature of Self-Attachment Therapy, asking the patient to gradually emerge from the view of themselves as a prisoner to their early relationships and create a more optimal internal working model for interpreting and managing relationships. This activity does not involve any direct interaction with the VR inner child. The patient simply reflects on a series of questions presented as part of the instruction set.

3.2 Designing the Instruction Sets

When redesigning these protocols for VR, a key consideration was the aim of building a platform which was also a comprehensive guide to administering SAT. As a self-help therapy, it was important that patients were able to guide themselves through it consistently and confidently. Therefore, for each protocol in the VR platform, a set of instructions is provided to guide the user through the activity (refer to Appendix A Protocol Instruction Outline).

3.2.1 Reflection vs Action Instructions

The process of connecting with, falling in love with and developing the inner child represents a series of introspective reflections to gradually transplant the patient's childhood psychology onto the inner child. Through SAT, the patient, in the role of an adult, can provide the care and support they lacked as a child. Thus, the basic structure of each protocol in Stage II - IV is to ask the patient to reflect on some of their past or current emotional affects or experiences before engaging in some therapeutic interaction with the inner child.

This two part pattern is reflected in the design of the instruction sets. Instructions that are not providing background information about SAT or how to progress through the platform are classified as either 'reflection' or 'action' instructions. These are clearly labeled to help the user distinguish between them (see Figures 3.11, 3.12, 3.13). This separation aimed to help users better understand what they were being asked to do. In general, action instruction indicated that a specific VR interaction should be performed with the child, i.e. cuddling.

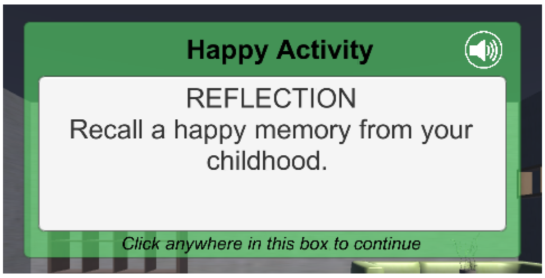


Figure 3.11: Reflection Instruction in Stage II Happy Activity

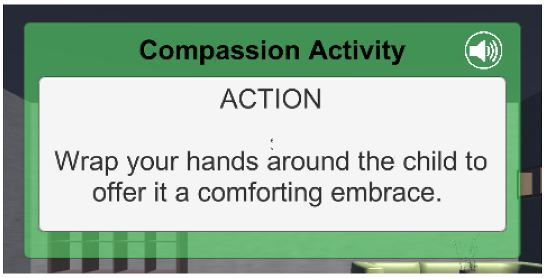


Figure 3.12: Action Instruction in Stage II Cuddle Activity

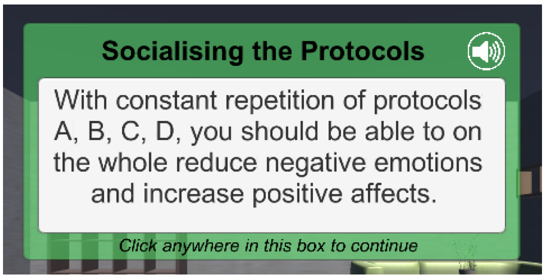


Figure 3.13: Background Information Instruction in Stage IV Outward Socialisation Protocol

When breaking down the protocols into smaller instructions, the reflection element of the protocols were the most complicated to convey as they often required long descriptions about what the patient should be imagining or reflecting on. To break this down into smaller, more digestible sections that the patient could step through, reflection questions were devised. Each question prompts the patient to consider a small part of the overall reflection required for each protocol. The answers to these questions should then then inform the action they are asked to perform.

For example, in Stage IV Protocol Type A instructions shown below, the patient is asked a series of questions as to how they thought a primary caregiver should have responded to a distressed child, and what words or actions of compassion would be optimal. Then, the patient is asked to offer these words or actions of compassion to the inner child.

1 REFLECTION: What support would you have wanted as a child?

2 REFLECTION: How can you offer compassion verbally?

3 ACTION: Offer the child your chosen words of comfort.

4 REFLECTION: How can you offer compassion physically?

5 ACTION: Wrap your hands around the child to offer it a comforting embrace.

6 Congratulations. The child has been successfully consoled.

3.2.2 Transitioning to Non-VR Self Attachment Therapy

Ensuring the patient is able to perform the therapy outside of VR is an important goal of this VR platform. Long term repetition and habituation to daily life is required in successful Self-Attachment Therapy. Therefore, as regular access to VR technology may be difficult to achieve, especially for high end VR, it is important that the VR platform take steps towards helping the user perform the therapy outside of VR. In addition, it is difficult to habituate the therapy into everyday life if it requires plugging in a VR headset.

In designing the instructions, the reflection and action separation were intended to be easily compatible with a non-VR administration of SAT. In addition, throughout all four stages, the instructions emphasise the importance of repetition and habituation so as to familiarise the patient with the idea that SAT continues even outside of VR (for examples of these instructions see B.4 Stage IV). Therefore, while it is possible to always administer SAT via the VR platform, once it has successfully helped the patient overcome difficulties imagining an inner child, the hope is that they will be able to conduct the therapy without it.

3.3 Physical Design of Therapy Environment

The idea that the physical environment should reflect the patient's mental state is drawn from Self-Attachment Therapy. The patient is encouraged to imagine their progress and emotional growth through self-attachment therapy as the gradual emergence from a derelict house to a grand, bright house. This symbolises the difference between the despair of the patient's inner world and the new, hopeful vision for the future. [16]

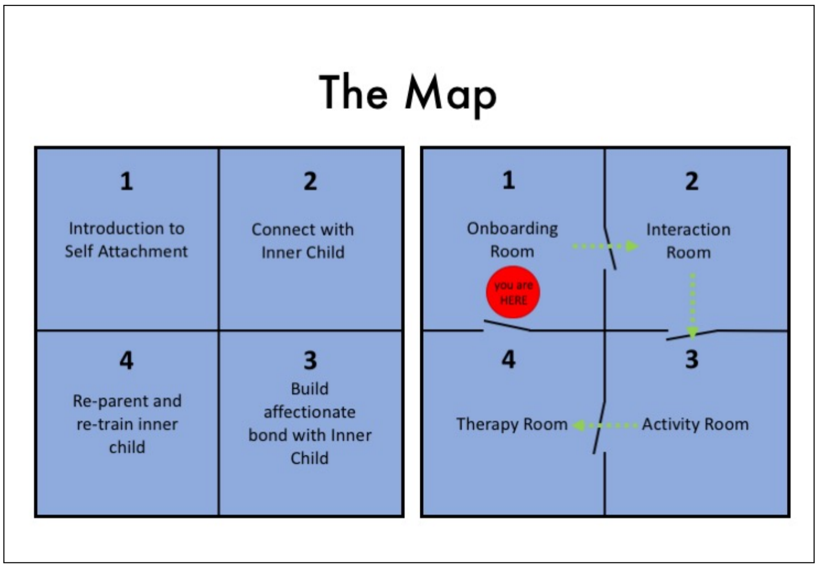


Figure 3.14: The map of the VR environment shown to users as part of onboarding process

In an attempt to apply this concept in the design of the platform's environment, the idea of designing the VR environment to complement the structure of SAT was derived. The aim was to make patients create associations between a certain room in the environment and a specific stage in SAT. This geographical grounding would provide consistency, familiarity and augment the user's sense of presence in the VR environment. It would also bring a physical interpretation of the user's journey through the four stages, making progress more tangible. Therefore, as part of the onboarding process, users were shown a map of how each stage in SAT mapped to a certain room, shown in Figure 3.14. This idea was carried through the structural design of the rooms, from door positions to signs to help consolidate the desired geographical associations.

3.4 Tracking Progress with Patient Health Questionnaire 9

The Patient Health Questionnaire 9 (PHQ-9) is a self-administered questionnaire used to monitor the severity of depression and response to treatment.[7] It is a series of nine questions scored on frequency of occurrence: 0 - Not at all, 1 - Several Days, 2 - More than half the days, 3 - Nearly everyday.

The decision to incorporate the PHQ-9 was made in recognition of the need for a quantitative measure of the platform's success as a psychotherapeutic intervention and in comparison to SAT administered without VR. By integrating the PHQ-9 into the user's journey through the platform, it facilitated the collection of data about the user's severity of depression before and after using the platform, both in the long term and short term. In addition, since SAT is intended as a self-administered intervention, providing patients structured access to PHQ-9 can help them track their own progress.

The patient is offered the opportunity to do the PHQ-9 twice in the standard user journey through the platform. First in Stage I, after completing the onboarding section and again in Stage IV as part of the list of protocols that the patient could perform. The intention was to encourage patients to before and after completing all four stages of the therapy, regardless of whether they are done in one sitting.

As shown in Figure 3.15, the questionnaire is administered in its own room on the same style of screen used in Stage I. Upon completing the questionnaire, patients are given their depression severity score and if applicable, their previous score on the PHQ-9.

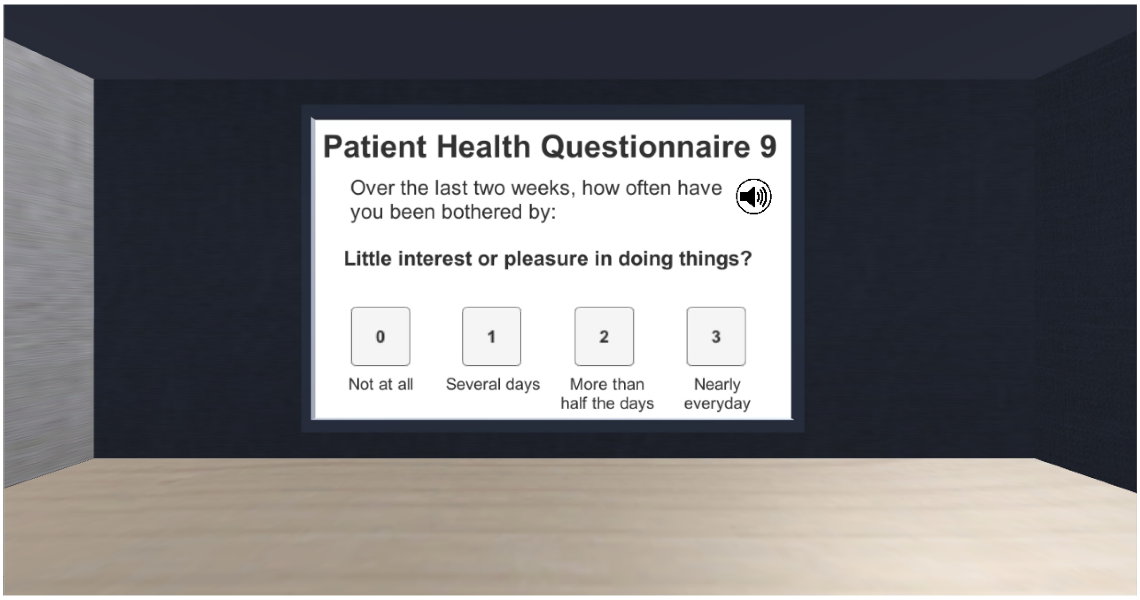


Figure 3.15: Patient Health Questionnaire 9 as delivered in VR

4 Designing for Virtual Reality

4.1 User Interface Design

Conventional user interfaces (UI) are two-dimensional and interacted with via mouse or keyboard inputs. In VR, to be something the user interacts with, the object must form part of the three dimensional environment. It is possible to build an experimental UI where menus are physical objects that users can pick up and use to navigate between scenes. However, in the interest of usability via familiarity, for this VR platform it was decided that mapping conventional UI into the virtual space as intuitively as possible would be the better approach.

4.1.1 Accessing User Inputs

Entering VR using the Oculus Rift, requires two sensors and three pieces of equipment the user interacts with: the headset and one controller for each hand (see Figure 4.1). This allows the two sensors to track the location of the user's head and hands. These are the only inputs that the user can access in VR, making them central to designing a suitable UI input system.

Figure 4.1: Equipment required for basic Oculus Rift set up with Controllers. 2 sensors, 2 controllers and a headset. [56]

The basic cursor, conventionally controlled by a mouse, is mapped to either the headset's movement or one of the controllers. Demonstrative programs provided by Oculus have default control given to the headset, switching to the controllers only when they are connected. With headset control, the cursor stays in a fixed point in the center of the field of view and the user moves their head to position the cursor on anything they'd like to select. With controller control, the cursor is positioned through raycasting such that it it positioned a fixed distance away in the direction the controller is pointing. For detail on how this was implemented see 5.3.1 Cursors.

With this cursor control system, UI elements, i.e. buttons, in the scene could be interacted with using an intuitive point-and-click method. Although the VR platform offers a choice, controller control is recommended as headset control caused nausea in some test users. It also requires users to choose between using the headset for what they want to see and what they want to select. For example, it was inconvenient and nausea-inducing for users to keep turning their heads to and from a menu on the side of the room.

4.1.2 Virtual Hands

The Oculus Touch Controllers have touch capacitive sensors that detect when the user is touching a button, in addition to when they are pressing a button. This allows them to detect their hand's pose when holding the controller and adjust the pose of their virtual hands (shown in Figure 4.2) accordingly. This responsiveness, combined with the tracking of hand position makes the virtual hands very realistic. They form an important part of creating the user's sense of presence in the virtual scene. For an evaluation of user feedback on virtual hands see 6.1.1 Creating Presence and Embodiment.

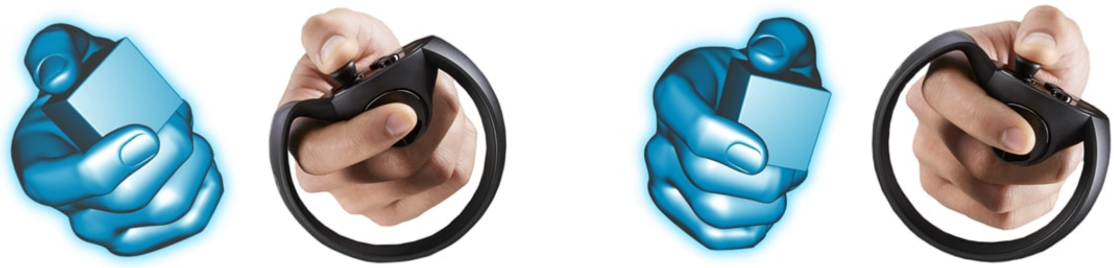


Figure 4.2: An example of how hand pose it mapped from controllers to virtual hands [56]

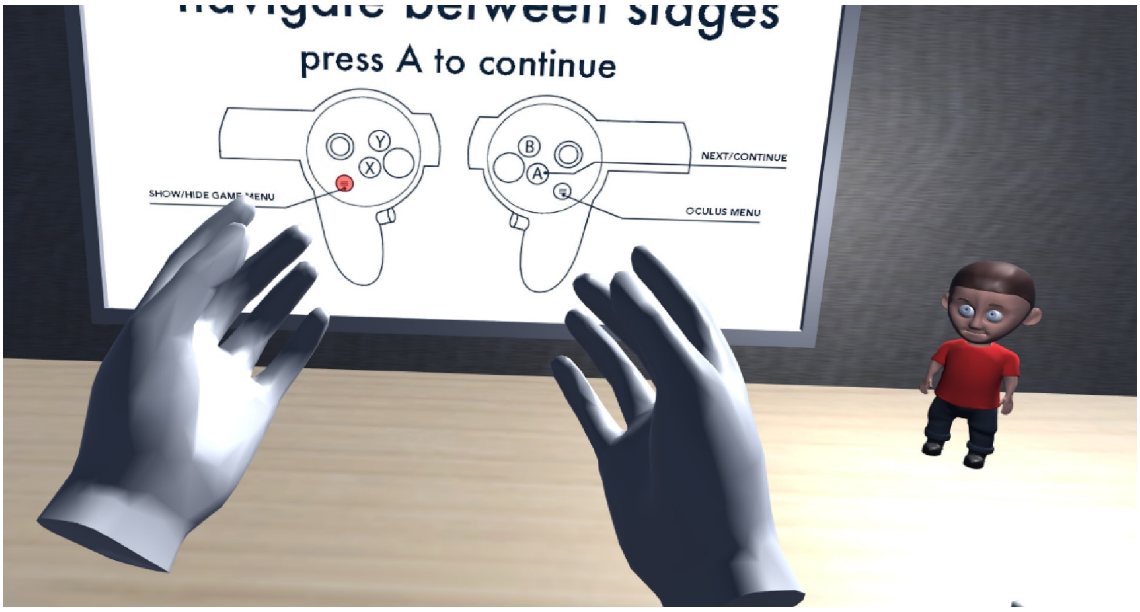


Figure 4.3: The VR hands displayed in the platform. Disconnected from any body, they provide users with a physical link to the VR environment without the bulkiness of a full bodied avatar.

When incorporating virtual hands into the platform (see Figure 4.3), there was a choice between displaying hands holding virtual controllers, or just hands. The advantage of displaying the controllers in VR is that the user can see the buttons. With a headset on, users cannot see the actual controllers they are holding in their hands, making instructions to press a certain button confusing if they are not familiar with the layout of the controllers.

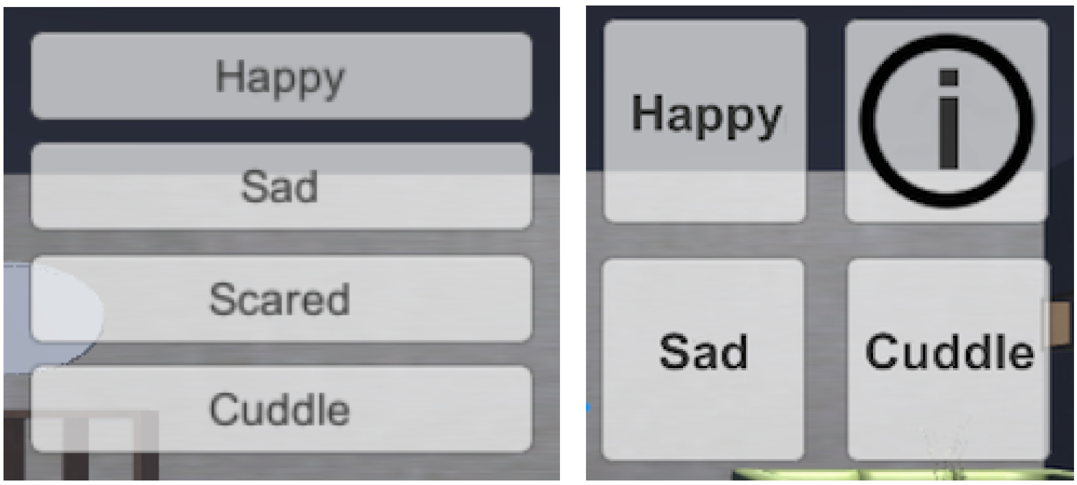
However, creating and maintaining a strong sense of presence and embodiment was easier when the user was not constantly reminded of the controllers in their hands. This was particularly important for the cuddling interactions with the inner child. The challenge of users being confused by the location of the buttons was addressed in two ways. First, users are shown an instructive image of the controllers as part of the onboarding process, indicating where all the buttons were, with important buttons highlighted. Second, the design of the platform aimed to minimise and simplify interactions with the controllers' buttons. In the final iteration, users are only asked to press two buttons throughout the entire platform.

4.1.3 Designing for Accessibility

In the first iteration, buttons were designed following the Unity default visual language. However, in response to user feedback about making VR more accessible to people with unstable hands, a series of changes were made to the UI.

The UI system relied on users being able to control a pointer positioned relative to direction the controller is pointing. Successfully clicking a button requires that the pointer is held on the button while the primary index trigger is pressed. For those with shaking hands, e.g. elderly, it can be difficult to achieve both of these conditions as they can't hold their hands steady enough to keep the pointer on the button.

There were several proposed methods to alleviate this. (1) A selection system based on the physical buttons on the controller; (2) decreasing the sensitivity of the pointer, making it less responsive to small movements; (3) a new visual language with large buttons to provide a larger target area. A pair of Oculus Touch Controllers have 8 buttons and two joysticks as input methods. Therefore, it is possible to implement a UI selection system where users use the joysticks to toggle between options and press a controller button to select it. However, having this option and the point and click method active simultaneously could be confusing to users because there would be two active methods of moving the cursor, one moving it at discrete intervals with the other creating continuous movement. In addition, with users unable to see the buttons on the controller with the headset on, navigating using these buttons would rely on their knowledge of the controller's layout and their sense of touch.



(a) Flat buttons in first iteration (b) Square buttons in final iteration

Figure 4.4: Compared to the rectangular buttons, square buttons maximise the error tolerance of pointer positioning in both vertical in horizontal directions.

Decreasing the sensitivity of the pointer to counteract hand tremors was discounted because it intentionally reduced an important measure of the system's responsiveness. Therefore, it divided the target audience into those who saw this feature as a benefit and those who thought it made the system slow and unresponsive. Ideally, this sensitivity could be implemented as a parameter that could be adjusted to suit each user individually. However, the third option of adjusting button size and shape (see Figure 4.4) to increase the target area when selecting a button, served to provide the similar effect of creating a buffer zone around each button where clicks were still accepted. Therefore, larger buttons were the simplest solution to this problem in terms of implementation and not requiring users to learn a new selection system.

4.1.4 The Main Menu

The main menu was provided to allow the user to navigate between stages. This functionality was complemented by speech commands (see 4.3 Voice Interaction Design) which provided an alternative method for users to move between stages. In the design of the main menu, key questions were: (1) should the main menu always be visible (2) where should it positioned and (3) how should it be accessed?

It was quickly decided that the main menu should not be constantly visible, because this would be intrusive to some of the protocol's experiences, i.e. Stage 4 Type A and B. The options for menu positioning were either a fixed position in every scene or being dynamically positioned to overlay the scene. A fixed position was in line with existing UI conventions in the platform, i.e. the menus in each stage had a fixed position in 3D space. However, this would require setting aside a physical space in every scene for the menu, preferably the same location for continuity. Even though the menu could be hidden, this would be intrusive for protocols where the physical design of the space was important. For example,the blackout space in Stage IV Type A and B is not designed to be interpreted as 3D and a 3D main menu would conflict with this.

Figure 4.5: Dynamic positioning of Main Menu a fixed distance away from user.

As a result, the idea of a overlaid main menu was preferred (see Figure 4.5). It complemented the idea that the main menu was a globally accessible UI element that took priority whenever it was visible. This was reflected in the choice of how to access the main menu. There were two main options, either the main menu could be toggled between on and off by a small button that would be made visible at all times, or one of the physical buttons on the controller. The small button had the same disadvantages as having an always visible main menu albeit smaller in size. It also meant that the VR UI interaction system would always have to be active, including the VR hands and cursor. The intrusiveness of this for the experience of certain protocols meant that a physical controller button was preferable.

The main challenge with an overlay main menu was how it would be positioned. Putting it in the center of the screen would be ideal, but in VR this position constantly changed. Thus, the constant adjustment of its position relative to the user's position would be required. Details on how this was achieved is covered in 5.7.1 Dynamic Menu Positioning.

4.2 Designing Physical Interactions with the Inner Child

The ability to interact intuitively with the inner child is crucial to establishing its realism and consolidates its successful embodiment of the patient's childhood psychological profile. Although patients may have turned to VR due to difficulty performing the therapy using their imagination, the VR platform faces the challenge of providing a viable alternative beyond presenting a simple child model to the patient. The platform aims to provide an experience similar to that which can be achieved through successful SAT with an imagined inner child. This meant designing realistic interactions with the VR inner child, within the constraints of VR.

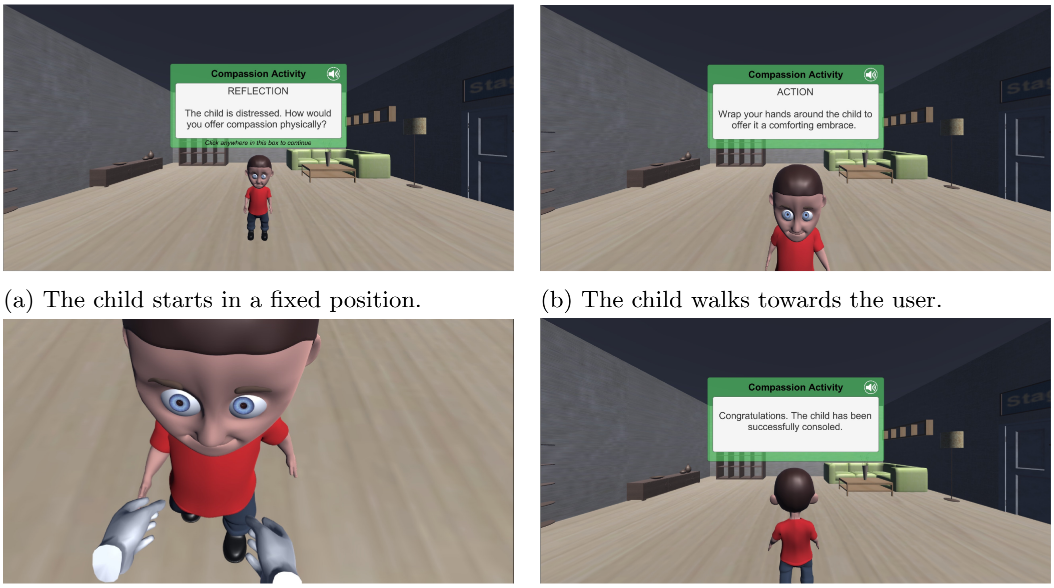
4.2.1 Designing the Cuddling Experience

Cuddling, or embracing the inner child is an important part of the affection the patient is asked to offer the inner child throughout SAT. When the inner child is imagined, the patient is asked to self-embrace or self-massage to simulate this physical connection. With a VR inner child, it is intuitive to allow patients to physically cuddle the VR child instead of themselves. However, the idea of physically embracing a child the patient knows exists only in the virtual world and has no physical body in the real world can initially prove confusing. As a result, the design of the cuddling experience in VR went through several iterations.

In the first iteration, users were asked to use joystick navigation to move closer to the distressed child. Once they were within range they would be asked to wrap their hands around the child model. Upon detecting that the users hand had reached a certain proximity to the child, the embracing motion was assumed to have taken place and the distressed child would become happy. For technical details as to how this was implemented see 5.5 Building the Cuddling Experience.

In the second iteration, the process of cuddling the child remained the same, but how the user was initially set up to be in the right position was modified. Instead of having the user navigate all the way to the child and orient correctly, the child would always be facing the user, and if they were further than a certain distance from the user for an extended period of time would automatically walk closer. This meant that users no longer had to make sure they were on the right side of the child to hug them and there was a upper limit to the distance they would have to travel to reach the child. This helped simplify the initial set up required for successful cuddling to occur as user testing found it to be confusing and unnecessarily complicated for many people.

In the third and final iteration, joystick navigation had been removed from the platform in favour of a more stationary experience. For a detailed breakdown of the design thinking behind this decision see 4.4 Stationary vs Mobile Experiences. In this iteration, the assumption that the user would be relatively stationary meant the child no longer followed the user around constantly. Instead, it stays in a fixed position until the protocol requires a cuddle. It then walks directly forward until it is close enough to the user to receive a cuddle. The user may still have to make slight adjustments to get closer or lower, but these are very small and quite intuitive. Once the user's hands are detected to have 'cuddled' the child, the child turns and walks back to its original position. These steps are shown in Figure 4.6. In this way, the bulk of the set up for cuddling is performed by the VR platform by guiding the child towards the user. For an evaluation of the experience following user testing see 6.2.1 Physical Interactions with the Child.



(a) The child starts in a fixed position.

(b) The child walks towards the user.

(c) The user reaches out with both hands to give the child a cuddle.

(d) After a successful cuddle, the child walks back to its starting position.

Figure 4.6: Cuddling interaction from Stage II Cuddle Activity.

4.2.2 Designing the Mirroring Experience

The mirroring component of Stage IV Protocol Type C presented a unique design challenge. The non-VR protocol asked users to perform the protocol standing in front of a mirror. Therefore, it followed that the VR platform should provide a mirror in the VR environment. The aim of the mirror was to help users imagine that their image in the mirror was that of their inner child. In VR, it is possible to create the illusion that the user's body is physically embodied within the child's body. Therefore, when looking in a mirror they actually see the child's reflection as though it is their own.

However, it became evident that the quality of the illusion's realism was dependent not on the mirror, but the ability for the child model to copy the user's movements in real time. This was limited by the number of animations available for the child model and the level of tracking the Oculus provided. For example, it would be difficult to animate the child to copy the user's walking motion as there are no sensors on the user's feet or legs. Therefore, the design of the mirroring experience was limited by what was viable in the time available given it was only a small section of the platform. It represents a proof of concept towards what could be possible if more time was dedicated to build and calibrate real time avatar mirroring into the child model. For technical details on how mirroring was implemented see 5.6 Building the Mirroring Experience. For an evaluation of the experience following user testing see 6.2.1 Physical Interactions with the Child.

The child model mirrors user position and rotation without animation. The model can also detect and mimic the motion of raising a hand above the head. The protocol also calls for users to dance and sing to their happy song in front of the mirror. To facilitate this, a dancing motion was defined based on the child model's provided dancing animation. Users move their arms from side to side and once this motion is detected, the child mirrors this motion until the user stops moving. This is intended to provide the experience of dancing while embodied within the child body. The user is introduced to what activities can be performed with the child in the instruction set for the protocol. The instructions incorporate a guided tutorial for how to engage with the motion detection capabilities available before allowing users to experiment freely.

4.3 Voice Interaction Design

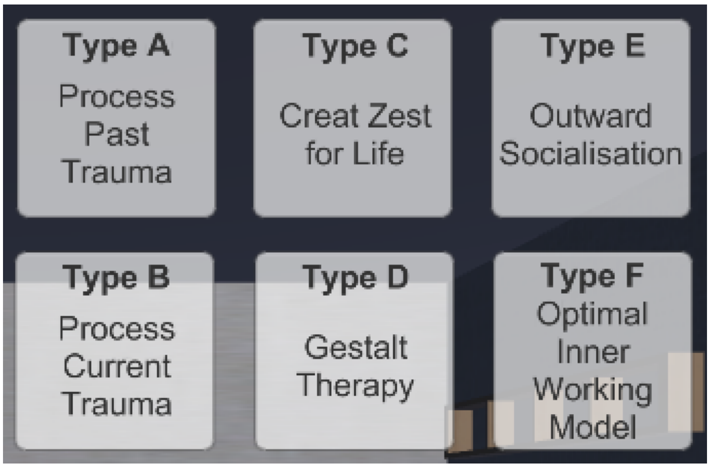
The Oculus Rift headset has a built in microphone and headphones, facilitating speech based interactions. For the VR platform, the motivation for incorporating this was increasing accessibility. By adding another layer of interactability, those who struggle with using the controllers, e.g. those with unstable hands, to interact with the UI would have the option of using speech commands. Alternatively, those with difficulty reading or with poor eyesight could benefit from instructions being read aloud. The design challenge was incorporating voice interaction into the VR platform intuitively and so it complemented the static interaction system.

4.3.1 Speech Recognition

Speech recognition in the VR platform is based on keyword recognition. A word or a short phrase is used to trigger an action. The challenge was designing what commands to use and which actions warranted having a speech command. It was important to balance convenience with simplicity as attaching a speech command to every possible tiny interaction could make the system less robust.

Every button in the VR platform is accessible via a speech command. These commands are made distinct through a bold typeface, shown in Figure 4.7. This was necessary to extract shorter phrases as speech commands, especially where the button's label was long.

(a) Menu Buttons in Stage III



(b) Menu Buttons in Stage IV

Figure 4.7: Bold text highlights which words form the speech command for that button.

Speech control also allows users to navigate through the different stages of the therapy. Specific control is offered with speech commands "Stage 1", "Stage 2", etc. taking the user directly to that stage. Relative control with the command "Next Stage" helps guide the user through the intended flow of the platform. The command "Speak" allows users to access the Text to Speech button used to activate the Text to Speech functionality discussed below.

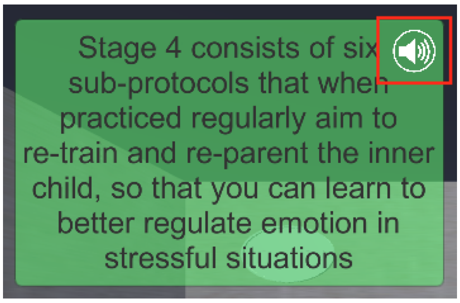
Navigating through each instruction set is not speech controlled as this is a micro interaction that, when coupled with speech control, felt unnecessarily delayed. In user testing, speech recognition had a noticeable delay and error, requiring users to speak clearly and often repeat the command until it was recognised. For an interaction as small as clicking through the next instruction, speech control was more distracting than helpful.

To tackle the error rate of speech recognition, the confidence level of the speech recognition API used could be tuned. This was a measure of how certain the system had to be that the speech input was a match with its dictionary before it would accept it. However, with only three distinct levels: Low, Medium and High, representing ranges values between 0 and 1 that would constitute acceptable, tuning this value was an exercise in compromise. Initial iterations had a medium confidence level, but in user testing it became evident that to account for different accents, voices and background noise, a low confidence level was a better choice. Although it occasionally accepted the wrong word as a speech command, especially when accidentally used in normal conversation, there was a marked increase in speed and phrases correctly matched on the first try. Therefore, although the trade off was a higher possibility of accidentally triggering an action, this was less detrimental to the speech control feature than requiring users to repeat the phrase until it was accepted.

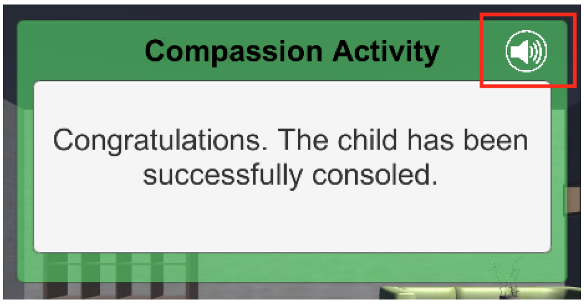
4.3.2 Text to Speech

The nature of the platform as an instructive guide to SAT lends itself to large amounts of text, both for instructions and background information necessary to help users fully engage with the therapy. Therefore, the idea of a guiding voice was a natural extension to the accessibility focus of the VR platform's design, especially given headphones were built into the headset.

As illustrated in Figure 4.8, incorporating text to speech functionality into the existing UI consisted of adding two access points. (1) A button and (2) the speech command "Speak" to activate an automated reading of the current text, which is either an introduction to the stage or some part of the active instruction set.



(a) Text to Speech Button for Stage IV Introduction



(b) Text to Speech Button for Instruction Sets

Figure 4.8: Clicking the Text to Speech Button begins an automated reading of the corresponding text. For instruction sets, the button must be pressed for each instruction. The speech command "Speak" as a trigger for the active text to speech button and must also be said for each instruction.

4.4 Stationary vs Mobile Experiences

The position tracking of the Oculus Rift upon entering a virtual scene is relative. The user begins in a defined location and any movement they make (i.e. by walking around) is mirrored in VR relative to their initial location. This means that for the user to be able to physically walk around a large room in VR, they must be in a physical room of the same size.

The recommended minimum play area when setting up the Oculus is 2m x 1.5m. The Guardian Boundary System asks users to define the outer limits of the play area, and shows a blue enclosing box (shown in Figure 4.9) within the VR environment if the user is about to step outside of their defined play area. This is a safety feature designed to prevent users from venturing outside the space they have cleared for VR and unexpectedly encountering furniture and other obstacles.

This set up and the wired nature of the VR headset requires VR experiences to be stationary in that the user does not move more than a few steps in any direction. However, large movements

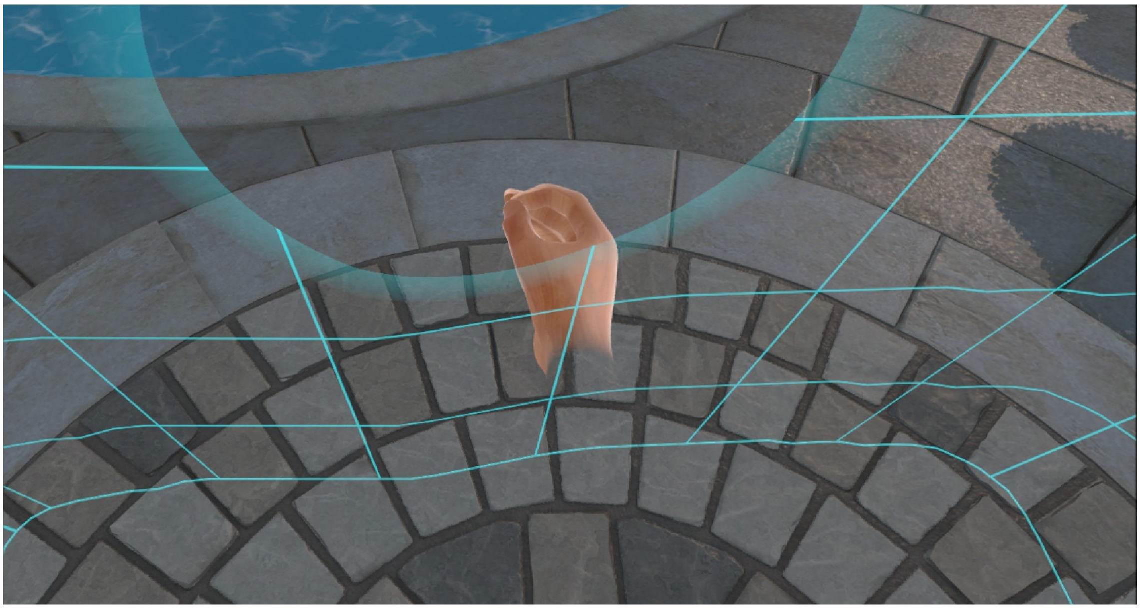


Figure 4.9: The Guardian Boundary System shows a blue box defining the boundaries of play area defined during the initial set up. It is shown when the user is about to step outside this area.

within the VR environment are still possible through a variety of methods, most commonly joystick navigation and point to point navigation.

Early iterations of the VR platform featured joystick navigation as the VR therapy environment was not large enough to warrant point to point navigation. The left joystick controlled position, while the right joystick adjusting rotation. However, as the protocols were designed, it became clear that the ability to move freely around the VR environment beyond a few steps was not particularly useful except for the cuddling experience where users had to use it to fine-tune their position. In addition, early user testing raised concerns about motion sickness and the ease of use of the joystick controls. This indicated it could become a further barrier to access for less technologically acquainted users.

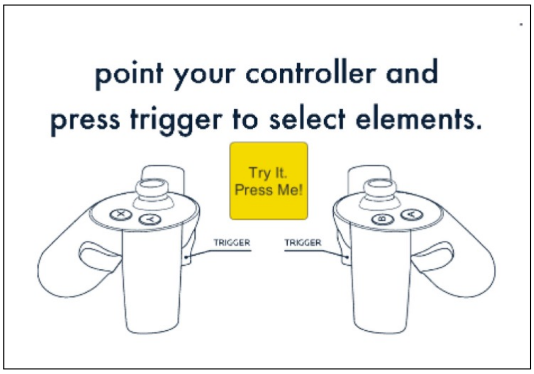
Therefore, to minimise the amount of work the user would have to do to proceed through the VR platform and successfully administer SAT, joystick navigation was removed and the experience of each protocol was specifically designed with a stationary user in mind.

4.5 Designing the Onboarding Experience

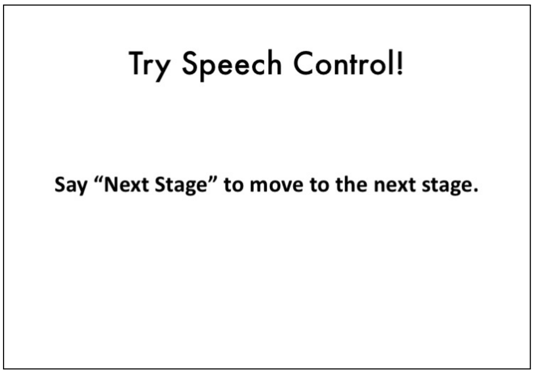
The onboarding experience is the process of teaching the user how to use the VR platform and familiarising them with how to use the controls. It is particularly important because for many patients it would likely be their first experience with VR. Ideally, part of their introduction to VR and the Oculus Rift system will be performed by a therapist guiding them through the platform. However, as a platform for a self-help therapy it is important it takes into account the possibility that users simply download the platform and try it out alone.

In designing the experience, there was a focus on making it an interactive tutorial rather than blocks of explanatory text, especially for practical elements like how to click buttons. Combining onboarding with Stage I of SAT meant that VR tutorials could be delivered alongside an introduction to self-attachment and how the platform aimed to administer the therapy. As a result, it was possible to build an entire room specifically for this 'educational' purpose. The interior design of this room aims to create a school or presentation atmosphere, delivering information as a series of slides.

The slides are combined with interactive elements (see Figure 4.10) for users to put into practice the information they are being given. For the full set of introductory slides refer to B.1 Stage I.



(a) Slide teaching users how to interact with buttons in the platform



(b) Slide encouraging users to use the newly introduced speech control feature.

Figure 4.10: Introductory slides that aim to provide an interactive experience and more effectively teach the user how to use with the VR platform

5 Implementation Details

5.1 Choice of Technology

Access to the Oculus Rift's input modalities are exposed through the software development kit (OVR SDK) provided by Oculus for use with the Unity game engine. It is an important tool for developers looking to develop programs for use with the Oculus Rift. Documentation for the SDK is sparse and inconsistent outside of a series of tutorials provided by Oculus. There exist other third party plugins that provide scripts and prefabs (a Unity specific object) built on top of the OVR SDK to make VR development easier. For example, the Virtual Reality Toolkit (VRTK) [62] provides high level scripts that simplify dynamic processing of Oculus inputs so developers can quickly build experiences without delving into the source code of the OVR SDK.

The decision not to use VRTK in this VR platform came after a week of integrating it into the platform. The more components imported into the Unity project, the more unstable and difficult to debug the program became. In addition, the scripts provided reduced the need to fully understand the code behind the functionality being built. To increase the technical ownership of the project, and ensure a maximum level of customisability, it was decided that the advantages of VRTK did not justify the the time required to integrate and learn it, especially when compared to the comparative return of becoming more familiar with OVR SDK instead.

Third party assets from the Unity Asset Store [66] were also used in building the platform. The Unity Asset Store is a online store provided by Unity where creators can sell ready-made assets that can save other developers time, especially if they require a skillset that they do not have i.e. 3D modelling. The Asset Store contains a vast range of items that developers may want to use in their platforms, including 2D models, 3D models, plugins, frameworks, environments and animations. Some features in the VR platform have been built with assets available for free on the Asset Store. They represent small building blocks from a wide variety of sources that were combined to create a new product. The decision to use pre-made assets was motivated by time restrictions and the understanding that the skills required to make these assets from scratch were not computing related. In particular, the creation of these assets were outside the technical requirements of the design and construction of the platform itself, which was the focus of the project.

5.2 Code Design

Developing with the Unity game engine requires both coding skill and learning a more specific skillset for working with the game engine itself. Unity provides a graphical interface for interacting with much of the functionality exposed in its scripting API, however, in general for a higher level of control and to properly interact with the OVR SDK, scripting is necessary. However, it is not possible to build a platform without any interaction with Unity's graphical interface.

Scripts must be attached to gameObjects in the scene to be active. This does not mean they have a physical presence in the scene as gameObjects can be 'empty' or 'invisible' if no physical mesh component is attached. However, everything in the scene is a gameObject, with special script based components attached. For components provided by Unity, i.e. colliders, the code may not be accessible and can only be modified through its exposed public parameters. Scripts written in the development of this platform are attached as components onto gameObjects.

Therefore, the use of Unity represented a challenge to the code hygiene of the project. Not only was it necessary to maintain a clear code structure, the organisation of gameObjects in each scene also needed a cohesive structure. The interplay between scripts and gameObjects also impeded the ability of scripts to follow design patterns and maintain any uniform practices on how to pass references between objects.

Every scene in the platform contains these foundation objects:

- **Scene Environment**: This is the 3D environment of the platform. It is constructed of Unity planes and 3D furniture models from the Unity Asset Store. It is not dynamic or interactive and does not contain any scripts.
- **Selection Visualiser**: This contains the cursor objects controlled by the headset and the controllers. The OVRPointerVisualiser script is attached to this object.
- **Camera**: The OVRCameraRig script is attached to this object, which contains functions that constantly updates the transform values of the tracking anchors (Left Eye, Center Eye, Right Eye, Left Hand, Right Hand). The camera represents where the user is and is the central point for accessing real time inputs from the Oculus Rift.
- **Hands**: This contains the 3D models for user's hands. Their position is dependent on the OVRCameraRig script's updates to the left and right hand tracking anchors. The Hand script is attached to handle the animations of the hand relative to the controller's button inputs.
- **Speech Control**: This is an empty gameObject that has the stage specific speech control script attached.
- **Event System**: This is a default object in any Unity scene with UI elements, however for VR the Standard Input Module is replaced with the script OVRInputModule to allow the scene to accept Oculus Rift inputs.
- **Child**: This object contains the child model. Built as part of a work exploring Immersive Self-Attachment Therapy through Personalised Avatar Generation[27], it was exported from Blender for Unity compatibility. To facilitate the cuddling interaction, the child is augmented with Unity Components Capsule Collider and RigidBody, and two scripts CuddleTrigger and Haptics.
- **Main Menu**: This is an empty gameObject which controls the active state of the child object that actually contains the UI elements of the main menu. This is done through MainMenu script attached to it that also sets the active canvas to itself to adjust cursor distance. This nested object structure is necessary because scripts on gameObjects that are set inactive are also deactivated and do not continue to listen for actionable inputs.
- **Scene Menu**: This object contains all the instruction sets for the stage. It is very stage specific and is the key differentiator between scenes. However, a generalised nested structure of this object can be defined. This is broken down below.

The Scene Menu encompasses all the stage specific UI elements. The nested structure is necessary to allow gameObjects to be freely set to active or inactive without affecting the active state of important control scripts. The structure of the Scene Menu object and the corresponding scripts is illustrated in Figure 5.1.

The MenuController and InstructionController scripts are stage specific and are implemented as interface classes which each stage specific MenuController class implements, i.e. Stage2MenuController, Stage3InstructionController. MenuController scripts manage which UI elements should be active at any time, toggling between displaying the menu to choose between protocols and the relevant instruction set. The InstructionController script manages which instruction set should be active

Scene Menu

- Menu Controller: *MenuController*
  - Instruction Controller: *InstructionController*
    - Instruction Sets:
      - Instruction Set 1: *InstrNav*
      - Instruction Set 2: *InstrNav*

        ⋮
    - Menu
      - Scene Intro Text
      - Buttons

Figure 5.1: Nested Structure of Scene Menu gameObject.

in the scene. The gameObject with this script attached is the parent object of all instruction set objects, which are instances of the InstrNav class.

This InstrNav script defines the behaviour of the scene at specific points during the instruction set and when it ends. It tracks the user's progression through each instruction set and triggers the correct activities accordingly. This is particularly important because every protocol in the platform is designed around an instruction set. All activities happen during, or after an instruction set is shown. The trigger for these activities is the activation of a certain instruction in the instruction set, i.e. after instruction five, the child should walk towards the user for a cuddle. Therefore, the InstrNav script encodes the generalised behaviour of all protocols, with small protocol specific adjustments controlled through switch statements.

5.3 Input Processing

5.3.1 Cursors

The OVR SDK contains the OVRInput and OVRInputHelper class which contain functions which continuously update the controllers' positions and any button inputs as well as higher level functions controlling active controller selection and ray processing.

The cursor control system described in 4.0.1 User Interface Design switches between controlling the position of the cursor via the headset or the controllers. This is dependent on whether any active controllers are detected, if they have not been paired into the system or if no buttons have been pressed to bring them out of standby mode.

Every Unity scene for the platform contains a cursor sprite stored in a gameObject, with the OVRPointerVisualiser script attached. This script was provided as part of the OVRInputSelection package installed from an Oculus tutorial[63]. However, it was modified to better suit the needs of the platform. Specifically, instead of rendering a line of infinite distance to visualise the ray cast from the controller in the direction it was pointing, the cursor sprite was positioned a fixed distance along the ray. This was more aesthetically pleasing and less intrusive than having a long line connected to the user's VR hands.

The cursor sprite acts as a selection tool by using its attached collider, a built-in Unity functionality which tracks its collisions with other objects in the scene, in particular UI elements like buttons. Visually the depth of the cursor can be hard to determine, i.e. how far away it is from the user. However, it is important that it is positioned so that it can 'collide' with the UI elements in the scene. Otherwise, if it is positioned too close to the user, it would look as though the cursor is correctly positioned to select the button, but would be ineffective. This could be avoided by setting the cursor distance to be the distance between the user and the UI elements they would be interacting with. However, since there were often interactable canvases in the scene, a static cursor distance for each scene would be insufficient.

This problem was addressed by implementing dynamic cursor positioning. The distance between the user and the Canvas where UI elements were placed was defined as a new parameter inside OVRPointerVisualiser and used in Update() to adjust the cursor's position every frame. In initial iterations, joystick navigation meant that this was constantly changing. While it was possible to update the distance of the cursor every frame, this constant adjustment made the collider system unreliable when the cursor was used to highlight and select buttons. It was often necessary for the user to stand still, so the cursor distance could remain fixed for some time before attempting to select anything.

This issue was mitigated when joystick navigation was removed because the distance could now be calculated on initialisation for each scene and did not change unless the active Canvas changed. For example, in most scenes in the platform, users are expected first to interact with the menu for selecting an activity, then with the instruction sets for that activity. These are often placed on two separate canvases and are different distances from the user. Therefore, it was necessary to define an 'active' canvas, which the cursor's distance would be set to.

Canvases did not become active following a defined user progression. Instead, a change in active status could be triggered by specific user action. For example, clicking a menu button would switch the active canvas from the menu canvas to the instruction set canvas and bringing up the main menu would indiscriminately make it the active canvas. Therefore, it was necessary to constantly check the state of the current platform to determine which canvas should be defined active.

A public variable TargetCanvas was defined in the OVRPointerVisualiser class. In each stage the activation and deactivation of UI elements was controlled by its corresponding StageController script. This was a script that maintained up to date information on all UI elements in the scene. Every stage controller contained a reference to the singleton Cursor object and its attached OVRPointerVisualiser script so cursor distance could be recalculated and reassigned. Its Update function checked and readjusted which canvas in the scene was assigned active every frame. The main menu was an exception to this because it overrode the target canvas assignment of the stage controller whenever the main menu was shown. Therefore, it contained its own reference to the cursor object and the OVRPointerVisualiser script attached, allowing it to toggle the target canvas between itself and its previous value whenever it shown and hidden respectively.

5.3.2 Controller Button Input

The buttons on the controller are an important part of the UI interaction system, and the OVRInput script maintains up to date information on the state of these buttons. Figure 5.2 illustrates all the buttons available on the controllers. The primary index trigger button is used in conjunction with the cursor system to select UI elements, behaving like the 'click' of a mouse. This behaviour was built into the OVRInputModule script that controlled Event System so no additional code was necessary.

Recognising controller button inputs was necessary for implementing the main menu, as pressing the Start button would toggle the main menu on and off. Recognising that the user was holding down both primary hand triggers down was also necessary in early iterations of the motion detection feature in the mirroring experience (see 5.6 Building the Mirroring Experience). For these more specific uses of the controller's buttons, it was necessary to use the Get and GetDown functions provided by the OVRInput script to access the state of any button. These functions returned booleans dependent on whether a button was currently pressed. The Get function returned true if the button was currently pressed, the GetDown function only returned true when in the previous frame the button was not pressed, but in the current frame it was. It was necessary to use these functions in conjunction with the Update function to constantly poll whether the button was in the desired state for executing some action. For this reason the GetDown function was particularly important because most actions triggered by a button press only needed to occur once. If the Get function were used, the check would return true for as many frames as the button was held

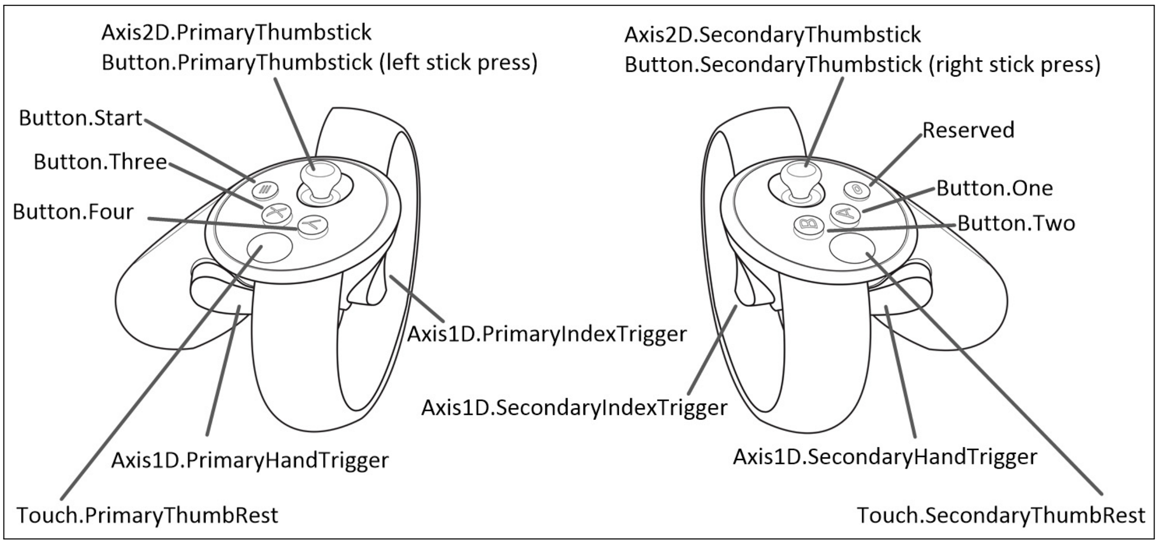


Figure 5.2: Buttons on Oculus Touch Controllers as defined in OVRInput script

down resulting in multiple executions. This most often manifested as flickering UI or jagged animations.

5.3.3 Speech Recognition

The speech recognition functionality used in this VR platform is built using the Unity integration of the Windows Speech API. It is only functional with Windows 10 as it is only a wrapper for accessing native Windows Speech functionality, unavailable in older versions of Windows. Despite this limitation, it was the only speech recognition API that was available unrestrictedly for free and integrated into Unity's Scripting API. Alternative cross platform speech recognition technologies such as Google Cloud Speech Recognition, IBM Watson and Wit.ai have Unity compatibility through plugins, but have additional costs associated with the cloud service on which it depended, i.e. Google Cloud or Watson Service, charging per word processed. In addition, given that the Oculus Rift is not cross platform compatible with Mac OSX or Linux, requiring the use of Windows 10 was not as restrictive as it initially seemed.

The Unity Windows.Speech class exposes three ways to add Voice Input into a Unity application: KeywordRecognizer, DictationRecognizer and GrammarRecognizer. Each of these have different methods of defining the speech input to be recognised. For the purposes of this platform, the KeywordRecognizer was the optimal choice, as the concept of speech commands to navigate the platform required the recognition of short phrases and words which can be pre-defined and hard-coded into the KeywordRecognizer's library.

The speech recognition code was initially written as a single SpeechControl script that was attached to a DoNotDestroyOnLoad object, meaning the object would persist across scenes. It was essentially a static instance of the SpeechControl and all the keywords needed across the platform would be stored in a single library. However, as the platform grew, the switch statement required to manage the behaviour triggered by each speech command quickly became unmanageable.

The code was then refactored so that each stage had its own SpeechControl script each containing a separate KeywordRecognizer. This SpeechControl script would then be passed the references it needed to perform the relevant actions for each speech command, such as that Stage's Button-Manager. This created some duplication in the code and in the keyword library as some keywords did the same thing in every scene, i.e. "Stage One" always loads the Stage I scene. However, this trade off was necessary to keep the SpeechControl script a manageable size. It could have been possible to allow two listeners in each scene, one listening for global commands and another for scene-specific commands. However, even global commands can be context specific, for example the command "Next Stage" is available in every scene, however it loads a different scene depending on what scene the user is currently in. Therefore, some duplication was considered preferable to multiple nested switch statements.

5.4 Integrating the Child Model

The 3D child model built as part of a work exploring Immersive Self-Attachment Therapy through Personalised Avatar Generation[27]. Built in Blender and exported for Unity compatibility it was integrated into this platform as a humanoid avatar. It also provided animation clips for the child with the basic emotions, happy, sad, angry and scared as well as the actions of walking and dancing.

Animation in Unity is controlled through animation state machines which define how and when the model should transition between its different animation states. The animation state machine for the child is shown in Figure 5.3. The transitions between these are controlled via parameters which Unity allows to be type float, int, bool or trigger. In the state machine, all transitions are controlled by triggers, meaning that a one-off 'signal' is sent telling to model to change state. For example, the transition between AnyState and Happy is waiting on a Happy trigger, which is set when the user selects Happy Activity in the StageII menu. The child model transitions from its current animation into the happy animation state and remains there until another trigger tells it to transition to a different state.

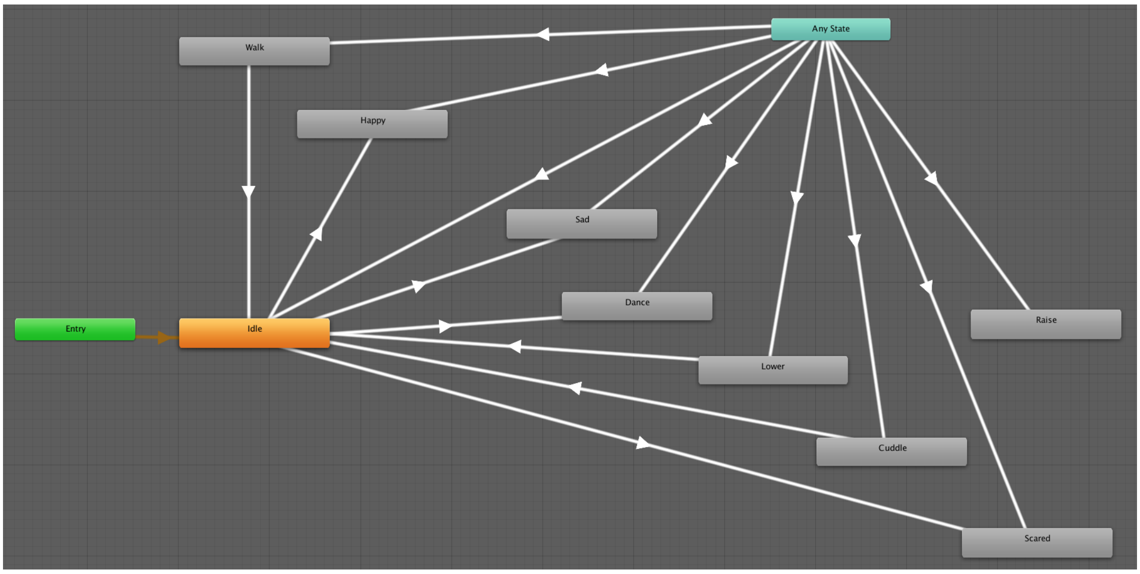


Figure 5.3: Animation State Machine of Child Model. A transition (represented as an arrow) pointing outward from Any State indicates that from any state, if the parameter required by the transition is satisfied, the transition can be followed. This is important when animations do not follow a fixed linear progression and could occur in any order.

5.4.1 Controlling Continuous Animation

The animations for emotional states are stationary. Once in that state, the clip can loop indefinitely without creating any jarring motions. This is different from walking, or dancing which is provided as a short five second clip that can be looped indefinitely. This caused difficulty when setting animation triggers in the Update function of any script as this function is called every frame, meaning that triggers were repeatedly set every frame, causing the animation loop to restart and the child to constantly repeat the first few frames of the animation.

It is necessary to set triggers in the Update function because animation triggers are often sent in response to a change made by another script that this script controlling the animation needs to continuously poll for. For example, if the child should start to walk towards the user when the user is a certain distance away, the distance between them is dependent on the position of the user. This is continuously updated and continuously checked by the script controlling the child's walking to determine if the walking condition is satisfied.

The solution to this problem was to distinguish between the first time the conditions requiring the animation trigger to be sent were met and all the times immediately afterwards where the model should already be in the correct state. This was intended to ensure that the trigger would only be sent once. This solution was an important standard established for writing code to animate the child model to ensure smooth continuous animation for actions like walking and dancing as it significantly increased the realism and interactability of the child model.

5.5 Building the Cuddling Experience

Cuddling forms an important part of several protocols in Stage II and Stage IV. A description of these protocols and how VR cuddling has been integrated into the experience is covered in 3.0.2 Mapping Self Attachment Protocols to Virtual Reality.

5.5.1 Dynamic Child Positioning

Positioning the child model dynamically refers to the idea of positioning the child relative to the user's position. In initial iterations this was done constantly in order to keep up with the user's movements via joystick navigation. However, in later iterations where joystick navigation was removed in favour of a stationary experience (see 4.04 Stationary vs Mobile Experiences), dynamic positioning was still used to allow the child to walk to the user when necessary rather than the user walking to the child.

In the initial iterations, the child 'followed' the user around. First, the child's rotation was calculated based on the user's location so that it would constantly rotate to be facing the user. Second, the child's position was readjusted to constantly less than a certain distance away from the user. To allow for the case where the user used joystick navigation to move towards the child, this repositioning was only triggered if the child was further than a certain distance from the user for longer than 5 seconds.

This can be illustrated as a circle of a fixed radius being drawn around the user (see Figure 5.4), with the child actively endeavouring to be within this circle. Once within the circle, no repositioning is necessary when the user moves, so long as it does not render the child outside the circle.

The main challenge of implementing this dynamic repositioning was the need to linearly interpolate the child's position while the walking animation was played so that it would look like the child was walking between positions rather than moving instantaneously. The Unity function provided for linear interpolation requires the current position and the target position as inputs. The target position was calculated by defining a vector from the user's position to the child's position. The length of this vector was checked against the allowable distance between the user and child. If it was too far, the new target position for the child would be calculated by locating the point along the vector that was the allowable distance away from the user. Once linear interpolation has started the walk animation trigger is sent, using the method described in 5.4 Integrating the Child Model.

Recognising the child has reached the target position is the precondition to sending the animation trigger telling the child's animation state machine to stop playing the walk animation. However, it

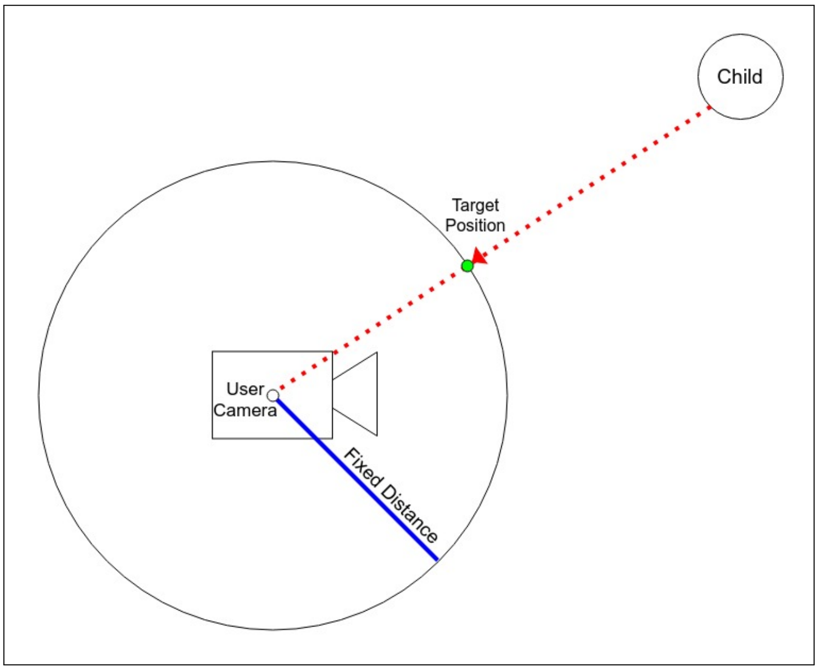


Figure 5.4: Diagram illustrating child movement. Here, the child is further than the maximum allowable distance from the camera. To rectify this, the target position is calculated as the intersection between the vector drawn between child and camera and the circle that encompasses all points within a fixed distance from the camera.

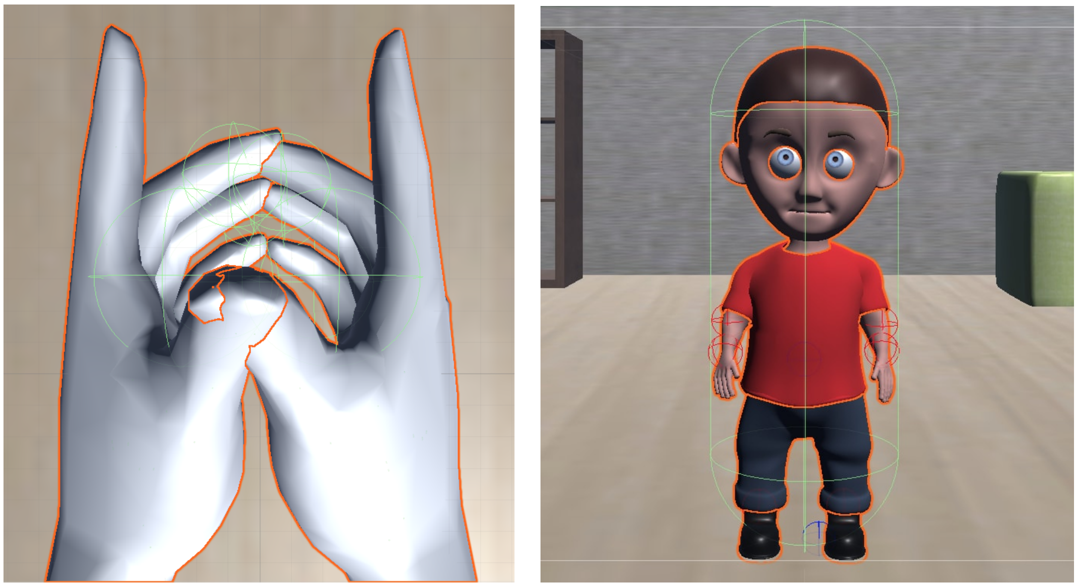
was not as straightforward as checking if the child's position is equal to the target position, because linear interpolation does not terminate when these values are equal, but when they are very close. Therefore, it was necessary to define reaching the target position as being within a certain range of the calculated target position. This applied when interpolating rotation as well as position.

5.5.2 Collision Detection

After the child has walked to be within cuddling distance of the user, the next step in the cuddling experience is for the user to embrace the child. This is distinct from non-VR SAT where self-massage and self-cuddling is used to simulate an exchange of physical affection with the child. With a VR inner child, it is possible to provide the virtual experience of cuddling the child, albeit without actual physical contact.

Users are asked to wrap their virtual hands around the child model to cuddle it. Since control of the virtual hands are mapped to the movements of the user's real hands that hold the controller, the users physically do perform a hugging motion. Whether this action is successfully performed is detected through collision detection. Colliders are a Unity component that allows the collisions between objects to be detected. They define a space enclosing the object such that if any other object with an attached collider enters this space, a collision is said to have occurred and the OnTriggerEnter function is called. The behaviour of this function is user defined. Colliders come in different shapes to allow for the accurate enclosure of objects of all shapes, i.e. Mesh, Sphere, Box and Capsule.

Capsule colliders were attached to the virtual hands and positioned around the palm region, since if colliders enclosed the shape of the outstretched hand, they would be overextended should the user make a fist (see Figure 5.5a). A capsule collider was also attached to the child (see Figure 5.5b), however it was not fitted to the shape of the child. Instead, it formed a 'bubble' around the child, so that if the user's virtual hands breached the bubble a collision would be detected. This was so that the user didn't have to physically touch the child to give it a VR hug. This helped to maintain a heightened sense of realism because since the user didn't have a virtual body, only hands, requiring the user to go too close to the child or touch the child often created clipping problems where the user went through or could see through the child. Tuning the size of the collider so that a reasonable hugging motion was necessary to be detected was important because the smaller it was the more specific the action required to trigger it had to be. This required significant trial and error as it is difficult to infer scale within the Unity development environment and how it will map to life scale. User testing was also an important step because every person performs the hugging motion differently and the system needed to be able to detect them all with a reasonable rate of error.



(a) Capsule colliders for virtual hands

(b) Capsule collider around the child model

Figure 5.5: Positioning of capsule colliders used for detecting cuddling related collisions outlined in green.

Attaching a collider to a gameObject provided two functions onCollisionEnter and onTriggerEnter that would be called when a collision with the gameObject was detected. If the isTrigger boolean of the collider was set to true, the onTriggerEnter function would be called. If not, the onCollisionEnter function would be called. The behaviour of these functions can be user-defined to send information about the collision where it was needed. A collider should have its isTrigger boolean set if it does not require the physics engine to operate on the collision, i.e. the collision objects did not 'bounce off' each other. Instead, the collision was used to 'trigger' an action or indicate the object had passed through a certain physical location. This functionality is commonly used to implement invisible checkpoints in games. Therefore, for the purposes of cuddle detection, the collider attached to the child model had its isTrigger boolean set to true, and collisions were processed by the onTriggerEnter function.

The use of colliders and their corresponding functions had specific requirements for script structure. In particular, the onTriggerEnter functions were only valid for any object with a collider attached. This meant the function had to be declared in a script attached to an object whose collisions were needed as inputs elsewhere. In this case, the ChildTrigger script containing a declaration of the onTriggerEnter function was attached to the child model so that any collisions between the child's and another collider would be detected. If this other collider was identified as a virtual hand, then the function would pass knowledge of this collision to the scene controller so that it could be acted on as required i.e. after a cuddle is detected the child should walk back to its original position. Therefore, collision detection was performed constantly using Unity's collider components, these collisions were processed by the ChildTrigger script that filtered the collisions based on a list of conditions, then the information was sent to the scripts with code waiting on the successful detection of a valid collision.

5.5.3 Haptic Feedback

The virtual cuddling experience has no physical element in that users can't actually touch the inner child when they give it a hug. This resulted in a lack of feedback to indicate that a cuddle had been successful. The only way the user could tell that they had successfully embraced the child was through visual feedback. In initial iterations this was textual, the instruction set would display a congratulatory message and the child's emotion animation would change from scared to happy. For the iterations where the child walked to and from the user, there was the additional element of the child walking back to its original position. However, for a display of physical interaction there was a distinct lack of physical feedback. In response to this, a haptic feedback system was implemented.

Haptic feedback is the use of vibrations in the controller to communicate with the user. The functionality is provided by the OVR SDK in the scripts OVRHaptics and OVRHapticsClip, which use bit masks to allow customisation of the strength, length and pattern of vibrations. A Haptics script was written to integrate the functionality into the platform. Its Update function polled continuously for a valid collision to be detected and upon receiving one, triggered a single short vibration in both controllers. This had the effect of providing sensory feedback to the user when a cuddling action had been successfully detected, in addition to existing visual cues.

5.6 Building the Mirroring Experience

Mirroring involved mapping the user's real life actions onto the child model. This was necessary for the Stage IV Type C protocol because the platform sought to provide the experience of being embodied in the child's body and reflection in the mirror with the image of the child as their own reflection. To make this as realistic as possible, actions performed by the user should then be reflected in the mirror. The mirror was a free asset downloaded from the Unity Asset Store that provided a 'reflective' surface by projecting the view from a camera that faced away from the mirror surface onto a flat surface. Therefore, for the reflection in the mirror to copy the actions of the user, it was necessary to map these actions onto the child model such that the mirror's camera could see it and project it as a 'reflection'. Figure 5.6 illustrates the resultant camera layout. Therefore, the most important step in mirroring was detecting specific user motions so that the child could mimic them by entering into a corresponding animation state. This would then be reflected in the mirror. However, the actions that could be mapped onto the child were restricted by the available animations for the child, rather than what actions could be detected.

The illusion of embodiment into the child's body was created by placing the child in the scene such that the mirror camera could see it, but the camera that supplied the user's view could not. This was done by placing the child on a separate layer and removing it from the culling mask of the user's camera. This created the illusion that the image in the mirror was actually the reflection of the user.

Basic mirroring of position and rotation was implemented without child animation. The user's position and orientation were read from the Oculus headset and the child's position constantly adjusted to match it. This appeared as though the child glided between positions, but it demonstrated that the model could smoothly copy changes in position. Mirroring the small steps taken would have been difficult even if the animations had been available because the Oculus Rift system had no sensors to detect foot movement. Because of the difference in height between an adult user and the child model in VR, it was necessary to offset the position of the child along the vertical axis so that it was on the ground. Setting the child position to equal headset position would rendered the child in mid air.

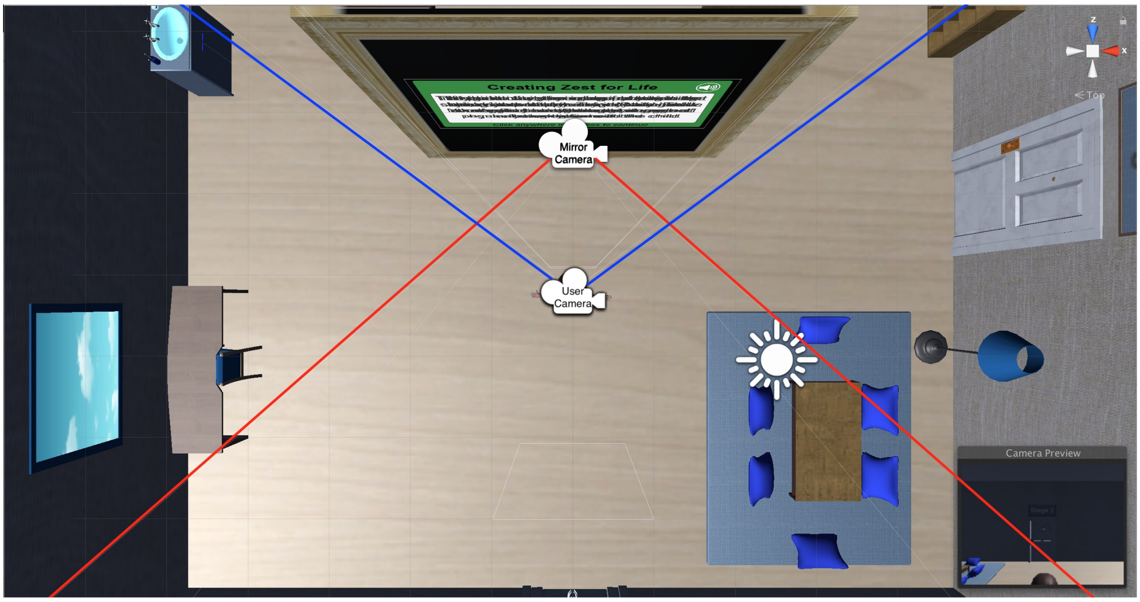


Figure 5.6: Position of mirror camera and user camera and the respective fields of view.

Due to the limited range of animations for the child, the options for what motions to detect for use with mirroring was restricted to dancing and walking. Since dancing in front of the mirror was part of the protocol's instruction, this was a priority. In addition, a hand raising animation was adapted from a hand wave animation downloaded from the asset store for a different humanoid model that was found to be compatible with the child model. As a result, hand raising was added to the list of motions to detect.

The cuddle detection implemented as part of the cuddling experience was motion detection facilitated by colliders. This is different from motion detection based on the processing of raw position data from the Oculus Rift. Both of these methods were used to detect motion for mirroring, each with their advantages and disadvantages. The decision of which to use was determined by the motion to be detected as each method lent itself to different types of actions. In addition, while broad implementation strategies could be used across different motions, every motion required a significant amount of customisation and tuning, making the implementation of motion detection in this VR platform a very small subset of what is possible. Motion detection methods are more extensively explored in the work described in Self Attachment Therapy using Virtual Reality [42], a project which uses motion detection to facilitate gesture control of the platform.

5.6.1 Recognising a Raised Hand

Recognising that the user had raised their hand was implemented by processing the position data read from the Oculus Rift. Raising a hand was defined as when the controller had a vertical position higher than that of the headset, i.e. the user had their hand above their head. The script TrackHands was written to track the position of the Oculus Rift's input mediums: the headset and two controllers. The position data was accessed through functions provided by Unity's Mixed Reality integration UnityEngine.XR. The values are returned in 3D vector form, so values were easy to compare along the vertical axis. This comparison needed to be done constantly as the position of the controllers relative to the headset is always changing and it is important for convincing mirroring that actions are recognised as quickly as possible.

Unlike the cuddle motion, raising a hand does not trigger a discrete action, but one that continues for as long as the hand is raised. The child should remain in the Raised animation state for as long as the necessary conditions are true. Therefore, the challenges associated with sending animation triggers every frame discussed in 5.4 Integrating the Child Model apply here too. If a trigger to raise the child's hand is sent for every frame the user holds the controllers above the headset, the child would receive as many triggers as the frame rate, resulting in the animation being stuck in its first few frames. Therefore, it is necessary to first check the value of the condition in the previous frame and only send a trigger if its value differs. With this strategy, the result was a near instant change in the child's animation state when the user raised and lowered their hand.

5.6.2 Recognising Dancing

Recognising dancing was more difficult as it was not a motion that could be defined as a fixed pose, i.e. arms outstretched or hand raised. The dancing animation for the child defined the motion that needed to be detected. It was a repetitive side-to-side movement of the arms. Ideally, when the user began to make this motion the child would immediately begin to mirror it. However, it became evident that recognising this movement as quickly as detecting a raised hand would not be possible, because a higher level of certainty was required to determine that the user was attempting to dance and not just moving their arms around. It was decided that the definition of successfully performing the dancing motion would require the user to move their arms side to side at least four times (see 4.2.2 Designing the Mirroring Experience).

An initial implementation required that users hold down both primary hand trigger buttons on the controller when they wanted to perform the dancing motion. Motion tracking would then begin to check if the the controllers were moving side by side as required.

Detecting this side to side movement was initially attempted similarly to how a hand raise was detected. The position of the controllers was easily accessible but in order to detect the controllers were moving from side to side it was necessary to have an initial starting position to compare against. The proposed solution to this was to ask users to hold down both primary index triggers when they were about to begin performing the dancing motion. Releasing the triggers would terminate that session of detection with the assumption that the user had stopped dancing, returning the child to its idle state. The position the controllers were at when the triggers were first held down would be saved as a point that the controller had to pass through four times for a dancing motion to be recognised. However, users could not be expected to be accurate enough pass through exactly the same 3D coordinate multiple times. Therefore, a significant amount of error was built in so all the points that were considered acceptable were defined as all points within a sphere centered around the initial point with radius equivalent to the allowable error. In addition, it was important to ensure that the users actually moved the controllers side to side, as an up and down movement would also satisfy the above criteria. Therefore, an extra condition was added such that the controllers' position could not vary significantly in the vertical axis. During the implementation of this method of detection, defining the spheres of points that the controllers had to pass through was reminiscent of how colliders worked. The code was essentially building a collision zone around a point. Therefore, the idea of trying to detect dancing using colliders became quite appealing for reasons of simplicity and robustness, because colliders have a reliability lent to them by being a component provided by Unity. The implementation was still completed, but the collider method was also built to see how performance differed.

After some trial and error, the arrangement of colliders that was implemented combined the checks that the user was (1) moving the controllers side to side and (2) passed through the same 'area' four times. This was achieved by positioning two large box colliders on either side of the user (see Figure 5.7) and requiring that the detected collisions alternate between them. This also removed the need for the user to hold down the trigger buttons to start the motion tracking. If 4 successive collisions were detected following a pattern of alternating between the left and right box colliders, this was considered a successful dancing motion and the child was sent a trigger to play the dancing animation. However, continued collisions are required to maintain the dancing state. If no collisions are detected for more than 2 seconds, the child returns to its idle state. This need to detect no motion was a result of not being able to rely on the user's release of the trigger buttons to indicate they had stopped dancing.

The main benefit of the collider method was that it did not require users to hold down the triggers

Figure 5.7: Position of box colliders for dance motion detection

while they performed the dancing action, making the mirroring seem more natural and the user is providing less input for the same experience. The main disadvantage was the delay in stopping the dancing animation, but given that a delay was expected for initiating the dancing motion, it was found to be tolerable and within expectations in user testing. The collider method was also more tolerant of a wider range of motion, thus successfully detected the dancing motion in more users. The position data method could be tuned to increase its error tolerance to a similar level, but these kinds of modifications also proved simpler with the collider method. Therefore, given that the collider method was (1) more extensible and adjustable (2) more often successful in detecting the desired motion and (3) required less user input, it is the method used in the final iteration.

5.7 Building the User Interface

The UI was built using Unity's default User Interface system. It provides an EventSystem for processing user inputs that trigger buttons. For VR development, the Standard Input Module was replaced with the OVRInputModule. User Interface objects are different from regular objects in the Unity Scene in that they need to be placed on a UI canvas and they are 2D instead of 3D. There are three options available for UI positioning: Screen Space-Overlay, Screen Space - Camera and WorldSpace. Screen Space - Overlay UI is common for mobile applications, but in VR, Screen Space UI would remain in a fixed position on top of the user camera's field of view, while the user's view of the scene changes behind it when the headset moves. This has been known to cause discomfort because of the disjoint between the movement of the scene framed by completely fixed UI.

World Space UI is part of the scene and behaves like a 3D object. It stays in a fixed place in the scene and the user must turn so it is in their field of view. This was the preferred UI standard for most VR platforms explored for design research and thus was used in this platform. The main challenge with world space UI was needing to readjust the cursor distance so that the user would be able to interact with the UI. The details of how this was implemented and why it was necessary were covered in 5.3.1 Cursors.

5.7.1 Dynamic Menu Positioning

The chosen design for main menu visualisation (see 4.1.4 The Main Menu) was for it to always appear directly in front of the user in the position they were standing when they requested it be shown, an action that was mapped to a specific controller button. It was still a world space UI element, so if after it was activated, the user were to turn away, the menu would remain where it was in 3D space, rather than move with the headset to remain in the centre of its field of view.

This behaviour was implemented in the MainMenu script, which also managed showing and hiding the menu in response to the user's controller inputs. The script was attached to an empty gameObject with a child object that contained the main menu's UI elements. This was so the script could freely set the child object to active or inactive without deactivating itself. When the user asked to display the main menu, the child object was repositioned by first giving it the position of the user, then translating it a fixed distance in the forward direction. This distance was calibrated so the full menu was visible in the camera's field of view. It was close enough to interact with comfortably but it did not fill the whole of the screen. It was also always positioned closer to the user than any other UI elements in the scene, giving it a higher priority. This meant that when the main menu was active, it overrode any previous setting for cursor distance and made itself the target canvas. This is discussed in detail in 5.3.1 Cursors.

5.7.2 Text to Speech

The text to speech functionality was an important addition to the accessibility of the platform's user interface. Unlike for speech recognition, Unity did not have text to speech functionality built into its scripting API. However, the Windows Speech API that provided the integrated speech recognition functionality also provided text to speech functionality, Unity simply hadn't integrated it. A third party wrapper[70] for this API was found and used to implement this functionality into the platform. The wrapper also relied on functions provided by another third party unity plugin UniExtensions[72] with had to be imported. Like the speech recognition functionality, this implementation of text to speech was platform dependent, working only on Windows as it relied on a native Windows API.

The third party wrapper provided a WindowsVoice script that had to be attached to an empty gameObject in the scene for called to the function WindowsVoice.speak() to work. This gameObject was created in the introductory Stage I scene and designated DoNotDestroyOnLoad status, so that it would persist through all scene changes. The instrTTS script was written and attached to every instruction set object. Upon pressing the speaker button, it was responsible for passing the current instruction string to the WindowsVoice.Speak function, resulting in an automated reading of this text.

6 Evaluation

6.1 Therapeutic Effectiveness

The inability to perform clinical trials on this platform limits the ability to evaluate its effectiveness as a therapeutic intervention. It was not possible to test the platform on patients and evaluate its effect on their psychological condition, although the means to do so was implemented by integrating the PHQ9 into the platform. Therefore, statements comparing the clinical efficacy of Self-Attachment Therapy with and without VR cannot be made. However, an evaluation of how this platform fared in satisfying the conditions necessary for facilitating a successful VR intervention can be made. This stems from an understanding of the theoretical advantages of using VR in psychotherapy and why VR can be effective in stimulating changes in patient neurobiology. Details on these topics are covered in 2.3.2 Presence, 2.3.3 Embodiment in VR and 2.3.5 Advantages of VR in Psychotherapy.

6.1.1 Creating Presence and Embodiment

Embodiment in VR is defined as the feeling of being 'inside' the virtual body. It is a feeling that is necessary for the user to feel 'present' in the virtual environment. As discussed in 2.3.3 Embodiment in VR, the feeling of embodiment is combination of (1) sense of self-location (2) sense of agency and (3) sense of body ownership. There is no concrete evidence that all three must be present for embodiment to be achieved, but they are important markers that guide the development of this platform, because SAT in VR aims to use this feeling of embodiment to effect therapeutic change. If patients do not feel like they are fully present in the virtual environment, that they have the ability to affect change and interact with the environment, then the therapy is less likely to be effective. In particular, the relationship between the patient and their VR inner child is crucial to the success of self-attachment and the platform provides the environment in which they interact. If the patient does not feel fully present in the environment, this can affect the depth of the bond formed with the child.

In this platform, the user has no physical body in VR. Virtual hands form the main point of interaction between the user and the scene. This is a partial transferal of body ownership, without transferring the location of the user's self. The sense of self-location refers to the spatial experience of being inside a body. By not providing a physical body in VR, the user's sense of self remains in their physical body. However, their hands are given control of the VR hands and the illusion of body ownership is created by making them responsive to changes in hand movement and pose. This sense of ownership over the virtual hands facilitates the user's transferal of presence from their real world environment into the virtual environment. Thus, the sense of self-location still exists, it is simply not migrated into a virtual body. In addition, ownership over the virtual hands provides a sense of agency because the user now has the power to interact with and affect change in the virtual environment. Therefore, in theory, the implementation of virtual hands in this VR platform should be sufficient to create the sense of presence and embodiment necessary for providing a successful therapeutic intervention.

This was supported in the usability feedback gathered from user testing (for detailed user feedback data from the usability testing see C.1 Usability Data). In response to the question "How much ownership did you feel over the virtual hands in the scene?", the average response was 9.25 on a scale of 1 to 10 (see Figure 6.1). This was a positive indicator for the successful transferal of body ownership from the user's hands to the virtual hands. When asked to explain why they felt a sense of ownership over the virtual hands, 60% of users attributed it to the accurate mirroring of hand pose and the other 40% credited motion tracking.

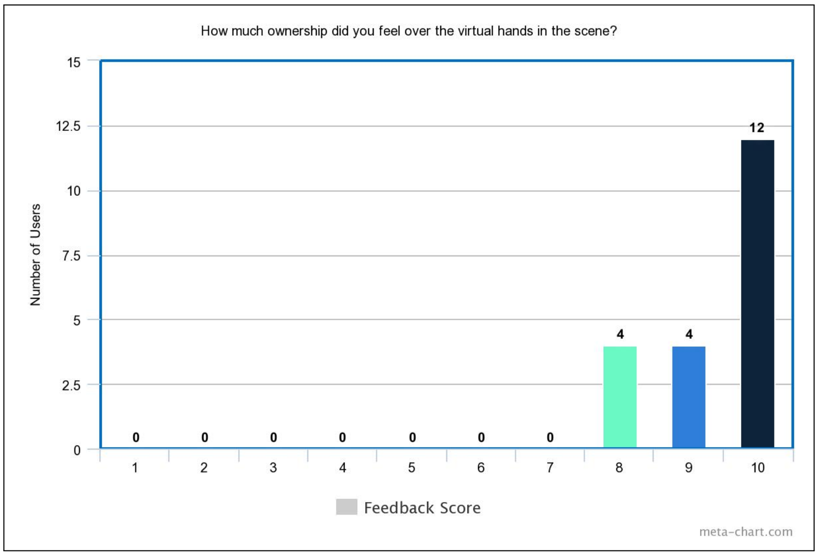


Figure 6.1: User responses to usability survey question: "How much ownership did you feel over the virtual hands in the scene?"

The success of the VR hands in creating body ownership was further supported by the speed at which users were able to begin interacting with the scene using the VR hands. Amongst users in the 18 - 25 demographic with no prior VR experience, 70% required no instruction as to how to begin interacting with the scene with the hands, while the remaining 30% did not require more than two prompts. For users outside this demographic, 50% required no instruction, but 20% of these had used VR before. Amongst the remaining 50%, none required more than three prompts. The significance of the virtual hands was also highlighted by the fact that the first action of 95% of users was to examine their hands either by turning them over, or by moving their fingers. Overall, these results support the conclusion that the level of presence and embodiment achieved in this VR platform is sufficient to facilitate therapeutic change.

6.1.2 Achieving Realism

The more realistic a VR environment is, the less suspension of disbelief is required from the user. However, while level of immersion does have a positive linear correlation with level of realism, the theory of the uncanny valley suggests that at high levels of realism, the level of immersion achieved may be negatively affected by a sense of discomfort (see 2.3.4 Uncanny Valley). This is particularly significant in the digital reconstruction of the human image, as humans are highly sensitive to and can react negatively to the subtle imperfections. In comparison to past and existing work in developing VR solutions for therapy, this platform has at least an equivalent level of realism. For this reason, while a higher level of realism could have been achieved in this platform, it was not considered necessary for a successful therapeutic intervention.

Controlling the realism of the child model was outside the scope of this project as the model was taken from work done by Summer Jones[27]. However, it was necessary for the realism of the environment built for this platform to match that of the child in order to maintain cohesiveness.

The Environment

In this platform, the user does not interact with the 3D environment, it was simply the backdrop to the therapy. User feedback indicated a general indifference to how it affected the user experience. In response to the question "How realistic was the VR environment?", the average response on a scale of 1 to 10 was 5.6. However, in response to the statement "Would a more realistic VR environment have improved the experience?", 60% answered no. This supports the conclusion that while the 3D environment of this platform had room for improvement, it was not crucial to the effectiveness of the platform so much as an improvement to its aesthetic value.

6.1.3 Overcoming Barriers to Access

The primary motivation of this VR platform was to enable those who struggled to sufficiently imagine an inner child to administer SAT. The success of SAT as a therapeutic intervention is entirely dependent on the successful imagining of an inner child and being able to interact with it. It represents a barrier to accessing the therapy if it cannot be easily achieved. The success of this VR platform in mitigating the incidence of this issue as a barrier to access can be quantitatively measured. However, it is important to note that success in this area does not directly imply the success of the platform in administering the therapy as this cannot be accurately measured without clinical trials.

Before using the VR platform, users were given a brief introduction to SAT and how it was administered without VR. They were then asked to perform a series of simplified activities involving an imaginary inner child. Ideally, users should be asked to perform a full round of SAT without VR for better comparison, but these activities are meant to be an indicative sample to streamline user testing.

1 Visualise your childhood self, imagine they are standing in front of you.

2 Give the child a hug.

3 Imagine the child is distressed. Give the child some words of encouragement.

They are then asked a few questions to gauge how difficult they found the activity:

1 From these activities, would you consider administering SAT?

2 Did you experience difficulties imagining and interacting with your childhood self?

3 Could you see yourself performing these activities as part of your daily routine?

After using the VR platform, they were asked:

1 After using the VR platform, would you consider administering SAT?

2 If yes, would you prefer to perform the therapy with or without VR?

3 Could you see yourself performing these activities in VR as part of your daily routine?

4 Has the VR platform changed how you will imagine the experience if asked to perform SAT without VR?

5 Did the likeness of the child affect your ability to project your childhood self onto the VR child model?

Detailed user feedback data for these questions is provided in C.2 Before and After Virtual Reality. An analysis of results showed that before trying the VR platform, 45% of users would consider administering SAT. This corresponded with the same 45% of users who experienced little or no difficulty imagining and interacting with the child. This suggests a direct correlation between ability to imagine an inner child and support for SAT. Of the 45% of users who would consider SAT, 89% would perform these activities as part of their daily routine.

After trying the VR platform, 70% of users would consider administering SAT, of which 79% would perform these activities as part of their daily routine. Of the 70% of users that would consider administering SAT, 50% would prefer administering it without VR.

Therefore, as a method of encouraging more people to try SAT, the VR platform generated a 25% increase in people who would consider administering it. 45% of people who experienced difficulty imagining an inner child, and therefore could not see themselves administering it, expressed support for SAT after trying the VR platform. However, the percentage of people who would then perform SAT activities decreased by 10%. This aspect of SAT is important for the facilitation of long term potentiation.

An important observation was that everyone who expressed a preference for non VR SAT, indicated little or no difficulty with the initial imagination activities. Only 22% of users who experienced no difficulty preferred SAT in VR. However for all those who did experience difficulty and consequently would not consider administering SAT, if they changed their minds about whether they would considering administering SAT after the platform, they also indicated a preference for a VR administration. This suggests that in general, users who felt they could administer SAT without VR, preferred doing it without VR, while supporters of VR SAT felt unable to administer it without VR.

Interestingly, 80% of people indicated that the likeness of the child did not affect their experience, suggesting their imagination was able to supplement VR in making them feel like the child model was their childhood self. In addition, all 35% of people who said that the VR platform would not change how they would experience SAT without VR indicated a preference for SAT without VR.

Overall, these results support the conclusion that the VR platform, by providing a VR inner child can increase the likelihood that patients try SAT as a therapeutic intervention. However, the number of patients likely to integrate the therapy into their daily lives did not experience a proportional increase, suggesting that this may be an area of accessibility that needs to be addressed. In particular because this is important for facilitating the long term potentiation needed to generate long term results. In addition, VR SAT is not superior to non-VR SAT, with non-VR maintaining a strong following even after trying VR SAT.

6.2 Mapping Protocols to VR

6.2.1 Physical Interactions with the Child

The effectiveness of physical interactions with the child is important in creating the realism necessary to make VR SAT a viable alternative to non-VR SAT. In particular, given that the main objective of VR SAT is to help those who are unable to access conventional SAT, due to difficulty imagining an inner child, the higher the quality of the physical interactions with the VR inner child, the less imagination the user is required to supply. Therefore, the platform is more successful in addressing the needs of its target audience.

The physical interactions with the child in the VR platform can be evaluated with respect to two main criteria: authenticity and ease of execution. Authenticity refers to how realistic the interaction was and how effective users felt it was in simulating the non-VR version of that interaction. It is quantified using user feedback surveys. Ease of execution refers to how easily users were able to perform the interaction as it was designed in the platform. It is quantified through user observation data, measuring how often the user was successful in executing the interaction and how long it took for the interaction to be successfully performed for the first time.

Cuddling Interaction

The authenticity of the cuddling interaction was surveyed in the Usability Questionnaire (see C.1 Usability Data) with the question "How effective was the cuddling interaction with the child as a simulation of a real hug?". The average response on a scale of 1 to 10 was 6.45 with the most common score being 7 (see Figure 6.2). This score suggested that the authenticity of the cuddling interaction had room for improvement and further quantitative feedback was sought.

Figure 6.2: User responses to usability survey question: "How effective was the VR mirror in making you feel as though you were in the child's body?"

Quantitative feedback found that a large number of users felt that the interaction was too short. They did not feel like they were cuddling the child - just touching it before the platform recognised the interaction as an embrace. This corresponded with how the interaction was built, as it was implemented with colliders that sent success signals when the user's virtual hand crossed a invisible boundary area surrounding the child (for more detail on implementation methods see 5.5.2 Collision Detection).

A suggested solution to this was to require users to maintain the embrace for a longer period of time. From an technical perspective, this would require that users hold their virtual hands inside the collider surrounding the child for a few seconds before detecting the action as a cuddle. Compared to recognising the collision between virtual hands and collider as a successful cuddle, this would increase the duration of the cuddling interaction and potentially increase its authenticity.

Observing users performing the cuddling interaction showed that user interpretation of the instruction "wrap your hands around the child" did not vary significantly, with the majority of users performing an action resembling the extension of both arms. 70% of users succeeded in executing the cuddling interaction without any additional guidance or a second attempt and 100% of users succeeded within three attempts. After one successful attempt at cuddling, the rate of first time success increased significantly with 90% successfully cuddling the child on their first attempt. These results indicate a high ease of execution.

Overall, user feedback supports the conclusion that the cuddling experience was easy to perform, and consistently repeatable albeit not as realistic as users would have liked. It was generally well received by users, and amongst users that changed their view on whether they would use Self-Attachment Therapy in the Before and After VR questionnaires, the cuddling experience was a decisive factor, especially since they struggled to imagine the same interaction in the sample non-VR activities. The overwhelming user sentiment was that the experience was adequate as a replacement for an imaginary embrace and preferable to a self-hug. It was interesting to note that many users were very aware of the limitations of VR technology in this experience and adjusted their expectations accordingly.

Mirroring Interaction

The authenticity of the mirroring interaction is twofold: how realistic the mirroring of user actions was and how effective it was in altering the user's sense of embodiment. This was surveyed in the Usability Questionnaire (see C.1 Usability Data) with the question "How effective was the VR mirror in making you feel as though you were in the child's body?" The average response on a scale of 1 to 10 was 6.6 with the most common score being 7 (see Figure 6.3). This score suggested that the authenticity of the mirroring interaction had room for improvement and further quantitative feedback was sought. It was assumed that realism of the mirror had a positive correlation to sense of embodiment achieved.

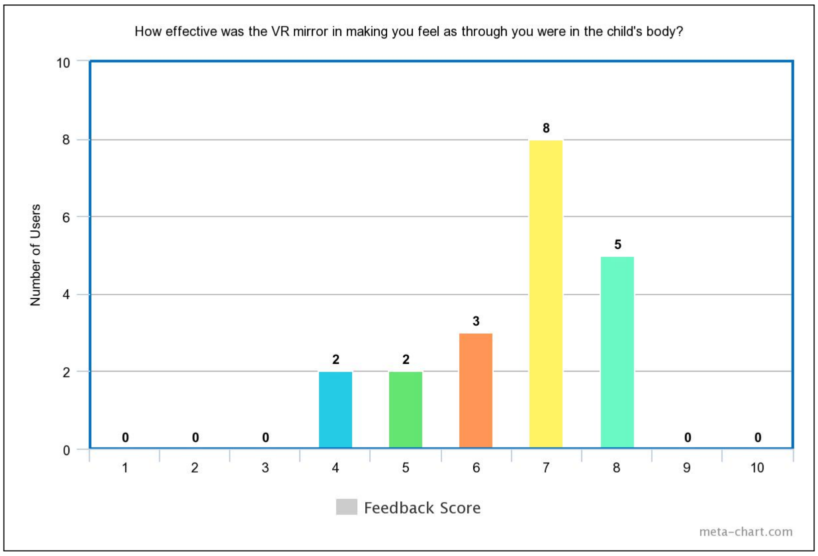


Figure 6.3: User responses to usability survey question: "How effective was the VR mirror in making you feel as though you were in the child's body?"

Quantitative feedback indicated that users felt limited by the number of mirrored actions and this inhibited the level of realism and embodiment achieved. This was supported by user observation data. For example, upon seeing that the child could mirror the action of raising their right hand above their head, 80% of users proceeded to attempt to use their left hand. However, this behaviour had not been implemented into the interaction because the corresponding animation for the child was not provided and the creation of these animations was outside the scope of this project. If the necessary animations were available, this interaction would be easily integrated using the same implementation methods.

The lack of available child animations proved a significant limitation on the quality of mirroring that could be achieved. User feedback also suggested that the child's turning and repositioning relative to user movement could be improved by making the child turn rather than rotate on the spot, stepping between positions rather than gliding. These improvements would be achievable if the child animations were available. Therefore, the mirroring interaction as it currently is represents more of a proof of concept rather than a finished product. It demonstrates what is possible, and presents opportunity for future extension.

Observing users performing the mirroring interaction as it was implemented indicated that their interpretation of the instructions "raise your right hand above your head" did not vary significantly. 100% of users succeeded in having their hand raising motion detected on their first attempt. This indicated a very high ease of execution.

Users seeking to have their dancing motion mirrored were instructed to "move your arms from side to side" and shown the child dancing. Initially, users were only given the text instruction, without a visual demonstration from the child. In this case, users were only able to perform a successfully detected dancing motion on their first attempt 30% of the time. This increased to 65% when they were also shown how the child danced. A dancing motion was successfully detected within three attempts for 80% of users, and within five attempts for 80%. Therefore, the ease of execution of the dance motion was lower than both hand raising and cuddling. However, this was to be expected because hand raising and cuddling both required only one action to be performed, while the dancing required four movements to be recognised. This was a trade off made during implementation to ensure that stray hand movements would not be mistaken for the dancing motion (see 5.6.2 Recognising Dancing). Given this, since the rate of successful of execution did not decrease fourfold, the ease of execution of the dancing motion appears reasonable.

Overall, these results support the conclusion that the mirroring interaction, in its current form with two detectable motions is easy to perform and consistently repeatable, but not as realistic as users would have liked. Its weaknesses were not attributed to the design of the interaction, but limitations in its implementation. However, user sentiment about whether this protocol was better in VR was still mixed. The interaction is not as crucial to SAT as cuddling because mirroring is only used in one protocol (Stage IV Type C). However, unlike cuddling it was not decisive amongst users who struggled to imagine an inner child as a factor that would lead them to considering trying SAT. In general, users were a lot less forgiving of errors in mirroring and actually had higher expectations of the quality of the mirroring interaction than cuddling. This misconception was reflected in user satisfaction; because users expected more, they were less satisfied.

6.3 Usability

The usability of the VR platform does not directly affect how effective it is at administering SAT, and whether it helps users overcome a difficulty imagining an inner child. However, it is still an important development consideration because VR is a relatively new medium for delivering psychotherapy and poor usability represents an additional barrier to the acceptance of VR as a valid alternative to non-VR psychotherapy. It is important that difficulties using VR platform not deter users from engaging in the psychotherapy. This is particularly important for SAT, because it aims to be self-administrable.

6.3.1 Accessibility

Speech Recognition

The speech recognition functionality was implemented to increase the accessibility of the VR platform. As a medical platform, it was important that the platform did not assume that its users would be young and able-bodied. Instead, it should strive to be as accessible as possible.

However, in practice the usefulness of speech recognition was limited by the technology. The recognition capabilities were not at a high enough level to account for variations in voice, accent and background noise. Users often had to repeat commands multiple times before they were recognised. Only 22% of attempts to use a speech command were successful on the first try. 40% were successful within three tries and the remaining 38% either took more than three or did not achieve success before the user gave up.

This frustration was reflected in user feedback, where the average response to the question "How useful was the speech recognition functionality? Would you use it regularly?" was 6.75 on a scale of 1 to 10 (see Figure 6.4). Even though the most common response was 8, a significant proportion of users gave scores well below this, indicating a wide range of satisfaction levels. This was in line with the temperamental nature of the speech recognition functionality, creating a wide range of experiences for users, some of whom experienced few difficulties, while others had to constantly repeat themselves.

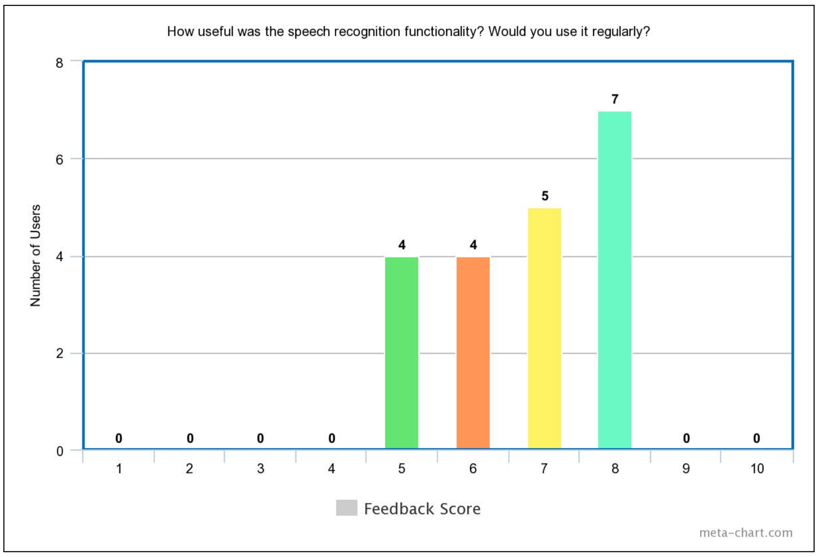


Figure 6.4: User responses to usability survey question: "How useful was the speech recognition functionality? Would you use it regularly?"

Initial observations suggested that accent, volume and speed were key differentiating factors. After a speech command failed to be recognised, 90% of users adjusted the speed or volume at which they said the word in their following attempts.

The speech recognition system implemented in this platform did not have learning capabilities. This made it less accessible to users with accents different from what the speech recognition system was trained on. In general, the system struggled with accents that did not resemble British received pronunciation and General American English, including regional accents.

Therefore, the unreliable nature of the speech recognition system undermined its goal of increasing accessibility by proving inaccessible to users outside of a specific accent demographic. The technology has not reached the level necessary to create natural human-computer speech interactions, especially without an active learning system.

Text to Speech

The text to speech functionality was also implemented to increase the accessibility of the VR platform, aiming to support those with learning difficulties. The idea was that users could have text read to them if they struggled to or did not want to read large sections of text. It was implemented such that users could press a button or use a speech command to activate an automated reading of the currently active text segment.

User feedback for this feature was more positive than for speech recognition. In response to the question "How useful was the text-to-speech functionality? Would you use it regularly?", the average response was 8.05 on a scale of 1 to 10 with 9 being the most common response (see Figure 6.5). This was in contrast to qualitative feedback indicating that users felt that while the functionality did not suffer the same drawbacks as speech recognition, in that it was easy to use and worked consistently, they simply did not find it that useful, preferring to just read the text.

However, none of the users in the testing group had reported any learning difficulties that would incline them towards the text to speech speech functionality. Therefore, the users in the group were not a representative sample of types of users the platform was expecting. It is possible that with a wider cross-section of users, the perceived usefulness of text to speech would increase. Further user testing would be necessary to ascertain this.

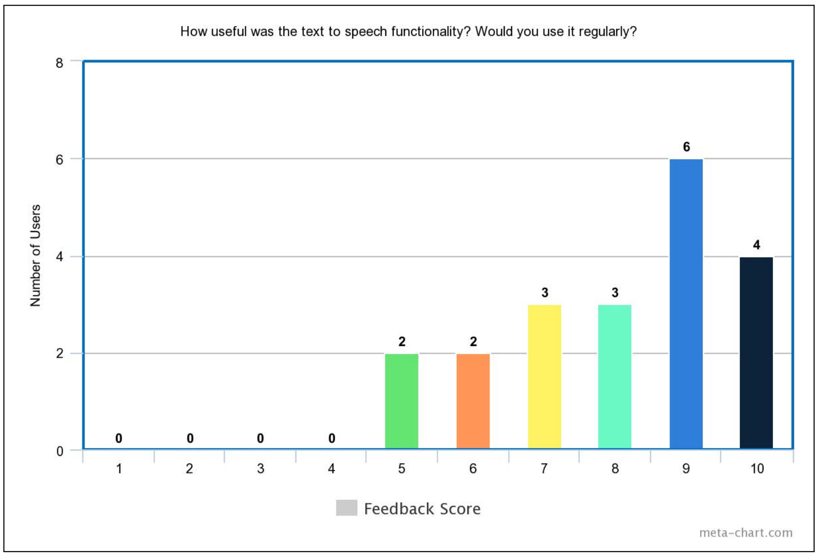


Figure 6.5: User responses to usability survey question: "How useful was the text-to-speech functionality? Would you use it regularly?"

6.3.2 Onboarding

Onboarding is the process of teaching the user how to use the platform. As a VR platform, this step is particularly important because many users would likely not have any prior experience with VR. In addition, unlike traditional interfaces i.e. web interfaces and touch screens, for which standard design and development practices exist and are widely used, VR is still a new medium with a wide range of new input methods. This means that user expectations are still undefined when given a VR interface. This gives developers more creative freedom to experiment, however it makes good onboarding very important because unlike a website or a mobile application, users cannot be expected to be familiar with how things work.

The design thinking being the structure of the onboarding experience built into this platform is detailed in 4.5 Designing the Onboarding Experience. Its effectiveness in guiding users through the platform and familiarising them with the controllers can be evaluated with reference to user observation data collected during user testing.

When users with no VR experience were placed directly into a SAT protocol without going through the onboarding experience, the average time taken for for users to perform their first interaction with the user interface from the moment they entered VR was 44 seconds. By comparison, in the onboarding experience, the average time to first interaction was 16 seconds. For 35% of users, this was an attempt to display the main menu after being shown the button that activated it in the first introduction slide (see B.1 Stage I). 100% of these attempts were successful on the first attempt.

For the remaining 65% of users, their first interaction was an attempt to click the "Try It! Press Me!" button on the second introduction slide. Only 70% were successful on their first attempt, 85% within two attempts and 100% with additional verbal prompting. These results support the conclusion that while users were capable of discovering how to interact with the platform without a formal tutorial process through trial and error, onboarding dramatically increased the speed at which they could confidently perform interactions. In addition, the interactive design of the onboarding such that users were asked to perform interactions with the UI while instructions were given significantly increased the likelihood that users would attempt to use available functionality and succeed in fewer attempts.

Upon being introduced to the availability of speech control in the platform, no users attempted to use it until directly prompted to "Try Speech Control!" in the final introduction slide. This showed an initial user hesitation that successful onboarding aimed to minimise. For the use of speech control, despite this initial hesitation, 80% of users attempted to use speech control later in the platform. In contrast, although the text to speech functionality was also explained and a test interaction provided, only 5% of users attempted to use it later in the platform. Initially, this indicated poor onboarding in that users did not understand how to access it. However analysis of qualitative user feedback (see 6.3.1 Accessibility) later suggested that this was more likely a result of users not finding the feature very useful.

Without onboarding many of the accessibility features available in the platform remained unused. When users used the platform without onboarding, none attempted to use speech control or reported any knowledge of its availability. This was in contrast to the 80% of users who attempted to use it in the platform after they were told how it worked as part of onboarding. The impact of onboarding not as significant for the text to speech functionality because it can be accessed through a UI button, which 45% of users attempted to press without being directly prompted through onboarding.

6.4 Limitations of Inner Child's Emotional Model

The main limitation of the platform stems from the primitive emotional model used in the design of the inner child. This creates a lack of responsiveness to user input, in terms of their participation in the therapy techniques. Currently, changes in the child's emotional state are statically triggered by certain user actions. The user's experience of the platform is identical every time. For example, the child always becomes 'happy' after being consoled verbally and physically regardless of what the user has said. Therefore, the system does not change its behaviour relative to how well the user is performing the therapy. Ideally, the child's emotional state should gradually improve as the patient engages with them. This gradual improvement would require a more representative emotional model consisting of more graduated levels of emotion other the extremes of happy and sad.

In addition, the platform does not store user progress. This means that improvements in the child's emotional state achieved in previous sessions do not affect the user's experience of the therapy in later sessions. This would be useful because SAT intends for users to progress through the four stages sequentially. As the protocols become more complicated and more involved in trying to modify patients' thought patterns, it would be useful for user progress data to be stored and used to guide users toward protocols more representative of their progression through the therapy.

7 Conclusion

This project explored the application of VR to the delivery of the self-administered psychotherapy Self Attachment Therapy (SAT). It set out to build a platform that would guide patients through the process of administering SAT. It represents an alternative solution to the growing demand for mental health services as well as the addressing the barriers to accessing Self-Attachment Therapy identified in its first round of clinical trials. With ongoing research and existing applications of VR in psychotherapy showing positive results, the idea of administering SAT through VR was a promising premise.

As part of the development of this platform, a reinterpretation of the protocols of SAT was necessary. In particular, the use of a VR inner child instead of an imagined inner child was a central motivation for the VR platform. This change required that a lot of the protocols be adjusted for use with a 'physical' inner child rather than an imaginary one. Although VR is a multi-sensory experience, its strengths are in its replacement of visual and auditory stimulus rather than tactile stimulus. In the redesign of the protocols involving physical interactions this was a significant challenge that resulted in creative solutions that pushed the boundaries of what was possible in VR. However, it was necessary to balance this creativity with the needs of the platform in its role as a medical intervention.

The challenges of building for Virtual Reality extended beyond making SAT protocols VR compatible. Due to the inability to perform clinical trials, evaluating the success of this project lies not in its effectiveness as an intervention for the treatment of depression. Instead, it lies in its effectiveness in addressing the barriers to access that motivated the exploration of how SAT could be administered in VR. This resulted in a focus on usability and accessibility that guided the design of the platform. It also steered user testing toward investigating whether the strategies employed to increase the rate of participation in SAT, i.e. integrating a VR inner child, were effective.

In summary, the main outcomes of this work are (1) the implementation of suggested reinterpretations of SAT protocols for VR as a proof of concept and (2) the exploration of the state of VR technology and the value it can add to SAT as a therapeutic intervention. Together, they the basis on this this work contributes to the body of evidence that supports the validity of administering SAT in VR.

7.1 Future Work

While the work done in this project had reasonable success in achieving its key objectives, as an exploration of the viability of administering SAT in VR, it brought to light key directions that future development could take:

- **Improved Inner Child Embodiment** The mirroring experience in Stage IV Protocol Type C has room for improvement in its creation of a feeling of embodiment in the child's body. In particular, the level of realism of the experience could be increased if the child model had a wider range of animations to cover basic human motions. The integration of these animations into the platform would also require the extension of existing motion detection capabilities. The techniques used to detect motion in this platform are not exhaustive and further work could explore ways to mirror users' actions instantaneously without the delay required in the gesture-based motion detection implemented in this platform.

- **Clinical Trials** The performance of clinical trials using this platform would be beneficial to the evaluation of the effectiveness of VR SAT as a therapeutic intervention for the treatment of depression. Future work could focus on tailoring and polishing the platform for use in a clinical setting and achieving the level of rigour necessary for medical applications.

- **Integrating Avatar Personalisation** The inner child is meant to be a representation of the patient's childhood self. Therefore, ideally the VR child should resemble the patient. Currently, the platform has no such customisation options and uses the same child model for all patients. Work done as part of the exploration of Immersive Self-Attachment Therapy through Personalised Avatar Generation[27] investigates techniques for mapping childhood photographs onto a 3D model to create a likeness of the patient's childhood self. The integration of this work into this VR platform could increase the faithfulness in which this platform recreates the experience of performing SAT without VR. It could also improve the effectiveness of the platform in addressing difficulty imagining an inner child as a barrier to accessing SAT.

- **Dynamic Child Responses to User Input** In this platform, changes in the child's emotional state are hard-coded into the platform's structure, i.e. the child always becomes happy after a successful cuddling action. Future development could aim to dynamically adjust the inner child's emotional state in response to specific user actions as well as having more graduated levels of emotion. This would be beneficial to making interactions with the inner child more realistic. It would also allow the child's emotional state to reflect how well the user was performing the therapy. This could be achieved by incorporating natural language processing to identify the content of the user's speech input when consoling the child and adjust the child's emotional state relatively.

- **Storing User Progress** SAT is a long-term intervention that aims to integrate into a patient's daily life. Currently, every session with this platform is independent and does not store data about previous sessions. Future development could aim to provide the ability to save their progress through the platform. This is especially useful because SAT intends for users to sequentially progress through its four stages and this would allow users maintain their progress between sessions. In addition, this progress data could also include the patient and their inner child's emotional state from previous sessions. This would make the platform a better reflection of the patient's psychological progress and growth.

- **Compatibility with Mobile VR** The need to access high-end VR equipment can present a barrier to using this platform. Accessibility is especially important to support the self-administrable nature of SAT. Future work could aim to adapt this platform for mobile VR solutions like the Samsung Gear VR or Google Cardboard. This would increase the accessibility of the platform by removing the need for expensive VR technology. By making the platform available on mobile phones, the ability to integrate the therapy into patient's daily life also increases, an important step in successful administrations of SAT.

A Overview of VR applications in Psychotherapy

This table has been adapted from a 2016 review of existing literature on the use of VR in different areas of behavioural health supporting the potential of VR as a clinical treatment tool. [53]

Table A.1: Meta-analyses and systematic reviews related to the use of VR in behavioural health

	Review Type	**Reference**	**Included Studies**	**Conclusions(from papers)**
Anxiety Disorders	Meta-analysis	Parsons and Rizzo[47]	21 studies	“Although meta-analysis revealed large declines in anxiety symptoms following VR Exposure Therapy (VRET), moderator analyses were limited due to inconsistent reporting in the VRET literature”
	Meta-analysis	Powers and Emmelkamp [51]	13 studies	“Analysis showed a large mean effect size for VRET compared to control conditions, Cohen’s d = 1.11 (SE = 0.15, 95% CI: 0.82–1.39). This finding was consistent across secondary outcome categories as well (domain-specific, general subjective distress, cognition, behavior, and psychophysiology). Also, as expected, in vivo treatment was not significantly more effective than VRET. In fact, there was a small effect size favoring VRET over in vivo conditions, Cohen’s d = 0.35 (SE = 0.15, 95% CI: 0.05–0.65)”
	Systematic review	Meyerbroker and Emmelkamp [40]	20 studies	“Only in fear of flying and acrophobia, there is considerable evidence that VRET indeed is effective. In more complex anxiety disorders as panic disorder and social phobia, which form the core clinical groups, first results of VRET are promising, but more and better controlled studies are needed before the status of empirically supported treatment is reached. More severe cases of panic disorder with agoraphobia and social phobia are often not reached with existing

Table A.1: Meta-analyses and systematic reviews related to the use of VR in behavioural health

Review Type	Reference	Included Studies	Conclusions(from papers)
Meta-analysis	Opris et al.[45]	23 studies	"The results show that VR does far better than the waitlist control, and similar efficacy between the behavioral and the cognitive behavioral interventions incorporating a VR exposure component and the classical evidence-based interventions. VR has a powerful real-life impact, similar to that of the classical evidence-based treatments, and a good stability of results over time, similar to that of the classical evidence-based treatments. There is a dose–response relationship for VRET, and there is no difference in the dropout rate between the VR exposure and the in vivo exposure"
Systematic review	McCann et al[39]	27 studies	"VRET may be an effective method of treatment but caution should be exercised in interpreting the existing body of literature supporting VRET relative to existing standards of care. The need for well-designed VRET research is discussed"
Meta-analysis	Ling et al.[34]	33 studies	"Analysis showed a medium effect size for the correlation between sense of presence and anxiety (r = 0.28; 95% CI: 0.18–0.38). Moderation analyses revealed that the effect size of the correlation differed across different anxiety disorders, with a large effect size for fear of animals (r = 0.50; 95% CI: 0.30–0.66) and a no to small effect size for social anxiety disorder (r = 0.001; 95% CI: −0.19 to 0.19). Further, the correlation between anxiety and presence was stronger in studies with participants who met criteria for an anxiety disorder than in studies with a non-clinical population"
Systematic review	Diemer et al.[13]	38 studies	"Despite several limitations, this review provides evidence that VR exposure elicits psychophysiological fear reactions in patients and healthy subjects, rendering VR a promising treatment for anxiety disorders, and a potent research tool for future investigations of psychophysiological processes and their significance during exposure treatment"

Table A.1: Meta-analyses and systematic reviews related to the use of VR in behavioural health

	Review Type	Reference	Included Studies	Conclusions(from papers)
Stress-Related Disorders	Systematic review	Gonclaves et al.[24]	10 studies	"The results suggest the potential efficacy of VRET in the treatment of PTSD for different types of trauma. VRET proved to be as efficacious as exposure therapy. VRET can be particularly useful in the treatment of PTSD that is resistant to traditional exposure because it allows for greater engagement by the patient and, consequently, greater activation of the traumatic memory, which is necessary for the extinction of the conditioned fear"
	Systematic review	Serino et al. [58]	10 studies	"VR-based cyber-SIT cyber-SIT may play an important role in the future clinical psychology, but it is crucial to enhance the validation of this approach from a methodological point of view: controlled trials testing a greater number of participants are needed"
	Systematic review	Motraghi et a. [41]	9 studies	"Although preliminary findings suggest some positive results for VRET as a form of exposure treatment for PTSD, additional research using well-specified randomization procedures, assessor blinding, and monitoring of treatment adherence is warranted. Movement toward greater standardization of treatment manuals, virtual environments, and equipment would further facilitate interpretation and consolidation of this literature"
	Systematic review	Botella et al. [4]	12 studies	"Results suggest VR is effective in the treatment of PTSD. Not all studies reported having followed the clinical guidelines for evidence-based interventions in the treatment of PTSD. Few studies evaluated acceptability, however, the findings are very promising, and patients reported high satisfaction and acceptability regarding the inclusion of VR in the treatment of PTSD. The main weaknesses identified focus on the need for more controlled studies, the need to standardize treatment protocols using VR, and the need to include assessments of acceptability and related variables"

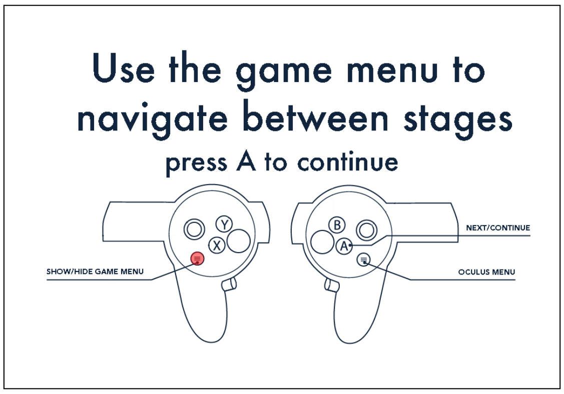
Table A.1: Meta-analyses and systematic reviews related to the use of VR in behavioural health

	Review Type	**Reference**	**Included Studies**	**Conclusions(from papers)**
Depression	Systematic review and meat-analysis	Li et al. [32]	19 studies	"The unique experience of virtual reality exposure therapy was reported to be particularly effective for reducing depression caused by fear. The meta-analysis revealed a moderate effect size of the game interventions for depression therapy at post-treatment [d = −0.47 (95% CI −0.69 to −0.24)]"

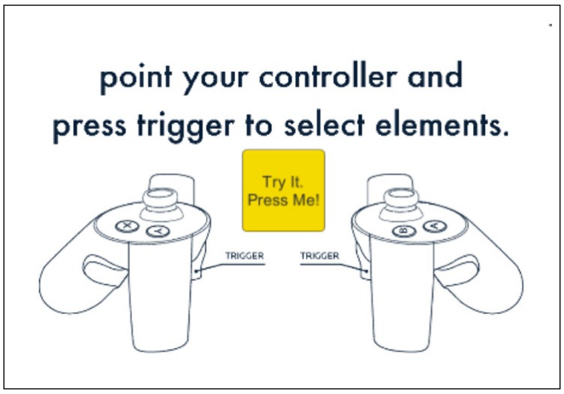
B Protocol Instruction Outline

B.1 Stage I

Instructions in Stage I are presented through a series of slides covering (1) how to interact with the VR platform and (2) an introduction to Self-Attachment Theory and how the therapy works.

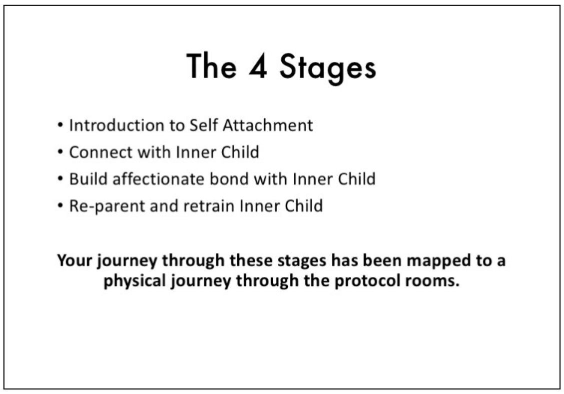


Slide 1

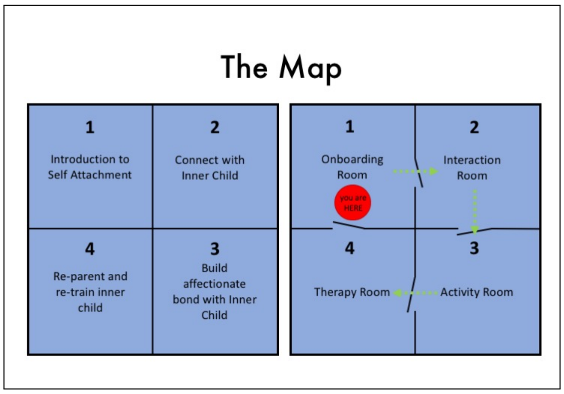


Slide 2

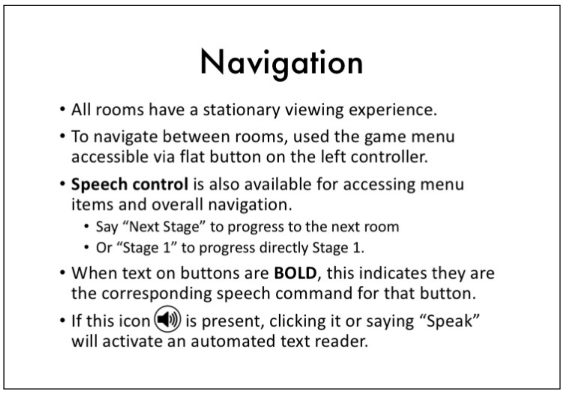
Slide 3



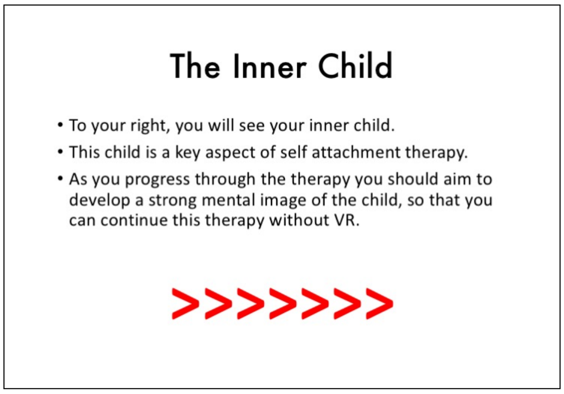
Slide 4



Slide 5

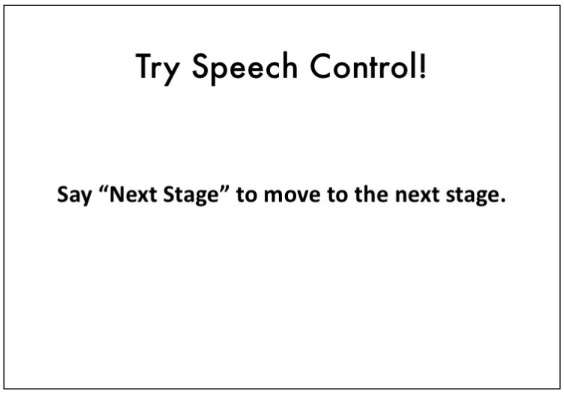


Slide 6



Slide 7

Slide 8



Slide 9

B.2 Stage II

Select an activity to encourage bonding with your inner child.

B.2.1 Happy

1 REFLECTION: Recall a happy memory from your childhood.

2 REFLECTION: Focus on why events had a positive effect on you.

3 REFLECTION: What was the role of your primary caregiver in the events of this memory?

4 REFLECTION: How did your primary caregiver exhibit good parenting?

5 REFLECTION: How did this experience make you feel as a child?

6 REFLECTION: What compassionate behaviours exhibited by your caregivers would you also adopt?

B.2.2 Sad

1 REFLECTION: Recall a sad memory from your childhood.

2 REFLECTION: Focus on why events had a negative effect on you.

3 REFLECTION: What was the role of your primary caregiver in the events of this memory?

4 REFLECTION: How did your primary caregiver exhibit poor parenting?

5 REFLECTION: How did this experience make you feel as a child?

6 REFLECTION: What negative behaviours exhibited by your caregivers would you avoid?

7 REFLECTION: How would you have liked your primary caregiver to have responded instead?

8 REFLECTION: How would you, in the role of a primary caregiver, have responded in this situation?

B.2.3 Cuddle

1 In this activity, focus on having compassion for your inner child.

2 REFLECTION: The child is distressed. How would you offer compassion verbally?

3 ACTION: Offer the child your chosen words of comfort.

4 REFLECTION: The child is distressed. How would you offer compassion physically?

5 ACTION: Wrap your hands around the child to offer it a comforting embrace.

6 Congratulations. The child has been successfully consoled.

B.3 Stage III

Stage 3 protocols aim to establish a passionate and loving relationship between you and your inner child. In practicing these protocols, you should aim to habituate them into your daily life so your relationship with the child can alleviate negative feelings.

B.3.1 Self-Massage

1 In this activity, follow the techniques shown to perform self-massage.

2 When performing the massage, imagine you are having a physical interaction with the inner child. Focus on building an affectionate bond.

B.3.2 Happy Singing

1 As you sing along to your chosen happy song, imagine you are forming a deep affectionate bond with the inner child.

2 Feel free to move your body to the music. Imagine you are engaging in a loving dialogue with the child, building a bond.

B.3.3 Sad Singing

1 REFLECTION: Focus on any negative emotions you are feeling, or felt as a child.

2 As you sing along to your chosen happy song, imagine you are forming a deep affectionate bond with the inner child.

3 Feel free to move your body to the music. Imagine you are engaging in a loving dialogue with the child, building a bond.

B.3.4 Dance

1 As you dance along with the child, focus on relaxing your body and moving with the music.

2 Imagine you are engaging in a loving dialogue with the child, building a bond.

B.3.5 Pledge Your Love

1 In this activity, a ceremonial pledging of love to the inner child will be performed.

2 REFLECTION: How would a devoted and loving parent provide care and support to their child?

3 REFLECTION: What kind of commitments would you have wanted your primary caregiver to have given you as a child?

4 REFLECTION: What kind of caring behaviours would you like to promise to engage in and provide to the child?

5 ACTION: Loudly and solemnly pledge your love and commitment to the child.

6 REFLECTION: What does this promise of care and support mean for the child?

7 REFLECTION: What does this promise of care and support mean for you as an adult?

B.4 Stage IV

Stage 4 consists of six sub-protocols that when practiced regularly aim to re-train and re-parent the inner child, so that you can learn to better regulate emotion in stressful situations.

B.4.1 Type A: Process Past Trauma

Recall a traumatic event from your past you would like to revisit. Focus on how your child self interpreted events and how you would have liked your parental figures to have supported you instead.

1 REFLECTION: What support would you have wanted as a child?

2 REFLECTION: How can you offer compassion verbally?

3 ACTION: Offer the child your chosen words of comfort.

4 REFLECTION: How can you offer compassion physically?

5 ACTION: Wrap your hands around the child to offer it a comforting embrace.

6 Congratulations. The child has been successfully consoled.

B.4.2 Type B: Process Current Trauma

Reflect on any negative emotions you are currently experiencing. This could include anger, fear, anxiety, depression in relation to family, friends, work, education or social affairs.

1 ACTION: Project your negative emotions onto the child. Imagine that the child is experiencing your current trauma.

2 REFLECTION: In your position as your adult self, how would you attempt to console the child verbally.

3 ACTION: Console the child verbally.

4 REFLECTION: How would you offer compassion physically?

5 ACTION: Wrap your hands around the child to offer it a comforting embrace.

6 Congratulations. The child has been successfully consoled.

B.4.3 Type C: Create Zest for Life

1 In this activity, the image of you in the mirror is that of the inner child. This allows you to better imagine yourself as being the inner child.

2 The child can mirror basic actions that you can perform. Try it! Raise and lower your right hand above and below your head.

3 In this activity, you should begin to sing your happy song. Move and shake your body along to engage in a physical connection with the child.

4 If you move your arms from side to side, as the child is demonstrating now. Your 'reflection' will dance along too!

5 Integrate these singing and dancing behaviours into your everyday life. It should be as though you are regularly having fun with the child.

6 In particular, these happy activities should become a tool for you to tackle negative emotions, habits and addictions.

B.4.4 Type D: Gestalt Therapy

1 Gestalt Therapy is an experiential therapy that emphasises personal responsibility and focuses on experiencing the present moment.

2 It encourages self-regulation and adjusting our perspectives toward a more positive interpretation of different experiences.

3 The Gestalt Vase shown here can be interpreted as a vase of dark and negative emotions.

4 Alternatively, it can be interpreted as two faces looking at each other, representing the intimate bond between inner child and adult self.

5 In this activity, focus on transforming negative emotions into positives by recalling the powerful pattern of love built with the inner child.

6 Click the screen to toggle between different interpretations of the Gestalt vase. Reflect on how you can positively re-frame your experiences positively.

B.4.5 Type E: Outward Socialisation

1 With constant repetition of protocols A, B, C, D you should be able to on the whole reduce negative emotions and increase positive affects.

2 With habituation, you should be able to carry out these protocols outside of VR, integrate them into your daily life.

3 ACTION: Try to extend the compassion you have developed for your inner child toward others.

4 Try to be aware of the narcissistic tendencies and anti-social feelings of the inner child i.e. envy, greed, hatred, mistrust and revengeful feelings.

5 ACTION: Be a good parent. Discourage the inner child from acting on negative emotions through an inner dialogue.

6 ACTION: In being a good parent, continue to express affection towards the inner child.

B.4.6 Type F: Optimise Internal Working Model

1 REFLECTION: How have some of the inner child's negative schemes of thoughts and feelings directly stemmed from your parents?

2 REFLECTION: How have some of the inner child's negative schemes of thoughts and feelings developed in interaction with your parents?

3 ACTION: When practicing Type B protocols to reduce negative emotions, try to find the roots of these emotions in your family background and childhood relationships.

4 This should help you become aware of the nature and character of your internal working model, how it is shaped and how it works.

5 As you grow in emotional maturity through therapy, you should no longer need to see yourself as a prisoner of early relationships and the feelings and emotions originating from them.

6 With the assistance and support of the adult self, it is possible to create a more optimal internal working model for interpreting and managing our relationships with others.

C User Feedback

C.1 Usability Data

C.1.1 Questionnaire

1 How intuitive did you find the controllers to use and click with?

1 2 3 4 5 6 7 8 9 10

2 How much ownership did you feel over the virtual hands in the scene?

1 2 3 4 5 6 7 8 9 10

3 How intuitive is navigating the platform?

1 2 3 4 5 6 7 8 9 10

4 How realistic was the VR environment?

1 2 3 4 5 6 7 8 9 10

5 Would a more realistic VR environment have improved the experience?

Yes No

6 How effective was the cuddling interaction with the child as a simulation of a real hug?

1 2 3 4 5 6 7 8 9 10

7 How useful was the text to speech functionality? Would you use it regularly?

1 2 3 4 5 6 7 8 9 10

8 How useful was the speech recognition functionality? Would you use it regularly?

1 2 3 4 5 6 7 8 9 10

9 How important is the ability to navigate around the scene beyond a few steps? i.e. joy stick navigation.

1 2 3 4 5 6 7 8 9 10

10 How effective was the VR mirror in making you feel as through you were in the child's body?

1 2 3 4 5 6 7 8 9 10

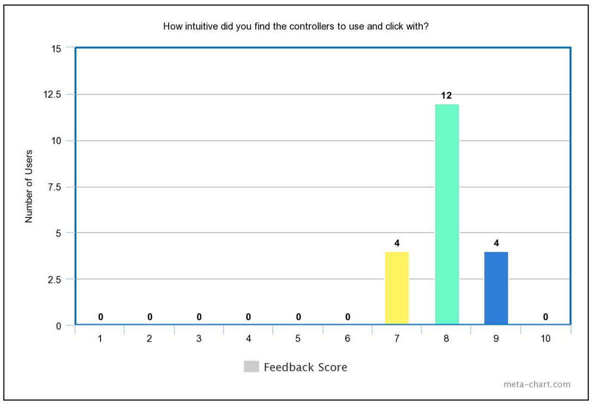
11 Is this your first experience with a VR headset?

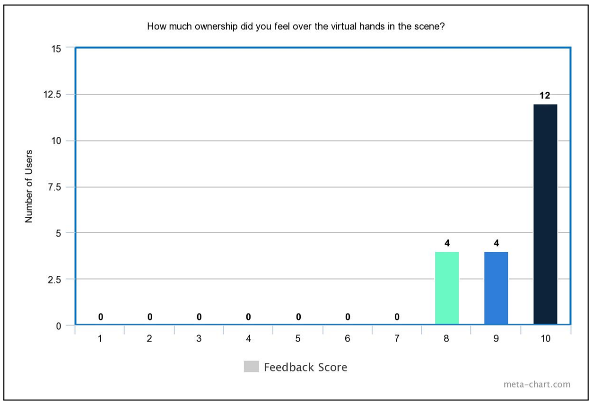
Yes No

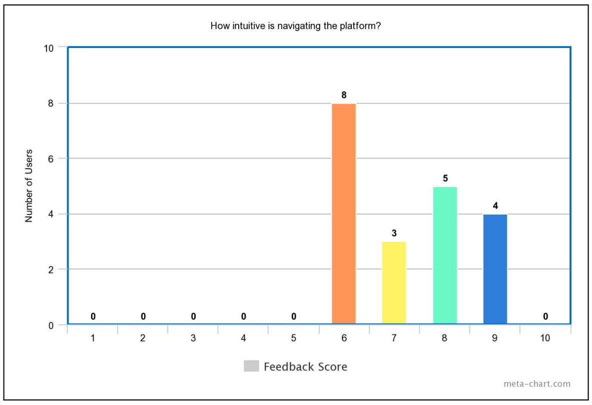
12 Did you experience any motion sickness during or after the session?

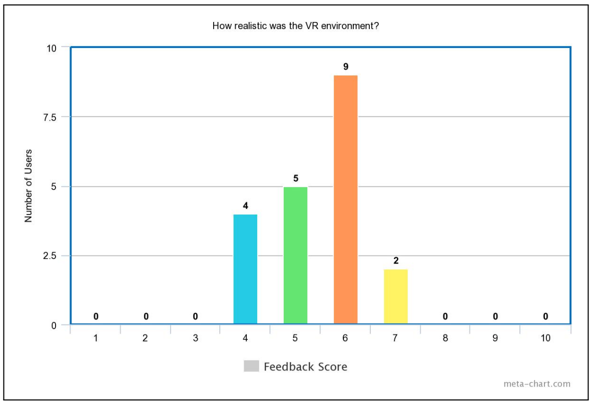
Yes No

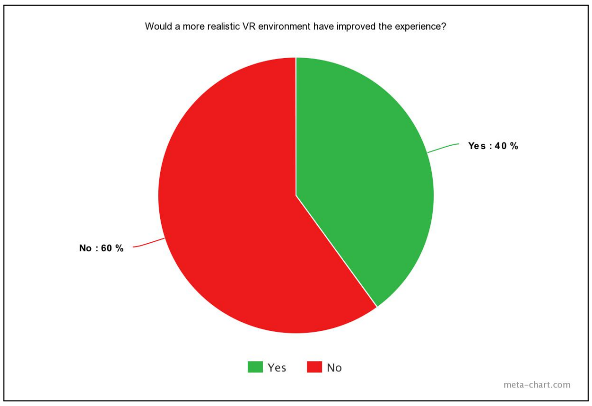
C.1.2 Results

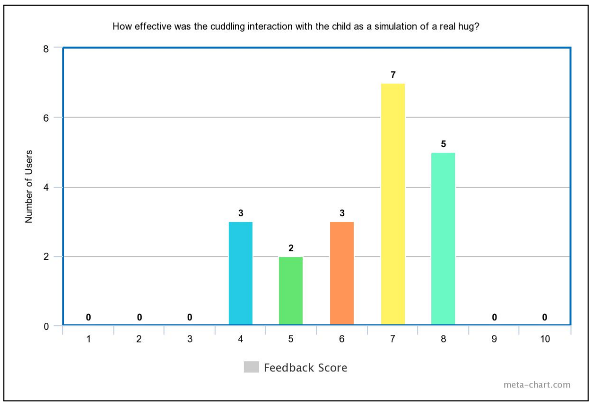

How intuitive did you find the controllers to use and click with?
Number of Users
Feedback Score
meta-chart.com

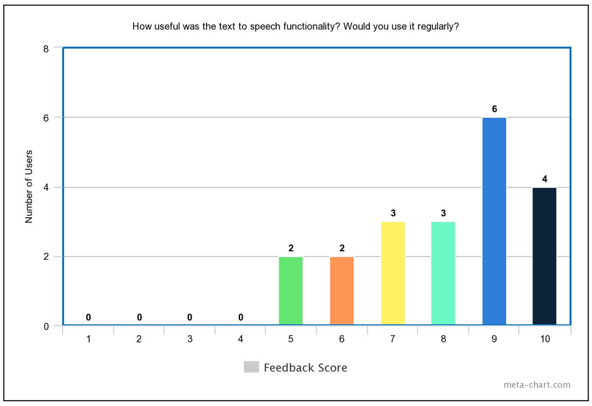

How much ownership did you feel over the virtual hands in the scene?
Number of Users
Feedback Score
meta-chart.com

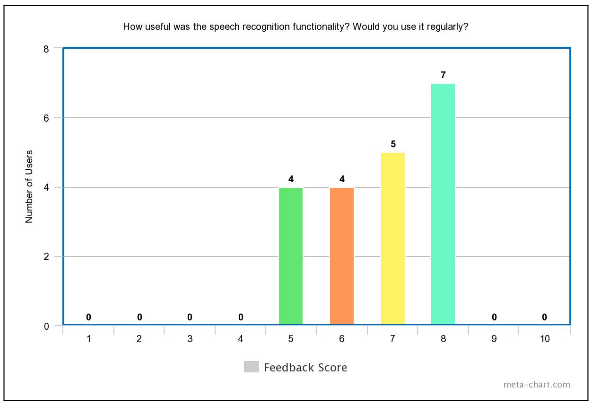

How intuitive is navigating the platform?
Number of Users
Feedback Score
meta-chart.com

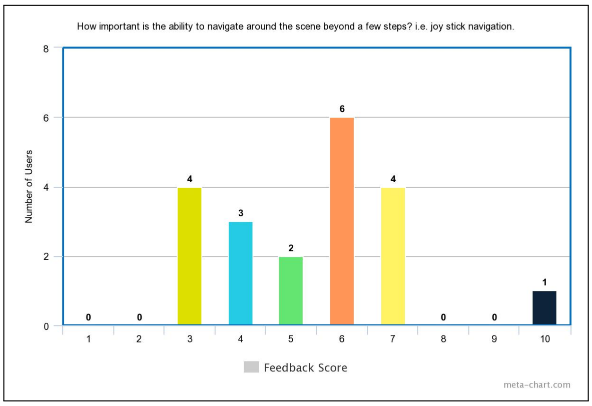

How realistic was the VR environment?
Number of Users
Feedback Score
meta-chart.com

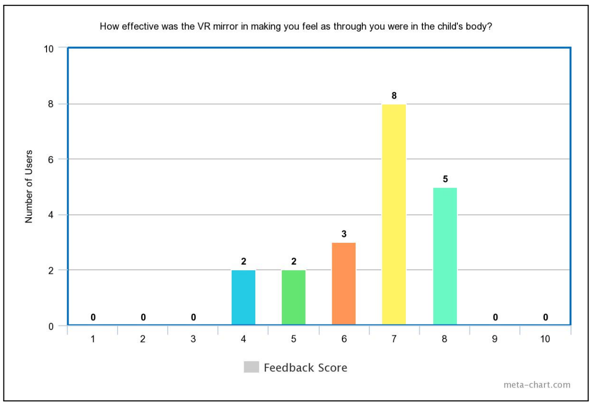

Would a more realistic VR environment have improved the experience?
Yes : 40 %
No : 60 %
Yes
No
meta-chart.com

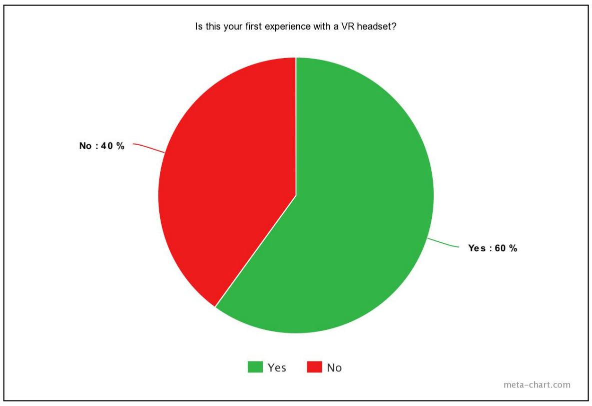

How effective was the cuddling interaction with the child as a simulation of a real hug?
Number of Users
Feedback Score
meta-chart.com

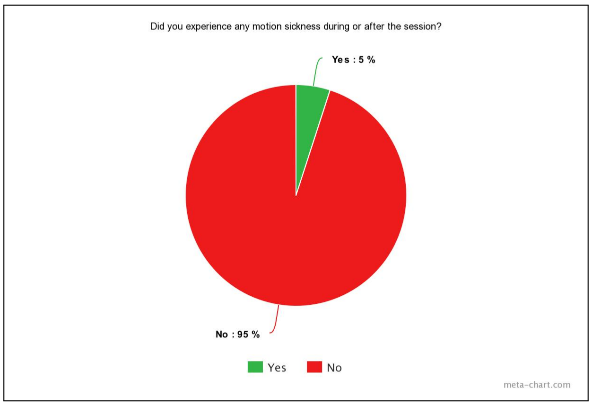

How useful was the text to speech functionality? Would you use it regularly?
Number of Users
Feedback Score
meta-chart.com


How useful was the speech recognition functionality? Would you use it regularly?
Number of Users
Feedback Score
meta-chart.com


How important is the ability to navigate around the scene beyond a few steps? i.e. joy stick navigation.
Number of Users
Feedback Score
meta-chart.com


How effective was the VR mirror in making you feel as through you were in the child's body?
Number of Users
Feedback Score
meta-chart.com


Is this your first experience with a VR headset?
No : 40 %
Yes : 60 %
Yes
No
meta-chart.com


Did you experience any motion sickness during or after the session?
Yes : 5 %
No : 95 %
Yes
No
meta-chart.com

C.2 Before and After Virtual Reality

C.2.1 Before VR Questionnaire

1 From these activities, would you consider administering SAT?

Yes No

2 Did you experience difficulties imagining and interacting with your childhood self?

Yes No

3 Could you see yourself performing these activities as part of your daily routine?

Yes No

C.2.2 After VR Questionnaire

1 After using the VR platform, would you consider administering SAT?

Yes No

2 If yes, would you prefer to perform the therapy with or without VR?

With Without

3 Could you see yourself performing these activities in VR as part of your daily routine?

Yes No

4 Has the VR platform changed how you will imagine the experience if asked to perform SAT without VR?

Yes No

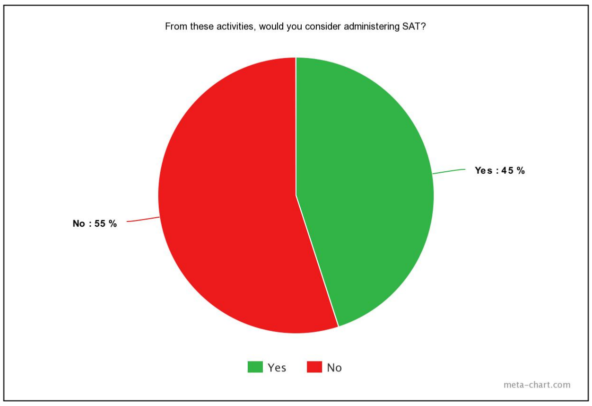
5 Did the likeness of the child affect your ability to project your childhood self onto the VR child model?

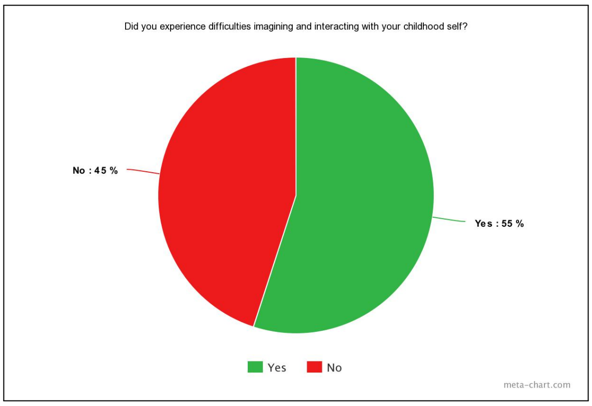
Yes No

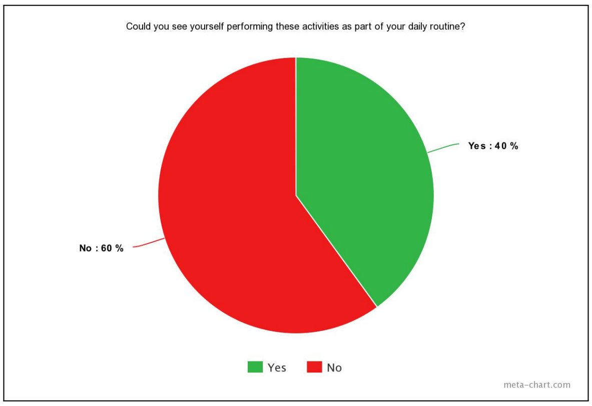
C.2.3 Results

These results were collected from a survey of 20 users.

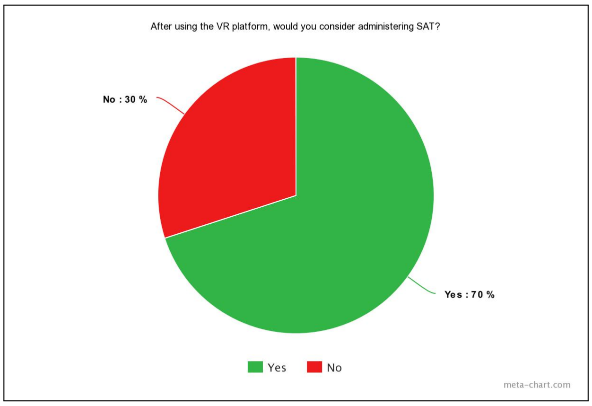
Before VR Questionnaire

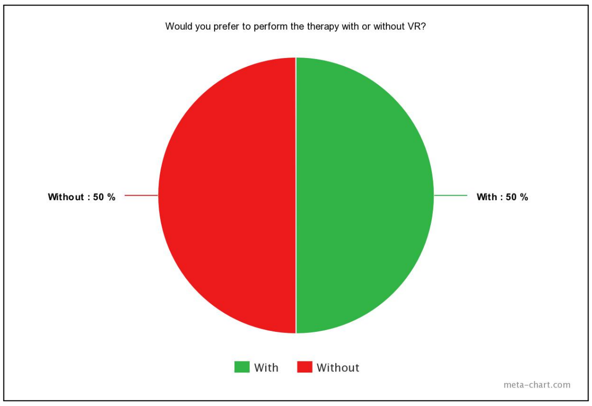


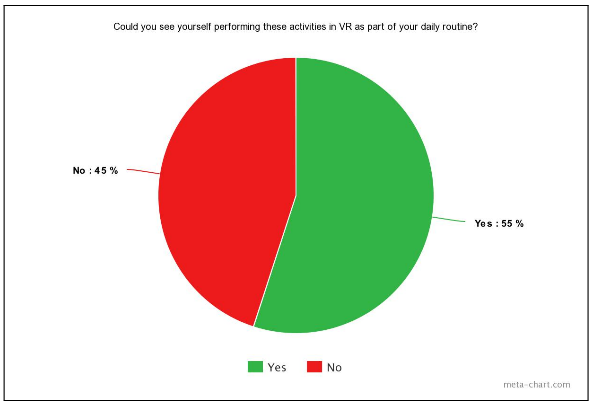


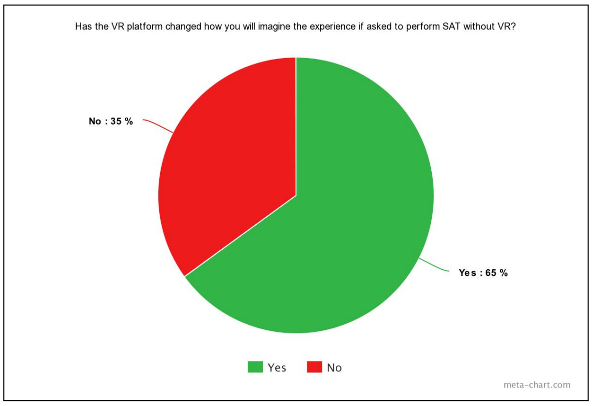


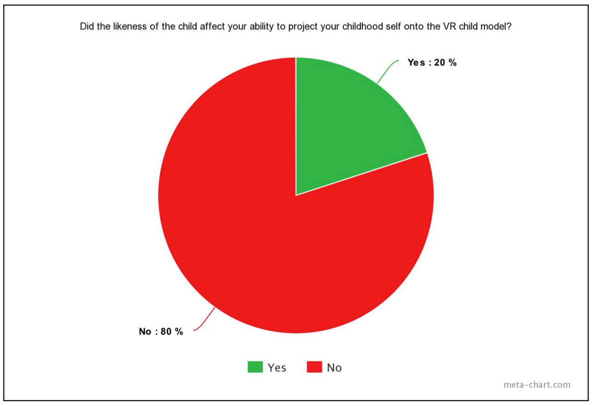
After VR Questionnaire











Bibliography

[1] Banakou, D., and Slater, M. Body ownership causes illusory self-attribution of speaking and influences subsequent real speaking. *Proceedings of the National Academy of Sciences 111*, 49 (2014), 17678–17683.

[2] Baxter, L. J., Schwartz, J., KS, B., and et al. Caudate glucose metabolic rate changes with both drug and behavior therapy for obsessive–compulsive disorder. *Arch Gen Psychiatry 42* (1992), 681–689.

[3] Bliss, T., and Cooke, S. Long-term potentiation and long-term depression: A clinical perspective. *Clinics (Sao Paulo, Brazil) 66* (2011), 3–17.

[4] Botella, C., Serrano, B., Banos, B., and Garcia-Palacious, A. Virtual reality exposure-based therapy for the treatment of posttraumatic stress disorder. a review of its efficacy, the adequacy of the treatment protocol and its acceptability. *Neuropsychiatric Disease and Treatment 15* (2015), 2533–2545.

[5] Botvinick, M., and Cohen, J. Rubber hands 'feel' touch that eyes see. *Nature 391* (1998), 756.

[6] Brody, A., Saxena, S., Stoessel, P., and et al. Regional brain metabolic changes in patients with major depression treated with either paroxetine or interpersonal therapy. *Arch Gen Psychiatry 58* (2001), 631–640.

[7] Chawathey, K., and Ford, A. Cognitive behavioural therapy. *InnovAiT: Education and Inspiration for General Practice 9* (2016), 518–523.

[8] Cittern, D., Edalat, A., and Ghaznavi, I. An immersive virtual reality mobile platform for self-attachment. 1–8.

[9] Corsini, R. *Role Playing in Psychotherapy.* AldineTransaction, 2011.

[10] D, B., PD, H., and M, S. Virtual embodiment of white people in a black virtual body leads to a sustained reduction in their implicit racial bias. *Frontiers in Human Neuroscience 10* (2016), 1 – 12.

[11] Dean, J., and Keshavan, M. The neurobiology of depression: An integrated view. *Asian Journal of Psychiatry 27* (2017), 101–111.

[12] Diemer, J., Alpers, G. W., Peperkorn, H. M., Shiban, Y., and Mühlberger, A. The impact of perception and presence on emotional reactions: A review of research in virtual reality. *Frontiers in Psychology 6* (2015), 1–9.

[13] Diemer, J., Muhlberger, A., Pauli, P., and Zwanzger, P. Virtual reality exposure in anxiety disorders: Impact on psychophysiological reactivity. *World Journal of Biological Psychiatry 15* (2014), 427–42.

[14] Directory, C. Statistics about mental health treatment services, 2016. [Online: accessed June 16, 2018].

[15] Edalat, A. *Self-attachment: A Holistic Approach to Computational Psychiatry.* Springer International Publishing, Cham, 2017, pp. 273–314.

[16] Edalat, A. Self-Attachment: A Self-Administrable Intervention for Chronic Anxiety and Depression. Tech. rep., Imperial College London, Department of Computing, 03 2017.

[17] Etkin, A., Pittenger, C., Polan, H. J., and Kandel, E. R. Toward a neurobiology of psychotherapy: Basic science and clinical applications. *The Journal of Neuropsychiatry and Clinical Neurosciences 17* (2005), 145–158.

[18] Falconer, C., Rovira, A., King, J. A., Gilbert, P., Antley, A., and Fearon, P. Embodying self-compassion within virtual reality and its effects on patients with depression. *British Journal of Psychiatry Open 2* (2016), 74–80.

[19] for Children & Young People, F. Attachment Theory into Practice. Tech. rep., The British Psychological Society, 02 2007.

[20] for Presence Research, I. S. Presence defined, Mar 2016.

[21] for Psychotherapy, U. C. Common types of psychotherapies. `https://www.psychotherapy.org.uk/about-psychotherapy/types/`, 2018.

[22] Freeman, D., Reeve, S., Robinson, S., Ehlers, A., Clark, D., Spanlang, B., and Slater, M. Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological Medicine 47* (2017), 2393–2400.

[23] Fuchs, T. Neurobiology and psychotherapy: An emerging dialogue. *Current Opinion in Psychiatry 17* (2004), 479–485.

[24] Gonclaves, R., Pedrozo, A., Countinho, E., Figueira, I., and Ventura, P. Efficacy of virtual reality exposure therapy in the treatment of ptsd: A systematic review. *PLoS One 7* (2012).

[25] González-Franco, M., Peck, T. C., Rodríguez-Fornells, A., and Slater, M. A threat to a virtual hand elicits motor cortex activation. *Experimental Brain Research 232*, 3 (Mar 2014), 875–887.

[26] Google. Google cardboard. `https://vr.google.com/cardboard/`.

[27] Jones, S. Immersive self-attachment therapy through personalised avatar generation. Tech. rep., Imperial College London, Department of Computing, 06 2018.

[28] Karpman, B. The principles and methods of objective psychotherapy. *Journal of Clinical Psychology 56* (2000), 877–887.

[29] Kilteni, K., Groten, R., and Slater, M. Conversations between self and self as sigmund freud - a virtual body ownership paradigm for self counselling. *Presence: Teleoperators and Virtual Environments 21* (2012), 373–387.

[30] Lenggenhager, B. Video ergo sum: Manipulating bodily self-consciousness. 1095–1099.

[31] LG. Lg 360 vr. `http://www.lg.com/uk/lg-friends/lg-LGR100`, Jun 2016.

[32] Li, J., Theng, Y., and Foo, S. Game-based digital interventions for depression therapy: a systematic review and meta-analysis. *CyberPsychology, Behaviour and Social Networking 17* (2014), 519–527.

[33] Liggan, D., and Kay, J. Some neurobiological aspects of psychotherapy: A review. *The Journal of Psychotherapy Practice and Research 8* (1999), 103–114.

[34] Ling, Y., Nefs, H., Morina, N., Heynderickx, I., and Brinkman, W. A meta-analysis on the relationship between self-reported presence and anxiety in virtual reality exposure therapy for anxiety disorders. *PLoS One 9* (2014).

[35] London, M. H. F. Fundamental facts about mental health, 2016.

[36] Maples-Keller, J., Bunnell, B., Kim, S., and Rothbaum, B. The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders. *Harvard Review of Psychiatry 25* (2017), 103–113.

[37] Martin, S., Martin, E., Rai, S., and et al. Brain blood flow changes in depressed patients treated with interpersonal psychotherapy or venlafaxine hydrochlor- ide. *Arch Gen Psychiatry 58* (2001), 641–648.

[38] Matthews, M., Gay, G., and Doherty, G. Taking part: role-play in the design of therapeutic systems. *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14* (2014), 643–652.

[39] McCann, R., Armstrong, C., Skopp, N., Edwards-Stewart, A., Smolenski, D., June, J., and et al. Virtual reality exposure therapy for the treatment of anxiety disorders: An evaluation of research quality. *Journal of Anxiety Disorders 28* (2014), 625–631.

[40] Meyerbroker, K., and Emmelkamp, P. Virtual reality exposure therapy in anxiety disorders: A systematic review of process-and-outcome studies. *Depression and Anxiety 27* (2010), 933–944.

[41] Motraghi, T., Seim, R., Meyer, E., and Morissette, S. Virtual reality exposure therapy for the treatment of posttraumatic stress disorder: A methodological review using consort guidelines. *Journal of Clinical Psychology 70* (2014), 197–208.

[42] Munnangi, J. Self attachment therapy using virtual reality. Tech. rep., Imperial College London, Department of Computing, 06 2018.

[43] Oculus. Oculus. `https://www.oculus.com`.

[44] of Health, U. K. D. Achieving better access to mental health services by 2020, 2014.

[45] Opris, D., Pintea, A., Garcia-Palacios, A., Botella, C., Szamoskozi, S., and David, D. Virtual reality exposure therapy in anxiety disorders: A quantitative meta-analysis. *Depression and Anxiety 29* (2012), 85–93.

[46] Osimo, S., Pizarro, R., Spanlang, B., and Slater, M. Conversations between self and self as sigmund freud - a virtual body ownership paradigm for self counselling. *Scientific Reports 5* (2015), 1–14.

[47] Parsons, T., and Rizzo, A. Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: a meta-analysis. *Journal of Behaviour Therapy and Experimental Psychiatry 39* (2008), 250–261.

[48] Peck, T. C., Seinfeld, S., Aglioti, S. M., and Slater, M. Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition 22*, 3 (2013), 779 – 787.

[49] Playstation. Playstation vr. `https://www.playstation.com/en-gb/explore/playstation-vr/buy-now/`.

[50] Pollick, F. In search of the uncanny valley. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering 40* (2010), 69–78.

[51] Powers, M., and PM, E. Virtual reality exposure therapy for anxiety disorders: A meta-analysis. *Journal of Anxiety Disorders 22* (2008), 561–569.

[52] Riva, G. Virtual reality in psychotherapy: Review. *CyberPsychology & Behaviour 8* (2005), 220–230.

[53] Riva, G., Baños, R. M., Botella, C., Mantovani, F., and Gaggioli, A. Transforming experience: The potential of augmented reality and virtual reality for enhancing personal and clinical change. *Frontiers in Psychiatry 7* (2016), 1–14.

[54] Riva, G., and Mantovani, A. *Virtual Reality in Psychological, Medical and Pedagogical Applications*. InTech, 2012.

[55] Samsung. Samsung gear vr with controller. http://www.samsung.com/global/galaxy/gear-vr/.

[56] Scan UK.

[57] Schultheis, M., and Rizzo, A. The application of virtual reality technology in rehabilitation. *Rehabilitation Psychology 46* (2001), 296–311.

[58] Serino, S., Triberti, S., Villani, D., Cipresso, P., Gaggioli, A., and Riva, G. Toward a validation of cyber-interventions for stress disorders based on stress inoculation training: a systematic review. *Virtual Reality 18* (2014), 73–87.

[59] Sheridan, T. B. Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Environments 1*, 1 (Jan. 1992), 120–126.

[60] Slater, M., and Sanchez-Vives, M. Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI 3* (2016).

[61] Stein, J., and Ohler, P. Venturing into the uncanny valley of mind—the influence of mind attribution on the acceptance of human-like characters in a virtual reality setting. *Cognition 160* (2017), 43–50.

[62] Stonefox, T. Virtual reality toolkit. https://vrtoolkit.readme.io/, 2017. [Online: accessed June 10, 2018].

[63] Szauer, G. Easy controller selection. https://developer.oculus.com/blog/easy-controller-selection/, 2017. [Online: accessed June 10, 2018].

[64] Troendle, A. The use of virtual reality in psychotherapy for anxiety disorders. the state of the art and the evaluation of its effectiveness. Tech. rep., University of Basel, Department of Psychology, 10 2014.

[65] Tschacher, W., and Pfammatter, M. Embodiment in psychotherapy - a necessary complement to the canon of common factors? *European Psychotherapy* (2017), 9–25.

[66] Unity. Unity asset store. https://assetstore.unity.com/, 2018. [Online: accessed June 10, 2018].

[67] Viinamaki, H., Kuikka, J., Tiihonnen, J., and et al. Changes in monoamine transport density related to clinical treatment: a case controlled study. *Nordic Journal of Psychiatry 55* (1998), 39–44.

[68] Vive, H. Htc vive. https://www.vive.com/uk/.

[69] Weisman, J., and Rodebaugh, T. Exposure therapy augmentation: A review and extension of techniques informed by an inhibitory learning approach. *Clinical Psychology Review 59* (2018), 41–51.

[70] Weisshaar, C. Microsoft windows text-to-speech for unity. http://www.chadweisshaar.com/blog/2015/07/02/microsoft-speech-for-unity/, 2015. [Online: accessed June 14, 2018].

[71] Wilson, M. *Covert Imitation: How the Body Schema Acts as a Prediction Device.* Oxford University Press, 2006, pp. 211–228.

[72] Wittber, S. Uniextensions. https://github.com/simonwittber/uniextensions, 2018. [Online: accessed June 14, 2018].

[73] Zeiss. Zeiss vr one plus. https://www.zeiss.com/virtual-reality/home.html.