Use of Virtual Reality in Exposure Therapy and Other Psychological Treatment Methods

Contributors
Aman Sariya, Rishabh Nanawati
Computer Engineering, Mukesh Patel School of Technology, Management & Engineering
NMIMS University, Mumbai, India

Mentor
Supriya Agarwal
Assistant Professor
Computer Engineering, Mukesh Patel School of Technology, Management & Engineering
NMIMS University, Mumbai, India

Abstract: While technology has impacted every field of science, the impact on mental health treatments has been very little, despite significant potential. The focus of this chapter is to explore the use of virtual reality (VR), specifically in the treatment of mental health disorders. Throughout the past few decades, various studies have been conducted to validate the delivery and efficacy of VR in the treatment of mental health disorders. The highly immersive world that VR is able to provide makes it a suitable addition to Exposure Therapy, one of the most popular therapy techniques, where the level of realism and interaction directly affect the quality of treatment. Exposure therapy, a subsection of Cognitive Behavioural Therapy (CBT), involves mainly two delivery mechanisms - *imaginal*, where the patient imagines the feared situation, and *in-vivo*, where the patient is physically placed in the environment. VR has shown potential in being able to bridge the gap between the two, to compensate for the shortcomings of each. This chapter discusses Virtual Reality based Exposure Therapy (VRET) amongst other delivery mechanisms and cites other physical studies conducted for the same. VRET has been used to treat many mental health disorders ranging from anxiety to autism and suggests greater efficacy than traditional exposure therapy methods. However, VR users are known to suffer from symptoms of motion sickness like headaches and nausea. The moving graphics and the patterns of the simulation may cause seizures in some sensitive users. There is also the risk of increased dependency on the VR environment. With promising results fetched by VRET studies, many techniques are being explored to reduce these side-effects. Before applying VR in psychiatric treatments, establishing good doctor-patient relationships and receiving relevant education is advised. As the applications of VRET grow, guidelines must be established to apply VR treatments to patients with psychiatric illnesses. This chapter further discusses how VRET can be delivered in a clinical environment, involving selection of the mode of delivery, the specifications of the headset and simulation, duration of delivery and the level of gamification required. Multiple studies have been explored that indicate how VR has the opportunity to develop into an alternative option for psychiatrists to use in supporting psychiatric assessments and treatments in patients. This chapter will provide a broad overview of the studies conducted on the use of VR in therapy, the use of VR for the treatment of specific disorders, benefits of using VR in psychotherapy, the issues faced and how to alleviate them, and the proposed methods for psychologists to administer VRET in a clinical setting.

Keywords: anxiety disorders, exposure therapy, mental health, psychotherapy, virtual reality, virtual reality exposure therapy.

1. Introduction

Virtual Reality (VR) is a well-known technology that has seen a surge of growth across multiple fields like gaming, marketing, customer service training and education. In the field of medical sciences, it is known to be used in medical training for a deeper understanding and research of anatomy and surgery. It is also used by doctors and surgeons in diagnosis and surgery, to visualise various body parts of a patient, developed from scanning techniques like MRI and CT scans [1]. Its applications in the field of healthcare are expanding universally and gaining traction as its potential is being recognised.

Although there are many applications of VR in physical healthcare, it has proved to benefit one's mental well-being as well. Several VR applications have been developed in the last two decades for the understanding, assessment and treatment of mental health disorders [2]. Many studies have been conducted involving trials of these applications on patients with various disorders. Results show that participants are already being affected by an array of virtual environments, fully knowing they are not real [3].

While early development of VR dates back to the 1950s, psychologists did not start using VR as a part of their treatment until the 1990s. The first study to examine the use of VR in exposure therapy investigated its effects on the treatment of acrophobia (fear of heights) and positive results prompted further research in the field [4]. Thus far, VR has been studied as a tool in the treatment of many psychiatric disorders like anxiety disorders, stress-related disorders, psychosis and eating disorders.

In terms of economic worth, VR in healthcare was valued at USD 2.14 billion as of 2019, and is estimated to grow to USD 33.72 billion by 2027 in the continent of North America alone. The share of mental-health applications in this valuation was 33.4% [5].

In this chapter, various studies that highlight the different applications of VR in the field of mental health have been reviewed. To provide the context that is needed to understand these applications, it begins with an introduction of the psychological science behind the applications. This is followed by an explanation of the working of a VR simulation and how it manages to create a virtual near-real environment. After highlighting the features and benefits of such a VR application, it focuses on different types of mental health disorders and the effectiveness of VR based treatments on them. Additionally, it then explores various issues associated with the use of such an application, which is followed by a discussion where the authors provide a look into their own research efforts and the future scope of this technology.

2. Psychology

Stimuli are events or objects that induce a particular chain of thoughts. Stimuli drive feelings like happiness, sadness, and fear. Steinman et al. defines exposure therapy as *any treatment that encourages the systematic confrontation of stimuli that are feared, with the aim of decreasing fearful physiological, cognitive, and behavioural reactions* [6]. These feared stimuli can be external to the patient, like real-life circumstances or environmental objects on which the patient has no control, or entities internal to the patient, like feared notions or sensations of which the patient has some control, if not all.

Here is an example of how a therapist helps its patient overcome their atrocities. Amit's daughter Agni has been nagging him to teach her how to cycle. Amit follows the classical approach - He asks Agni to get on the bike and ensures her that he will support her. Agni is facing her fear of falling from the lack of balance with additional support from Amit. They do a test run and Agni starts feeling confident because she knows she does not have to worry because her father is supporting her balance. In the next run, Amit supports the bike intermittently, without Agni knowing when he leaves and catches on again.

The realisation between Amit supporting the bike and leaving is blurred and unrecognisable to Agni. To her, she is being supported constantly. This makes her mind forget about her actual fear and focuses more on moving forward. Agni, constantly facing her fears, is slowly getting desensitised to them and starts gaining trust in her own abilities. For the final run, Amit may just hold the bike initially and leave as soon as his daughter starts peddling. She has gained momentum, confidence and trust in her abilities.

Amit provides the support mechanism needed, Agni is the patient, the fear is the loss of balance leading to Agni falling down and the environment corresponds to the cycle, the support and the road.

In exposure therapy, clients are first subjected to lower intensity stimuli (at the bottom of the exposure hierarchy) repeatedly until that fear abates. They then move on to the higher intensity stimuli. This process is repeated until no stimuli in the process elicits fear any more [7]. This level-wise graded approach usually involves construction of an exposure hierarchy by the mental health professional and the patient, where stimuli are ranked based on how fearful the patient is of various scenarios. The client is then subjected to a series of scenarios that trigger their fears. The scenarios increase in intensity based on the progress of the patient through the course of treatment. A commonly used scale for these rankings is the 'Subjective Units of Discomfort (SUD)' scale [8]. It assigns values 0 to 100 to measure the intensity of the disturbance that the patient is feeling. The pathological fear that is to be made redundant, is modified by integrating corrective information with the same fear structure through exposure therapy [9].

Difficulty Level	Scenario
1	Patient stands in an empty room.
2	Patient observes a group of people having a discussion from a large distance.
3	Patient observes the same group of people from a shorter distance.
4	Patient becomes a part of the same group and observes the participants but does not engage in conversation.
5	Patient is now engaged in small talk with the characters in the simulation with one-word answers.
6	Patient is placed in a similar environment but with more people with question prompts requiring longer answers.
7	Patient is placed on stage in an empty auditorium with spotlights on them. They may be required to read out a small paragraph to serve as a speech.
8	Patient is placed in a full capacity auditorium with spotlights and is required to read out a prompt or personal speech to which the audience may applaud.

Table 1 - Example of exposure hierarchy for the fear of public speaking.

The two common approaches for clinical delivery of exposure therapy are imaginal exposure and in-vivo exposure [10].

Imaginal Exposure (IE) [11] involves encouraging the patient to imagine their feared scenarios or traumatic events. A therapist sits the client down on a comfortable chair and asks them to close their eyes while performing relaxation exercises. The client is then made to imagine a scenario as though they are in a movie. Scenarios, based on the discomfort level, can be very elaborate. They involve descriptions of sensory elements like taste, touch, smell, sound and vision along with descriptions of the settings, the people, if any, around the client as well as his or her actions. For example, for social anxiety, the client may be made to imagine that they are entering a coffee shop. Their actions might be picking a table, ordering coffee at the counter, encountering other customers, waiting in line for the

washroom, etc. They can be made to imagine the taste and aroma of the coffee, what they see around them, the music playing, the texture of the coffee mug, etc. These intricacies generate a sense of immersion and introduce a sense of realism for the client. The therapist may continuously gauge the reaction of the client. After the therapist concludes the description of the scenario, they ask the client a series of questions about what they see, hear, think, feel emotionally or physiologically, etc. Some therapists may choose to record these sessions for clients to listen to them as homework and rate their level of discomfort. This serves as a benchmark to measure progress of the client through the course of the treatment.

The second, perhaps a more effective method to deliver exposure therapy, is the in-vivo approach. This approach involves subjecting the client to the actual fear-evoking stimuli. Here, the therapist is present with the client when they experience thoughts of fear and anxiety. The therapist guides them towards navigating these thoughts and dealing with them in the best way possible. Slowly, the need for the therapist's guidance diminishes and the patient becomes independent enough to be able to deal with their fears. In-vivo is a more effective method for the simple reason that it has the potential to stimulate all your senses to provide a sense of authenticity.

Let us take a look at how virtual reality fits in exposure therapy. While imaginal exposure has proven to be an effective way to begin therapy, it tends to be very slow unless supported by in-vivo exposure because it depends on the capabilities of the client to evoke feared imagery in depth [7] [12]. This may be an added stressor for the patient, as they already feel overwhelmed by their feelings of anxiety, and imagining the situation that caused it may not help. Assuming that they do imagine it, their overburdened mind might not be able to imagine all the details accurately or for the amount of time required for it to be effective. It also does not stimulate the patient’s senses enough to have a solidified long-lasting effect.

In-vivo, on the other hand, is a very effective way to deliver exposure therapy because it involves the client actually being present in the situation. However, it does have multiple limitations. The client may be reluctant to participate in such a form of therapy because the scenarios could be unsettling and gravely anxiety-inducing. This leads to higher chances of abandonment of the treatment. Further, it is not easy to set up in-vivo scenarios. It may either be too costly, unrealistic, difficult or even impossible. If the client has a fear of flying, it is very difficult to simulate scenarios to tackle specific fears like take-off, landing or turbulence. Similarly, for other fears involving unpredictable events like a natural disaster or an existential fear like the fear of losing a loved one, in-vivo might not be of much use. Hence, the scope of fears that in-vivo can deal with is limited.

These are the gaps in imaginal and in-vivo exposure therapy that virtual reality has the potential to bridge. VR based Exposure Therapy (VRET) has the capability to stimulate one's sense of vision, hearing, touch, and with the correct clinical environment and delivery method, even smell and taste by replacing real anxiety-evoking scenarios with their virtual counterparts. This may help to encourage people who would be disinclined to confront high intensity stimuli to seek help, ultimately aiding in therapeutic habituation (i.e. a behavioural response decrement that results from repeated stimulation and that does not involve sensory adaptation [13]). There is a plethora of research, randomised controlled trials (RCTs) and meta-analysis that have been conducted that strengthen the proof of the efficacy of VRET.

3. The working and quality of the simulation

In order to work the VR simulation, the user must be equipped with a head-mounted display (HMD) and a software control system (which may be embedded in the HMD), along with other optional input devices (like data gloves, motion controllers, etc) and output devices (like in-ear earphones, haptic gloves, etc.). The user’s movements are fed to the software as input via the input devices. The software

performs various functions based on those inputs and produces outputs which are fed back in the form of graphic changes, auditory output, etc [14].

VR is viewed in medicine in one of two ways: VR as a simulation tool and VR as an interaction tool. For its use in psychotherapy, VR is more prevalent as a simulation tool because it provides a life-like human-computer interface paradigm that eliminates the need for the user to be a third-party observer disconnected from the virtual surroundings. Instead, it allows the user to be an active participant in a virtual world.

3.1. Intervention Approach

VRET may be employed in different ways to treat a particular disorder. At the foundation of these approaches lies the carefully designed virtual environment, consisting of both interactive and non-interactive objects. The traditional approach is to have the patient use the simulation in a clinic, where their therapist is able to see what the patient sees, giving them tasks to perform and guiding them throughout the process.

A new, rather modern approach, is to employ an automated and gamified simulation that would use tasks, that rely on game mechanics, and points, badges and trophies, that reinforce progress and achievements as the patient completes various tasks and progress with their conditions [15]. Modern games are quite immersive, and their elements like level design, story and narrative building, feedback of performance, and avatar assistance can be very helpful in the treatment of psychiatric disorders. Moreover, these characteristics would make the simulation guided by itself and would eliminate the need of a therapist's presence. However, the psychiatric community still remains apprehended about a gamified, automated simulation being delivered in the absence of a mental health professional. There are concerns of an automated simulation misguiding a patient, especially if the patient is not aware of his condition enough and cannot tell if something is right for them. There is also the added worry about absence of a professional to handle the patient if the patient's condition worsens or if they get triggered, causing undesirable reactions like episodes of panic attacks.

Hence, most VRET interventions employ a mixed approach. The simulation is gamified and assists patients wherever necessary, while being administered in the presence of a therapist. The therapist monitors the patient's actions, observes their reactions and is available to guide them throughout. This would make the treatment more interactive and immersive while remaining relatively safer.

3.2. Efficacy

In order to make the most effective use of VR simulations, developers must build a simulation that "tricks" the user's senses into believing that the virtual world is real [16]. Resource allocations and utilisation needs to be done carefully by the developer in this case. Which senses to stimulate, how much stimulation is necessary, what quality of stimulation to achieve for the user to perceive them as real – these are a few questions that every developer needs to answer before beginning with the development.

VR simulations can be employed in a number of ways, ranging from the use of only a head-mounted display (HMD) to full-body interaction with virtual object through motion capture. The user's perceptual experience depends on the *level of immersion*, which is a technical concept that can be applied to various intervention scenarios [17]. Level of immersion has been known to depend mainly on five aspects – inclusiveness, extensiveness, surroundings, vividness and matching.

- *Inclusivity* or *inclusiveness* relates to the ability of a VR simulation to eradicate indicators that remind the user of a physical world. This includes the role of devices like joysticks, noise from external sources, weight of instruments worn, etc.
- *Extensiveness* is the number of sensory modalities that have been manipulated.

- *Surrounding* refers to the appearance of the VR technology, which includes the head-mounted display and/or the computer screen.
- *Vividness* involves the resolution and accuracy of the depth and colour that is presented in the virtual environment and how close it is to reality.
- *Matching* refers to the field of view of the user, the various changes that occur in it and how synchronized they feel with the user's interactions.

Another component that plays an important role in developing VR for clinical use is the *sense of presence.* It is the perceptual experience of the user which is understood by how engaged the user feels in the virtual environment. It is facilitated by the user's perception thresholds and the tasks performed by them [18].

The two concepts are distinctly based on their method of determination. While level of immersion is a technical concept that is derived from the VR simulation, sense of presence is based on each individual's experience with the simulation. However, it is not possible to completely dissociate them, as sense of presence is facilitated by the level of immersion. Simulations with high levels of immersion are often known to offer a better sense of presence.

Visual cues capture the majority of our attention and are responsible for feeding maximum information to our brain. After vision, hearing is the second most important sense. Touch is usually less significant and rarely contributes to providing meaningful experiences. The senses of smell and taste, on account of them being very difficult to reproduce, are omitted from consideration in this case [19]. VR development majorly involves manipulating our senses via visual stimuli, followed by secondary contributions from sounds and noises.

Visual cues and the amount of interaction offered usually leads to an experience that is closer to reality. Ideally, we should be able to produce visuals that generate feedback that equals, if not exceeds, the human visual system [20]. The field of view (FOV) needs to be designed carefully, especially parts where the human is supposed to focus the most. The visual acuity, defined as the sharpness of viewing, should also be calibrated accordingly. The human eye can perceive a large spectrum of colours, ranging in ten orders of magnitude [21]. None of the screens, as of now, can cover the whole spectrum. Appropriate colour mapping techniques must be employed to achieve the best possible replication of the colour scheme [22].

There are other factors that contribute to the quality of a VR experience too [14]. Defects in the hardware, failing to provide perfect stimuli to the eyes, may generate a feeling of sickness. If they are not taken care of, they might cause simulator sickness [23]. However, there are other crucial design issues: system latency and frame rate variations. Higher frame rates are known to provide better stimuli to the eye while too much latency may cause the eyes to strain [24]. These issues are discussed in depth in later sections.

The production of audio stimulus is very different from traditional sound when it comes to VR. Given that immersion and interactivity are key characteristics of VR, special audio production techniques like spatial surround sound are used. In freer VR scenarios that provide 6 degrees of freedom, this audio needs to be programmed appropriately as well. For example, if the user is standing far from a barking dog, the audio should sound distant but if they are standing near the dog, the sound of the bark should seem nearer. Such design factors contribute to the quality of the simulation a lot as well [25].

The level of realism, decided by the quality of the simulation, is very important in the use of VRET in order to accurately replace real life scenarios with their virtual counterparts. The effectiveness of a particular VR simulation in aiding exposure therapy is directly proportional to the level of realism provided by it.

4. Benefits

VR has shown significant potential in exposure therapy in its comparison to traditional methods. Certain studies and meta-analyses have found evidence of greater or equivalent efficacy of VRET as compared to in-vivo – the gold standard [26] for treatment of anxiety disorders [27] [28] [29] [30] [31]. Multiple studies even suggest that systematic delivery of VR with cognitive interventions, homework, questionnaires, surveys and other additional methods could dramatically increase the efficacy of VRET [32] [33] [34]. This points at the alteration and adaptation of delivery of therapy on the same principles when using VR for therapy.

4.1. Lower refusal and drop-out rates

Often, confrontation of feared stimuli can be too intimidating or intense for a patient. This could lead to the patient either refusing treatment altogether or dropping out of treatment.

Previous research suggests that more patients would opt for VRET as compared to in-vivo exposure as a form of treatment, given the freedom to choose [35] [36]. A phobia-specific study with a sample of 150 patients has shown that 27% refused in-vivo exposure whereas only 3% refused VR based exposure. Moreover, 76% chose VR based exposure and 23.7% chose in-vivo exposure. Out of the set of patients that chose VR exposure, 90.4% claimed they chose it because they were afraid of confronting the feared object or situation in reality [37]. This shows a significantly stronger affinity of patients towards selecting VR based exposure. Another study [38] suggests that people are more likely to stay in a treatment of their choosing.

A study with a sample of 352 US soldiers suggests that VR may prove to address barriers to treatment. Majority of the soldiers, in the survey, mentioned they would be willing to use technology-based interventions for mental health care. It was also noted that 19% of those who said they would not be willing to talk to a mental health professional in person, agreed to access mental health care through VR [39].

Maples-Keller et al. [40] report that for certain disorders like Autism Spectrum Disorder (ASD), studies have shown lower drop-out rates with the use of VR. Another meta-analysis found that for social anxiety, the dropout rate for virtual reality for anxiety disorders is 16%, slightly lower the 19.6% reported using another technique (cognitive-behavioural) [41] and the 19.7% reported by a meta-analysis of attrition from traditional therapy [42].

Overall, the first generation of studies provides empirical evidence to prove how VR could help lower refusal and attrition rates in therapy. Abandonment could lead to additional problems and this could help tremendously in helping a patient endure through the entire course of therapy. This advantage could also serve as an asset in clinical delivery of VRET in places where the general population is apprehensive about seeking help.

4.2. More control to therapist

VRET affords complete control to the therapist who can expose the patient to the required stimuli in the doses he or she feels necessary. This is advantageous because it allows the therapist to tackle aspects of the simulation in a systematic manner, unlike in-vivo. For example, for a person with Entomophobia (the fear of insects), having to actually stand at a distance from insects while worrying about them flying, would cause an overwhelming reaction. VR eliminates this thought by limiting the possibilities of other anxiety-evoking triggers and focussing on the main one at hand. This serves as a safer way for patients to prepare for the feared stimulus in a real-world setting, without compromising on the level of realism [43]. VRET enables the therapists to see exactly what the environment is and what element within the virtual environment the patient is giving their attention to. Boeldt et al. highlight that this addresses the following four limitations of imaginal exposure effectively:

1. not every patient imagines well;
2. the ability to form mental images declines with age;
3. the patient's imagery may be too frightening;
4. the therapist neither knows nor controls what is being imagined [26].

VR also broadens the scope to include modification and personalization in content. Therapists can provide a guided intervention directing the focus on certain aspects of the simulation which can potentially improve the efficacy of the treatment and increase the success of patient outcomes.

VR may also serve as an excellent tool to conduct further experimental research and controlled clinical trials in the fields of psychiatry and psychology because of the advantage of being able to control exposure stimuli and dosage [40]. Ressler et al. examine the effects of combining D-cycloserine with exposure therapy on humans [44].

4.3. Data collection and its uses

Another potential area of the use of VR could be in the collection of data to improve the quality of treatment. With the use of VR head-mounted displayed and their additional hardware components, it is possible to collect relevant data for psychophysiological assessments, including specifications of exposure [40].

With the use of additional hardware or specialised VR head-mounted displays, we can also track eye movements. VR could potentially provide a major boost in the research and delivery of other therapy approaches like Eye Movement Desensitization and Reprocessing (EMDR), a psychotherapy approach designed to attenuate the severe affliction caused by traumatic memories [45]. It combines imaginal exposure with saccadic eye movements (rapid shifts of gaze that are normally executed with a single, smooth trajectory that ends near a selected visual target [46]) [47]. The client is made to focus on an external stimulus while they attend to brief doses of the trauma related thoughts or material. They hold this thought in their memory and track the therapist's hand as it moves across various points in their field of vision [48]. This external stimulus often also includes hand-tapping or audio stimulation. With developments and documentations over time [49], EMDR has shown empirical results to effectively reduce physiological arousal, alleviate and reformulate negative beliefs, fast-track to results, amongst other advantages. The integration of VR in EMDR could enhance the external stimulus provided to the clients including auditory stimulation. The entire scenario or hints of the scenario could be recreated in the virtual environment and the guided eye movements would be provided within the scenario. Along with additional hardware, eye movement could also be tracked to provide data related to assessment to the therapist. However, proof of its efficacy has yet to be provided by research and empirical studies.

4.4. Additional benefits

Since the efficacy of VRET has proven to be equivalent, if not superior to that of the gold standard – in-vivo [50] [51] [29] [30], it can serve as a widespread replacement for imaginal and in-vivo exposure. Therapists can leverage the fact that they do not have to leave the clinic or centre to deliver effective therapy on the spot without the need for prior planning in a case where the patient needs to be immersed in a higher or lower intensity simulation immediately. This leads to significantly reduced costs while increasing the feasibility of that stimulus. VRET also ensures high retention for the patient when combined with other psychological techniques. Another direct consequence of the fact that a superior immersive experience can be delivered within the four walls of a clinic can help ensure therapist-patient confidentiality [26] [52] [53]. Even when the patient is facing a stimulus which requires them to be in crowded areas, their identity is not revealed to outsiders. It is now possible to target specific aspects of the fear of flying example (refer Section 2) like take-off, landing and turbulence multiple

time without special permissions, prior planning and additional costs, all while maintaining patient confidentiality.

5. VR in the use of specific disorders

Exposure therapy has been proven to be quite an effective treatment method for multiple psychiatric disorders, especially mild ones like fear and anxiety [54]. Emotional processing theory is the basis for contemporary exposure therapy. It suggests that fear memories are structures that contain information regarding fear stimuli, responses, and meaning. Hence, the goal of exposure therapy is to present concrete new information that satisfyingly disproves previously held beliefs, allows changes in emotions to be consequentially processed and ultimately, alter the fear structures that form the foundation of the disorder. VRET provides the perfect environment for the patient to obtain new information related to their fears, where they can safely explore different ways of dealing with their fear stimuli and finding a comfortable way to deal with them.

5.1. Phobias

The condition in which specific objects or situations (like flying, insects or needles) trigger fear or anxiety inducing thoughts is characterized as specific phobia (SP). Usually, VRET of SPs involves simulating an environment in which the patient feels comfortable first. Slowly, as they proceed with their simulation, the objects or situations that trigger them are integrated. As they learn to deal with them, they become less and less anxious.

Many studies have investigated the efficiency of VRET on phobias in recent times. Most of them, conducted using RCTs with sufficient sample sizes, have found sizeable treatment effects and meaningful behavioural change. Moreover, data suggests that these effects are long-lasting [55].

The resulting information depicting effectiveness of VRET for specific phobias is very encouraging, especially for individuals fearing situations that may be unsafe, expensive, or unrealistic to conduct in-vivo [40].

Moreover, it is known that less than 15-20% of those who suffer from SPs ever seek treatment. Apart from the effectiveness of the use of VR in treating phobias, a study provides empirical evidence to suggest that VR exposure therapy may prove valuable for increasing the number of phobias who seek treatment [35].

5.2. Panic disorder

Characterized by a sudden rush of anxiety manifested by physiological (e.g., heart palpitations, sweating, choking sensations) and cognitive (e.g., racing thoughts, fear of dying) symptoms, Panic disorder and agoraphobia (PDA) leads to fear and/or avoidance of specific places or situations [56]. Usually, VRET for PDA would involve simulating scenes that trigger panic attacks, especially closed places like deserted highways, tunnels and parking lots.

While a lot of RCTs have praised VR-based cognitive behavioural therapy (CBT) for PDA, results vary between them relating to variations between VRET and traditional CBT. Some studies found that while VRET may deliver healthier treatment reaction [32, 57] and lesser number of sessions [33], long-term effects are very similar to those of traditional methods [14]. Long term effects, particularly for three [32], six [58], nine [59] and twelve months [60] post-treatment have been found to be stable.

For panic disorder and agoraphobia, like specific phobias, VRET seems to perform better (at least early-on in the treatment) if not equal to traditional CBT methods.

5.3. Anxiety disorders

Generalized anxiety disorder (GAD) is a condition in which the patient experiences persistent, excessive and intrusive worrying to the extent that daily functioning becomes difficult [56]. The cause of worrying differs from person to person and could be anything, from stress about personal troubles, to extreme worrying about climate change. Very few studies have investigated the use of VR simulations to inculcate relaxation techniques during treatment and they provide the initial foundation of feasibility for the usage of VRET in GAD cases [61]. One of the primary reasons of the smaller number of studies in GAD may be due to the fact that the cause of GAD is distinctive in every case and hence, it becomes very difficult to create a standardized VR simulation for the same. To battle this obstacle, VR simulations may focus on the most common worries between patients of GAD. One such example would be social anxiety disorder.

Social anxiety disorder (SAD) is a psychiatric condition in which the patient experiences anxiety in social interactions (e.g., conversations, meeting new people, public speaking) during which they might be judged or socially evaluated by others [56]. VRET simulations dealing with SAD usually build environments depicting social settings with virtual audiences like auditoriums and encourage the patient to voice their thoughts confidently in front of others.

Two RCTs involving such simulations found VRET to be equally helpful as traditional CBT [62] and better than control environments [63]. Studies researching stage-fright and fear of public speaking have shown similar results [64, 65, 66], which were stable even one-year post-treatment [64, 67].

At the foundation of it, using VR simulations is more practical than making the patient interact with different kinds of people in different settings. Given that SAD affects 16 million adults in the US alone [68], there is a lot of scope for VRET in helping with SAD.

Moreover, for all anxiety disorders, if it is not feasible to develop common VR simulations, they could be developed to encourage relaxation techniques, inculcate mindfulness and practice breathing exercises.

5.4. Post-traumatic stress disorder

Post-traumatic stress disorder (PTSD) involves a history of exposure to a traumatic event as well as symptoms of intrusion, avoidance, negative alterations in cognitions and mood, and alterations in arousal and reactivity [56]. VR simulations for PTSD usually involve simulating the setting of the traumatic event and slowly exposing the patient to a re-enactment of the traumatic event. Sometimes the trauma is very severe and it may take several sessions and only after is the patient deemed fit enough, they are exposed to the re-enactment of trauma. The ultimate goal is to make the patient come to terms with what happened and making them deal with such an event in a virtual world is of a big help.

PTSD is one of the most researched areas of VRET. In fact, some of the earliest investigations into VRET have focused mainly on PTSD [69]. Early studies did not find much difference between VRET and traditional treatment methods but signs of improvement showed in patients that underwent VRET 6 months post-treatment. While most of the research indicates that VRET is equally or more effective than traditional exposure therapy, one study found prolonged exposure therapy resulted in better results 3 and 6 months post-treatment [70].

It is important to note that the result of VRET depends on a large range of factors, from content of the simulation to the nature of the therapist's involvement. Difference in VR environments, especially in their abilities to help in engaging emotions, contribute heavily to the result of the treatment. Overall, the vast amount of literature on VRET shows promise however, it is worth mentioning that many studies had small sample sizes and/or lack comparison to other treatment techniques, among other

things. Research with larger sample sizes along with appropriate comparisons shall help strengthen the foundation of VRET in the field of PTSD.

5.5. Obsessive-compulsive disorder (OCD)

Obsessive-compulsive disorder (OCD) is a disorder in which people have recurring, unwanted thoughts, ideas or sensations (obsessions) that make them feel driven to do something repetitively (compulsions). The repetitive behaviours, such as hand washing, checking on things or cleaning, can significantly interfere with a person's daily activities and social interactions [56].

Not much research has been done in the field of OCD with respect to VR based interventions. While there have been no RCTs conducted so far, there have been a couple of studies that investigated the acceptance of a virtual environment [71, 72]. These studies found that patients presented same symptoms of OCD in the virtual environment as they would in reality.

Like GAD, the cause of OCD happens to be different for every patient, which makes creating a standardized simulation difficult. Also, VR may not be much needed for OCD, as the factors that trigger OCD in patients are usually easily found in reality or via imagination. However, VR may prove to be effective in cases where triggers are hard to find in real life and only further research can tell how much VR can help with that.

5.6. Pain management

Pain is an uncomfortable experience of emotions and senses that is felt most when one gives attention to it. Cognitive distraction is frequently used to manage pain, especially when undergoing painful medical procedures. VR has been found to be an excellent form of distraction, especially cases involving burn-related pain or physical therapy.

An investigation of four patients suffering from burns showed lower pain ratings when given occupational therapy via VR [73]. Another study comparing routine analgesia and analgesia coupled with a VR game found VR to be very helpful and more effective, as it distracts the patient from the feeling of numbness [74]. One such fMRI study that investigated brain activity relating to pain found that participants spent less time thinking about the pain along with decreased activity in regions corresponding to processing of pain related emotions [75]. All such studies provide enough support to the fact that VR techniques can help in pain reduction.

VR can also be used to assist in dealing with chronic pain by learning and practicing pain management, coupled with traditional techniques. One such system was developed which made its users take a mindful stroll virtually as they learn meditative techniques that reduce stress and ease the sensation of pain. Initial results suggest that this system is more effective compared to achieving the same goals via traditional (control) techniques only [76].

However, specific factors that help VR achieve these levels of pain "reduction" are still unknown and continue to provide researchers an interesting field to investigate in.

5.7. Addiction

When it comes to treatment of dependency and addiction, it is necessary to keep checking progress of the patient by exposing them to triggers (such as a bottle of alcoholic drink, syringe, needle) and observing their reactions. Triggers in the form of real objects carry the risk of consumption and consequence relapse. VR can provide trigger objects that can be safely placed in virtual environments that do not pose this risk. A pilot study involving VRET via cues and triggers showed that participants were able to fight symptoms like bodily arousal [77]. A simulation hosting virtual "cocaine" was found to be similarly effective [78]. VR has been used to help patients de-addict from nicotine effectively too, by helping them control their cravings and not fall prey to various subjective cues. Moreover, the

effect is not limited to just substance-abuse and alcohol. A study involving a virtual casino showed that participants were able to dodge and control their symptoms like physiological arousal and the urge to gamble [79, 80].

Many such studies involving treatment of addiction issues suggest that regular VR-based exposure therapy is effective in evoking reactions to cues and resulting craving, across various types of dependency problems.

5.8. More complex disorders

The results of studies investigating mild disorders indicate that the technology has the potential to benefit more complex disorders too, like schizophrenia and autism.

Schizophrenia is a severe mental illness which includes psychotic symptoms (e.g., hallucinations, delusions), disruptions to normal emotional/behavioural functioning (e.g., flat affect, reduced pleasurable experiences, isolation), and difficulty with cognitive processing [56]. VR simulations would allow patients to practice their social skills and learn to cope in situations of social distress that are coupled with delusions. A small randomized control trial discovered that patient showed decreased levels of delusions and better in-vivo social interactions after undergoing social skill training (SST) along with a VR system [81]. A few pilot studies have found similar results, that support the efficacy of using VR to help combat schizophrenia [82, 83]. A study found an increased interest in SST when it was coupled with VR, encouraging patients to undergo treatment [78].

Another complex disorder, autism spectrum disorder (ASD), is a developmental disorder marked by repetitive or restrictive patterns of behaviour and difficulties with social communication and interaction [40]. Research investigating the use of VR in the field of autism is very limited but does seem promising.

Preliminary results from a study involving autistic teenagers that used VR-based computer tasks to enhance social skills and interactions, has seen improved social performance [84]. However, it is worth noting that the study involved autistic teenagers whose intelligence was categorized as average or above, the sample size was very small (N=8) and the system was designed in a special way to allow better communication with the challenged. A couple of studies also highlighted improvements with respect to recognition of emotion and enhancement of communication techniques along with other improvements [50].

VR needs to tread carefully in the waters of complex disorders as it is a relatively new and modern technology. However, given its promising results with mild disorders, a carefully designed VR simulation may go a long way in benefitting patients with such complicated conditions as well.

6. Methods to Administer VRET in Therapy

The use of VR in widespread clinical treatment is currently still in its nascent stage with experiments and proposals still defining a set standard and structure for delivery of VRET. An established framework could serve as an optimised method to reduce triggers, set protocols to handle triggers, induce relaxation, increase retention and reduce attrition rates. Several studies and experiments have addressed the same [32] [33]. However, it is important to note that it may be very difficult, if not impossible, to generalise a single framework for all possible disorders that VR may be used to treat.

6.1. Components of VR clinical system

It is inadvisable to replace mental health professionals by a VRET system as they serve as the key component of this process. Their clinical skills serve as essential support mechanisms in delivering

VRET and may be considered irreplaceable [85]. The VR system component required to deliver VRET in clinics could potentially be as follows:

- The output tool that immerses the user in the virtual environment. Depending on the method of immersion, this could potentially be an HMD (phone or individual). This could include providing combinations of various stimulatory experiences including visual, auditory and haptic feedback.
- The input tools that allow the user to interact with the virtual environment while continually recording and reporting the movement of the patient. This would most commonly include hardware like remotes, data gloves, trackers or mice. For more sophisticated systems that could provide Natural Language Processing capabilities to tune the elements of a virtual environment based on verbal cues, an internal or external microphone would be used.
- The therapist's interface (software) that serves as the control panel for therapeutic habituation by enabling anxiety modulation capabilities using VR. The importance of the clinician's interface has been highlighted by Rizzo et al [86]. This ability to control the required triggers involved in the simulation in real time provides great flexibility, functionality and customisation potential to improve the quality of VRET.

A major advantage is that VR is compatible with multiple kinds of clinical approaches to treat a variety of mental health disorders: cognitive, experiential or behavioural [87]. There are controlled trials and studies that are critical in shaping research in this field. They majorly focus on two psychological approaches: Experiential Cognitive Approach [32] [33] [88] [89] [90] [91] [92] and Cognitive Behavioural Approach [4] [93] [94] [36] [95] [96] [52]. These approaches, while having disparities, broadly refer to providing the patient with a graded exposure dosage in VR.

Broadly, the treatment course for therapy using VR would include beginning with understanding the link between the patient and the disorder. This could include a background check involving psychoeducation about the disorder and the patient history (possible trauma, triggers) [40]. The therapist gauges the avoidance strategies, best described as a temporary solution to a long-term problem. It is a coping mechanism that may be used by patients in a bid to escape an uncomfortable feeling, thought or scenario. This pushes them away from addressing the actual issue at hand.

Vincelli et al. approach the session by subjecting the patients to scenarios that may be relevant to the disorder and then having the patient report their experience on the SUDs scale. [32] This can help create the hierarchy of virtual environments. The next step is to establish a hierarchy of stimuli within the selected virtual environment. Once these parameters are set, the therapist can begin session-wise treatment. Between-session interventions (also known as homework) are important especially for VR in therapy. Benbow & Anderson provide empirical evidence hinting at their potential to reduce attrition rates [97].

Each subsequent session can begin by checking on homework followed by gradation of experience. This can help set the difficulty level for the simulation for that session and gauge the progress. Based on the approach, the therapist can then move on to cognitive restructuring through VR. Depending on the quality and availability of a customisable VR system, each exposure session can be individualised for each patient. This is where the therapist's interface comes in. As the simulation progresses, the therapist can tune the parameters of the exposure as well as control the location, nature, intensity, timing and duration of the stimulus to be provided. For example, in the example of stage-fright (Table 1, Section 2), the therapists can control the number of people engaging in conversation, the intensity of applause or other such potential triggers based on the level of tolerance of the patient. Special emphasis can be put on background auditory elements like indistinct surrounding conversations, breathing sounds, cars passing by, doors opening and closing, etc. The patient can be put through the virtual environment repeatedly until they report lower distress rates based on the therapist's

observations and the SUDs scale. The patient can move to a higher difficulty level when both the patient and the therapist feel that they are ready. Therapists can even look at the effects of coupling VR based therapy with imaginal and feasible in-vivo components. Depending on the judgement of the therapist, the patient can be called in for follow up sessions in the future as they help with retention. However, there is a need for training therapists in the use of VR in clinical treatment due to the deviations from traditional therapeutic protocols.

However, this is not the only proposed approach or even the best approach. Research suggests that trials and studies have not become methodologically rigorous [50] [98] [84] [99] over the years as they should have. Additional research is required to affirm the role of VR in clinical treatments.

7. Issues and Resolution

VRs use in therapy does not come without its technical and therapeutic hindrances. This section explores the possible technical and physical limitations, their solutions (if any).

One of the primary concerns with any VR based application is cybersickness, which is an unwanted side-effect of using immersive interfaces. It is triggered by moving visual stimuli and has symptoms similar to motion sickness [100]. It causes a broad range of discomforting reactions the likes of nausea, dizziness, tiredness, fatigue, vomiting, double vision, decreased hearing, headaches, seizures and disorientation [101]. There may be no permanent fix to this problem, but it can be reduced with regulated usage of VR during therapy, not just based on duration of immersion, but also on other factors like refresh rates, method of delivery, comfort of HMD, etc. The therapist can use predesigned questionnaires to gauge how susceptible a potential user may be to cybersickness. While studies point towards decreased rates of cybersickness with newer improved hardware [102], the disparities are not drastic enough to be able to rule out that this issue may be a hindrance in the adoption of VR as a therapeutic tool.

Another area of possible concern would be the potential to lead to addiction and social isolation, especially amongst younger generations [103]. There is also the possibility of a patient experiencing a loss of reality. This may encourage more dangerous behaviour if the patient is unable to distinguish the real world and a virtual environment, where they are safe under the assumption that their actions will not have any real-life consequences. Such a danger is more prominent amongst people with pathological disorders like personality disorders or schizophrenia, who have a tendency to get disoriented by switching between real and virtual worlds [28].

Quality VRET is personalised for the patient. In order to boost efficacy rates and provide surety of treatment, the content library must be vast. In spite of introduction of newer technology and consistent reduction of headset costs, development of accurate virtual environments is computationally heavy, requires a certain skillset for creation and is significantly expensive. This may pose as an obstacle in adoption of VRET as a preferred form of treatment.

When in use, technological glitches may pose as an impediment and troubleshooting them is essential for a smooth therapy session. Therapists may also not be used to delivering effective therapy which is why initial training may be necessary in order to alleviate any technology related problems.

There may also be some deep-rooted issues with gamification, for environments that may include a reward system on completion of certain tasks. Similar to video game addiction [104], the provided reinforcements may lead to an unsolicited dependency and an unwanted fixation to the environment. In cases where gamification can enhance therapy, an arbitrary therapist-devised reward system may foster non-addictive positive reinforcement as encouragement to patients to overcome tougher tasks.

8. Discussion

Apart from the technical benefits VRET can provide, it is also interesting to dive into the societal impact it can have. VR has shown potential in reducing the time taken for treatment. Based on the empirical evidence that further research may provide us in solidifying the basis of this statement, VRET could help patients as well as mental health professionals:

- Reduction of cost: Mental health awareness is especially low amongst people lower on the socio-economic scale. Seeking mental health treatment is known to be costly and is charged per session. Reduction in time of treatment is directly proportional to the cost the patient bears. This could potentially encourage more people to seek help.
- Accommodation of additional patients: In the time saved by VRET, therapists can accommodate additional patients. Hence, lesser time for treatment does not mean loss of revenue for psychologists.

Additionally, if future studies can provide more evidence of a lower attrition rate being associated with VR, widespread adoption of VR may help reduce relapse in patients.

Most of the research in the field of VRET has been concentrated in developed countries like the US and the UK. The adaptations, beliefs and challenges associated with psychotherapy vary from culture to culture [105]. Further research needs to be conducted in populations of different cultures, especially in non-western countries like India, as the population's psychologies differ a lot [106]. A survey conducted by the authors found that most psychologists are excited about the introduction of VRET and are eager to test the technology out. Consequently, further research is being conducted.

It is estimated that 1 in every 10 people may need mental health care at some point in their life [107]. Knowing that, it is terrifying to learn that the ratio of mental health professionals to general population can be as low as 2:100000. Of the 65 countries that have established policies and plans related to mental health, they have often failed to enforce them, especially in spreading awareness about the most common conditions and reducing the stigma around it. In countries where the mental health infrastructure is so fragile, the introduction of VRET will not only reduce the pressure on mental health professionals by reducing cost, treatment time, and chances of drop-out and relapse but will also attract the general population to take an interest in the field.

It is important to note that the technology is simply not a direct answer to the need of an improvement in exposure therapy. The content delivered by the technology plays a major role in the outcome of the therapy [72, 108]. While the authors advocate for the use of this technology, there is need for further research as studies have usually been small, causing negative results less likely to be reported. Compared to the potential of it, the technology has not been applied enough to mental health.

VR can be used not just for treatment, but for assessment of psychiatric symptoms as well. Though the technology has the potential of becoming the benchmark in assessment, very few reliable and robust tests have been conducted related to it [43]. Even as a form of treatment, VR can be used to innovate so many treatment methods. Many common disorders, like depression, remain relatively less explored with respect to VR based treatment. While exposure therapy remains a common and simple form of treatment, the innovative approach of VR can be applied to many more treatment techniques, especially complex ones that are used for disorders like schizophrenia and autism.

With leaping innovations in artificial intelligence, the possibility of a fully automated VR-based therapy, that might eliminate the need of a therapist's presence, is still intriguing. Technologies like augmented reality can also assist in the treatment, add several more features and benefits to treatments.

Our review offers a look into the current scenario and a small glimpse of the future of mental health treatments. VR for mental health is still in its early days. Simulations are quite limited in quantity. They lack features, special training is needed for operation, if not creation of, suitable environments, and simulator sickness still remains a hurdle that needs to be overcome carefully with content and hardware design. However, the technology is developing fast and these are probably short-term concerns.

As VR is able to simulate scenarios that are not easily found in the real world, maybe it will help deliver treatment results that are not easily found with traditional techniques as well. VR has revolutionised many a field, and it is time mental health got a taste of it too.

References

[1] M. C. Hsieh and J. J. Lee, "Preliminary Study of VR and AR Applications in Medical and Healthcare Education," *Journal of Nursing and Health Studies,* vol. 03, 2018.

[2] L. Gregg and N. Tarrier, "Virtual reality in mental health," *Social Psychiatry and Psychiatric Epidemiology,* vol. 42, p. 343–354, 3 2007.

[3] R. T. da Costa, M. R. de Carvalho and A. E. Nardi, "Virtual reality exposure therapy in the treatment of driving phobia," *Psicologia: Teoria e Pesquisa,* vol. 26, p. 131–137, 3 2010.

[4] B. O. Rothbaum, L. F. Hodges, R. Kooper, D. Opdyke, J. S. Williford and M. North, "Effectiveness of computer-generated (virtual reality) graded exposure in the treatment of acrophobia," *American Journal of Psychiatry,* vol. 152, p. 626–628, 4 1995.

[5] Fortune Business Insights, "Virtual Reality (VR) in Healthcare Market Size, Share & Industry Analysis," Nov 2019.

[6] S. A. Steinman, B. M. Wootton and D. F. Tolin, "Exposure Therapy for Anxiety Disorders," in *Encyclopedia of Mental Health*, Elsevier, 2016, p. 186–191.

[7] S. Taylor, "Exposure," in *Encyclopedia of Psychotherapy*, Elsevier, 2002, p. 755–759.

[8] J. Wolpe, *The practice of behavior therapy, 4th ed.,* Elmsford, NY: Pergamon Press, 1990, pp. xvi, 421–xvi, 421.

[9] S. L. Johnson, "Transtheoretical and Multimodal Interventions," in *Therapist\textquotesingles Guide to Posttraumatic Stress Disorder Intervention*, Elsevier, 2009, p. 123–169.

[10] K. B. Wolitzky-Taylor, J. D. Horowitz, M. B. Powers and M. J. Telch, "Psychological approaches in the treatment of specific phobias: A meta-analysis," *Clinical Psychology Review,* vol. 28, p. 1021–1037, 7 2008.

[11] M. A. Tompkins, "Nuts and Bolts of Imaginal Exposure," [Online]. Available: http://sfbacct.com/from-ocd-to-anxiety/nuts-and-bolts-of-imaginal-exposure/.

[12] C. Miller, "Flooding," in *Encyclopedia of Psychotherapy*, Elsevier, 2002, p. 809–813.

[13] C. H. Rankin, T. Abrams, R. J. Barry, S. Bhatnagar, D. F. Clayton, J. Colombo, G. Coppola, M. A. Geyer, D. L. Glanzman, S. Marsland, F. K. McSweeney, D. A. Wilson, C.-F. Wu and R. F. Thompson, "Habituation revisited: An updated and revised description of the behavioral characteristics of habituation," *Neurobiology of Learning and Memory,* vol. 92, p. 135–138, 9 2009.

[14] A. Pelissolo, M. Zaoui, G. Aguayo, N. Sai, Yao, S. Roche, R. Ecochard, C. Pull, A. Berthoz, R. Jouvent and J. Cottraux, "Virtual reality exposure therapy versus cognitive behavior therapy for panic disorder with agoraphobia: A randomized comparison study," *Journal of Cybertherapy and Rehabilitation,* vol. 5, 1 2012.

[15] P. Lindner, A. Rozental, A. Jurell, L. Reuterskiöld, G. Andersson, W. Hamilton, A. Miloff and P. Carlbring, “Experiences of Gamified and Automated Virtual Reality Exposure Therapy for Spider Phobia: Qualitative Study,” *JMIR Serious Games,* vol. 8, p. e17807, 4 2020.

[16] R. Holloway and A. Lastra, “Virtual Environments: A Survey of the Technology,” 1993.

[17] M. Slater and S. Wilbur, "A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments," *Presence: Teleoperators and Virtual Environments,* vol. 6, p. 603–616, 12 1997.

[18] H. L. Miller and N. L. Bugnariu, "Level of Immersion in Virtual Environments Impacts the Ability to Assess and Teach Social Skills in Autism Spectrum Disorder," *Cyberpsychology, Behavior, and Social Networking,* vol. 19, p. 246–256, 4 2016.

[19] M. L. Heilig, “EL Cine del Futuro: The Cinema of the Future,” *Presence: Teleoperators & Virtual Environments,* vol. 1, pp. 279-294, 1992.

[20] J. Helman, “Performance Requirements and Human Factors,” 1995.

[21] S. Hüttermann, N. J. Smeeton, P. R. Ford and A. M. Williams, “Color Perception and Attentional Load in Dynamic, Time-Constrained Environments,” *Frontiers in Psychology,* vol. 9, 1 2019.

[22] H. S. Faridul, T. Pouli, C. Chamaret, J. Stauder, A. Tremeau and E. Reinhard, *A Survey of Color Mapping and its Applications,* The Eurographics Association, 2014.

[23] J. Lee, M. Kim and J. Kim, “A Study on Immersion and VR Sickness in Walking Interaction for Immersive Virtual Reality Applications,” *Symmetry,* vol. 9, p. 78, 5 2017.

[24] L. Sidenmark, N. Kiefer and H. Gellersen, “Subtitles in interactive virtual reality: Using gaze to address depth conflicts,” in *Workshop on Emerging Novel Input Devices and Interaction Techniques*, 2019.

[25] Z. Yan, J. Wang and Z. Li, “A Multi-criteria Subjective Evaluation Method for Binaural Audio Rendering Techniques in Virtual Reality Applications,” in *2019 IEEE International Conference on Multimedia & Expo Workshops (ICMEW)*, 2019.

[26] D. Boeldt, E. McMahon, M. McFaul and W. Greenleaf, “Using Virtual Reality Exposure Therapy to Enhance Treatment of Anxiety Disorders: Identifying Areas of Clinical Adoption and Potential Obstacles,” *Frontiers in Psychiatry,* vol. 10, 10 2019.

[27] B. K. Wiederhold, D. P. Jang, R. G. Gevirtz, S. I. Kim, I. Y. Kim and M. D. Wiederhold, “The treatment of fear of flying: a controlled study of imaginal and virtual reality graded exposure therapy,” *IEEE Transactions on Information Technology in Biomedicine,* vol. 6, p. 218–223, 9 2002.

[28] A. Gorini and G. Riva, “Virtual reality in anxiety disorders: the past and the future,” *Expert Review of Neurotherapeutics,* vol. 8, p. 215–233, 2 2008.

[29] M. B. Powers and P. M. G. Emmelkamp, “Virtual reality exposure therapy for anxiety disorders: A meta-analysis,” *Journal of Anxiety Disorders,* vol. 22, p. 561–569, 4 2008.

[30] T. D. Parsons and A. A. Rizzo, "Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis," *Journal of Behavior Therapy and Experimental Psychiatry,* vol. 39, p. 250–261, 9 2008.

[31] C. Suso-Ribera, J. Fernández-Álvarez, A. García-Palacios, H. G. Hoffman, J. Bretón-López, R. M. Baños, S. Quero and C. Botella, "Virtual Reality, Augmented Reality, and In Vivo Exposure Therapy: A Preliminary Comparison of Treatment Efficacy in Small Animal Phobia," *Cyberpsychology, Behavior, and Social Networking,* vol. 22, p. 31–38, 1 2019.

[32] F. Vincelli, L. Anolli, S. Bouchard, B. K. Wiederhold, V. Zurloni and G. Riva, "Experiential Cognitive Therapy in the Treatment of Panic Disorders with Agoraphobia: A Controlled Study," *CyberPsychology & Behavior,* vol. 6, p. 321–328, 6 2003.

[33] Y.-H. Choi, F. Vincelli, G. Riva, B. K. Wiederhold, J.-H. Lee and K.-H. Park, "Effects of Group Experiential Cognitive Therapy for the Treatment of Panic Disorder with Agoraphobia," *CyberPsychology & Behavior,* vol. 8, p. 387–393, 8 2005.

[34] T. F. Wechsler, F. Kümpers and A. Mühlberger, "Inferiority or Even Superiority of Virtual Reality Exposure Therapy in Phobias?—A Systematic Review and Quantitative Meta-Analysis on Randomized Controlled Trials Specifically Comparing the Efficacy of Virtual Reality Exposure to Gold Standard in vivo Exposure in Agoraphobia, Specific Phobia, and Social Phobia," *Frontiers in Psychology,* vol. 10, 9 2019.

[35] A. Garcia-Palacios, H. G. Hoffman, S. K. See, A. Tsai and C. Botella, "Redefining Therapeutic Success with Virtual Reality Exposure Therapy," *CyberPsychology & Behavior,* vol. 4, p. 341–348, 6 2001.

[36] A. Garcia-Palacios, H. Hoffman, A. Carlin, T. A. Furness and C. Botella, "Virtual reality in the treatment of spider phobia: a controlled study," *Behaviour Research and Therapy,* vol. 40, p. 983–993, 9 2002.

[37] A. Garcia-Palacios, C. Botella, H. Hoffman and S. Fabregat, "Comparing Acceptance and Refusal Rates of Virtual Reality Exposure vs. In Vivo Exposure by Patients with Specific Phobias," *CyberPsychology & Behavior,* vol. 10, p. 722–724, 10 2007.

[38] D. Steidtmann, R. Manber, B. A. Arnow, D. N. Klein, J. C. Markowitz, B. O. Rothbaum, M. E. Thase and J. H. Kocsis, "PATIENT TREATMENT PREFERENCE AS A PREDICTOR OF RESPONSE AND ATTRITION IN TREATMENT FOR CHRONIC DEPRESSION," *Depression and Anxiety,* vol. 29, p. 896–905, 7 2012.

[39] J. A. B. Wilson, K. Onorati, M. Mishkind, M. A. Reger and G. A. Gahm, "Soldier Attitudes about Technology-Based Approaches to Mental Health Care," *CyberPsychology & Behavior,* vol. 11, p. 767–769, 12 2008.

[40] J. L. Maples-Keller, B. E. Bunnell, S.-J. Kim and B. O. Rothbaum, "The Use of Virtual Reality Technology in the Treatment of Anxiety and Other Psychiatric Disorders," *Harvard Review of Psychiatry,* vol. 25, p. 103–113, 2017.

[41] E. Fernandez, D. Salem, J. K. Swift and N. Ramtahal, "Meta-analysis of dropout from cognitive behavioral therapy: Magnitude, timing, and moderators.," *Journal of Consulting and Clinical Psychology,* vol. 83, p. 1108–1122, 2015.

[42] J. K. Swift and R. P. Greenberg, "Premature discontinuation in adult psychotherapy: A meta-analysis.," *Journal of Consulting and Clinical Psychology,* vol. 80, p. 547–559, 2012.

[43] D. Freeman, S. Reeve, A. Robinson, A. Ehlers, D. Clark, B. Spanlang and M. Slater, "Virtual reality in the assessment, understanding, and treatment of mental health disorders," *Psychological Medicine,* vol. 47, p. 2393–2400, 3 2017.

[44] K. J. Ressler, B. O. Rothbaum, L. Tannenbaum, P. Anderson, K. Graap, E. Zimand, L. Hodges and M. Davis, "Cognitive Enhancers as Adjuncts to Psychotherapy," *Archives of General Psychiatry,* vol. 61, p. 1136, 11 2004.

[45] F. Shapiro, "Efficacy of the eye movement desensitization procedure in the treatment of traumatic memories," *Journal of Traumatic Stress,* vol. 2, p. 199–223, 4 1989.

[46] E. L. Keller, B.-T. Lee and K.-M. Lee, "Frontal eye field signals that may trigger the brainstem saccade generator," in *Progress in Brain Research*, Elsevier, 2008, p. 107–114.

[47] L. H. Jaycox and E. B. Foa, "Post-traumatic Stress Disorder," in *Comprehensive Clinical Psychology*, Elsevier, 1998, p. 499–517.

[48] "What is EMDR?," [Online]. Available: https://www.emdr.com/what-is-emdr/.

[49] F. Shapiro, *Eye movement desensitization and reprocessing: Basic principles, protocols, and procedures, 2nd ed.,* New York, NY, US: Guilford Press, 2001, pp. xxiv, 472–xxiv, 472.

[50] K. Meyerbröker and P. M. G. Emmelkamp, "Virtual reality exposure therapy in anxiety disorders: a systematic review of process-and-outcome studies," *Depression and Anxiety,* vol. 27, p. 933–944, 8 2010.

[51] D. Opriş, S. Pintea, A. García-Palacios, C. Botella, Ş. Szamosközi and D. David, "Virtual reality exposure therapy in anxiety disorders: a quantitative meta-analysis," *Depression and Anxiety,* vol. 29, p. 85–93, 11 2011.

[52] B. O. Rothbaum, P. Anderson, E. Zimand, L. Hodges, D. Lang and J. Wilson, "Virtual Reality Exposure Therapy and Standard (in Vivo) Exposure Therapy in the Treatment of Fear of Flying," *Behavior Therapy,* vol. 37, p. 80–90, 3 2006.

[53] A. Pittig, R. Kotter and J. Hoyer, "The Struggle of Behavioral Therapists With Exposure: Self-Reported Practicability, Negative Beliefs, and Therapist Distress About Exposure-Based Interventions," *Behavior Therapy,* vol. 50, p. 353–366, 3 2019.

[54] B. Bandelow, M. Reitt, C. Röver, S. Michaelis, Y. Görlich and D. Wedekind, "Efficacy of treatments for anxiety disorders," *International Clinical Psychopharmacology,* vol. 30, p. 183–192, 7 2015.

[55] C. Thng, N. Lim-Ashworth, B. Poh and C. G. Lim, "Recent developments in the intervention of specific phobia among adults: A rapid review.," *F1000Research,* vol. 9, p. 195, 3 2020.

[56] A. P. Association, Diagnostic and Statistical Manual of Mental Disorders (DSM-5 (R)), American Psychiatric Association Publishing, 2013.

[57] E. Malbos, R. M. Rapee and M. Kavakli, "A controlled study of agoraphobia and the independent effect of virtual reality exposure therapy.," *The Australian and New Zealand journal of psychiatry,* vol. 47, no. 2, p. 160–168, 2 2013.

[58] C. Botella, A. García-Palacios, H. Villa, R. M. Baños, S. Quero, M. Alcañiz and G. Riva, "Virtual reality exposure in the treatment of panic disorder and agoraphobia: A controlled study," *Clinical Psychology & Psychotherapy,* vol. 14, p. 164–175, 2007.

[59] A. Gorini, F. Pallavicini, D. Algeri, C. Repetto, A. Gaggioli and G. Riva, "Virtual reality in the treatment of generalized anxiety disorders.," *Studies in health technology and informatics,* vol. 154, p. 39–43, 2010.

[60] A. Belloch, E. Cabedo, C. Carrió, J. A. Lozano-Quilis, J. A. Gil-Gómez and H. Gil-Gómez, "Virtual reality exposure for OCD: Is it feasible? [Exposición mediante realidad virtual para el TOC: ¿Es factible?]," *Revista de Psicopatología y Psicología Clínica,* vol. 19, p. 37, 9 2014.

[61] K. Kim, C.-H. Kim, K. R. Cha, J. Park, K. Han, Y. K. Kim, J.-J. Kim, I. Y. Kim and S. I. Kim, "Anxiety Provocation and Measurement Using Virtual Reality in Patients with Obsessive-Compulsive Disorder," *CyberPsychology & Behavior,* vol. 11, p. 637–641, 12 2008.

[62] G. Robillard, S. Bouchard, S. Dumoulin, T. Guitard and E. Klinger, "Using virtual humans to alleviate social anxiety: preliminary report from a comparative outcome study.," *Studies in health technology and informatics,* vol. 154, p. 57–60, 2010.

[63] P. L. Anderson, M. Price, S. M. Edwards, M. A. Obasaju, S. K. Schmertz, E. Zimand and M. R. Calamaras, "Virtual reality exposure therapy for social anxiety disorder: a randomized controlled trial.," *Journal of consulting and clinical psychology,* vol. 81, no. 5, p. 751–760, 10 2013.

[64] S. R. Harris, R. L. Kemmerling and M. M. North, "Brief virtual reality therapy for public speaking anxiety.," *Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society,* vol. 5, no. 6, p. 543–550, 12 2002.

[65] H. S. Wallach, M. P. Safir and M. Bar-Zvi, "Virtual reality cognitive behavior therapy for public speaking anxiety: a randomized clinical trial.," *Behavior modification,* vol. 33, no. 3, p. 314–338, 5 2009.

[66] M. P. Safir, H. S. Wallach and M. Bar-Zvi, "Virtual reality cognitive-behavior therapy for public speaking anxiety: one-year follow-up.," *Behavior modification,* vol. 36, no. 2, p. 235–246, 3 2012.

[67] I. Alsina-Jurnet, C. Carvallo-Beciu and J. Gutiérez-Maldonado, "Validity of virtual reality as a method of exposure in the treatment of test anxiety," *Behavior Research Methods,* vol. 39, pp. 844-851, 12 2007.

[68] Anxiety and Depression Association of America , "Facts & Statistics," [Online]. Available: https://adaa.org/about-adaa/press-room/facts-statistics. [Accessed 9 11 2020].

[69] B. O. Rothbaum, L. F. Hodges, D. Ready, K. Graap and R. D. Alarcon, "Virtual Reality Exposure Therapy for Vietnam Veterans With Posttraumatic Stress Disorder," *The Journal of Clinical Psychiatry,* vol. 62, p. 617–622, 8 2001.

[70] C. Pitti, J. Bethencourt-Pére, J. Fuente, G. Ramón and W. Peñate, "The effects of a treatment based on the use of virtual reality exposure and cognitive-behavioral therapy applied to patients with agoraphobia," *International Journal of Clinical and Health Psychology,* vol. 8, 1 2008.

[71] J. Ku, K. Han, H. R. Lee, H. J. Jang, K. U. Kim, S. H. Park, J. J. Kim, C. H. Kim, I. Y. Kim and S. I. Kim, "VR-based conversation training program for patients with schizophrenia: a preliminary clinical trial.," *Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society,* vol. 10, no. 4, p. 567–574, 8 2007.

[72] D. Freeman, J. Bradley, A. Antley, E. Bourke, N. DeWeever, N. Evans, E. Černis, B. Sheaves, F. Waite, G. Dunn, M. Slater and D. M. Clark, "Virtual reality in the treatment of persecutory delusions: Randomised controlled experimental study testing how to reduce delusional conviction," *British Journal of Psychiatry,* vol. 209, no. 1, p. 62–67, 7 2016.

[73] D. A. Das, K. A. Grimmer, A. L. Sparnon, S. E. McRae and B. H. Thomas, "The efficacy of playing a virtual reality game in modulating pain for children with acute burn injuries: a randomized controlled trial [ISRCTN87413556].," *BMC pediatrics,* vol. 5, no. 1, p. 1, 3 2005.

[74] F. J. Keefe, D. A. Huling, M. J. Coggins and D. F. Keefe, "Virtual Reality for Persistent Pain: A New Direction for Behavioral Pain Management," *Pain,* vol. 153, pp. 2163-6, 7 2012.

[75] H. G. Hoffman, T. L. Richards, B. Coda, A. R. Bills, D. Blough, A. L. Richards and S. R. Sharar, "Modulation of thermal pain-related brain activity with virtual reality: evidence from fMRI.," *Neuroreport,* vol. 15, no. 8, p. 1245–1248, 6 2004.

[76] D. Gromala, X. Tong, A. Choo, M. Karamnejad and C. D. Shaw, "The Virtual Meditative Walk," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI \textquotesingle15*, 2015.

[77] J.-S. Choi, S. Park, J.-Y. Lee, H.-Y. Jung, H. W. Lee, C.-H. Jin and D.-H. Kang, "The Effect of Repeated Virtual Nicotine Cue Exposure Therapy on the Psychophysiological Responses: A Preliminary Study," *Psychiatry investigation ,* vol. 8, no. 2, pp. 155-60, 6 2011.

[78] D. G. Y. Thompson-Lake, K. N. Cooper, J. J. Mahoney, P. S. Bordnick, R. Salas, T. R. Kosten, J. A. Dani and R. De La Garza, "Withdrawal Symptoms and Nicotine Dependence Severity Predict Virtual Reality Craving in Cigarette-Deprived Smokers.," *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco,* vol. 17, no. 7, p. 796–802, 7 2015.

[79] J. H. Yoon, T. F. Newton, C. N. Haile, P. S. Bordnick, R. E. Fintzy, C. Culbertson, J. J. Mahoney, R. Y. Hawkins, K. R. LaBounty, E. L. Ross, A. I. Aziziyeh and R. D. La Garza, "Effects of D-cycloserine on cue-induced craving and cigarette smoking among concurrent cocaine- and nicotine-dependent volunteers.," *Addictive behaviors,* vol. 38, no. 2, p. 1518–1526, 2 2013.

[80] C. PERPIÑÁ, C. BOTELLA, R. BAÑOS, H. MARCO, M. ALCAÑIZ and S. QUERO, "Body Image and Virtual Reality in Eating Disorders: Is Exposure to Virtual Reality More Effective than the Classical Body Image Treatment?," *CyberPsychology & Behavior,* vol. 2, p. 149–155, 4 1999.

[81] M. Rus-Calafell, J. Gutiérrez-Maldonado and J. Ribas-Sabaté, "A virtual reality-integrated program for improving social skills in patients with schizophrenia: a pilot study.," *Journal of behavior therapy and experimental psychiatry,* vol. 45, no. 1, p. 81–89, 3 2014.

[82] K.-M. Park, J. Ku, S.-H. Choi, H.-J. Jang, J.-Y. Park, S. I. Kim and J.-J. Kim, "A virtual reality application in role-plays of social skills training for schizophrenia: a randomized, controlled trial.," *Psychiatry research,* vol. 189, no. 2, p. 166–172, 9 2011.

[83] H. G. Hoffman, D. R. Patterson, G. J. Carrougher and S. R. Sharar, "Effectiveness of virtual reality-based pain control with multiple treatments.," *The Clinical journal of pain,* vol. 17, no. 3, p. 229–235, 9 2001.

[84] S. Page and M. Coxon, "Virtual Reality Exposure Therapy for Anxiety Disorders: Small Samples and No Controls?," *Frontiers in Psychology,* vol. 7, 3 2016.

[85] N. Nascivera, Y. M. Alfano, T. Annunziato, M. Messina, V. S. Iorio, V. Cioffi, R. Sperandeo, M. Rosato, T. Longobardi and N. M. Maldonato, "Virtual Empathy : The added value of Virtual Reality in Psychotherapy," in *2018 9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 2018.

[86] A. Rizzo, J. Difede, B. O. Rothbaum, J. M. Daughtry and G. Reger, "Virtual Reality as a Tool for Delivering PTSD Exposure Therapy," in *Post-Traumatic Stress Disorder: Future Directions in Prevention, Diagnosis, and Treatment*, Springer, 2013.

[87] G. Riva, "Virtual Reality in Psychotherapy: Review," *CyberPsychology & Behavior,* vol. 8, p. 220–230, 6 2005.

[88] R. Giuseppe, B. Monica, B. Margherita, R. Silvia and M. Enrico, "EXPERIENTIAL COGNITIVE THERAPY: A VR BASED APPROACH FOR THE ASSESSMENT AND TREATMENT OF EATING DISORDERS," *Studies in Health Technology and Informatics,* vol. 58, pp. 120-135, 1998.

[89] F. Vincelli, Y. H. Choi, E. Molinari, B. K. Wiederhold and G. Riva, "Experiential Cognitive Therapy for the Treatment of Panic Disorder With Agoraphobia: Definition of a Clinical Protocol," *CyberPsychology & Behavior,* vol. 3, p. 375–385, 6 2000.

[90] G. Riva, M. Bacchetta, M. Baruffi and E. Molinari, "Virtual Reality–Based Multidimensional Therapy for the Treatment of Body Image Disturbances in Obesity: A Controlled Study," *CyberPsychology & Behavior,* vol. 4, p. 511–526, 8 2001.

[91] G. Riva, M. Bacchetta, M. Baruffi and E. Molinari, "Virtual-reality-based multidimensional therapy for the treatment of body image disturbances in binge eating disorders: a preliminary controlled study," *IEEE Transactions on Information Technology in Biomedicine,* vol. 6, p. 224–234, 9 2002.

[92] G. Riva, M. Bacchetta, G. Cesa, S. Conti and E. Molinari, "Six-Month Follow-Up of In-Patient Experiential Cognitive Therapy for Binge Eating Disorders," *CyberPsychology & Behavior,* vol. 6, p. 251–258, 6 2003.

[93] P. M. G. Emmelkamp, M. Bruynzeel, L. Drost and C. A. P. G. van der Mast, "Virtual Reality Treatment in Acrophobia: A Comparison with Exposure in Vivo," *CyberPsychology & Behavior,* vol. 4, p. 335–339, 6 2001.

[94] P. M. G. Emmelkamp, M. Krijn, A. M. Hulsbosch, S. de Vries, M. J. Schuemie and C. A. P. G. van der Mast, "Virtual reality treatment versus exposure in vivo: a comparative evaluation in acrophobia," *Behaviour Research and Therapy,* vol. 40, p. 509–516, 5 2002.

[95] N. Maltby, I. Kirsch, M. Mayers and G. J. Allen, "Virtual reality exposure therapy for the treatment of fear of flying: A controlled investigation.," *Journal of Consulting and Clinical Psychology,* vol. 70, p. 1112–1118, 10 2002.

[96] B. K. Wiederhold, D. P. Jang, S. I. Kim and M. D. Wiederhold, "Physiological Monitoring as an Objective Tool in Virtual Reality Therapy," *CyberPsychology & Behavior,* vol. 5, p. 77–82, 2 2002.

[97] A. A. Benbow and P. L. Anderson, "A meta-analytic examination of attrition in virtual reality exposure therapy for anxiety disorders," *Journal of Anxiety Disorders,* vol. 61, p. 18–26, 1 2019.

[98] R. A. McCann, C. M. Armstrong, N. A. Skopp, A. Edwards-Stewart, D. J. Smolenski, J. D. June, M. Metzger-Abamukong and G. M. Reger, "Virtual reality exposure therapy for the treatment of anxiety disorders: An evaluation of research quality," *Journal of Anxiety Disorders,* vol. 28, p. 625–631, 8 2014.

[99] O. D. Kothgassner and A. Felnhofer, "Lack of research on efficacy of virtual reality exposure therapy (VRET) for anxiety disorders in children and adolescents," *neuropsychiatrie,* 5 2020.

[100] F. Bonato, A. Bubka, S. Palmisano, D. Phillip and G. Moreno, "Vection Change Exacerbates Simulator Sickness in Virtual Environments," *Presence: Teleoperators and Virtual Environments,* vol. 17, p. 283–292, 6 2008.

[101] K. Nesbitt and E. Nalivaiko, "Cybersickness," in *Encyclopedia of Computer Graphics and Games*, Springer International Publishing, 2018, p. 1–6.

[102] L. Rebenitsch and C. Owen, "Estimating cybersickness from virtual reality applications," *Virtual Reality,* 5 2020.

[103] M. Plusquellec, "Les mondes virtuels menacent-ils la santé mentale des enfants et des adolescents ?," *Archives de Pédiatrie,* vol. 7, p. 209–210, 2 2000.

[104] C. L. Mathews, H. E. R. Morrell and J. E. Molle, "Video game addiction, ADHD symptomatology, and video game reinforcement," *The American Journal of Drug and Alcohol Abuse,* vol. 45, p. 67–76, 6 2018.

[105] F. Naeem, P. Phiri, T. Munshi, S. Rathod, M. Ayub, M. Gobbi and D. Kingdon, "Using cognitive behaviour therapy with South Asian Muslims: Findings from the culturally sensitive CBT project," *International Review of Psychiatry,* vol. 27, pp. 233-246, 2015.

[106] N. Kumar and P. Gupta, "Cognitive Behaviour Therapy in India: Adaptations, Beliefs and Challenges," in *CBT in non-western Cultures*, F. Naeem and D. Kingdon, Eds., Nova Publishers Inc, 2012.

[107] Mental health atlas 2017, Geneva, Switzerland: World Health Organization, 2018.

[108] G. M. Reger, P. Koenen-Woods, K. Zetocha, D. J. Smolenski, K. M. Holloway, B. O. Rothbaum, J. Difede, A. A. Rizzo, A. Edwards-Stewart, N. A. Skopp, M. Mishkind, M. A.

Reger and G. A. Gahm, “Randomized controlled trial of prolonged exposure using imaginal exposure vs. virtual reality exposure in active duty soldiers with deployment-related posttraumatic stress disorder (PTSD).,” *Journal of Consulting and Clinical Psychology,* vol. 84, p. 946–959, 11 2016.