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**IMMERSIVE VIRTUAL REALITY
PLATFORM FOR SELF-ATTACHMENT
THERAPY**

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DECLARATION OF ORIGINALITY

I herewith certify that all material in this dissertation which is not my work has been acknowledged.

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ABSTRACT

We have designed, developed, and tested an immersive virtual reality (VR) platform to practise protocols of the Self-attachment psychotherapy for treatment of depression and anxiety. The VR platform consists of both a high-end version based on Facebook's Oculus and a low-end mobile version based on Google's cardboard.

Under the Self-attachment therapeutic framework, the causes of mental disorders are traced back to the individual's insecure attachment with their primary caregiver during childhood. Self-attachment offers a self-administrable protocol in which the user imaginatively creates an internal affectional bond with their childhood self, based on mental imagery, and then simulates optimal parent-child interactions to re-parent the childhood self to emotional maturity, thus earning themselves secure attachment.

The platform offers a complementary visual tool for administering Self-attachment protocols; it enables the user to interact with their customised photorealistic childhood avatar (childhood self). The platform is developed in Unity 3D, a cross-platform game engine, and takes advantage of the itSeez3D Avatar SDK for generating a customised photorealistic 3D avatar head from a 2D childhood image of the user. The platform also offers facial and body animations for some of the basic emotions such as happy, sad, scared and joyful and it allows modifications to the avatar body and clothing colour.

A pilot study to compare the use of the avatar-based approach (VR) to Self-attachment with the conventional photo based approach showed promising results. More than 85% of the participants reported that their photorealistic childhood avatar in VR, in both the high-end version and the low-end version, was more relatable than their ordinary childhood photo. Participants also reported that the high-end version of the VR platform was more realistic and immersive than the low-end mobile version.

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DISCLAIMER

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LIST OF ABBREVIATIONS

SAT:	Self-Attachment Therapy
VR:	virtual reality
HMD:	head mounted display
WHO:	World Health Organization
CBT:	cognitive-behavioural therapy
PTSD:	Post-traumatic stress disorder
CBT:	Cognitive behavioural therapy
VE:	virtual environment
I-CBT:	internet cognitive behavioural therapy
3D:	three dimensional
2D:	two dimensional
PTSD:	post-traumatic stress disorder
SDK:	software development kit
VRTK	virtual reality tool kit
GVR:	Google virtual reality
BDI:	Beck Depression Inventory

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1 INTRODUCTION

Currently there is a global mental health crisis of an unprecedented scale, and conventional, non-digital, methods are unable to respond to it effectively. Existing psychotherapeutic approaches are beginning to harness the power of virtual reality (VR) to enhance their efficacy in treating mental disorders and phobias. Similarly, Self-attachment therapy - a set of protocols which simulates compassionate relationship between a child and a primary caregiver - leverages VR to increase its overall efficacy by enabling the user to role play as an adult and interact with their customised photorealistic childhood avatar in the VR.

1.1 Scope and Motivation

Mental disorders are health conditions which limit a person's ability to function normally in social, professional and family activities; it can impair memory and can cause emotional difficulties [1]. Mental disorders not only impact the individual but also their whole social circle especially their family [2]. Depression is one of the most common disorders worldwide; it is predicted that it will become the largest burden of disease by 2030. Globally, more than 300 million people are affected by depression and it is costing approximately a trillion dollars to the global economy in lost productivity annually [3][4]. A report by NHS states that: "Mental health problems represent the largest single cause of disability in the UK. The cost to the economy is estimated at £105 billion a year – roughly the cost of the entire NHS." [5, p. 4]. The mental health crisis now spans the globe; it is affecting both the developing and the developed countries. Dr. Saxena, Director of the department of Mental Health at the World Health Organization (WHO) has stated that "When it comes to mental health, all countries are developing countries" [6].

Conventional treatments for depression involve medication and/or collaborative face-to-face psychotherapy. Cognitive behavioural therapy (CBT) is one of the most widely practised forms. It involves changing patterns of thought to alter behaviour. It is proven to be effective [7]. The traditional approach to CBT is collaborative, highly structured and needs to be administered by a trained clinician which makes it less cost-effective, limits its accessibility and thus makes it less scalable [8]. In the US there are only 14.7 licensed psychologists per 100,000 people [9], therefore the majority of the patients have to wait for weeks if not months before they can access health care;

this supply problem is further exacerbated in other parts of the world. According to WHO, for 50% of the global population there is only one trained mental health clinician per 200,000 people [10].

There is an urgent need to bridge this mental health accessibility gap via easily disseminable and highly scalable psychotherapeutic tools and techniques. Technology-based intervention has the potential to make digital psychotherapeutic platforms more accessible at a low cost [11]. Internet and mobile-based psychotherapeutic interventions offer a novel solution for the diagnosis and treatment of various mental disorders [12][13]. Internet cognitive-behavioural therapy (I-CBT), offers patients online access to CBT related resources such as psychoeducational material, information on exercises and standardized worksheets. I-CBT saves time and is cost-effective both for the patient and the psychotherapist, as, in most cases, they are required to spend less face-to-face time per patient [14].

1.2 Clinical Applications of Virtual Reality

Availability of low-cost consumer grade VR systems has accelerated the development and testing of novel VR-based psychotherapeutic interventions. Virtual Reality is also beginning to be explored as a way to enhance the efficacy of various psychotherapies [15][16]. Using VR, we can create and deliver highly realistic and immersive environments customised for specific psychotherapeutic intervention; furthermore, clinicians can control stimulus conditions which are costly and difficult - if not impossible- to achieve in the physical world. Clinical Virtual Reality applications are being investigated for treatment of phobias [17][18][19][20], paranoid delusions [21], posttraumatic stress disorders (PTSD) [22], chronic pain [23][24], eating disorders [25] and cognitive rehabilitation [26]. Virtual reality enables treatment specific customisations of the Virtual environments (VE). For example a customised VE could be designed to make acrophobic people experience different levels of heights in the VR. Similarly, environments could be customized to include treatment specific stimuli, interactivity and embodiment.

Use of virtual reality has shown promise in enhancing the efficacy of various psychotherapeutic techniques to tackle common mental disorders such as depression and anxiety. Shah et al. [27] investigated the effects of a 3-day (1 hour daily) VR-based stress management program on 22 patients diagnosed with major depressive disorder and bipolar disorder. The stress management program consisted of both 1) a psychoeducation component and 2) a relaxation component (via VR). All the participants reported significantly lower symptoms of depression and anxiety after the 3-day program. The study was conducted in a hospital setting and was carried out by a number of facilitators and

investigators it required face-to-face in-person expert time which limited its accessibility and scalability.

Falconer et al. [28] uses VR to increase positive tendencies (self-compassion) and reduce negative tendencies (self-criticism) in healthy female volunteers who were high in self-criticism. The protocol required participants to first get embodied in an adult avatar body to deliver compassion to a child avatar and then switch the role to be in the child avatar body and receive compassion from the adult avatar. The study consisted of two groups, the first group delivered and received compassion from a first-person (1pp) perspective and the participants of the second group experienced the same protocol from a third person (3pp) perspective. The 1pp group reported greater gains than the 3pp group. The results of the study are promising, and the technique can be applied to treating people, with similar symptoms of increased levels of self-criticism, such as clinical patients experiencing depression.

In another study, Falconer et al. [29] used immersive VR to enable patients with symptoms of depression to practice self-compassion in a simulated environment. First the participant was embodied in a virtual representation of themselves (avatar) to deliver compassion towards a (generic) distressed virtual child (avatar). Then, the participant was embodied in the virtual child and experiences receiving compassion from their virtual self. Each scenario was 8 mins and there were three repetitions of the scenario; nine participants (N=15) reported decrease in self-criticism and depressive symptoms and increase in self-compassion and another four reported clinically significant improvements. The study makes a strong case regarding reduction in depression symptomology via delivering and receiving compassion in the VR. The results of the study are promising and it is from this study that we drew motivation for our work on designing, building and testing the VR platform for the Self-attachment psychotherapy [30].

Our Self-attachment [30] based approach is similar (to some extent) as it also involves delivering compassion to a child avatar. In the Falconer et al. [29] approach, the compassion is delivered to a generic child avatar, which did not have resemblance or relevance to the user undertaking psychotherapy, however, in the Self-attachment based approach the compassion is delivered to the user's customised self-resembling photorealistic childhood avatar. Also re-parenting protocols [30] include pleasurable activities such as dancing, messaging and singing which may promote the reward hormones and decrease the stress hormone [31][32].

1.3 Self-attachment Therapy

Self-attachment is a new, self-administrable, attachment-based psychotherapy which starts from the premise that at the root of many affect dysregulation, mood and anxiety disorders is a suboptimal attachment experience during early childhood [33][30][34]. Showing success in initial preclinical trials, the therapy aims to stimulate the release of oxytocin and dopamine naturally in order to promote neural plasticity in key attachment related areas of the brain, in order to enhance the individual's capacities to self-regulate their emotion. This is achieved by the application of a number of attachment-based protocols involving, for example, the mental simulation of interactions with a good care giver [35].

Application of these protocols supplies the individual with the unconditional affection and love that characterises secure forms of attachment and provides scaffolding for the development of mental resilience and overall emotional well-being. Under the Self-attachment paradigm, the individual undergoing therapy is conceptualised as comprising both a child self and adult self. The child self corresponds to the emotional self that becomes dominant under stress, whereas the adult self relates to the more rational part of the self, dominant under times of calm and low perceived threat.

The aim of the therapy is to create a secure attachment and affectional bond between the adult self and child self in order to enhance the capacity for emotion regulation within the individual and this is achieved using techniques such as mental imagery, which has the capacity to evoke emotional responses at neurophysiological and subjective levels and has been utilised in a wide variety of psychotherapeutic contexts [35][36].

1.4 Thesis Objective and Summary of Contributions

The aim of my research is to:

- 1) Develop and extend ideas from recent research literature on virtual reality technologies and investigate their application to treating mental disorders especially depression and anxiety.
- 2) Design, build and test following two versions of an Immersive Virtual Reality Platform to administer protocols of the Self-attachment therapy:
 - a. High-end version based-on Facebook's Oculus platform.
 - b. Low-end mobileVR version based-on Google's Cardboard platform.
- 3) Conduct Usability Evaluation of the high-end version of the VR platform for SAT.

- 4) Conduct a pilot study to determine whether users find their customised photorealistic avatars more relatable than their ordinary photographs in both the high-end and the low-end versions of the platform.

1.5 Structure of the Thesis

Subsequent chapters are organised as follows: Chapter 2 discusses related work on VR for mental health, and Chapter 3 explains Self-attachment therapy and its protocols. The platform's design and implementation are presented in Chapter 4. The results of a pilot study, to investigate whether avatars in VR are more relatable than photos for administering Self-attachment protocols, are discussed in Chapter 5. Chapter 6 concludes this thesis with a discussion on the contributions, limitations, and future work.

2 BACKGROUND

This research involved building an immersive, interactive and scalable virtual reality platform prototype for Self-attachment psychotherapy to treat patients with symptoms of chronic anxiety and depression. Therefore our interest lay in design, implementation and testing of a customised environment which could be used to practise protocols of the Self-attachment therapy. As a first step we discuss some of the widely practised conventional psychotherapies and their evolution after the revolution in traditional information and communication technologies; then we discuss how recent advances in virtual reality technology have fuelled the growth of novel virtual reality based therapies. We further consolidate impact and important findings from each of these platform in a taxonomy section at the end of this chapter.

2.1 Conventional Approaches to Treating Mental Disorders.

There are several evidence-based approaches to treating mental disorders such as medication and psychotherapy. Anti-depressant medication balance neurotransmitters in a person's brain which eventually improves their mood and emotion, however, it is frequently reported that stopping medication can cause the symptoms to reappear [37]. Medication is thought to be addictive and it is popularly believed that it can take a serious toll on alertness levels. However, evidence also suggests that a combination of both the medication as well as the psychological therapy could be useful in treating psychiatric illnesses [38]. Generally, patients experiencing depression and/or anxiety often prefer psychotherapy over medication [39]. Therefore, in this section we explain evidence-based psychotherapeutic treatments and their evolution, especially how they are harnessing advances in technology to enhance their efficacy and accessibility.

There are a number of established psychotherapies such as cognitive behavioural therapy (CBT), psychodynamic therapy, compassion focused therapy, interpersonal therapy and mindfulness-based cognitive therapy. One of the most widely practised approaches is the Cognitive Behavioural Therapy - a highly-structured talking therapy which can positively alter the patient's thinking and behaviour. Typical CBT treatment can have between 5 to 20 weekly or bimonthly sessions, and each session lasts for 30-60 minutes [40]. It is based on the premise that most of our behaviours are driven by our thoughts, and therefore, we can change our thoughts to change behaviour. A trained clinician helps

the patient change their unrealistic unhelpful thoughts, beliefs and behaviours. In the long-term CBT can improve emotional regulation and can further equip the patient with stress/anxiety coping strategies which can be used in everyday life even after the treatment has finished. CBT is as effective as the pharmacotherapy; it may also be helpful in cases where medication is not effective [12].

CBT intervention involves learning to set realistic goals, stress and anxiety management techniques and also engaging in pleasurable activities such exercise and/or social activities; it is time-efficient in comparison with other talking therapies. During therapy patients also learn to keep track of their feelings, thoughts and behaviours and also gradually learn to challenge their negative thoughts, behaviour and actions [8]. The patient also learns the relationship between cognition, emotion and their behaviour and how it contributes to their illness. CBT is one of the most popular and established psychotherapies and has proven to be effective for a number of mental disorders [41][42].

Other effective talk therapies include psychodynamic and interpersonal therapy. Psychodynamic therapy (PT) aims to relieve distressing and unhelpful symptoms. The goals of psychodynamic therapy is to enable patients to increase their understanding of self and others and also to help them learn how to avoid distressful thoughts and feelings. It explores impacts of the past events on the current state of the patient; it can also help people cope with relationship issues as well as the demands of shifting roles [43]. Another effective psychotherapy is exposure therapy in which the patient learns to confront their fears. The individual usually avoids feared object, situation, or activity. As part of the therapy the clinician ‘expose’ the individual to the fearful situation/event to help them develop resilience.

Interpersonal therapy (IPT) takes a similar approach but it also combines elements from CBT and other relevant techniques. IPT focuses on established interpersonal issues; IPT is based on the idea that psychological symptoms (e.g. depression) are often due to our inability to effectively interact with people around us, therefore, we can curtail symptoms by developing capacities to effectively interact with others. It helps the patients identify unhelpful thoughts and techniques to cope with them and eventually change their behaviour [44]. Furthermore, social interventions such as peer support, group-based activities and exercise are also effective in treating depression. It can be tailored to groups and has the potential to decrease population-level depression [45].

In summary, evidence-based psychotherapies are a viable alternative to pharmacotherapy and are helpful in reducing/eliminating symptoms of various mental disorders, however, most of these interventions require in-person psychotherapist time which limits their accessibility and scalability. There is an acute shortage of trained clinicians even in developed countries like the USA and UK, therefore, many patients do not get the required treatment. Patients refrain from seeking mental health services due to their inability to recognize mental health problems, long wait times, social stigma, reluctance to seek help, physical disability, cost of travel and treatment. Conventional, non-digital, psychotherapeutic intervention is unable to respond effectively to the scale of the global mental health crisis. Therefore, to address these issues there is a need for technology-mediated psychotherapeutic interventions which we discuss in the following section.

2.2 Information Platforms for Mental Healthcare.

Psychotherapy is one of the most effective and widely practiced techniques to combat mental health issues. Most of the psychotherapeutic approaches rely on sessions administered by a trained mental health professional. There is an acute shortage of trained mental health professionals globally. Often at times the patients have to wait for months to begin their treatment. To fill this void, mental health service providers are increasingly leveraging internet and information & communication technologies to provide psychoeducation and do online diagnostics/assessment. In this section we discuss evolution of technology in psychotherapy; how in the beginning it was only used for information dissemination and educational purposes and how gradually it evolved to offer full scale web-based treatment to mental disorders.

Initially the role of technology in psychotherapy was limited to digitization and information dissemination of treatment manuals, health education and history taking questionnaires. Web-based platforms made digital content pertaining to psychotherapeutic treatments available to patients in the hard to reach areas. In many cases online availability of psychotherapeutic content saved patient's visit to a psychotherapist and hence decreased their treatment cost. As the internet expanded the information became more accessible to an even greater number of people. Demand for trained mental health professionals and clinicians kept growing and there was an ever increasing need to make the psychotherapeutic procedures efficient to cater to the needs of a growing number of patients. Eventually the first computerized CBT was developed and offered in 1982 [46]. Usually the face-to-face CBT consisted of 20 sessions over a 12-week period, however, the computerized CBT was a 6 week long psychoeducational therapy program consisting of 6-8 sessions; each session lasted between

40-50 mins. Patients interacted with a virtual therapist. They could listen to an automated voice and could type in their responses. Furthermore, each session started with the Beck Depression Inventory (BDI) questionnaire [47]; feedback was also shared with the patient if there were any significant change in BDI score of the previous session. Through these sessions patient's got to learn about the CBT paradigm. The program also included homework exercises between the sessions.

Digital psychotherapeutic tools have the potential to bridge this treatment gap. It is through technological intervention that we can make the treatment accessible to a greater number of people at a much lower cost and waiting time. State of the art digital psychotherapeutic tools - which include computer software or web-based and mobile phone apps – not only offer psychoeducation but also can be used for diagnoses, assessment and treatment. Moreover using digital platforms avoids the social stigma associated with seeking mental health treatment [39]. There is a range of digital mental health treatment options available such as web-based psychoeducation systems, interactive voice response (IVR) systems, advanced interactive chat-bots and other virtual conversational agents, virtual reality exposure therapy platforms, and mobile phone based systems. Additional platform features include generic support via asynchronous text messaging, voice calls and interactive sessions with trained clinicians. Many platforms provides therapist contact however the number of sessions and the time per session varies based on the type of issue addressed as well as on a case to case basis [48]. Many of the studies have progressed until the prototype phase which is usually followed by a small scale trial. Some of these systems are now described.

“Beating the Blues” [49][50] is a web platform which offers computerized cognitive behavioural therapy for patients with symptoms of mild and moderate depression. It consists of 8 video sessions of 50 minutes each. Each video session also requires the patient to perform certain follow-up task(s) before continuing to the next video. By the end of the treatment the patients develops the ability to be more compassionate and less critical towards themselves. Similarly, “Living life to the fullest” [51][52] is another web based platform for cognitive behavioural therapy; it consists of customized audio-recorded lectures and slides on topics such as ‘regaining confidence’, ‘be happier’ and ‘coping with your problems’. These are intended to help the patients improve their mental wellbeing, by helping them change their thoughts and eventually their behaviour. MoodGYM is one of the most wide practiced free-to-use computerized CBT program with 850,000 registered users [53]. It consists of 5 sessions, each 1 hour long, usually conducted on a weekly basis. Sessions consist of written text,

animations and interactive exercises and quizzes. The program is based on CBT and helps the user prevent and manage symptoms of depression [54].

Another promising area of research is mobile phone based well-being apps for treating mental disorders. Currently, thousands of mental health apps are available on the market [55] mostly for the general population. These treatments are more accessible, less structured, and less time-consuming and offer anonymized treatment allowing patients to avoid the social stigma associated with seeking mental health treatment. A review by Anna et al. [55] identified 117 applications (on Google Playstore and Apple Appstore) offering CBT and behavioural activation based treatments but unfortunately the majority of these apps don't include all the core ingredients of a CBT or a BA program and haven't been evaluated scientifically for their efficacy. Given the scale of the mental health crisis, smartphone intervention has the potential to remove barriers to care and alleviate suffering for millions of people with mental disabilities at a modest cost [56]. However, mobile based mental health treatments need further research.

In the 1990s VR technologies were costly and less accessible; high demand for VR based entertainment and games fuelled innovation in VR hardware. This demand further sparked competition between tech giants to produce latest low-cost commercial consumer-grade VR equipment like Facebook's Oculus, HTC Vive and Google's cardboard. Many clinicians are now trying to make use of the state of the art consumer-grade VR technologies to create virtual simulations high reality to enhance the efficacy of various psychotherapeutic protocols [57]. Immersive VR technologies enable the creation of psychotherapy that is specific and highly realistic interactive virtual environments where the assessment and treatment takes place under controlled conditions that are difficult, if not impossible, to replicate in the real world. As one of the main contributions of this thesis involves designing, developing and then testing a novel VR platform for Self-attachment psychotherapy the next section explains how various psychotherapeutic treatments have benefited from VR and how our proposed platform for SAT is different from existing VR platforms.

2.3 VR Platforms in Medical Healthcare.

Technological and web-based platforms have, for a number of years, been used to assist in the administration of various psychotherapeutic treatments [58]. Recent advances in the field of VR have shown promise in the pursuit of devising new techniques for the treatment of a variety of psychological and medical conditions involving phobias, pain, anxiety and depression. Meta-

analyses have shown that individuals undergoing VR based exposure therapy performs better or similar to those undergoing in-vivo treatments -which is often costly and less customisable- for specific phobias [59] and anxiety disorders [60]. Here we review some key platforms which harness the power of VR to treat patients with mental disorders.

2.3.1 Post-Traumatic Stress Disorders (PTSD)

Virtual reality could be used to create immersive environments for patient-specific trauma, which provokes anxiety while the patient is in that environment to make their fear become manageable. VR applications have shown success in reducing PTSD symptoms for returning soldiers from war-ridden areas and for post-road accident victims. Rizzo et al. [22] developed an interactive VR-based exposure therapy tool which allows psychotherapists to immerse post-traumatic stress disorder patients into virtual environments in a controlled, stepwise fashion. This immersive VR platform enables the clinician to control multi-sensory emotional stimuli and monitor the intensity of the patient's stress using brain imaging and psychophysiological assessment.

Rizzo et al. [61] also developed the STRIVE immersive VR platform for stress treatment. Veterans are first exposed to a virtual war-like environment in order to provoke physical, social and emotional stress, and after each war episode a virtual mentor explains the underlying causes and physiology of stress. Then in the second stage physical, social and cognitive exercises utilising Cognitive Behavioural Therapy (CBT) are undertaken. Winer et al. [62] developed a Virtual Reality platform for treating post- traumatic stress disorder (PTSD) symptoms of patients who have undergone a serious motor vehicle accident. The platform consisted of 10 virtual reality exposure therapy sessions which include customizable driving scenarios. The clinician can change the amount and type of traffic, the time of day, the weather conditions such as snow and rain, and specific driving events like speeding and tailgating. All participants who completed the program reported significant reductions in post-trauma symptoms.

2.3.2 Anxiety and Phobias

Fernando et al. [17] used VR to treat anxiety and phobias, with customised virtual environments designed according to the specific type of phobia. The platform, dubbed 'Phobos', also has support for standard CBT treatments. Anderson et al. [63] developed a VR platform to help people overcome their fear of public speaking. The experience consisted of 8 sessions offering 3 different levels of

social public speaking experiences were held in a virtual conference room, virtual classroom or virtual auditorium with 5, 35 and 100+ audience members respectively. Furthermore, therapists could manipulate audience reactions ranging between friendly and hostile; the virtual audience could also pose questions. Their study reported that virtual reality exposure therapy was effective in treating people with public speaking anxiety/fears.

Osimo et al. [64] used virtual embodiment as a method for improving patient mood. They conducted two experiments, for first experiment the individuals were first embodied in a virtual body that closely resembled themselves, from which they described a personal problem to another virtual counsellor body representing (Dr Sigmund Freud or Self). Then the individual was embodied in the counsellor body where they heard the problem and then offered counselling to their virtual self. They again switch to their look-alike avatar body to hear to the counselling offered by the counsellor avatar. The session could be repeated as many times as the participant wanted. Another 10 participants were recruited to see the difference in gains when testing under two conditions i.e. (synchronous or asynchronous (with fixed animations) avatar movements). The study presents interesting findings such as visuomotor synchrony greatly influences the level of ownership and agency experienced by the participants. The proposed virtual embodiment technique result in sufficient detachment from conventional and habitual ways of thinking about problems, and can ultimately be used to create and retain positive cognitive changes.

2.3.3 Acute Pain

Hoffman et al. [24] made use of VR to create a virtual environment containing snow and water, with the aim of relieving burn patients from their pain. The main idea is to immerse the patient in this virtual environment in order to drain their attention resources (which would otherwise be used to process pain signals). The team conducted fMRI brain scans which revealed a significant reduction in pain-related brain activity in response to using the application. This study also revealed another interesting finding, which high-quality VR equipment proved to be more effective in burn-pain reduction than low-quality VR. To study this effect, patients were divided into two groups: 26 were provided with a high-end head mounted displays (HMDs) and 28 were provided with a low-end HMDs. 67% of the participants who were provided with high-quality HMDs reported clinically meaningful reduction (CMR) in pain compared with only 29% of with low-end HMD.

Garrett et al. [65] investigated an application called Virtual Meditative Walk (VMW), an immersive VR environment incorporating sensors and sound, which was intended to help chronic pain patients practice mindfulness-based stress reduction. Patients experiencing pain can see their mirrored version and using VMW they learn to control inner emotional states to reduce pain.

2.3.4 Persecutory Delusions

People with persecutory delusions believe that others around them are trying to cause them harm; to counter the distress caused by this erroneous belief they try to resort to safe-seeking behaviour and often at times they tend to avoid public spaces altogether. This behaviour hinders patients' day to day activity and can cause them unnecessary distress. Freeman et al. [21] used immersive VR technology to treat patients experiencing persecutory delusions by enabling them to test the threat predictions in virtual social environments; 30 patients with persecutory delusions were recruited to experience two scenarios: a train ride and a lift scenario. Results of a randomised controlled trial study of the proposed therapy revealed reductions in delusional conviction and real-world distress.

2.3.5 VR for Treating Depression

Virtual reality (VR) is a computer-generated graphical simulation with which a user can interact. It can make use of various modalities such as sound, vibration, movement tracking and smell to achieve greater levels of immersion. VR has enabled the creation of highly realistic virtual environments, customised for specific psychotherapeutic intervention, to deliver and control stimuli as and when required by the psychotherapeutic protocols to maximize treatment gains [57]. Patients can experience simulations of difficult situations and be trained (gradually) to handle those stressful situations appropriately. It is now being used in a range of clinical applications such as treating anxiety disorders, phobias, PTSD and for acute pain management.

Much of the progress in VR hardware and software is attributed to the gaming industry. More than 230 companies – including Microsoft, Google and Facebook – are involved in research and development of products related to VR [66]. This has reduced cost of consumer grade high-end VR equipment. Availability of low cost high-performance VR has created an enabling environment to develop and test novel VR psychotherapeutic platforms; some significant successes have been claimed recently by VR based psychotherapeutic treatments for a variety of mental disorders [16]. In this section we investigate state of the art VR based interventions for treating patients with symptoms of depression.

Shah et al. [27] investigated the effectiveness of a VR-based stress management program to treat patients with symptoms of major depressive disorders. The stress management program had a psychoeducation component to teach different stress management techniques, positive thinking and relaxation techniques and a VR relaxation component which involved abdominal breathing control, muscle relaxation exercises and relaxing imagery such as a view of a beach. The study was conducted by professional trained clinicians. All the participants reported significantly lower symptoms of depression and anxiety after the program. The study was conducted in a hospital setting and was carried out by a number of facilitators and investigators. It required face-to-face in-person expert time which limited its accessibility and scalability.

Hussain et al. [67] proposed a technique to promote positive emotions and help-seeking behaviour in patients experiencing depression. The protocol involved patients watching 360 videos (in VR) of others who experienced depression, followed by an opportunity to say-out-loud their own experience with depression. The protocol was repeated 5 times, and participants were required to fill in an online survey after the VR session. The whole exercise was to encourage patients to express their thoughts and feelings without worrying about the social stigma associated with seeking mental health support and also to promote help-seeking attitude. Participants generally expressed more positive emotions and help seeking-behaviour after administering the VR protocols.

Gamito et al. [68] harnessed VR technology to investigate whether VR exposure therapy -in comparison to imaginal therapy- can reduce symptoms of depression, anxiety and PTSD. The program consists of 12 sessions. The first session was dedicated to psychoeducation and the remaining sessions were based on three stressful war scenarios. All participants who completed the study reported decreased anxiety and depression and PTSD symptomology. A recent systematic literature review by Freeman et al [69] revealed that the VR-exposure based therapy could be very effective in treating anxiety disorders.

Cai et al. [70] proposed a Virtual-Reality based neurofeedback therapy, in the form of a game, for treating depression. The prototype used three-electrode EEG collectors to record physiological activity of patients (in real-time) which is then fed to a data processing module which computes variables to dynamically change the VR game environment. For example, in a Nature Hike game prototype, changes could be made to sunlight intensity and bird-singing. The idea is to dynamically

control the VR game stimuli to offer various levels of relaxation based on a patient's physiological feedback via EEG measurements. More than 90% of the participants reported the VR game platform to be effective and were willing to use it again.

Falconer et al. [28] employs VR to increase self-compassion and reduce self-criticism in healthy female volunteers who were high in self-criticism. The study found that delivering and receiving compassion, in immersive virtual reality environment, the volunteers can reduce their self-criticism and increase self-compassion. The participants first, embodied in adult avatar, delivered compassion to a child avatar, and then switched role to receive compassion (from adult avatar) while embodied in the child avatar. Furthermore, virtual embodiment also increased self-compassion in participants with tendencies of self-criticism. The study involved two groups: the first group of 24 undergraduate female students who experienced the VR scenario from the first-person perspective. While the other group (N=24) performed same delivering and receiving compassion but from a third person perspective (without embodiment). The participants who experienced from a first-person perspective reported greater positive gains such as reduction in self-criticism and increase in self-compassion. The study presents valuable insights regarding the role VR can play in reducing negative affect and increasing positive affect.

In another study, Falconer et al. [29] used immersive VR to enable patients to practice self-compassion. First the individual is embodied in a virtual representation of themselves in order to deliver compassion towards a (generic) distressed virtual child. Then, the individual is embodied in the virtual child and experiences receiving compassion from their virtual self. Participants undertaking this procedure were found to decrease self-criticism and depressive symptoms, and increase self-compassion. The therapy consisted of three weekly 8 mins sessions and comprised of 15 participants (10 women and 5 men); 4 participants showed clinically significant improvements and another 5 reported reliable improvement. The findings of this study are very promising, and our work is greatly inspired by the results of this trial. The proposed approach is similar to Self-attachment [40] to some degrees, however, there are differences as follows.

In the Falconer et al. [29] approach, the generic child avatar did not have any similarity to the participant undergoing psychotherapy. However, in the Self-attachment based approach [30], the user gets to interact with their customised photorealistic childhood avatar which resembles the user's childhood-self. We postulate that a user's interaction with their own customised photorealistic

childhood avatar can make the protocol more effective because of empathically motivated caregiving behaviour [71]. We also plan to conduct a study to investigate whether the users prefer their customised photorealistic childhood avatars over generic child avatars to administer protocols of the Self-attachment psychotherapy.

Another important difference is that the SAT protocol [30] requires the formation of an ‘affectional bond’ between the adult self and the child self which activates dopaminergic pathways that can make the therapy more rewarding and can therefore motivate the user to continue practicing compassion-focused protocols. Similarly, developmental re-training exercises (protocol 4) [30] include pleasurable activities such as dancing, messaging and singing which are known to promote reward hormones such as dopamine and decrease stress hormones [31][32].

Depression is one of the leading causes of disability worldwide; one in six adults in the UK experience some form of depression or anxiety or both [20]. According to the world health organization, the majority of mental disorders are treatable, however, less than half of the patients affected by these disorders manage to get the required treatment. There is an acute shortage of trained psychotherapists, so much so, that in some cases patients have to wait up to months for an in-person psychotherapy session [10].

The mental health crisis is worsening year after year and it is costing approximately a billion dollar each year to the global economy. Digital psychotherapeutic tools (especially VR) have the potential to address the daunting challenges in mental health, especially in the wake of the COVID pandemic). Recent developments in virtual reality could be leveraged to not only enhance the efficacy of existing psychotherapies, but also to help clinicians develop and test psychotherapeutic procedures on a larger scale. We end this section with a taxonomy of the digital psychotherapeutic platforms for treating mental disorders.

2.4 Taxonomy of the Technology Platforms

Project		
Beating the blues (BTB) [50][51]	Purpose	Web platform to treat mild/moderate depression
	Theory	Computerized Cognitive Behavioural Therapy (CCBT)
	Procedure	Consists of 1 introductory video session followed by 8 interactive video lectures; 50 minutes each
	Findings	Offered to: 829 patients; Opted for therapy: 555 ;Completers: 394 ;Dropouts: 161 = All completers experienced decrease in their symptoms of anxiety/depression = Usually patients require an average of 15 sessions with the psychotherapist, however, those who undertook CCBT via BTB their average decreased to 3.5 sessions
Living life to the fullest [51][52]	Purpose	Web platform to treat mild/moderate depression
	Theory	Cognitive Behavioural Therapy (CBT)
	Procedure	It consists of 8 sessions followed by the 9 th re-union session (6 weeks after the class); one session per week; usually consisting of 90 minutes PHQ-9 (patient health questionnaire); GAD-7; HADS; CSQ-8 (client satisfaction scale);
	Findings	Total patients: 356 Patients were divided in two group immediate access (IC) and delayed access (DA). More than 50% of the participants who completed the program reported improvements.
MoodGym [72]	Purpose	Web platform to treat mild/moderate depression
	Theory	Computerized Cognitive Behavioural Therapy (CCBT)
	Procedure	The study recruited 525 participants; 318 were assigned MoodGYM;

		Mood gym consist of 5 core CBT sessions (1hr each) usually conducted on a weekly basis; sessions consists of written text, animations and interactive exercises and quizzes Measures: PHQ-9; GAD-7; WSAS
	Findings	Most of the participants who completed the study reported decrease in their PHQ-9 scores i.e. decrease in their symptoms of depression.
3: Bravemind [73]	Purpose	Virtual Reality (VR) platform to treat Post-traumatic stress disorder
	Theory	VR exposure therapy (VRET)
	Procedure	13 VR exposure therapy sessions; delivered in 5= to 7 week time. Two customized environments for soldiers returning from Vietnam and Iraq. Measures: DSM-4 (detect mental disorder); CGI; CAPS (to detect/rate PTSD)
	Findings	Total patients offered: 36 32 patients reported improvements; Improvement ranged between 15% to 67%
Strive [61]	Purpose	Virtual Reality (VR) platform to treat Post-traumatic stress disorder
	Theory	VR Platform To develop Pre-deployment stress resilience training
	Procedure	Two customized environments; one for Afghanistan and one for Iraq.
	Findings	Not tested in the real-world yet.
Motor vehicle accident PTSD [62]	Purpose	VR Platform to treat post motor vehicle accident PTSD
	Theory	VR exposure therapy

	Procedure	Virtual reality exposure therapy was administered in 10 individual sessions. Measures: DSM-4; CAPS; PSS-SR; IES-R; BAI; BDI-2; CSQ; SSQ
	Findings	11 participants were offered entry to the program, 6 patients who completed the program reported significant reduction in PTSD symptoms involving re-experiencing and avoidance.
Burn Pain Reduction [24]	Purpose	VR Platform to reduce burn pain
	Theory	VR exposure therapy
	Procedure	Study consisted of 2 sessions i.e. 3 minutes session with VR and another 3 minutes session without VR. Idea: VR environment provides distraction and leaves less attention available for pain processing. Measure: Reduction in pain is measured using subjective pain ratings using GRS (graphical rating scale) on a 0-10 scale.
	Findings	Total Patients: 11 fMRI scans were done for both session with VR and without VR and it was revealed that during VR there was less activity in pain-related areas of the brain. All experienced reduction in pain; some experienced up to 50% reduction in pain. Patients with severe burn pain also experienced 41% improvements
PHOBOS [17]	Purpose	VR platform To treat phobias (height, road crossing, water, darkness, driving, bridges etc.)
	Theory	VR exposure therapy
	Procedure	Customized VR environment for different types of Phobias

		To treat Height phobia they have VR environment which displays an elevator which gradually attains height. Similarly, different environment for other phobias.
	Findings	They are yet to conduct RCT in real-world setting
VR for treating Paranoia [74]	Purpose	Virtual reality platform to treat severe paranoia
	Theory	VR exposure therapy for treating severe paranoia
	Procedure	Consists of 7 therapy sessions; Each session consists of a virtual environment i.e. trains, elevators; Initially there are no human-avatars in the scenes and then gradually avatars are added to the scene. A 20 minutes questionnaire is presented to the users both before and after the therapy to measure progress/impact of the therapy. Measures: PANSS; PSYRATS ; BAI; BDI
	Findings	Total patients: 30 Majority of the patients, especially those who underwent VR cognitive therapy, experienced improvements
VR for mood regulation [64]	Purpose	Virtual Reality platform to improve mood.
	Theory	Virtual exposure therapy
	Procedure	Each participant is embodied in a look-alike avatar; he then shares his/her problem with an avatar of Dr. Sigmund Freud and then get embodied in Dr. Sigmund Freud's avatar and provide solution (or provide counselling) to that problem. This is repeated until the participant wants to stop. Measures: Body ownership and agency questionnaire (ownership; scale 1-7) (POMS) Profile of mood states (measure mood; post-pre exp.)

		SAM (self-assessment manikin) (measure pleasure; scale - 4(saddest) to 4(happiest) SUDS (0-10) for measuring subjective intensity of distress or disturbance.
	Findings	Total patients: 22 (male) Group1: 12 (Self counsellor or Dr. Freud) Group2: 10 (counsellor with synchronous vs asynchronous visuomotor) Group1 first they were embodied in their look alike avatar to share a problem and then switched to the counsellor body (self or Dr. Freud) to first hear to the problem and then present a solution for that problem. Switch back to their body and hear to the solution. Repeat till then want to stop. Group2 counsellor is always Dr. Freud but two embodiment phases (synchronous or asynchronous.) All scores were considerably higher for the synchronous group.
VR for treating mild depression [29]	Purpose	Immersive VR platform to treat mild/moderate depression.
	Theory	Computerized Cognitive Behavioural Therapy (CCBT)
	Procedure	Patients were required to perform following exercises (2 mins each): Stage:1 Adult-embodiment exercise followed by delivering-compassion exercise (facing avatar child avatar). Stage:2 Child-embodiment exercise followed by receiving-compassion exercise (while facing adult avatar). The scenario was repeated weekly for 3 weeks. Measures: PHQ-9; ZungSDS ; DSM-4; BDI; SCCS(self-compassion & criticism scale)
	Findings	Offered to: 18 patients Opted-in: 15 (10 Males, 5 females) The scenario helped patients cope with self-criticism and increase self-compassion; 5 patients showed reliable change

		(5 points decrease in PHQ-9) and 4 showed clinically significant improvement (5 pts decrease and score 9 or less).
VR for treating depression via psychoeducation and relaxation in VR [27]	Purpose	VR platform to treat patients with major depressive disorder and bipolar disorder
	Theory	De-stress program
	Procedure	VR DE-STRESS Program for patients with mood disorders Stage1: Psychoeducation session about stress, stress management, mood disorders, positive thinking and relaxation exercises. Stage 2: VR sessions on relaxation techniques i.e. abdominal breathing, muscle relaxation and guided imagery. Measures: DASS-21 (depression and anxiety); PRS; KSSMQ
	Findings	Study conducted at a mental health ward of a tertiary hospital in Singapore. 26 patients were approached for the study of which (mostly Chinese) 22 completed the trial. The program consisted of 1 hour session every day for three consecutive days. Participants reported decrease in depression and anxiety related symptomology. The relaxation exercises helped reduce stress and increase positive emotions.
360 VR videos for treating depression [67]	Purpose	Immersive VR platform to treat mild/ moderate levels of depression
	Theory	VR-video program to promote self-disclosure and expression
	Procedure	The participants were required to watch 360 videos (in VR) of patients narrating their experience living with depression and then they were required to explain their own experience (out-loud) with depression. The protocol was repeated 5 times.

		Measures: PHQ-9; Positive Negative emotion test [75]; ATSPPHS; Scale to measure behavioral intention to seek help [76]
	Findings	80 participants signed up for the study, only 12 participants were recruited for the trials as others either had either no depression or had severe depression. All completers expressed more positive emotions than negative and were more willing to seek psychological help.
Neuro feedback game for treating depression [70]	Purpose	VR platform for mostly healthy subjects; some under exam stress
	Theory	Neuro feedback VR game
	Procedure	Participant's physiological state is captured using three-electrode EEG collector; EEG data is processed and fed to game engine to dynamically change the VR game experience i.e. to make experience more relaxing for the participants. Measure: All participants were interviewed after the VR experience.
	Findings	12 participants were recruited to test the prototype; 11 reported that the system is effective. Another 8 reported the system to sensitive to their changing state. All of the participants find the platform to be immersive and engaging and agreed that it can help them relax.
VR platform to treat depression, anxiety and PTSD [68]	Purpose	Immersive VR technology to treat patients with symptoms of depression and PTSD
	Theory	Virtual reality exposure therapy.
	Procedure	The trial consist of 12 sessions; each session had three war-related cues like ambush, mortar and evacuation. First session was informative and remaining 11 sessions were exposure sessions (war-related). Measures: BDI; SCL-90-R; CAPS; DSM-4; IES-R

	Findings	10 former military personal were recruited; they were randomly assigned to three groups: VR exposure (5), Exposure in imagination (2) and waitlist control (3). The VR exposure group reported notable decrease in their levels of anxiety, depression and PTSD.
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3 SELF-ATTACHMENT THERAPY

Self-attachment is a new attachment-based psychotherapy that has been proposed as a method for re-training an individual's sub-optimal attachment schema (or internal working model) [30][34]. It has shown success in preclinical trials and is based on the idea that many psychiatric illnesses have their roots in sub-optimal childhood development experiences [34]. It consists of a number of protocols which aim to recreate the effects of positive child-parent interactions using in its place interactions that are fully internalised within the individual.

3.1 Attachment Theory

Attachment theory is a scientific paradigm proposed by renowned British psychologist and psychoanalyst John Bowlby [77] based on his observations of proximity seeking behaviour of a child for his/her primary care-giver, usually a mother. According to the attachment paradigm human beings and other higher primates are born with the inclination to seek proximity with their primary caregiver to feel safe and secure. Similarly, attachment behaviour in adults (primary caregiver) requires that they respond to the child's distress quickly and compassionately [78].

According to Bowlby, the quality of these dyadic attachment experiences during early developmental years forms the foundations of the 'internal working model' or attachment schema - a cognitive framework which enables an individual to understand the world, self and others [79]. This internal working model, he argues, enables an individual to interpret the social world around them and helps in generating expectations and making predictions about social situations which plays a crucial role in their ability to form and sustain relationships.

If a child gets optimal attachment experiences and their social and emotional needs are timely and appropriately met by their primary caregiver, they form a secure attachment schema. Individuals with secure attachment schema are better at affect regulation and more resilient to stressful situations both during their childhood as well as during their adulthood. Conversely, if a child is deprived of positive attachment experiences during their early developmental years they are insecurely attached and therefore are poor at affect regulation and more prone to psychiatric illnesses in later stages of their lives.

Ainsworth proposed that the securely attached child uses their caregiver as a secure base from which to explore the world around them and periodically returning to renew their sense of security and safety. Furthermore, the infants who are securely attached and are sure of their caregiver's availability are more confident in their exploration. According to Julian Ford a 'learning brain' then develops [80]. On the contrary, negative attachment interactions in the early developmental years could traumatize the infant and may make them avoid the primary caregiver altogether, and hence, a 'survival brain' develops.

3.2 Neuroscience of Self-attachment

The premature infant's brain consists of the brainstem and the limbic system (also amygdala), however, it still lacks cortical networks which regulate these regions. A child's proximity seeking behaviour during these developmental years enables him/her to develop these regions via positive attachment interactions. As stated by Cozolino "It is an unfortunate twist of evolutionary fate that the amygdala is mature before birth while the systems that inhibit it take years to develop..... evolution has also provided us with caretakers who allow us to link into their developed cortex until our own is ready" [83, p.253]. During the early development phase the child-caregiver dyadic repetitive interactions contribute to the development of an infant's orbitofrontal cortex, amygdala and hypothalamus which are responsible for emotional processing, social cognition and homeostatic regulation. These regions are believed to enable us to form an affectionate dyad with our primary caregiver and also helps us in the predictions for our interaction outcomes. During early infancy, visual experiences play a crucial role in the social development of the infant. A strong link is formed visually through mutual gaze. It is through this link - between the right brains of both the child and the primary caregiver - that the infant learns to minimize their negative affect and maximize their positive affect. An infant also learns to moderate their arousal levels during this phase. Positive attachment experiences result in the release of high levels of dopamine which facilitates rapid growth of the child's brain, in particular the Orbital Frontal Cortex (OFC) which is involved in memory and emotions [82]. It is through these early interactions that the child develops a schema of their parents and can bear their separation in order to explore the world.

Similarly, if the primary caregiver is avoidant, which could be due to many reasons such as postnatal depression [83], and deprives the child of their affection and unconditional love then gradually the child too becomes disinterested in engaging with them. This severely disrupts the attachment between

the child and the caregiver which leaves the child's social brain - such as Orbitofrontal Cortex (OFC), insular and cingulate cortices, amygdala and hypothalamus - underdeveloped [84]. It further disturbs psychobiological equilibrium which leads to permanent changes in dopamine (reward hormone) receptors. The primary caregiver's neglectful attitude perturb and causes anxiety in the child after which they are not interested to seek social support from their caregiver, therefore, they don't have a secure base which could have enabled them to overcome their fears and give them confidence to explore the world around them and therefore a 'survival brain' is developed [85].

Numerous neuroimaging studies have investigated the neural correlates of attachment in various contexts. Lemche et al. [86] conducted a study to investigate correlation between insecure attachment and amygdala activity levels. The participants were classified as securely or insecurely attached via Adult Attachment Interview (AAI) [87]. They were then shown sentences elaborating neutral or negative attachment experiences and were required to either agree or disagree with the statements while being scanned for fMRI. It was revealed that the amygdala activity was positively correlated with attachment insecurity. Similarly, in another study Riem et al. [88], investigated amygdala activity in women without children when they were exposed to the sounds of a random crying infant. Women with a severe insecure attachment history (as per AAI) showed elevated amygdala activation, and were more irritable and aggressive (when measured with handgrip meter).

Similar responses are seen with other important relationships, Bartels et al. [89] used fMRI imagery to investigate activity in reward circuitry in adults (N=17) who were in passionate romantic relationships. They were required to look at the photo of their partner for 17 seconds while being scanned with fMRI. An increased activity was observed in dopaminergic related brain areas (putamen and caudate nucleus) while the participants were staring at their partners image. In another experiment Bartels et al. [90] recruited mothers (N=20); they were tasked with staring at their child's images, then another child's image who they knew, their best friend and finally staring at an image of an acquaintance (adult). Due to the exposure, increased activity in dopaminergic rich subcortical regions (caudate nucleus and putamen) of the brain was observed in the participating mothers.

There is evidence that humans are capable, rather driven, to form bonds with inanimate objects which are abstract in nature [30] for example in case of infants we observe how they form bonds with transitional objects (primary caregiver's substitute) [91] to feel a sense of security and also to make up for times when their primary caregiver will be absent. There is also evidence that God too could be treated as an attachment object [92]. To this end, Uffe et al. [93] conducted a study to investigate

effects of religious prayers on practising individual's dopaminergic system. The participants were devout Christians, who performed two activities 1) reciting the Lord's prayer and 2) reciting an individual prayer. An increased activity in the dopaminergic region of the brain was observed for all the participants; the results of the study supports the hypothesis that religious prayer is capable of stimulating the dopaminergic system in practising individuals. According to a review by Granvist et al. [92] the concept of religious bonding with God has many parallels with the bonding between an infant and their parents. The God like parents are assumed to be more powerful and wiser than the devotee, and for example can alleviate an individual from any type or magnitude of suffering, and are always available to help an individual in a difficult or distressful time.

The attachment schema (or internal working model) has been theorised to be based in unconscious and implicit memories, rooted mainly in the right-hemispheric brain regions centred on the Orbitofrontal Cortex (OFC), amygdala and hypothalamus [94]; areas known to be central to a range of social cognition and emotional processing functions. In the framework outlined by Rolls [95] the OFC is involved in emotion, (reinforcement) learning and decision making as a result of two primary functions. The first of these functions is its representation of the reward or punishment value of the primarily reinforcing stimuli. A reward is anything that an individual will work to acquire, and a punishment is anything they will work to avoid. For example, good food is positively reinforcing and will increase the probability of an individual repeating the behaviours paired with it innately, without learning. Conversely pain will decrease the probability of repeating associated behaviours. OFC activity responds to many different types of primary reinforcers (including taste, touch, and visual and auditory stimuli). The second function is the OFC's involvement in the learning and reversal of associations between previously neutral stimuli and primary reinforcers, such that these previously neutral stimuli become rewarding or punishing themselves. Rolls argues that emotions are states elicited by reinforcers, defined in terms of the withholding or administration of rewards and punishments (for example, non-delivery of an expected reward might lead to anger, while delivery of a punishment might elicit a state of fear).

Based on existing neurobiological data, Cittern et al. [96] have previously hypothesised that a main effect of the Self-attachment bonding protocols (stage 3) is to associate broad classes of social stimuli that have previously been conditioned as being fearful or threatening in nature with representations of additional, naturally-induced reward which result from the various interactions associated with the protocols. For example directed singing with child self imagery, induces dopamine release. He proposed that these new associations in the OFC should increasingly facilitate endogenous oxytocin

release (associated with a range of bonding and attachment-related behaviours) and restrain the release of corticotrophin-releasing hormone (the precursor to cortisol, the stress hormone) via the strengthening of an inhibitory pathway to the amygdala.

In [71] he considered how the formation of an empathic state with the child self (stage 2) might stimulate neural circuitry, otherwise implicated in the onset of caregiving behaviour, in order to generate motivation for the application of these bonding protocols. Based on data concerning the strength of the empathic response with respect to the perceived innocence and closeness/relatedness of the other, it is proposed that the particular representation used in Self-attachment therapy for the target of this bonding (the child self) would assist in stimulating this motivational pathway.

3.3 Computational Models and Self-attachment

Mental disorders could be modelled as a dysfunctional cognitive prototype. Similarly, psychotherapeutic protocols could be a way to replace those suboptimal prototypes with desired optimal prototypes. Edalat et al. [97][98] considered attachment and behavioural prototypes with respect to patterns (strong) in a Hopfield network. It was demonstrated via simulations that strong patterns give rise to strongly stable attractors, which are patterns that have been stored multiple times compared to simple patterns. The relationship between strong attractors of different multiplicity is discussed, including how a new strong attractor can replace the impact of an existing strong attractor, and how this change (retraining) in the network could act as a model to depict change in attachment types.

In [99], Cittern et al. propose an arousal-based neural model of infant attachment using Deep Belief Networks. The model is an attempt to explain infant attachment behaviour with respect to situations which are strange to the infant, and physiology in a separation and reunion episode. The model focuses on the role of the amygdala and Orbital Medial Prefrontal Cortex in encoding former attachment interactions and their impact on future attachment behaviours such as approach or avoid. The model was able to capture, to a limited extent, the behaviours and physiology, especially arousal reduction, of infants with secure, avoidant, ambivalent and disorganised attachment profiles responding to caregivers with different levels of responsiveness and sensitivity and the infant's ability to regulate their arousal levels.

In another work, Cittern et al. [96] present a neural model, based on a former model by Levine [100], of orbitofrontal cortex arbitrated stress and bonding reactivity to social stimuli. The model attempts to explain how bonding may be strengthened and stress related activity curtailed due to the interactions undertaken as part of the Self-attachment protocol (i.e. Protocol 3). Stress related circuitry releases corticotropin and noradrenaline, whereas, activity in facilitative networks releases oxytocin and dopamine. Therefore, it is contended that additional reward representations emerge due to various activities performed as part of the protocol such as directed singing with the attachment object (child self). A deep belief network was employed to model connectivity between orbitofrontal cortex, basolateral amygdala and feedback networks. It is hypothesized that as the bonding protocol progress it further promotes the release of oxytocin and activation of dopaminergic pathways; it also dampens stress reactivity.

Edalat et al. [101] present a neural model for mentalization-based psychotherapy. The model is based on Neural model for pathways of cognitive decision making proposed by Dan et al. [102] and it integrates a concept of strong (i.e. multiply learned) patterns in neural networks. Furthermore, Q-learning is applied to model the psychotherapeutic processes. The proposed approach models the interaction between orbitofrontal cortex and amygdala to control emotionally influenced heuristic decisions, and coordination between orbitofrontal cortex and dorsolateral prefrontal cortex to mediate deliberate decision making. The decision-type depends on the output of both networks which were implemented using Restricted Boltzmann Machines (RBMs). These networks receive input from the hypothalamus (represented by a Hopfield network) and categorizes six emotions and a mindfulness pattern. The mindfulness pattern becomes more dominant than the negative emotions during psychotherapy and therefore the brain makes a thoughtful decision instead of an emotional one.

3.4 Self-attachment Therapy

Psychological development is hindered if the child's social emotional needs are not met during early developmental years. Individuals with sub optimal childhood development history can show reduced capacity to regulate their affect, especially under stress. There is increasing evidence that sub optimal capacities to regulate emotion is the root cause of many psychiatric disorders [103]. A number of longitudinal clinical and non-clinical studies reinforced the idea that early attachment insecurities are common among people with mild and severe mental disorders [104].

To this end, Abbas Edalat [30][34][105] presents a novel psychotherapeutic paradigm which enables an individual to re-train their sub-optimal attachment schema. The therapy is rooted in the idea that many affect dysregulation disorders have their basis in early insecure attachment experiences [34]. It consists of a number of self-administrable protocols which aim to recreate the positive effects similar to those of optimal infant-parent interactions. Under the Self-attachment paradigm, the individual undergoes therapy roleplay both as an adult self and the child self. The child self corresponds to the emotional self that becomes dominant under stress, whereas the adult self relates to the more rational part of the self, dominant under times of calm and low perceived threat. The individual thus establishes a compassionate relationship with their childhood self and then, using love songs and dancing, creates an affectional bond with them. Their adult self subsequently role plays a good parent and interacts with their imagined childhood self to perform various developmental and re-parenting activities. The goal is to enhance their capacities for self-regulation of emotion, which can lead them into earning secure attachment. The different stages of the Self-attachment are supported by several computational models of the human brain and of associative artificial neural networks [106][71][98][107]. Four stages of the Self-attachment therapy are as follows [30][34].

Protocol 1: Introduction to Self-attachment

In the first stage the individual is introduced to attachment theory, its scientific basis and the underlying hypotheses. The individual is familiarized with the basics of the neurobiology of attachment, love, bond making, emotion regulation, neuroplasticity and long term potentiation. The aim of this phase is to provide the initial motivation to the user for undertaking the therapy so that the individual can commit in terms of time and effort.

Protocol 2: Connecting with the child self

In this stage the individual begins to create a relationship with the child self to establish empathy and ultimately compassion. The user provides a positive (happy) and negative (sad) photograph of their childhood. Several highly-structured protocols are then performed in order to conceptualise the child self as much as possible. These protocols include using the power of imagination (with closed eyes) to visualise that the child (that they were) is now present with them and that they can interact (touch/hold) with this child.

Protocol 3: Building an affectional bond with the child self

During this stage of the therapy an affectional bond is created with the child self, which is subjectively experienced as falling in love with them. The adult self adopts the child self and assures consistent love and support. It is after establishing this affectional bond that the individual can reprocess previously traumatic experiences and re-parent them towards a state in which they are able to self-regulate their emotion(s). In this protocol, the individual (adult self) focuses on the images of the child self and attempts to bond with them, in order to create an attachment relationship. This bonding process is further enhanced with activities such as face-massaging (to mimic cuddling), singing and dancing directed towards the child self which are hypothesised to induce neural plasticity in key attachment-related neural circuitry.

Protocol 4: Developmental re-training and re-parenting of the child self

This stage consists of a number of re-parenting activities (sub-protocols) to emulate an affectionate bond between the adult self and the securely attached child; in order to minimise negative emotions and maximise positive affect. One example is a protocol that involves recalling a traumatic childhood episode and then imaginatively trying to re-experience it in as much detail as possible. Once this state has been recalled, the individual imagines that their adult self quickly intervenes to embrace the child and to vocally (loudly) reassure them. The protocols (re-parenting activities) should be repeated and rehearsed so that the individual is able to integrate them into their routines. The protocols of Self-attachment therapy mostly involves visualisation and imagery because the early attachment between a child and their primary caregiver is formed in the preverbal years, during which the visual senses are dominant over other senses. Therefore, the individual is also encouraged to construct a visually potent picture of the creation of their secure attachment object as they progress through the stages of the therapy. For example, it could be like building a new mansion (depicting secure attachment) which is incrementally constructed to replace a dark and derelict room (depicting insecure attachment). A Quick overview of the SAT protocols is immaculately captured in following Figure 3.1 by our late colleague David Cittern [108].

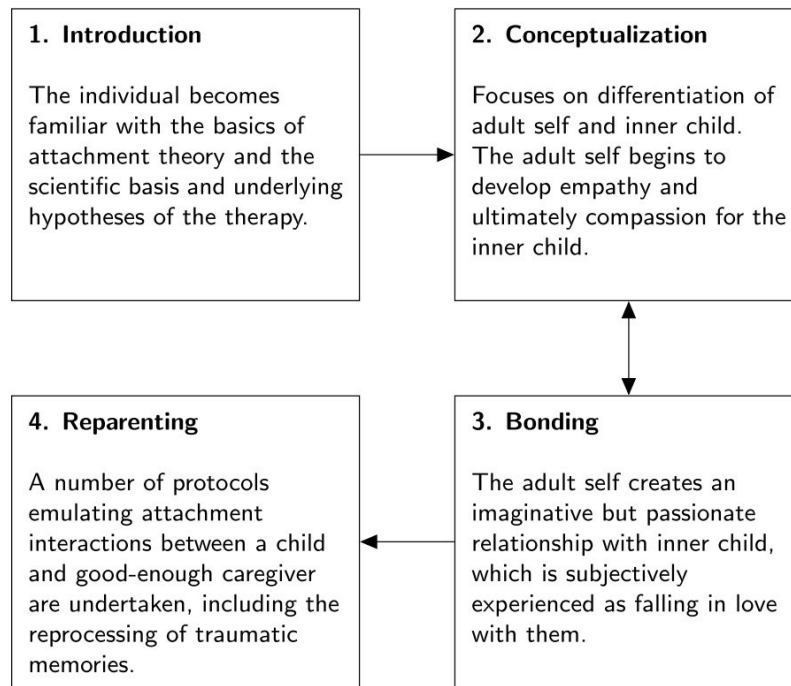


Figure 3.1: Overview of SAT protocols (image courtesy David Cittern [106, pg 100])

Protocol 4 has a number of sub protocols explained in [109] by Abbas Edalat, a brief account of these sub-protocols is as follows:

Protocol 4A: Sessions for processing a painful past

The individual is required to close their eye and recall a painful or traumatic episode from their childhood. Which could be any distressing moment. For example when they were subject to bullying, insults or had to face emotional or physical abuse. All efforts should be made to try to recall the episode in as much detail as possible. When the associated emotion (with the distressing episode) is evoked then the adult self quickly intervenes to comfort the child by embracing him while loudly reassuring their support for the child and then also cuddling the child self by giving themselves a facial massage. It is hypothesized that through these exercises an individual gets to revisit the sub-optimal neural circuits of the distressful episode from the past and tries to replace them with new optimal neural circuits by facilitating oxytocin release. It is recommended to repeat the protocol for as many recallable episodes as possible during the course of the psychotherapy. It is recommended to do protocol 4A or 4B no more than twice daily during initial couple of weeks.

Protocol 4B: Sessions for processing current negative emotions

In this protocol, the individual - with their eyes closed - is required to recall their current distressing moments until their negative emotions are evoked. These moments could involve their family, friends, study or job. The individual tries to project these emotions to their child self by looking at their unhappy photo. Again the adult self compassionately intervenes to loudly reassure the child and also performs cuddles by giving themselves a facial massage until they contain the negative affect and can imagine the distressed child self transitions to positive affect.

Protocol 4C: Protocols for creating zest for life

This protocol aims to energise the individual systematically by engaging them in pleasurable activities, twice daily, such as dancing, singing, playing and laughing. The individual is required to look in the mirror and try to imagine that the child that they were is now present, using the happy image if required, and singing a jolly song while shaking their upper body such as their head, shoulder, neck, eyebrows, hands and arms. It is advised to repeat these activities as many times as possible during chores/ house work. This protocol requires stimulation of different body and facial parts to counter stiffness as depression is generally known to cause rigidity in different body parts, including the facial muscles. The idea is to increase levels of dopamine, oxytocin and serotonin to remain motivated and energised and to continue to support the child. Joyful positive activities such as dancing, laughing, singing and playing will cause reduction of negative affect and could therefore help the individual overcome their negative habits.

Protocol 4D: Getting over negative emotions

The Inner world of a sufferer who is under immense negative affect is like a derelict room (or a store room) which is similar to focusing at the dark region of the following Gestalt vase (Figure 3.2) to project the negative affect on it. However, as the individual has already established a powerful internal affectionate bond, it could be used to dampen the strong negative pattern by singing a happy love song and eventually entering into the basin of a strong pattern of affection with the child self. This is like focusing on the white region Figure 3.2, discovering the two faces, one of the child self and the other of the adult self.



Figure 3.2: The gestalt vase representing negative emotions (image courtesy Abbas Edalat [106, Pg. 12])

Protocol 4E: Socialising protocols for the child self

Now that we have decreased negative affect and increased positive affects by practising former developmental protocols 4A, 4B, 4C and 4D we can now easily do protocols with our eyes open. We are generally able to extend positivity - earned through increasing positive affect – to others around us and therefore we engage in a compassionate internal dialogue with the child self to help them improve further and curb/discourage their anti-social feelings such as envy, jealousy, greed and hatred. During this dialogue we also cuddle the child self by giving ourselves a face massage.

Protocol 4F: Creating a more optimal internal working model

After reducing the negative affect and increasing the positive affect an individual try to realise that their negative affect and thoughts are due to our sub optimal interactions with our parents (the very foundation of the Self-attachment therapy). Therefore we attempt to make ourselves aware of our internal working model and its deficiencies by revisiting instances of sub-optimal interactions with our primary caregiver, and thereby come to terms with them and appreciate the new reality that harnessing our internal affectionate bond we can improve our internal working model to further ourselves socially and emotionally. We therefore complete our transition from a derelict room to a mansion (depicting our emotional maturity).

3.5 Self-attachment (without VR) Trial Results and Discussion

In 2010, uncontrolled Self-attachment trials were piloted using volunteers in the UK and the USA. At least two volunteers with symptoms of depression and anxiety reported reduction in their depression and anxiety symptoms and an improvement in their ability to contain negative affect; they also reported increased inner joy post-therapy. They did not recover completely, as sometimes they would

still experience depressive episode but the duration and frequency of the symptoms decreased to a great extent.

In 2014 Self-attachment psychotherapy [30] was also piloted in Iran; a number of psychotherapists and practitioners used SAT protocols for treating patients with symptoms of chronic anxiety and depression. To investigate its impact on patient's mental-health several patients, who had finished their course on SAT, were interviewed. The overall feedback from the SAT practitioners was promising as all the patients reported improvements in their psychological health after the therapy.

In 2020, an eight week trial with twenty five volunteers from different age groups was conducted to test the efficacy of SAT protocols. Seventeen participants who completed the course reported reduction in their anxiety and depression symptomology. A 3-month follow up study is also underway to investigate whether gains from the psychotherapy has been retained by the participants.

The Self-attachment psychotherapy trials (without VR) are promising; majority of the participants who administered SAT protocols experienced improvements in their depression symptomology. SAT protocols require that the user role plays as an adult and interact with their child self. To administer SAT protocols the users must revisit their childhood memories both positive and negative and then imagine that the child that they were is present with them and that they can connect and interact with their imaginary child. The user then does reparenting and training activities to demonstrate unconditional love and support to their child-self. The child usually responds to this affection by transitioning from Sad/Scared emotion to happy and joyful (dance) emotion. The psychotherapy experience may greatly vary for individuals based on their ability to recall their past and their power of imagination. We hypothesize that latest advances in VR, especially advances in avatar (dynamic) generation and animation, could be harnessed to facilitate both the recall and the imagination element of the Self-attachment therapy. The following Section 3.6 details the functional specifications of the immersive virtual reality platform for the Self-attachment psychotherapy.

3.6 Harnessing VR for Self-attachment Protocols:

The primary aim of this research was to build an immersive VR platform to enhance the efficacy of Self-attachment protocols. To achieve this, technologists in collaboration with expert clinicians extracted functional specifications for the VR platform which could improve the Self-attachment psychotherapy experience. Some of the main features discussed were as follows:

- A method was needed to create a customisable photorealistic child avatar, from a single childhood photo of the user, which has:
 - facial feature customisation options such as face shape, eyes, skin colour etc.,
 - body customisation options such as height, width and clothing colour etc.
- The avatar needed the ability to display basic emotions i.e. sad, angry, happy and fearful and to transition between them.
- The platform should be interactive and easy to use.
- The room should be customised for the child avatar.
- text to audio capability was needed to read out important guidelines to the user
- Voice command support was required to invoke transition between emotions.
- The platform should be available both as a high-end version offering greater realism, and a low end, low cost, scalable mobile version.

More details about these features and their implementation will be discussed in the subsequent chapter on design and implementation.

4 PLATFORM DESIGN AND IMPLEMENTATION

This chapter explains the state of the art tools and techniques which we employed for the design and development of the immersive virtual reality platform for the Self-attachment therapy. We also share our findings from the usability evaluation of the high-end (Oculus Rift) version of our platform in Section 4.6.

4.1 Virtual Reality Technology

Virtual reality is the state-of-the-art human computer interface which uses computer graphics to create a realistic-looking virtual world that the user can interact with in real-time. Immersive VR platforms, tools and technologies are now commonly used in a wide variety of sectors including military, healthcare, education, entertainment, and construction, as well as for scientific visualisation purposes. In recent years, virtual reality has attracted the interest of the public and investors alike; tech giants including Facebook (Oculus), Google (Daydream, Cardboard and Jump), Sony PlayStation (PlayStationVR) and HTC (Vive) have made huge investments to accelerate research and innovation in mass consumable VR technologies which has made them more accessible at a much lower cost.

Innovation in VR is mostly driven by the gaming sector, which is currently valued at 135 billion dollars and is expected to reach 174 billion dollars by 2021 [110]. With such promising profits in the gaming sector, it is becoming increasingly difficult to attract good programmers and designers to work in the healthcare sector which does not have such impressive budgets. Despite these challenges, innovations in virtual reality have impacted research in mental healthcare and psychotherapeutic interventions. Using VR, we can create and deliver highly realistic and immersive environments customised for specific psychotherapeutic intervention. Clinical Virtual Reality applications are being investigated for treatment of phobias, paranoid delusions, posttraumatic stress disorders (PTSD), chronic pain, eating disorders and cognitive rehabilitation. One of the main uses of VR in mental healthcare is to support complex exposure-based treatments which involve a patient's exposure to psychotherapy-specific customised virtual environment(s). VR based exposure therapy has provided a cheap alternative to real-world exposure therapies. Therefore, in recent years, a spike has been observed in the VR-based treatments for mental health conditions [111]. A recent literature review [110] on virtual reality in psychiatric disorders supports using virtual reality technology in treating

depression; it emphasises the scale of the mental health crisis and also establishes the need to invest in the research and development of a novel VR platform for treating depression.

4.2 Virtual Reality Platform for Self-attachment

The first prototype mobile application to assist the user in undertaking aspects of Self-attachment therapy was developed by Tirmizey (undergraduate project) [112]. The app included informational videos relating to appropriate and affectionate attachment behaviour between a child and their parent, along with textual information relating to the concepts behind Self-attachment protocols. To support the user with self-administration of Self-attachment protocols the app had features to store and retrieve digital happy and sad childhood photos as well as a favourite song. There was a feature to allow users to write a diary entry (after a fixed interval) to help them consolidate what they have experienced and learned. The user could both report and View their levels of anxiety [113], depression [114] and attachment [115] using well-established self-report questionnaires. The happy and sad images of the user could also be displayed in the VR environment to assist with the undertaking of the protocols in stages 2 and 3. This preliminary implementation of the mobile platform offered a way to store and display 2D pictures and also features for diary entry and depression and anxiety evaluation questionnaires. It did not have support for customised photorealistic avatars.

4.2.1 Prototype 1

Taking into account feedback on the preliminary mobile application for SAT and using our findings discussed in Section 3.6 our first prototype for the Oculus Rift was developed. Following on from Falconer et al's [29] promising results, the first prototype virtual environment consisted of a generic avatar which offered basic emotion animations. The environment mostly consisted of free assets available on the unity asset store such as a spacious furnished room, controls and buttons to transition between different emotions and a generic avatar. The generic avatar was created by Jones [116], following the blender character modelling tutorial by Lile [117], with preliminary sad and happy emotion animations shown in following Figure 4.1.



Figure 4.1: First generic child Prototype VE for SAT

It also had a canvas to display:

- information regarding Self-attachment therapy (Protocol 1);
- a list of activities that the user needs to perform for each protocol.

The canvas was positioned above the child’s head and in the centre (relative to the head mounted display). It moved with respect to user’s head movements; this feature enabled the user to conveniently position the canvas (while reading) such that it did not interfere with the child avatar. Moreover, to make the canvas interactive the renderer mode should be selected as ‘World space’ and the VRTK_UICanvas should be added as a new component. The interactive canvas for displaying information and navigation between different virtual environments is shown in Figure 4.2. The prototype 1 functionality was similar to the platform built by Koh [118], however, the controls, unity assets, animations and navigation were different for both platforms.

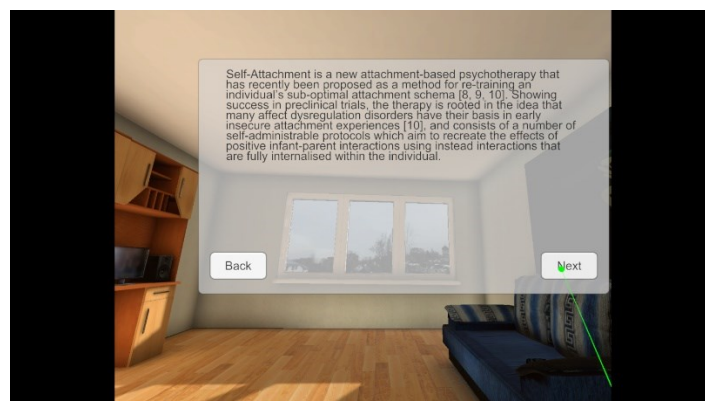


Figure 4.2: The interactive canvas for displaying information and navigation

4.2.2 Prototype 2

Facial feature customisation was introduced using Booth et al's [119] 3D morphable model. The model generates a 3D facial mesh from a 2D into-the-wild image of the user. The first technique developed by Jones [116] generated a head slightly resembling a cartoon (Figure 4.3) but wasn't able to produce the realistic avatar head which was required for the Self-attachment protocols.

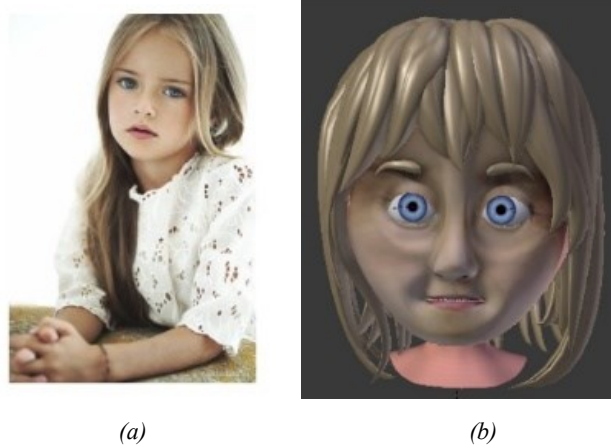


Figure 4.3: Sample image [120](a); generated avatar face (b)[116]

There were several reasons for this lack of visual realism. The skin colour, hair and eye colour all looked unnatural and lacked correspondence with the childhood photograph as can be seen in Figure 4.3 several other platforms were relatively better at generating a 3D head from a 2D picture, for example, GeminID [121], Natural front 3D [122] and AvatarSDK [123]. Among these, Natural front 3D and Avatar SDK generated quite realistic avatars as seen in Figure 4.4. We choose to employ the Avatar SDK as it generated more realistic avatar in comparison with the Natural front3D.

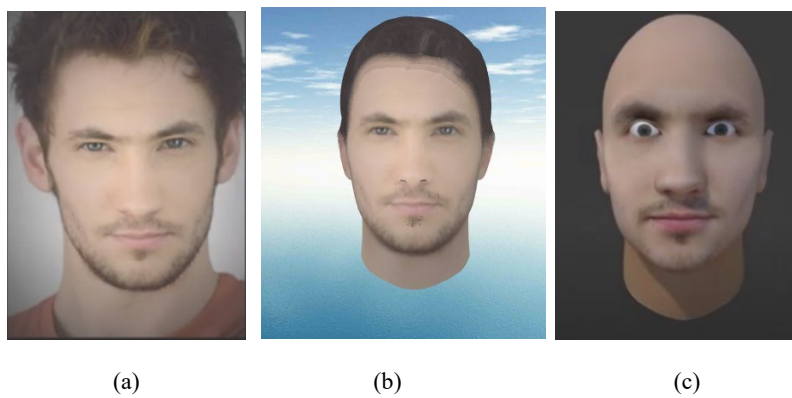


Figure 4.4: Original image (a) [124]; avatar head generated using AvatarSDK (b) [123]; avatar head generated using natural front 3D(c)

AvatarSDK offers the following additional features:

- An offline plugin for generating heads locally on desktop or mobile devices without internet.
- Customisation of the generated head including changing hair colour and style.
- Facial animations for some of the basic emotions.

Although the head generated via the Avatar SDK looked more realistic (see Figure 4.5) than Booth et al's [125], it appeared oval in shape like adult head rather than round like a child's head. As seen in the picture the body to head size ratio was also an issue. The body of the avatar was bigger in size and there was no way to adjust body size or clothing colour.

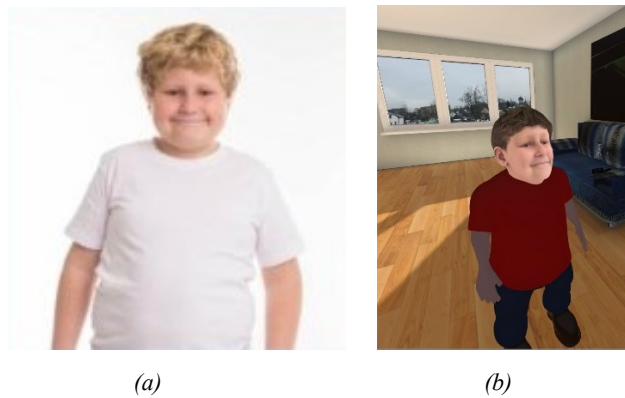


Figure 4.5: Avatar head generated using AvatarSDK 1.4 [123]

In a later build of the Avatar SDK some of these issues were addressed by the introduction of better 3D facial textures.

4.2.3 Final Version

Based on the investigations described above, more major modifications were made to the prototype as follows:

- The avatar body was upgraded to a child's body and features to change the body height, width and cloth-colour were implemented.
- The room was upgraded to resemble a child's room.
- It was ensured that both high-end and low-end versions of the platform offer virtual environments for all the protocols of the Self-attachment therapy.

- Once the high-end version (Oculus Rift) was finalised a separate build was created for the low-end version (Google's cardboard) for mobile VR experience.

Due to the COVID-19 pandemic, it was not possible to conduct trials for the Oculus Rift version. Our focus was therefore shifted to improving the low-end version and getting it ready for the validity study explained in Chapter 5. To improve the facial features, we employed AvatarSDK's Head2.0. After this upgrade the face looked more like a child's face as shown in Figure 4.6.

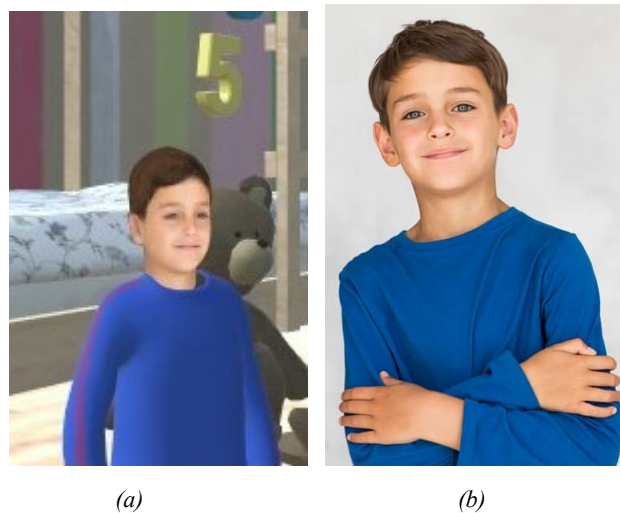


Figure 4.6: The avatar generated using Avatar SDK latest (Head2.0) [123] in (a) and (b) displays original picture [126] used to generate the avatar.

- Avatar SDK's Fullbodysample [127] scene was extended to implement a virtual environment for the Self-attachment psychotherapy. The Avatar SDK's customisation panel offered customisations to the generated head such as: changing hair colour, scaling head size, repositioning the head against the x, y and z axis. The panel functionality was extended to include following additional customisation (as shown in Figure 4.7):
 - The body was replaced with a child avatar body.
 - The child avatar (Figure 4.7) height can be increased or decreased via the first button set displayed under the avatar.
 - Similarly, the lower set of buttons can be used to increase/decrease the width of the avatar.
 - The X,Y and Z scale values of the transform are displayed towards the right side of the buttons.

- A dress colour panel under the child picture enables the user to choose between 10 different shirt colours, to match the colour in the image. Green is the default shirt colour.



Figure 4.7: Avatar customization panel

Once the user has done the customisations the avatar can be imported into the Self-attachment protocol scenes by pressing the ‘SAVE AVATAR’ button as shown in Figure 4.7. The scene then spawns the avatar onto the protocol-selection scene listing SAT protocols that the user can choose from as displayed in Figure 4.8.



Figure 4.8: Protocol selection scenes

4.2.4 Virtual Environments for Administering Self-attachment Protocols

Protocol 1: As explained earlier, SAT's first protocol requires that the user be informed about Self-attachment, its foundation, its protocols, and its success in initial trials. This was achieved by displaying the information in textual form (see Figure 4.9) in several scenes. Originally, the user can also hear this information in audio format for every scene via a text to speech feature. However, this feature was removed after negative feedback from the users; they generally preferred to read from paper or watch a video outside the head mounted display (VR).

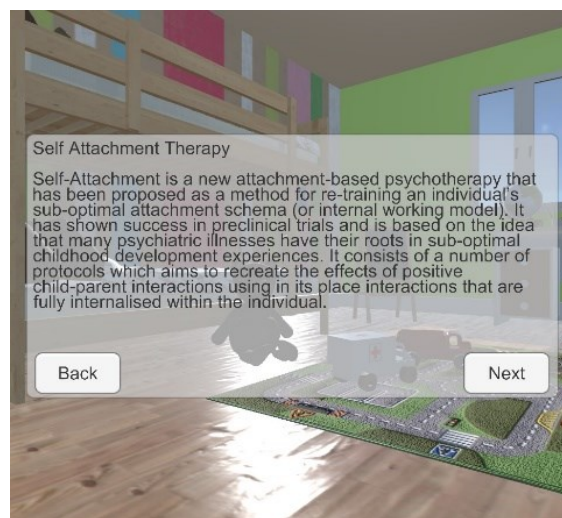


Figure 4.9: Image displaying textual information in the upgraded child room.

Protocol 2: In this protocol, the user is required to recall both their happy and sad childhood memories in as much details as possible by looking at their happy and Sad photos. The VR platform enables them to use their avatar (with different emotions) instead their photos. In the high-end version the user could either use voice command, for example, they can say happy, sad, neutral and scared or alternatively they can make a selection via casting a ray on the emotion button and then pressing the trigger button to select as displayed in Figure 4.10.



Figure 4.10: Protocol 2 Oculus Rift build, user casting ray (green) on the Happy button

In the low-end version, the platform enabled the users to see their photorealistic avatar displaying different emotions while in the VR, they can make a selection via a gaze controller (Figure 4.11) feature. The gaze controller is explained more in the upcoming Section 4.3 (Tools and Technology). The Instruction panel Figure 4.11a displays the steps which the user is required to take to administer SAT protocol 2. By pressing the neutral button, the user can redo this protocol as many times as they want. While practising protocol 2, the user can move towards or away from the child in the VR in the Oculus rift version, however, in the low-end version (MobileVR) the user cannot move in the scene, they can only look around. To save space we will either show the mobile or the Rift build unless there is a specific feature which requires comparison between the scenes from both builds.



Figure 4.11: Instruction panel (a) for the protocol two Mobile VR and Happy emotion selected using gaze controller (b).

Protocol 3: This protocol requires that the user establishes an affectional bond with their child self by singing a jolly love song while watching or holding the child-avatar and then cheerfully dancing and playing with the child. The virtual environment for this protocol enables the user to embrace the avatar by moving closer to it while holding the grip buttons on the Rift controllers. When in range of the child the avatar automatically transitions from neutral to happy state as shown in Figure 4.12a. If the user embraces the child, the second time then the child becomes jolly and starts to dance. Their favourite song, which they provide before the VR experience, is played as soon as the child starts to dance. The user can repeat this protocol by pressing the neutral button. The technical aspect of the interactive protocol is explained in Section 4.3. In the mobile version, this functionality is achieved using the gaze controller; if the user looks at the child for two seconds it becomes happy then if the user stares the second time for two seconds it transitions from a happy to joyful (dance) emotion, and their favourite song is played, as shown in Figure 4.12b. Alternatively, user can also use the emotion buttons on their right side.



Figure 4.12: Protocol 3 embrace to make the child happy in Oculus Rift build (a); child dancing after second gaze protocol 3 in mobile-VR (b).

Protocol 4: Consists of a number of reparenting sub-protocols as follows:

Protocol 4A/4B: The protocol 4A involves recalling a traumatic episode from the childhood in as much detail as possible, after which the patient projects the negative affect onto to their distressed child self (Figure 4.13a). The user then quickly intervenes to support their child self by themselves carrying out a face massage. The VR environment also offers a sample face massage video as shown in Figure 4.13b. For protocol 4B the user is required to do same steps as protocol 4A, the only

difference is that the user is required to recall their current negative event involving their study, work or family (instead from their childhood); rest of the steps are same as Protocols 4A.

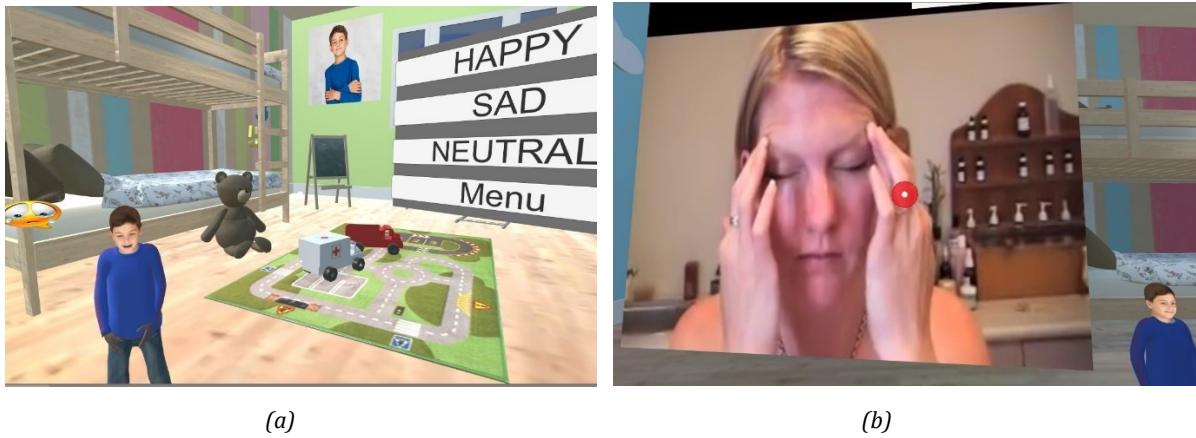


Figure 4.13: Virtual environment to practise protocol 4A/B to recall childhood and current negative episode(a); massage video by therapist kyle (b)[128]

Protocol 4C: This protocol requires that the users look in the mirror and imagine that the child that they were is now present with them. They then perform pleasurable activities such as singing a love song and dancing while moving their upper body, head, shoulders, neck, eyebrows, hands, and arms. The users can make use of the VR platform to help them imagine the child and also by performing activities can make the avatar transition between happy and joyful (dance) emotions, and a song is played, to enhance the experience of this protocol as displayed in Figure 4.14.



Figure 4.14: Virtual environment to administer protocol 4C

Protocol 4D: The sufferer's inner world under strong negative affect is like a derelict room like the black region of the gestalt vase. Hence the user can project their negative emotions on it and then can harness their affectionate bond with the child self to change their focus from the dark region to the

white region, two white faces looking at each other, which represents the compassionate relationship between the child self and the adult self. The VR environment allows the user to first look at the gestalt vase and then for the second phase they can press the trigger button on any of the rift controllers to make the white region prominent; the same feature can be accessed in the mobile version by staring at the gestalt vase for 2 seconds as displayed in Figure 4.15a, which makes the two faces prominent as displayed in Figure 4.15b.

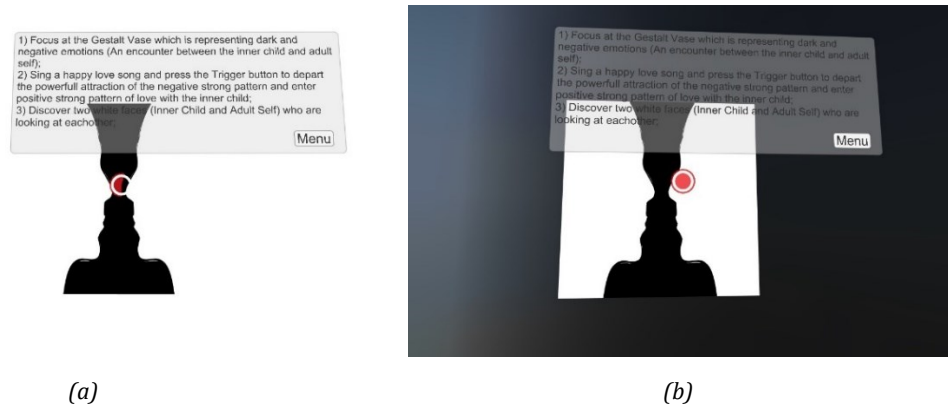


Figure 4.15: Virtual environment to practise protocol 4D, in image (a) the user can focus on the gestalt vase and in image (b) the user can focus on two white faces looking at each other.

Protocol 4E: After the user has practiced developmental protocols 4A, B, C, D for enhancing our capacities of emotional regulation, protocol 4E aims to train the user to curb other negative or anti-social feelings such as envy, jealousy and hatred. The user becomes involved in a compassionate internal dialogue with their child self to help them improve further. During the dialogue, the users also cuddle their child self by giving themselves a face message. The VR environment supports this protocol by enabling the user to interact with their child self (avatar) and see the transition between emotions (as displayed in Figure 4.13 (a)) during or after the dialogue.

Protocol 4F: Having practised all the sub protocols the user is now expected to have attained secure attachment via harnessing their affectional bond to practise Self-attachment protocols. As explained earlier, the inner world of the sufferer is like a derelict room and after attaining secure attachment their inner world looks totally different. They have transitioned from a derelict room to a well-lit large mansion. To support this protocol, the virtual experience starts with the user stranded in a derelict room Figure 4.16a and then, by pressing a trigger on any of the Rift controllers, transitions to a well-lit spacious room as shown in Figure 4.16b. Alternatively, for the mobile version the user

can stare at the child avatar for 2 seconds as shown in the following Figure 4.16 and the child then transitions to a well-lit spacious room.

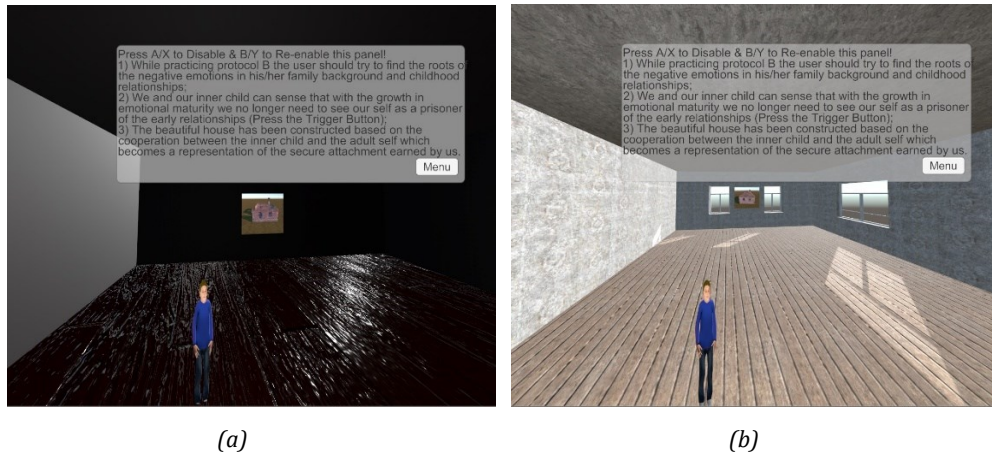


Figure 4.16: Virtual environment for protocol 4F in (a) the child avatar is in the derelict room in (b) the child is in the spacious well-lit room.

4.3 Tools and Technologies

In this section we explain the various tools, techniques, and technologies that we employed to implement the high-end (Oculus Rift) and low-end version (Google Cardboard) of the platforms.

4.3.1 Unity 3D

The Unity 3D by Unity Technologies [129] was the primary software development kit for building the customised virtual environment for both the high-end and the low-end versions of our platform. This tool is suitable for development of 2D and 3D environments for the desktop, mobile, VR and AR applications.

The Unity development environment usually consists of several game objects with components which could also be in the form of a C# script. It is through scripting that we can make the objects behave in a certain way. The game objects allow inheritance to share properties such as their relative position to each other. The editor has both an edit-mode to make changes to the code and a play mode to run the game.

The Unity platform has an asset store where the developers can import assets and props (paid and free). This is to facilitate the developers by speeding up the development by making assets and

features readily available. Due to budgetary constraints most of the assets used for our platform were free, except the room which was paid for [130]. Both the mobile and a web platform were required for the SAT, therefore, Unity 3D (multiplatform) emerged as the top choice. The platform also employed other tools such as the Android SDK, Google VR, Oculus SDK, Virtual Reality tool kit and Avatar SDK.

4.3.2 Avatar SDK

This SDK [123] is the state-of-the-art in technology which enables photorealistic 3D head creation from a single image. It offers both online and offline unity plugins. The Avatar SDK requires a minimum of 2GBs of RAM to operate. The SDK provides minimum set of features which could be extended to achieve desired functionality/features. For the platform we used the offline build therefore no internet connection was needed. The computation for generating photorealistic head was done locally on the machine or the mobile phone running the SDK. The Avatar SDK is like a black box as the company has not shared any implementation details for the SDK.

The user can select a picture using the file browser and the SDK generates the avatar head; the head is attached with the body by specifying the following (Figure 4.17):

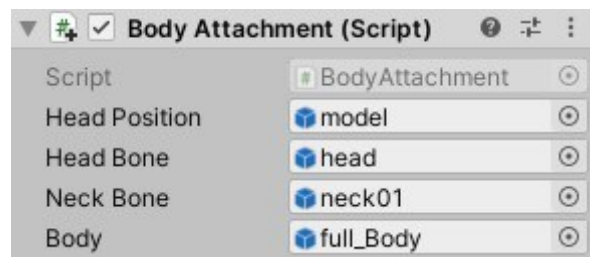


Figure 4.17: The body attachment suit for the avatar SDK.

The user needs to specify the head position, head bone, neck bone and the body to which the head needs to be attached. It is also important to carefully position the head at the right place before binding it with the body.

4.3.3 Control Implementation for the VR Platforms:

Some features of the Oculus Rift build were reused for the mobile build. However, since the control (selection) mechanism was different for both platforms i.e. ray-cast control for the Rift and gaze

controller for the android, most of the scenes had to be upgraded. All the buttons for the mobile build had to have extra event trigger components such as the On-Pointer-Enter and On-Pointer-Exit. The On-Pointer-Enter is called when the user looks at the button; if the user fix their gaze on the button for two seconds then the event is triggered automatically. If the On-Pointer-Exit is raised, then the time-counter is reset to Zero. The gaze controller feature for the mobile platform also casts an invisible ray (like the rift build) onto the object and therefore detects whether the object has any relevant component such as a trigger or a collider. For the gaze-control feature the Google-VR's reticle pointer needs to be added as the child of the main camera to allow the ray to follow the user's gaze. It is possible to limit the ray-cast range by configuring the 'Max Reticle Distance' (Figure 4.18); only objects within the reticle distance will be detected and therefore could be interacted with the reticle pointer.

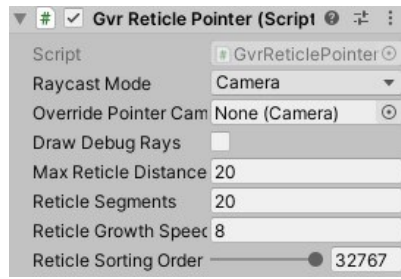


Figure 4.18: Reticle pointer variable

The platform controls for the high-end (Oculus rift) version were implemented using the Virtual reality tool kit (VRTK) [131] as it provides a UI layer to select the events for the controllers. To implement the interactive protocol 3 (Figure 4.12a) we attached a capsule collider as displayed in the following Figure 4.19.



Figure 4.19: Capsule collider in green attached to the avatar

When the user embraces the child for the first time it transitions from neutral to happy emotion, similarly, when the user embraces the child for the second time the child's emotion transitions from happy to joyful (dance) and a song gets played. The following code snippet (Figure 4.20) details the OnCollisionEnter function to achieve the embrace feature for the interactive protocol of the high-end Oculus Rift platform.

```
public void OnCollisionEnter (Collision col)
{
    MusicSource.clip = MusicClip;
    if (col.gameObject.tag == "Child" || col.gameObject.tag == "CustomAvatar") {

        if (var == 0)
        {
            child.GetComponent<ChildAnimator>().Happy();
            animationManager.GetComponent<SATChildAnimator>().Happy();
            var += 1;
        }
        else if (var == 1)
        {
            child.GetComponent<ChildAnimator>().Dancing();
            animationManager.GetComponent<SATChildAnimator>().Dancing();
            MusicSource.Play();
            var -= 1;
        }
    }
}
```

Figure 4.20: Avatar collision script for the interactive protocol.

The user can cast a ray on the buttons by pressing the joystick on any of the Rift controllers followed by the trigger button to make a selection. They can use the ray cast control to invoke different emotions and navigate between the different protocols of SAT in the virtual environment for each protocol. For implementing the ray cast feature, the following VRTK utilities were added to both the right and left Oculus Rift controllers. The VRTK_UI Pointer (see Figure 4.21) enables interaction with the UI elements. The 'Touchpad Press' (joystick on rift controllers) acts as an activation button and the 'Trigger Press' acts as a selection button.

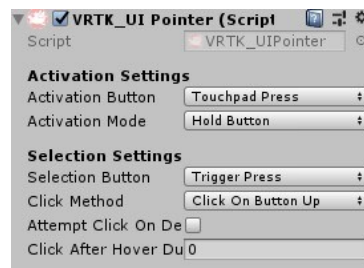


Figure 4.21: VRTK_UI pointer interface

The VRTK_Straight Pointer Renderer is attached to both controllers so that we can cast rays from both controllers. The VRTK interface (see Figure 4.22) for the pointer renderer allows customisation to the ray such as the colour and length.

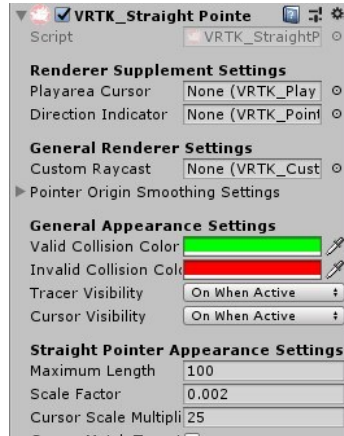


Figure 4.22: VRTK_Straight pointer renderer interface

4.4 Emotion Animations

An important aspect of Self-attachment is that the individual should be able to witness the child-avatar depicting joyful (dance), happy, sad and fearful faces and therefore try to empathise with all the basic emotions of the child and learn how to move back and forth between these emotions, loosening their own rigid affects and mind-set. One of the protocols requires that the individual also enjoys and is impressed by the lively, playful, and dynamic character of the child-avatar and its zest for life, which should be displayed in the VR. Consequently, they establish a compassionate attitude towards their child self. To this end, various emotional states offered by our platform are displayed in Figure 4.23. We have added relevant emoji-icons to amplify the emotion displayed by the child avatar.

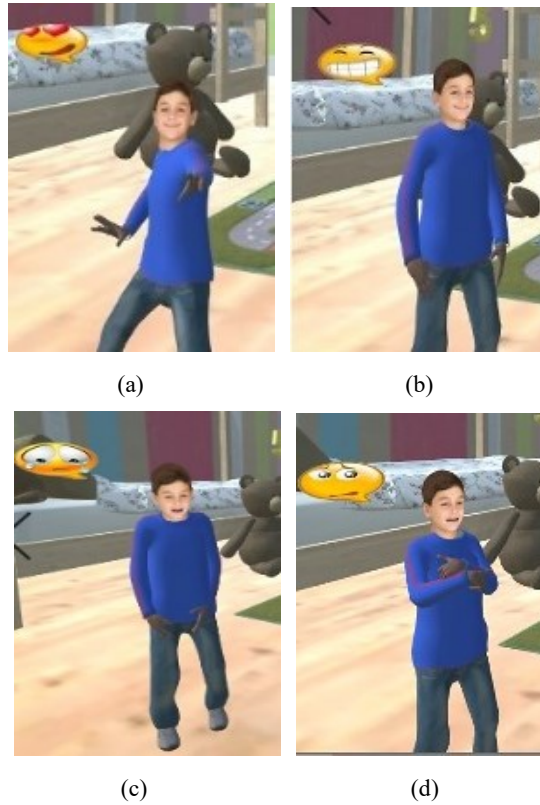


Figure 4.23: The child avatar displaying emotions: Joyful (a), Happy (b), Sad (b) and Scared (c)

An animator for each Self-attachment protocol has to be defined to allow transition between different animations. For example, for protocol 2 the avatar is idle at the start and then they participants are required to look at their happy childhood avatar and then their Sad childhood avatar. To achieve this, the avatar runs the idle animation at the start and then allows users to transition from idle to both sad and happy. They are also allowed to transition from sad to happy directly and from happy to sad. The animator for the protocol 2 is displayed in the following Figure 4.24:

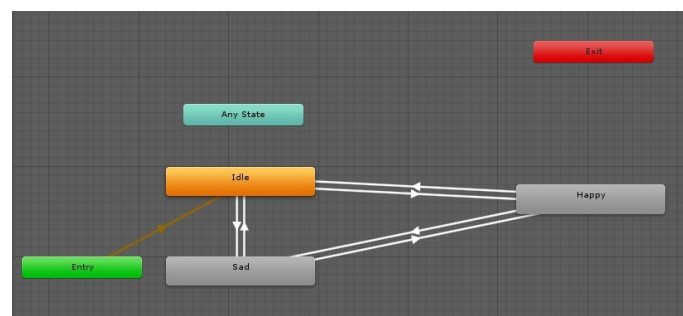


Figure 4.24: Animator for the protocol 2

The head is generated by the Avatar-SDK, which also provides nine different emotion animations which could run on the Avatar-SDK generated head. Our platform also requires laughter and anger animations; however, the Avatar-SDK does not support these facial emotions yet. Although there are five emotional states that are employed by our platform, after usability evaluation on volunteers (explained in Section 4.6) it was decided to keep the body stationary for happy and sad emotions and run both the body and face animations only for the remaining three emotions: scared, dance and idle. Figure 4.25 displays a code excerpt from *SATChildAnimator.cs* script file to invoke scared animation on both the body and the head of the child avatar :

```
public void Scared ()
{
    //Head Animation
    anim.SetBool ("isIdle", true);
    anim.Play ("scared");
    anim.SetBool ("isIdle", false);

    //Body Animation
    bodyAnim.SetBool ("isHappy", false);
    bodyAnim.SetBool ("isSad", false);
    bodyAnim.SetBool ("isIdle", false);
    bodyAnim.SetBool ("isScared", true);
    bodyAnim.SetBool ("isDancing", false);

    //Emoji Display
    customisedChild.GetComponent<SATCustomAvatar>().ScaredEmoji();
}
```

Figure 4.25: Scared animation function to invoke face and the body animation

The *SATChildAnimator.cs* contains functions to control animations for both the head and the body, for the following five emotions happy, sad, neutral, scared and dance required by the Self-attachment protocols.

4.5 Speech Recognition

Oculus Rift can receive audio input via a microphone, and this can be used to facilitate the selection of emotions. While practising SAT protocols the user can use the speech recognition feature to invoke emotions without having to use the ray-cast control. The speech recognition feature works for Windows 10 and was implemented using *UnityEngine.Windows.Speech API*. The *KeywordRecognizer* was used to listen to the voice input and match it with a list of stored keywords. Our platform has five voice commands corresponding to five emotions as displayed in the following code snippet (Figure 4.26) extracted from *Speechrecognition.cs* script:

```

void Start ()
{
    //Add Voice Commands to Dictionary and callback respective functions
    voiceCommands.Add ("Happy", () => {
        Happy ();
    });

    voiceCommands.Add ("Sad", () => {
        Sad ();
    });

    voiceCommands.Add ("Scarry", () => {
        Scared ();
    });

    voiceCommands.Add("Neutral", () => {
        Idle();
    });

    voiceCommands.Add ("Dance", () => {
        Dance ();
    });

    //Initialize the Speech Recogniser
    keyRecognizer = new KeywordRecognizer (voiceCommands.Keys.ToArray ());
    keyRecognizer.OnPhraseRecognized += KeywordRecognizerOnPhraseRecognized;
    keyRecognizer.Start ();
}

```

Figure 4.26: Speech recognition initialization and list of voice commands for the emotions

4.6 Usability Evaluation of the Oculus Rift Platform

For wide scale adaptation of consumer-level platforms it is important that they are built considering usability engineering principles specific to the virtual environments (VE). In this section we explain our experience applying systematic heuristic and formative evaluations to our VR platform (Prototype 2, see Section 4.2.2) to make it more usable. The participants who evaluated our platform were asked, via a follow-up questionnaire, to rate their level-of-immersion, learnability, and overall usability of the platform. Insights from our usability evaluation will help developers build better and more usable VR platforms in the future.

Advancements in VR hardware and software has enabled the creation of visually rich and perceptually realistic environments. Immersive VR platforms, tools and technologies are now commonly used in a wide variety of sectors including military, healthcare, education, entertainment, and gaming industries. With the increasing demand for virtual reality systems, there is a greater need to further the usability research to improve the virtual reality experience. It is only through early incorporation of usability assessment into the design process that we can build highly usable (and mass-consumable) applications which can effectively solve real-world problems.

To this end, Gabbard et al. [132] detail a taxonomy of usability guidelines for virtual environments, categorised by four main type of usability issues:

“Users and User Tasks in VEs, The Virtual Model, VE User Interface Input Mechanisms, and VE User Interface Presentation Components”

Bowman et al. [133], present an overview of the usability evaluation methods for virtual environments; the study provides an opportunity to compare and contrast major usability engineering approaches. Hix et al. [134] explain usability methods which are adapted from GUI development and have been applied to the VE development. The study also shares usability experience of three different virtual environments.

Hix et al. [135] present an iterative approach for user-centred design for VEs, including their experience in applying the user-centred design and evaluation approach to a real-world battle field visualisation virtual environment. Schultheis et al. [136] examined the usability aspects of the VR driving rehabilitation platform. It was tested on the following groups: 1) patients with traumatic brain injury (TBI); 2) patients with cerebral vascular accident (CVA); 3) healthy controls (HC). One of the main findings was that the TBIs and CVAs provided less favourable feedback, regarding the platform, than HCs. McComas et al. [137] evaluated a desktop virtual reality platform to educate children to safely cross intersections. The main objective of the study was to see whether children can effectively learn from the platform, and that are they able to effectively reproduce their learning in the real-world setting. A significant positive change in performance was observed after the VR intervention. Swartz et al. [138] proposed a new two-phased usability engineering strategy and also applied it on crumbs cave application – a tracking tool for medical imaging. They report on the usability methodology’s effectiveness in detecting issues in crumb CAVE.

4.7 Usability Inspection of SAT Virtual Environment for Oculus Rift

The Usability Evaluation was performed based on the usability design guidelines by Gabbard et al. [132] and Hix et al. [134]. The first part of the usability evaluation involved performing heuristic evaluation, it is recommended to have more than one evaluator for performing heuristic evaluation [139], therefore, I along with a research intern (Usman Jehanzeb) performed a couple of iterations of the design of the high-end VR platform to look for usability flaws. This involved navigating through the design while thinking out loud what we are trying to achieve. Particularly, focus was paid to any

difficulty experienced while administering a SAT protocol. At the end of the testing session any violation noticed to the VE design guideline was investigated. Some of the violations observed from these sessions were as follows: 1) It was noticed that the navigation choices weren't consistent across different protocols; 2) the VE was unable to provide feedback on the user's current state in the system or give any indication as to what the navigation possibilities from the current state might be.

For each violation, a recommendation to update the design was made. Once all the suggested changes were incorporated in the design, a formative evaluation was performed by employing ten volunteers from diverse backgrounds, genders, and expertise. Some of the participants have had VR experience prior to the study, most of them were students at the Imperial College London. A standard procedure for conducting formative evaluation was as follows: 1) the users were briefed about the experiments and psychotherapy; 2) the users were given 5 minutes to explore and familiarise themselves with the Oculus VR equipment, controls and the VE; 3) the users were tasked to undergo SAT protocols in the VE. During the evaluation session I kept track of completion times for the task, frequent errors committed and their improvement suggestions and other feedback.

The most common error (CE1) was in button-selection functionality. Participants found it difficult to cast a ray by pressing the thumb-stick button and simultaneously pressing the trigger-button to select the desired option in the VE. Another important constraint which further exacerbated this difficulty was that the participants must hold the Oculus controller (ray-cast) steady on the option. The second most common error (CE2) was not being able to embrace-the-child. Some users could not intuitively figure-out, on their own, that they have to move closer to the child before they can embrace or hug the child avatar as part of the protocol. To address CE1, the button size was increased to make it easier for the users to cast a ray onto it and the sensitivity of the ray cast control was decreased to make it easier for the users to make the correct selection. For CE2, I modified the protocol tooltip canvas to include instructions to embrace the child and the collider size was increased to make it also the .

After participating in formative evaluation, the participants were required to fill a follow-up usability and experience questionnaire. The questionnaire consisted of 5 questions each question could be marked on a scale of 1-5 (1 strongly disagree to 5 strongly agree). As seen from the results in Table 1, the majority of the participants were able to effectively connect with the photorealistic child avatar which indicates that the application will be effective in helping patients in creating a connection with

their child self. The scores for control and usability are all above average, which is because they are simple and have only a minimal user interface. The score also indicates that the text explanations for the Self-attachment protocols need to be improved and the placeholder text needs to be updated with proper elucidations. Another important observation is that the level of involvement score is 4.3 on a scale of 5 which means that the users find the environment quite immersive.

Question	Average Score
Overall how satisfied were you with the application?	3.2
How satisfied were you with the flow and controls of the application?	3.1
Rate the effectiveness of text to speech in increasing immersion and improving the understanding of Self-attachment therapy?	3.0
Rate the effectiveness of the photorealistic avatar, did it make you feel like you were looking at your younger self?	4.2
Rate how easy or difficult was it to understand the various protocols of Self-attachment therapy in the application?	2.2
How involved were you in the virtual environment experience?	4.3

Table 1: Usability and experience questionnaire

The usability and experience questionnaire provided evidence regarding hypothesis that people may find their photorealistic avatar in VR more relatable than their 2D pictures. To corroborate these findings, a formal validity study was conducted to test the platform's final version on volunteers. The findings of the validity study are shared in the upcoming Chapter 5.

5 VALIDITY STUDY

Conventional approach to Self-attachment protocols require that the user role-plays as an adult and interacts with their child version. The user employs their childhood photos to facilitate recall from their childhood and then imagines that their child version is present (virtually) with them, and that they can role play as an adult and perform optimal parenting activities with their child self. We contend that the efficacy of Self-attachment protocols can be increased by enabling the user to interact with their customised photorealistic childhood avatar in the virtual reality. To this end, an immersive virtual reality platform was designed, developed, and tested - consisting of both a high-end version (Oculus) and a low-end version (Google's cardboard) - on volunteers to see whether the participants would find their customised childhood avatar better and more relatable than their childhood photos. This chapter explains the results, lessons, and findings from the trials.

5.1 Methods and Materials

5.1.1 Motivation

Self-attachment therapy has shown promising results in treating patients with mental disorders. Several patients reported improvements in their health after administering an 8-week program on the Self-attachment [30][34]. The protocols of the Self-attachment require recall from the past, imagining that the child is present and that they can interact with him/her to offer unconditional support like a caring parent. In response to these optimal parenting interactions the child learns to affect regulate i.e. how to recover from a state of sadness/distress to neutral and then to happy and joyful. Most of the stages of the SAT are based on user's power of imagination. The better they are at imagining the more they can benefit from the psychotherapy. The user may quit the therapy after they find it difficult to employ their imagination for practising Self-attachment protocols. To this end, we envisaged an immersive virtual reality platform which could not only facilitate with the imagination-aspect (photorealistic avatars) of SAT protocols but also helps with the emotional-aspect of the therapy i.e. the user can see their childhood avatar transition between different emotions in the virtual reality in response to various positive re-parenting activities. After the development was completed it was decided to test both the high-end and the low-end versions of the platform on a group of volunteers from Canada and the United Kingdom to see whether they find their avatar in the VR more relatable than their childhood photos.

5.1.2 Procedure

Ethical approval was obtained from the Imperial College Research Ethics Committee (ICREC) for conducting trials, for both the low-end version and the high-end version, however, due the pandemic it was not possible to conduct trials for the Oculus Rift due to social distancing measures. Also, the volunteers (participating remotely) for our study did not have either the Rift or the required machine with graphics capabilities to run the Rift; but some had Oculus Quest. Therefore, reusing functionality of the Oculus Rift, another build was created for the Oculus Quest [140].

The participants were recruited via online social media platforms by using the advert (APPENDIX). To be eligible for the trials the participant should meet following criterion:

- Healthy participant aged between 18-50 years.
- Have childhood photos.
- Have an android phone with a gyro-sensor, running Android 9.0 or later, and screen size between 3.5 - 6 inches (to fit the google cardboard). Most of the 2-3 years old android phones met this criterion.
- Have a Google's cardboard (we also offered to buy a cardboard to all participants)
- Should be fluent in English.

Nineteen participants registered their interest; three participants were overaged (Age>50), and a participant was not able to produce a good quality childhood picture for the trials, therefore, fifteen participants were recruited for the study. Among the recruited participants, 6 volunteered to also participate in the Oculus Quest trials. All participants were required to go through the participation information sheet (APPENDIX) and then sign an online consent form (APPENDIX) before they could proceed with the trial. For each participant an Android VR application - which offers a virtual environment containing their customised avatar - was built and shared. Due to social distancing measures (COVID-19), all participants were required to administer the trials on their own. For the first part of the trial, the participants were to use their picture to recall happy moments from their childhood then imagine that the child that they were is present with them and that they can interact/relate with their child self. The second part required, that they now administer the same protocol as explained in the first part but use their customised photorealistic childhood avatar in VR instead their photo. The participants who volunteered to test the high-end version also had to repeat the same experiment but with the Oculus Quest. After administering sessions for a week (as many

times as they wanted) the participants filled a questionnaire to report their experience using photos versus their customised avatar in VR. The VR trial is explained in more detail in the upcoming Section 5.2.

5.1.3 Scenarios

MobileVR

All participants were provided with an android APK installation file which they installed on their phones and used it with a Google cardboard to experience VR. The participants were required to compare their experience using photos and their childhood avatar in MobileVR. It is important to note that the MobileVR experience greatly varies depending on the computation power and graphics capabilities of the mobile phone. In the VR, the user could make the avatar perform following emotions i.e. happy, sad, scared and joyful (Dance). The default posture of the child avatar was Neutral; the user could stare at the child avatar for 2 seconds to make him/her happy and then stare again at the child avatar (second time) to make the avatar joyful (Dance) as displayed in the following Figure 5.1. The favourite song of the user, which they shared before the trial, is also played along with the Dance animation. The stepwise protocol instruction is displayed on the tooltip canvas towards their left and in the background, they could also see their original picture which they supplied before the trial for avatar generation. All participants were given a week to use their avatar as many times as they wanted. At the end of the trial they were required to fill the online ‘VR impact test questionnaire’ and ‘Demographics information form’ (APPENDIX).



Figure 5.1: Scene for MobileVR trial

Oculus Quest

For the Oculus Quest's VR impact test another build was created [140] reusing most of the functionality from our Oculus Rift build. For the Oculus Quest trials the user were required to recall their childhood moments using first their childhood photo and then their photorealistic childhood avatar in the VR. The virtual environment for the Quest build had a scenic background as seen in the following Figure 5.2; it also had controls to choose between following four emotions: happy, sad, scared and dance (Figure 5.2). The user could simply touch the emotion button with bare hands without the need of a controller. The hand tracking feature for the Oculus Quest was very much appreciated by the volunteers. Moreover, most of the participants reported Oculus Quest experience to be more realistic, immersive, and engaging. The results of the trials are discussed in the upcoming Section 5.2. Like the mobile trial the user could use their avatar for a week as many times as they want. After completing the trials, they could fill the Impact test questionnaire for the Oculus Quest (APPENDIX). The Quest build had same seven questions as the MobileVR impact test and additional two Quest-specific questions (APPENDIX) to compare a participant's experience interacting with their avatar in Quest, MobileVR and their childhood photo.



Figure 5.2: Scene for Quest trial.

5.2 Impact Test Results

Most of the participants for our trials were in their twenties. The average age of the group was 30.3 (SD= 7.9) and both the mode and median age was 27. There were 11 males and 4 female participants; following histogram (Figure 5.3) shows the age distribution of the participants.

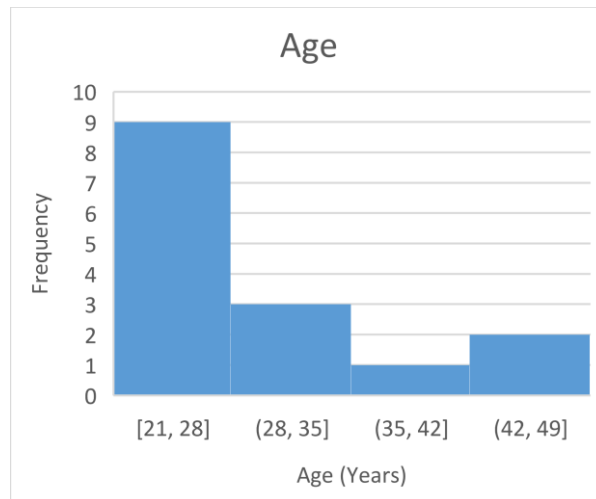


Figure 5.3: Age distribution of participants (N=15)

The majority of the participants were post-graduates, we had one participant who had secondary education and 5 participants who were graduates as shown in the following bar chart (Figure 5.4).

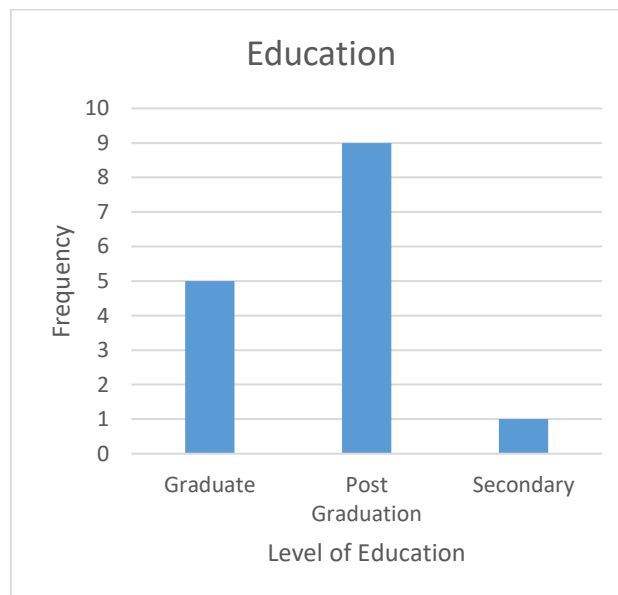


Figure 5.4: Education distribution of the participants (N=15)

The participants belonged to various professions; the majority were PhD students enrolled in various graduate programs at the Imperial College London. Furthermore, there were 3 bachelor's students, 2 healthcare professionals and rest were from other professions as shown in the following bar chart (Figure 5.5)

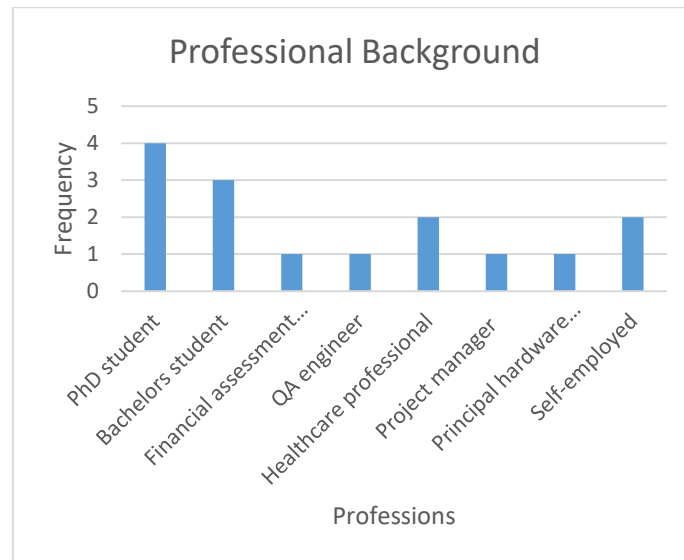


Figure 5.5: Professional background of participants (N=15)

One of the main objectives of this research was to investigate utility of photorealistic avatars to practise protocols of the Self-attachment therapy. The goal was pursued by answering following research question:

‘Can childhood avatars of the participants be as good as or even better than their childhood photos for administering the Self-attachment protocols?’

In this section we compiled results from both the MobileVR and Oculus Quest trials. Each of the following graphs are captioned with a question. The x-axis displays the frequency of the participants and the y-axis displays the Likert scale. The first seven questions were same for both the MobileVR and Quest trials, however, the last two questions were only specific to the Quest trials.

The first question was to measure the level of realism of the virtual environment. For the mobileVR environment it was a child’s room [130] as displayed in the Figure 5.1. For the Quest version a scenic background was chosen as seen in Figure 5.2; the environment was constructed using free assets from the asset store [141]. Scenes from both the high-end and low-end version of the platform had a tooltip canvas (on left side) to display the information regarding steps to make the child transition between happy and joyful (dance) emotions. The following graph display the results for user’s feedback regarding the environment, orange lines represent the frequency of the MobileVR participants against each Likert value and the blue lines displays results for the Oculus Quest VR trial. For the MobileVR

the modal Likert values are ‘Strongly (4)’ and ‘Moderately (3)’ and the average Likert value is 3.13. For the Quest build both the modal and average values are ‘Strongly (4)’.

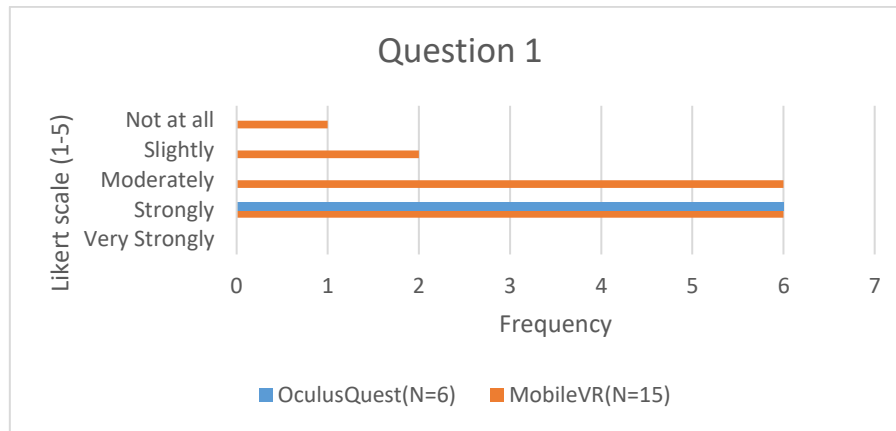


Figure 5.6: How realistic was the setting?

One of the main objectives of this research was to test whether the user can identify with their childhood avatar. Therefore, in the following question participants rate how much they were able to identify with their childhood avatar in VR. Figure 5.7 displays results for both the MobileVR and Oculus Quest trials. For the mobile VR the modal Likert value is ‘Strongly (4)’ and the mean value is 3.33. Except one participant, all participants were able to identify with their child avatar to variable degrees. For the quest trials, the participants were able to identify either ‘Strongly (4)’ or ‘Very Strongly (5)’ with their childhood avatar in VR. As we can see from the results, the users found their avatars in Quest to be more realistic and identifiable than the mobile version. The study does not include statistical analysis of the differences of the results from the MobileVR/Quest build; however, we plan to do that in subsequent study with greater sample size (post COVID).

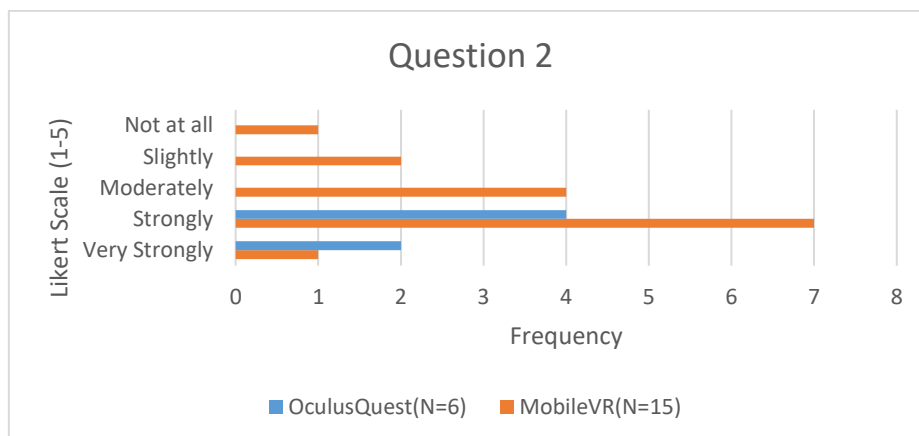


Figure 5.7: Were you able to identify with the child avatar?

Another important aspect of this research was to validate whether the user could project their emotions onto their childhood avatar and to what degree. Following graph (Figure 5.8) shows that for the mobileVR, except two participants, all participants were able to project their emotions onto the child avatar to variable degrees and the majority (mode=3) of the users were able to moderately project their emotions onto the child avatar; the mean Likert value is also 3. For the Quest trials we can see that all participants were able to project their emotions onto the child avatar either ‘Strongly (4)’ or ‘Very Strongly (5)’.

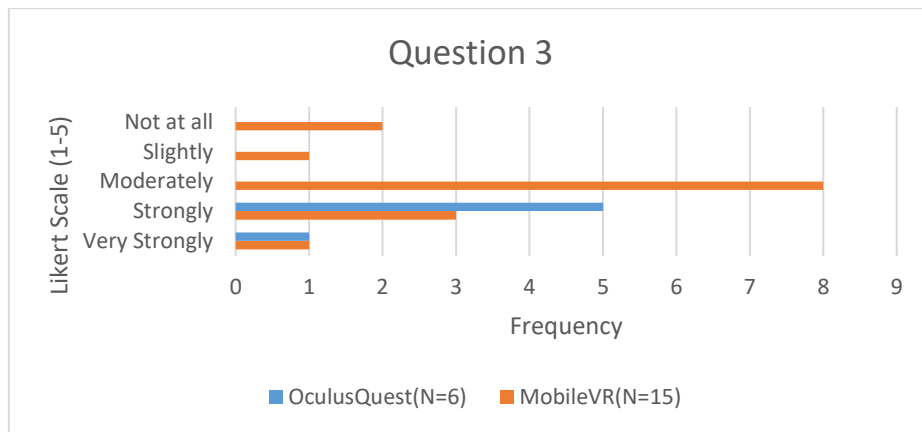


Figure 5.8: Were you able to project your emotions to the child avatar?

As part of the Self-attachment protocols the participants role-play as an adult and perform positive social interactions with their child self (avatar). In the VR, the child responds back to the participant’s emotional support by transitioning from negative (e.g. Sad, Scared) or neutral emotional states to positive emotional states (happy or joyful). We wanted to test to what degree the user found the child-avatar’s response realistic to their emotional support. For the mobileVR platform, it can be seen in Figure 5.9 that, except one, all participants found (to some degree) the avatar’s response to their emotional support realistic. The modal values for the mobileVR are ‘Strongly (4)’ and ‘Moderately (3)’ and the mean Likert value is 2.93. For the high-end version, all participants rated the realism of the child avatar’s response to their emotional support ‘Strongly (4)’.

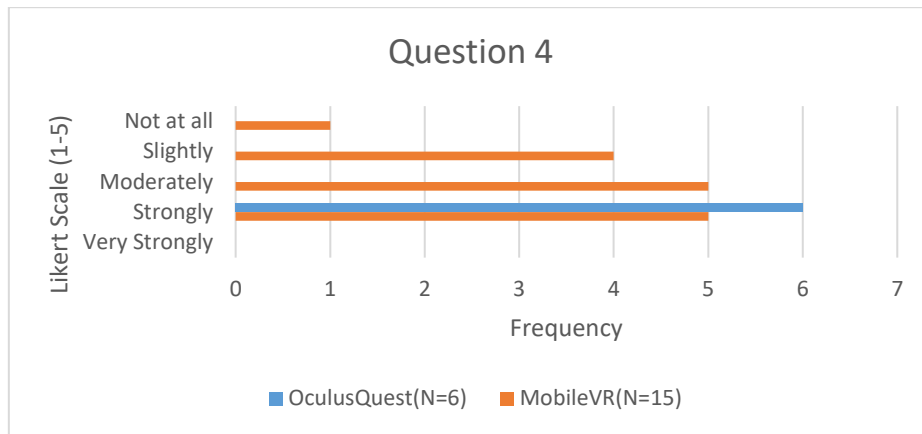


Figure 5.9: How realistic was the child's response to your emotional support?

We also wanted to test the overall emotional impact of both VR experiences on the participants. As shown in Figure 5.10 the VR experience had a positive emotional impact, although to variable degree, on all participants. For the mobileVR the modal value is ‘Strongly (4)’ and the mean is 3.53. For the high-end version, all participants reported that the VR experience ‘Strongly (4)’ had a positive emotional impact on them.

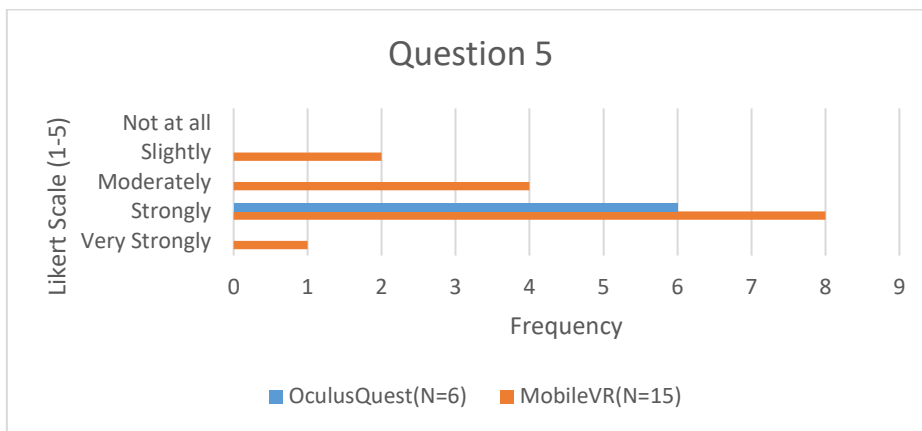


Figure 5.10: Did the experience have a positive emotional impact on you?

In Question 6, the participants rated the level of realism for both VR experiences. As displayed in the following graph the modal value for the mobile VR experience is ‘Moderately (3)’ and the mean value is 3.2, whereas, for the Quest experience all the participants rated the realism as ‘Strongly (4)’, therefore, the mean is 4. The difference in the level of realism for both the platforms is not surprising; as the Oculus Quest’s graphics and computation surely takes an edge on most mobile devices.

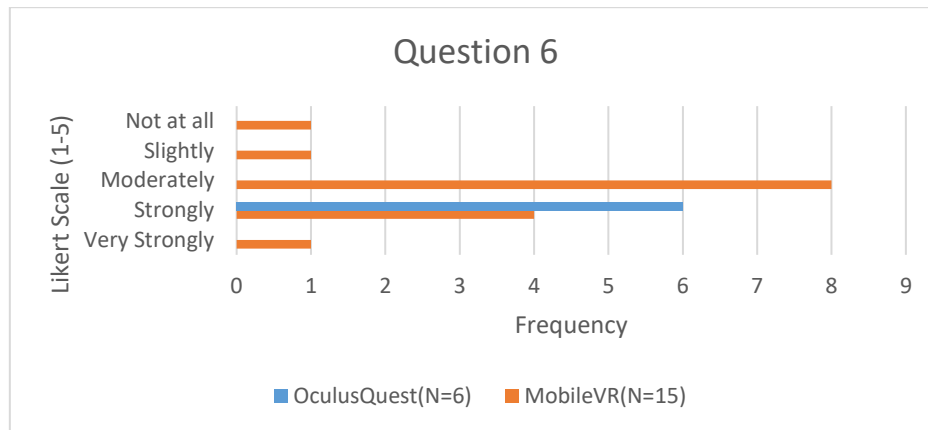


Figure 5.11: How realistic was the whole experience?

One of the motivations for the trial was to test whether the user finds their avatar in VR more relatable than their childhood photos. In the following question we see that the modal value for the both the mobileVR and Quest version is ‘Very Strongly (5)’ and ‘Strongly (4)’, respectively. Thirteen participants found, to variable degrees, their avatar in VR more relatable than their childhood photo. The mean values for the MobileVR and Quest platforms were 3.6 and 3.6, respectively. The results of this question provide more evidence to Quest’s greater level of realism than the mobile VR as all the users rated their experience for Question 7 as ‘Strongly (4)’ and ‘Very Strongly (5)’.

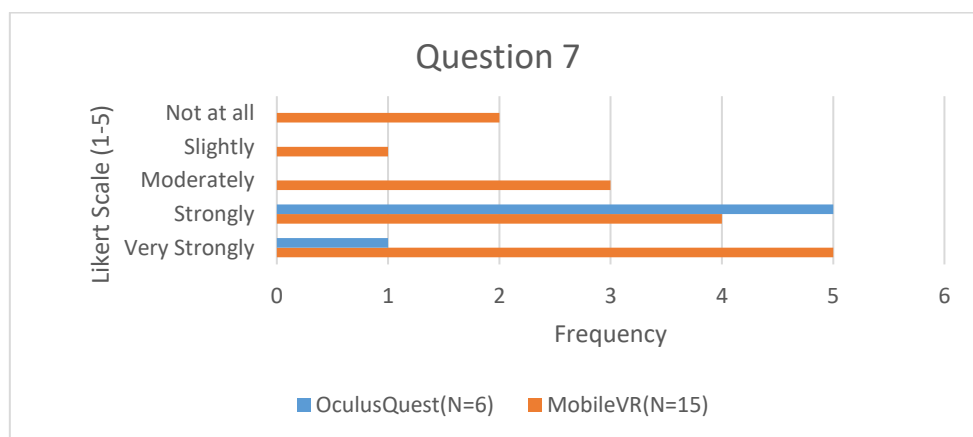


Figure 5.12: Were you able to relate with your childhood self emotionally better by interacting with the VR (mobile) than by interacting with your childhood photo?

The following graph (Figure 5.13), shows that all participants found their avatar in high-end version (Quest) to be more relatable than their photos. The modal values are ‘Strongly (4)’ and ‘Very Strongly (5)’ and the mean is 4.5.

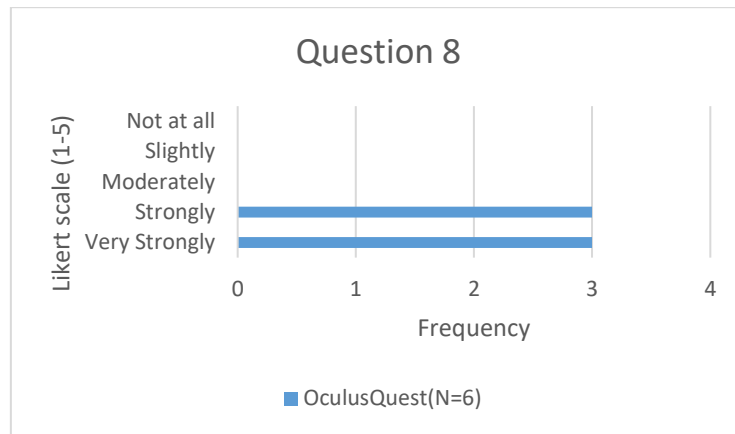


Figure 5.13: Were you able to relate to your childhood-self emotionally better by interacting with your childhood avatar in VR using Quest than by interacting with your childhood photo?

The following graph (Figure 5.14) shows comparison between the low-end and the high-end version of the platform. The graph shows that the participants rated the high-end (Oculus Quest) version as their preferred choice, they found their avatar in the Quest to be more relatable than their avatar in the MobileVR. The modal value for the trial is ‘Strongly (4)’ and the mean is 4.3.

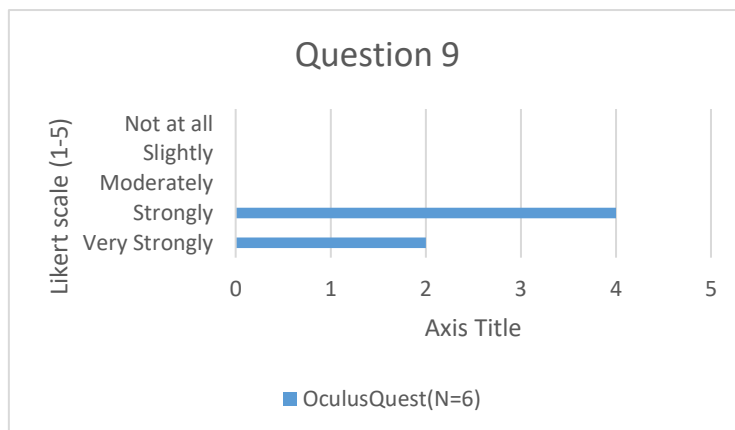


Figure 5.14: Were you able to relate to your childhood self emotionally better by interacting with your childhood avatar in VR using Quest than by using Mobile-VR (android)?

5.3 Discussion

Virtual reality for mental health is a rapidly growing research area, which has the potential to treat people suffering from psychiatric illnesses such as chronic depression and anxiety [68][29] [27][27]. Scalable digital psychotherapeutic platforms encourage optimism while we face the threat of increasing prevalence of mental disorders, globally. Technological advances in virtual reality, avatar animations and avatar-generation are driving innovation in sophisticated virtual reality based

psychotherapeutic interventions. To this end, this thesis presents the design and development of a novel VR-based psychotherapeutic tool to practise protocols of the Self-attachment psychotherapy. It also presents results of a validity study which investigates the efficacy of photorealistic avatar-based approach with the conventional photo-based approach for administering Self-attachment protocols.

The study is one of the first to investigate whether participants find their photorealistic childhood avatar in VR more relatable than their childhood photos. Our findings, although limited, warrant further investigation. Overall, the participants reported the high-end version of the platform to be more realistic and relatable than the both the MobileVR and their photos. They also found MobileVR to be more emotionally relatable than their photos. All participants experienced positive emotional impact, to variable degrees, after experiencing the VR. The high-end environment was reported to have a greater positive emotional impact than the low-end virtual environment.

The results reveal that the whole experience can be improved further to be more realistic as the realism was rated ‘Moderately (3)’ realistic by majority of the participants with a mean value of 3.2. Some of the users shared their following feedback regarding the whole experience:

- A participant was holding a doll in their childhood photo and therefore wanted that the childhood avatar in VR too should hold a doll, and also suggested that having different types of dance (cultural-specific) animations may also enhance her experience.
- A participant suggested that having more shirt colours and dressing styles could improve their experience.
- A participant wanted their dance moves to be synced with their favourite song beats.
- A participant also reported that the Google cardboard was uncomfortable, especially, when using it with glasses.

Some of these suggestions require development of new features which will require new animations. The suggestions are valuable and can be incorporated in the upcoming build of the platform, however, the cost of development of new features should be considered and a good practise is, as proposed by Cieslik et al. [110], to estimate the cost-efficiency (cost-effectiveness) ratio before planning to extend the software functionality. The platforms which enable customisations come with their own set of challenges. For our platform we employed AvatarSDK to generate photorealistic 3D childhood heads; most of the features of the head were extracted directly from the childhood images of the participants,

therefore, it was essential that the user provides us with their high quality images. However, for some aged volunteers it was difficult to find a good quality coloured childhood image as cameras considerably evolved during recent couple of decades. Therefore, any similar study should ensure that only participants with a reasonable quality of their childhood photo(s) should be recruited. Moreover, experiencing VR also requires a certain level of technology proficiency therefore the trial should consider extra training sessions for the aged participants as they are more likely to experience technology-anxiety [142]. In addition, consideration must be given to studies which investigate difference in sense-of-presence for people belonging to different age groups [143].

For the intervention to be scalable it has to be based on a technology that is easily accessible; with over 5 billion mobile subscribers [144] worldwide, the mobile technology is therefore a strong candidate to offer a breakthrough in digital psychotherapeutic research space. The latest phones have evolved from merely being phones to full-fledged computing devices with VR capabilities. It will be hardly surprising to see a scalable digital psychotherapeutic intervention to be based on the mobile technology. This research, thus, is a step in building a scalable VR psychotherapeutic tool to enhance the efficacy of the Self-attachment therapy to help treat patients with symptoms of chronic anxiety and depression. This thesis also present results of the first trial of the platform (healthy volunteers) to test whether user finds their photorealistic avatars in VR to be more relatable than their photos. Although the results are promising, however, no conclusive statement can be made at this stage regarding the effectiveness of the platform before conducting a full-scale randomised control trial.

5.4 Constraints due to Pandemic

The trials of our VR platform were scheduled after the development phase (i.e. year 2020) which got hindered due to the COVID-19 pandemic. Originally, we planned to setup and run the Rift trials at the Department of Computing at the Imperial College London; where we could invite volunteers to visit the VR room for the trials, however, due to social distancing measures this was not possible and therefore we had to cancel the Oculus Rift trials, but still proceeded with the low-end MobileVR trials (remotely). Furthermore, for the high-end version, we employed Oculus Quest as it does not require a high-end computer to run like the Oculus Rift and also because some of the participants already had a Quest.

All the data/information collection forms had to be moved online which again required more effort than usual. Extra online sessions had to be organised to help people with installations and

configurations of their phones and VR equipment to make it ready for the trials. The delivery times for the required Google cardboard also increased for some of the participants in Canada. The ethics application also had to be revamped to seek new approvals for the remote MobileVR trials. Sudden change in working conditions also had a toll on productivity and it was only after some time that everyone got adjusted to the new normal.

6 CONCLUSION

The Covid-19 pandemic has further exacerbated the ongoing global mental health crisis. Self-isolation and confinement measures, which are essential to curtail the infection, has also taken a toll at the mental healthcare globally. The healthcare system is stressed in the developed countries and it is increasing becoming unmanageable in the developing-world. Conventional psychotherapeutic interventions require several in-person (face-to-face or online) sessions for weeks, if not months, which makes the treatment less scalable as there is an acute shortage of trained clinicians [9][10]. Therefore, there is a need for technology-based rapidly scalable psychotherapeutic interventions. To this end, virtual reality has shown promise in treating anxiety, phobias, acute pain, paranoid delusions, depression, posttraumatic stress disorders (PTSD) and various other mental disorders [21][24][73][110]. In VR, we can create and deliver highly realistic and immersive environments which are customised for specific psychotherapeutic intervention; the clinician can control stimulus conditions which are difficult, costly and, in many cases, not possible to achieve in the real-world.

Under the Self-attachment framework [30], causes of mental disorders such as chronic anxiety and depression are traced back to individual's insecure attachment with their primary caregiver during early developmental years. It is in these years that the child develops their capacity to regulate affect. Sub-optimal developmental conditions during childhood can result in sub-optimal attachment schema, which therefore leaves an individual vulnerable to mental ailments in later stages of their life. Self-attachment is a new psychotherapeutic technique for re-training an individual's sub-optimal attachment schema. The patients are required to regularly practice SAT's self-administrable protocols which aim to recreate the positive effects of affectionate infant-parent interactions. The aim of the Self-attachment protocols is to re-create optimal neural circuits for emotional regulation.

Self-attachment protocols require that the user role-plays as an adult and interacts with their child self. The conventional approach to Self-attachment requires that the user employ their childhood pictures to recall moments from their childhood to facilitate imagining a child (their childhood self) and then performing different developmental and re-parenting activities. We posit that this recall could be complimented by employing customised photorealistic avatars via our virtual reality platform. To this end, we designed, developed, and tested an immersive virtual reality platform, consisting of both a high-end version and a low-end version, to administer protocols of the Self-attachment

psychotherapy. The platform makes use of the state-of-the-art avatar customisation tools, such as the AvatarSDK [123], to generate a photorealistic 3D childhood avatar of the user. The platform further enables hair and body modifications to match that of the user.

One of the important aspects of the Self-attachment is to enable the user (adult self) to see different emotions, and transition between them, on the child representation of themselves (avatar in VR) in response to their support. Therefore, the child avatar is programmed such that it displays animations (face and body) for the happy, joyful, sad, and scared emotions. For each protocol, an animator was defined such that it only allows protocol specific transition in animations. The emotions could be triggered via Virtual Reality Tool Kit's (VRTK) [131] ray-cast control for the high-end version and via Google VR's [145] gaze-controller in the low-end version. The user could also invoke emotions via speech in the high-end version of the platform. The low-end version of the platform employed AvatarSDK's latest release Head2.0. The quality of the avatar head for the MobileVR build, which employed Head 2.0, was considerably better than the head generated by the older version of the AvatarSDK. Unlike the Oculus Rift version, in the MobileVR the user could not move within the virtual environment and can only look around or make selection via looking at the controls available in the virtual environment.

Immersive virtual reality platforms, tools and technologies are now commonly used in a wide variety of sectors therefore it is important that they are built taking into account usability engineering practices. To this end, we conducted a usability evaluation study for the high-end version of the platform. We employed heuristic and formative evaluations [134][132] to the prototype 2 (See Section 4.2.2); based on our findings we made the navigation choices consistent and also readjusted the Oculus Rift's Ray-cast control. The participants also reported that they were quite involved in the VR experience and that they could identify with their photorealistic childhood avatar. The results were promising and therefore encouraged us to conduct a full-scale validity study for the platforms.

Results of the validity study were promising. The user found their photorealistic avatar in the VR more realistic, engaging and emotionally relatable than the conventional photo-based approach. This study is one of the first to investigate whether photo-realistic avatars are a better alternative to 2D photos for administering SAT protocols. of the Self-attachment psychotherapy. The majority of the participants had postgraduate degrees, belonged to different age groups and professions.

More than 90% of the MobileVR participants (N=15) could identify (to variable degrees) with their childhood avatar more in VR than using their childhood photos. Similarly, all the MobileVR participants reported experiencing positive emotional impact after administering protocols in the VR; some experienced less while others experienced more but not a single participant reported not experiencing positive emotional impact after administering the VR experience. Except two participants all were able to relate with their avatars in VR. More than 60% of the participants reported that they found their avatars to be ‘Strongly (4)’ or ‘Very strongly (5)’ emotionally relatable than their ordinary photos. Most of the participants rated the ‘setting’ to be moderately realistic, therefore, there is a room for improvement.

The average Likert rating for the Quest experience for all the impact test questions was above the MobileVR. Although the sample size was only 6 due to recruitment limitations (COVID-19). Still it is evident from the results that the users found Oculus Quest experience to be much more realistic, engaging, and interactive than the MobileVR; which is not surprising because of the difference in their hardware, computation, graphics and their cost. However, our findings - emotional relatability of avatars in MobileVR - are encouraging in the pursuit of devising an effective, self-administrable, and highly scalable digital psychotherapeutic intervention for treating mental disorders.

6.1 Limitations

Our proposed immersive virtual reality (IVR) platform focally relies on the emerging VR technology and as with any emerging technology, high-end VR might not be available in some countries (esp. developing countries) as it may take a while until the technology will be accessible globally. Several state-of-the-art virtual reality platforms (like Oculus Rift) require costly hardware such as an expensive computer and a dedicated graphics card which too limits accessibility of VR based treatments. Another limitation is that the clinicians and patients may have to undertake a training program in VR before they could incorporate it successfully in their practise.

To design a new VR mental health intervention, it is also important to employ VR usability guidelines earlier in the development process which can improve design choices of technology-based interventions for the treatment of depression. It can also help us gain better understanding of what the individual need and what they expect from the platform. Usability evaluation can further help us understand how different components of the VR platform are rated by the user with respect their usefulness, efficiency, and overall usability. Both qualitative and quantitative user feedback might

reveal gaps between the user's expectation and actual implementation choices made by the developers. Therefore, tailoring the intervention based on user's feedback can help us create/deliver highly usable VR experiences.

The proposed VR intervention for SAT for treating anxiety and depression is yet to be tested on clinical patients. Before conducting a full scale randomised clinical trial on a clinical population, with and without VR, we cannot be certain of the efficacy of the platform. As the MobileVR trial require people to administer VR using their phones with various levels of hardware and software capabilities, therefore, it is reasonable to assume that another study done with people belonging to a different social class (possessing better quality phones) may yield different results. To investigate our VR platform's efficacy further, we need to compare our results and findings with an already established digital psychotherapeutic intervention such as I-CBT (Internet cognitive behavioural therapy).

In a pre-trial session with the participants, the user only agreed to install our app if we ensure them that our app will not collect any data. Therefore, for this trial we were not able to collect the data. However, for the clinical trial we plan to integrate a data module. Data on patterns of use of the application could further offer an opportunity to improve the platform to adapt both the needs and preferences of the users. Such data could also help us understand what type of platform features (or SAT protocols) were employed by the patients and for how long who reported clinically significant improvements after the psychotherapy.

The COVID-19 Pandemic hindered the trials and testing of the platform as everything had to be moved online and more time was spent to train participants to administer MobileVR sessions on their own. Furthermore, the study could have employed greater sample size if it were conducted in an in-lab setting, which was not possible due to lock-down and social distancing measures in place. The platform uses AvatarSDK for generating head and therefore uses facial animations which are readily provided by the SDK. The Avatar SDK's current version does not provide animations for all basic emotions i.e. they do not have animations for anger and laughter, which may be provided in the future. The AvatarSDK's generated head borrows features from the picture provided by the user, therefore, the quality of the head greatly depends on the quality of the image. To this end, it is important to keep an image-quality requirement in the inclusion criterion for the future studies who wish to employ the AvatarSDK.

The results from our validity study shows a potentially effective approach for administering SAT protocols, although results are promising but they are not conclusive. Further research, randomised controlled trials, are needed for the conclusive judgement of VR platform's effectiveness in administering Self-attachment protocols.

6.2 Future Research Direction

To further enhance the efficacy of the Self-attachment protocols an internal dialogue module will be incorporated, that is, while administering the Self-attachment protocol, the user (role playing as an adult self) could start a conversational dialogue with their child self. The child could first describe their current or past distressful moments, concerns and emotional states, after which, the adult self intervenes by compassionately responding to the child's distress call, with a series of affectionate exchanges until their child self (avatar) recovers from that state of distress (transitions to happy emotion). This will be implemented as a conversational agent which has the ability to detect emotions via speech (see e.g. [146] for real-time speech emotion and sentiment recognition in an interactive dialogue system). Automated sentiment analysis via speech might additionally help in determining the severity of depression [147] and may also assist in tracking the user's progress with the therapy. It can also enhance the interactivity of the platform by automatically detecting change in the emotional state of the user, and appropriately reflecting that emotional state on to the child avatar.

To enhance the usability of the VR platform development of a new build for the Oculus Quest is underway. The Oculus Quest's hand tracking feature can make the platform more usable, by enabling the user to control the navigation in the virtual environment via hand gestures without the need for any controllers. The build will also include features to enable the internal dialogue module and our aim moving forward is to conduct a randomised control trial in order to fully assess the efficacy of virtual reality based Self-attachment intervention for treating mental disorders.

Our team at the Algorithmic Human Development [148], in collaboration with a group of clinicians from the Department of Brain Sciences at the Imperial College London, are planning to conduct a full-scale clinical trial. While administering these trials, it will be interesting to investigate user's platform usage data such as, daily number of sessions administered, time spent per session, patterns of usage and the type of SAT protocols employed during the course of the therapy. To this end, a data collection module will be integrated in the next version of the MobileVR platform by employing Google's Firebase [149] application development platform.

To conclude, VR for mental health is a rapidly growing area of research, which has the potential to effectively treat people suffering from psychological ailments. Despite the need for improvement in the research and practise of the VR based psychotherapeutic tools, it has shown promise in the pursuit of devising novel scalable techniques for treating mental disorders.

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APPENDIX

This appendix contains materials used in the validity study for the immersive virtual reality platform for the Self-attachment therapy as presented in Chapter 5. These include, in order of appearance:

- 1) Participation information sheet
- 2) Consent form for participants
- 3) Demographic information form
- 4) VR impact test questionnaire for MobileVR.
- 5) VR impact test questionnaire for Oculus Quest
- 6) Advertisement for recruitment

PARTICIPANT INFORMATION SHEET



Algorithmic Human Development

Impact evaluation of an Immersive Virtual reality platform for Self-attachment

You are being invited to take part in a research study. Before you decide whether you would like to take part, it is important to understand why the research is being done and what it involves. This information sheet tells you the purpose of the research study and aims to give you more detailed information about how the research study will be carried out. Do not hesitate to ask us if anything is not clear or if you would like more information.

Thank you for reading this.

1. What is the purpose of this study?

Our team have developed an immersive virtual reality (VR) platform for Self-Attachment. The aim of our study is to test (remotely) whether the users find these realistic looking avatars, created by their favourite childhood photo, as relatable as their ordinary childhood photographs. To achieve this the subject will be immersed in a VR environment where they get to interact with their customized avatar, which resembles them when they were a child. This study is being conducted as part of my PhD.

2. Why have I been invited to take part?

Because you meet the inclusion criterion i.e. Healthy subject aged between 18-50 years, who have their childhood picture?

3. Do I have to take part?

It is up to you whether you decide to join the research study. If you agree to take part, we will ask you to sign a consent form and allow your demographic information to be used for the study. You are free to withdraw at any time, without giving a reason.

4. What will happen to me if I take part?

If you decide to take part, you will be asked to fill in an online demographic questionnaire (via Qualtrics). After that there will be an online introductory meeting and a 5-minute video tutorial (YouTube) about using VR; the tutorial will familiarise you with basic controls and features of the Virtual reality. After providing your favourite childhood photo, you will be sent an App both for android phone and/or Oculus Quest which you can download on your device to interact with your childhood avatar. After one week you will be asked to fill out a questionnaire on your experience with the VR and provide your feedback in an online meeting. All participants will be offered a participation allowance of 10 pounds (opt-in) via PayPal or wire transfer for their participation in the study and we will offer to buy a google cardboard for all volunteers who do not already have one. We'll also organize a participant feedback session at the end of the study.

5. What are the potential disadvantages of taking part?

Our study involves interaction with the realistic child avatar which is somewhat similar to looking to your favourite childhood photo. Although we don't at all expect it, there is a slight chance that some participants may find interaction with their realistic avatar unpleasant, we will follow Haigh et al's distress protocol (attached) in this case.

6. What are the potential benefits of taking part?

The information you give us could help us to understand whether VR-based approach enhances efficacy of Self-Attachment. You will get to experience Google's cardboard VR technology, a state-of-the-art human computer interface.

What if something goes wrong?

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Investigator (Abbas Edalat and a.edalat@imperial.ac.uk; ****022339). If you are still not satisfied with the response, you may contact the Imperial College Joint Research Compliance Office.

7. Will my taking part in the study be kept confidential?

Yes. We will follow ethical and legal practice and all information about you be handled in confidence.

8. What will happen to the results of the research?

The results of the research study will be published as a paper in a relevant academic journal/conference. Participants will not be identifiable in this paper.

9. Who is organising and funding the research?

This research is being funded by the registered charity Science and Arts Foundation.

10. Who has reviewed the study?

This study was given ethical approval by Head of Department and Joint Research Compliance Office (JRCO).

Contact for Further Information

Thank you for reading this. If you have any queries, please contact the graduate researcher for the study, Ibrahim Ghaznavi, on ***304446 or preferably email Ibrahim at s.ghaznavi16@imperial.ac.uk or the Chief Investigator, Prof. Abbas Edalat at: a.edalat@imperial.ac.uk. You may retain this information sheet for reference.

Thank you for taking part in this study!

HOW WILL WE USE INFORMATION ABOUT YOU?

Research Study Title: Impact evaluation of an Immersive Virtual reality platform for Self-attachment

20IC5725

Imperial College London is the sponsor for this study and will act as the data controller for this study. This means that we are responsible for looking after your information and using it properly. Imperial College London will keep your personal data for:

- 10 years after the study has finished in relation to data subject consent forms.

- 10 years after the study has completed in relation to primary research data.

We will need to use information from this research project.

This information will include your

- ID:
- Email:
- Date of Birth:
- Your postcode:
- Telephone Number:
- Level of education: (secondary education; graduation; post-graduation)
- Profession: (current; retired)
- Marital status: (single; with partner))
- Country of residence:
- Psychotherapy: (current or past; please state the number of years in therapy)

People will use this information to do the research or to check your records to make sure that the research is being done properly.

People who do not need to know who you are will not be able to see your name or contact details. Your data will have a code number instead.

We will keep all information about you safe and secure.

Once we have finished the study, we will keep some of the data so we can check the results. We will write our reports in a way that no-one can work out that you took part in the study.

LEGAL BASIS

As a university we use personal information to conduct research that will either be in the public interest, or the legitimate interests of the College.

As a publicly-funded organisation we have to ensure that when we use personally-identifiable information from people who have agreed to take part in research, it is either in the public interest, or that our legitimate purposes are both properly notified to you and are not overridden by your rights.

We will conduct scientific research in compliance with the law and the recommendations and guidance published by the UK Information Commissioners Office (ICO). This will follow similar rules to health and care research but may not meet the definition of the College's public interest task. In such cases we will be holding and using your data for what are deemed our "legitimate interests".

INTERNATIONAL TRANSFERS

There may be a requirement to transfer information to countries outside the European Economic Area (for example, to a research partner). Where this information contains your personal data, Imperial College London will ensure that it is transferred in accordance with data protection legislation. If the data is transferred to a country which is not subject to a European Commission (EC) adequacy decision in respect of its data protection standards, Imperial College London will enter into a data sharing agreement with the recipient organisation that incorporates EC approved standard contractual clauses that safeguard how your personal data is processed.

SHARING YOUR INFORMATION WITH OTHERS

For the purposes referred to in this privacy notice and relying on the bases for processing as set out above, we will share your personal data with certain third parties.

- Other College employees, agents, contractors and service providers (for example, suppliers of printing and mailing services, email communication services or web services, or suppliers who help us carry out any of the activities described above). Our third-party service providers are required to enter into data processing agreements with us. We only permit them to process your personal data for specified purposes and in accordance with our policies.

WHAT ARE YOUR CHOICES ABOUT HOW YOUR INFORMATION IS USED?

You can stop being part of the study at any time, without giving a reason, but we will keep information about you that we already have.

- If you agree to take part in this study, you will have the option to take part in future research using your data saved from this study. [Algorithmic Human Development Lab]

WHERE CAN YOU FIND OUT MORE ABOUT HOW YOUR INFORMATION IS USED

You can find out more about how we use your information

- by asking one of the research team
- by sending an email to [s.ghaznavi16@imperial.ac.uk], or
- by ringing us on [*****04446].
- Link to Research website – if there is one

COMPLAINT

If you wish to raise a complaint on how we have handled your personal data, please contact Imperial College London's Data Protection Officer via email at dpo@imperial.ac.uk, via telephone on 020

7594 3502 and/or via post at Imperial College London, Data Protection Officer, Faculty Building Level 4, London SW7 2AZ.

If you are not satisfied with our response or believe we are processing your personal data in a way that is not lawful you can complain to the Information Commissioner's Office (ICO). The ICO does recommend that you seek to resolve matters with the data controller (us) first before involving the regulator.

CONSENT FORM



Algorithmic Human Development

Name of Principal Investigator: Prof. Abbas Edalat **Please check box (where applicable)**

I confirm that I have read and understand the participant information sheet dated - -/- - version 1.14 for the above study and have had the opportunity to ask questions which have been answered fully.

☐

I understand that my participation is voluntary, and I am free to withdraw at any time, without giving any reason and without my legal rights being affected.

☐

I give permission for Imperial College London to access my records that are relevant to this research

☐

I give/do not give consent for information collected about me to be used to support other research in the future, including those outside of the European Economic Area.

☐ Give

☐ Do not give

I consent to take part in the above study.

☐

I consent for my evaluation interview to be video recorded.

☐

I give/do not give consent to being contacted to potentially taking part in other research studies.

☐ Give

☐ Do not give

Your name:

Signature:

Date:

1 copy for participant; 1 copy for Principal Investigator

Personal Information Form

Please complete and submit before completing the questionnaire.

Date:	
ID:	
Email:	
Date of Birth:	
Your postcode:	
Telephone Number:	
Level of education: (secondary education; graduation; post- graduation)	
Profession: (current; retired)	
Marital status: (single; with partner)	
Country of residence:	
Psychotherapy: (current or past; please state the number of years in therapy)	

IMPACT TEST FOR MOBILE VR

Case No: Name: DoB:
Date:

On the scale below, please rate the following questions according to the scale below.

1 ----- 2 ----- 3 ----- 4 ----- 5

Not at all Slightly Moderately Strongly Very strongly

- 1- How realistic was the setting?
- 2- Were you able to identify with the child avatar?
- 3- Were you able to project your emotions to the child avatar?
- 4- How realistic was the child's response to your emotional support?
- 5- Did the experience have a positive emotional impact on you?
- 6- How realistic was the whole experience?
- 7- Were you able to relate to your childhood self emotionally better by interacting with the VR than by interacting with your childhood photo?

IMPACT TEST FOR OCULUS QUEST

Case No: Name: DoB:
Date:

On the scale below, please rate the following questions according to the scale below.

1 ----- 2 ----- 3 ----- 4 ----- 5

Not at all Slightly Moderately Strongly Very strongly

- 1- How realistic was the setting?
- 2- Were you able to identify with the child avatar?
- 3- Were you able to project your emotions to the child avatar?
- 4- How realistic was the child's response to your emotional support?
- 5- Did the experience have a positive emotional impact on you?
- 6- How realistic was the whole experience?
- 7- Were you able to relate to your childhood-self emotionally better by interacting with your childhood avatar in VR using Quest than by interacting with your childhood photo?
- 8- Were you able to relate to your childhood-self emotionally better by interacting with your childhood avatar in VR using MobileVR (android) than by interacting with your childhood photo?
- 9- Were you able to relate to your childhood self emotionally better by interacting with your childhood avatar using Quest than by using mobile-VR (android)?

Advertisement for recruitment

Impact evaluation of an Immersive Virtual reality platform for Self-attachment

Algorithmic Human Development Lab at the Department of Computing is recruiting volunteers to investigate how state of the art Virtual Reality (VR) technologies could enhance psychotherapeutic experience. Psychotherapy is among the most effective techniques for combating mental health issues, and VR is beginning to be explored as a way to enhance the efficacy of various psychotherapeutic treatments. In this validity study, we plan to test our mobile VR platform to investigate whether volunteer could relate with their customised child avatar, using both the Oculus-Quest and Mobile-VR, more than their childhood photos.

The results of this study will help us better our understanding as to how latest VR technologies could enhance psychotherapeutic experience. All volunteers will be offered participation allowance of 10 pounds (opt-in) and we will offer to buy a google cardboard for all volunteers who do not already have one.

If you are 18-50 years old, fluent in English, have an android phone and some of your childhood photos then you are eligible to participate. Please email s.ghaznavi16@imperial.ac.uk to register your interest.