Implementations of Virtual Reality for Anxiety-related Disorders: A Systematic Review

Abstract

**Background:** While traditional forms of therapy for anxiety-related disorders (e.g.: cognitive-behavioural therapy) have been effective, there have been longstanding issues with these therapies that largely centre around the costs and risks associated with the components comprising the therapeutic process. To treat certain types of specific phobias, sessions may need to be held in public, therefore risking patient confidentiality and the occurrence of uncontrollable circumstances (e.g.: weather, bystander behaviour), or additional expenses such as travel to reach a destination. To address these issues, past studies have implemented virtual reality (VR) technologies for VR exposure therapy (VRET) to provide an immersive, interactive experience that can be conducted privately. Although the outcomes from these studies have been generally positive despite the limitations of legacy VR systems, it is necessary to review these studies to identify how modern VR systems should improve to provide the best care possible.

**Objective:** The aim of this review was to establish the efficacy of virtual reality-based treatment for anxiety-related disorders, as well as to outline how modern VR systems need to address the shortcomings of legacy VR systems.

**Methods:** A systematic search was conducted for any VR-related, peer-reviewed articles focused on the treatment or assessment of anxiety-based disorders published prior to 31-August-2017 within the ProQuest Central, PsycINFO, and PsycARTICLES databases. References from these articles were also evaluated.

**Results:** A total of 49 studies met the inclusion criteria from an initial pool of 2,419 studies. These studies were a mix of case studies focused solely on VRET, experimental studies comparing the efficacy of VRET to various forms of CBT (e.g.: in-vivo exposure, imaginal exposure, and exposure group therapy), and studies evaluating the usefulness of VR technology as a diagnostic tool for paranoid ideations. The majority of studies reported positive findings in favour of VRET despite the VR technology’s limitations.

**Conclusions:** Although past studies have demonstrated promising and emerging efficacy for the use of VR as a treatment and diagnostic tool for anxiety-related disorders, it is clear that VR technology as a whole needs to improve in order to provide a completely immersive and interactive experience that is capable of blurring the lines between the real and virtual world.

**Trial Registration:** N/A

**Keywords:** Virtual Reality; Virtual Reality Exposure Therapy; Phobic Disorders; Anxiety Disorders
Anxiety-related disorders, such as specific phobias, posttraumatic stress disorder (PTSD), and general or specific anxiety (e.g.: public speaking or social anxiety) disorders stands as one of the most common, growing mental health disorders worldwide [1]. In 2014, 19.5% of individuals over the age of 16 had shown signs of anxiety or depression, with the United Kingdom alone experiencing a 1.5% increase from 2013 [1]. To combat the symptoms of anxiety-related disorders, one of the most effective treatment methods has been exposure therapy, which stems from the broader practice of cognitive-behavioural therapy (CBT) [2]. In exposure therapy, patients undergo a process of systematic desensitization, where a series of systematic steps are employed to gradually expose the patient to an anxiety or fear-inducing stimulus with the ultimate goal of minimizing the patient’s intense and adverse behaviour towards the stimulus. Furthermore, the therapists may employ methods to change the patient’s cognitions about the stimulus, such as through psychoeducation, to reinforce treatment gains from systematic desensitization [3].

Traditionally, stimuli in exposure therapy are presented through in-vivo exposure (IVE) or imaginal exposure (IE), each of which carries its own set of advantages and disadvantages. IVE involves live exposure to the stimuli, often being utilized to treat specific phobias or anxieties such as arachnophobia (fear of spiders) [4], acrophobia (fear of heights) [5], and social anxiety [6]. Although IVE is considered to be the most effective method for helping the patient overcome their anxiety or fear, disorders such as aviophobia (fear of flying) and social anxiety may require sessions to be conducted in public, therefore posing a risk of breaking patient confidentiality, become too expensive to perform single or repeated exposure sessions, and introduce uncontrollable variables that may hinder the overall treatment (e.g.: behaviour of living organisms, weather conditions) [7-9]. Even if these issues can be addressed, some individuals may feel that confronting an anxiety or fear-inducing stimulus may be too aversive, which may lead to participants dropping out of treatment or not seeking treatment at all [5]. IE can address many of the limitations of IVE, as patients are tasked with generating the stimulus in his/her imagination rather than confronting a live version of the stimulus, however, the patient may be potentially unable or unwilling to generate a vivid imaginal representation of the stimulus [10].

Since the early to mid-1990’s, therapists have attempted to seek an alternative to IVE and IE through the use of virtual reality (VR) technologies through a process known as virtual reality exposure therapy (VRET). VR technology includes a wide range of configurations, including head-mounted displays (HMDs), external projection setups such as the CAVE Automatic Virtual Environment [11], and simulators [12], all of which vary in terms of technical specifications (e.g.: display resolution, tracking accuracy, field of view). Regardless of the form of VR, VRET generally follows the same treatment protocols as traditional exposure therapy, but renders the anxiety or fear-inducing stimulus within a virtual environment (VE) that immerses the user with sensory stimuli; these stimuli will often involve visual and auditory immersion, but may sometimes include tactile immersion. By utilizing a customizable VE, VRET offers an unparalleled level of control for the therapist to
manipulate factors that could not be controlled in a standard IVE session and tailor the sessions based on the patient’s needs—all in the confines of the therapist’s office [9,13].

Despite a major interest in VR during its inception, VR was often expensive, underpowered, uncomfortable, and required special training to operate. A deficit in computational power led to low quality VR experiences that could lead to simulator sickness, characterized by symptoms of nausea, headaches, and dizziness [6]. HMDs also tended to be heavy, resulting in users experiencing neck pain after prolonged use. Furthermore, without adequate software distribution systems to sell or share VR programs, special training would often be required to create VR programs to suit the research or therapist’s needs. These limitations ultimately restricted the use and research of VR-based psychotherapy to well-funded or specialized institutions [14].

While early VR technologies have been largely inaccessible to a mass audience, recent developments in VR technologies have addressed many of the issues that plagued legacy units. Both the HTC Vive and Oculus Rift, which released in 2016, were lighter and powerful enough to render high quality visual and auditory stimuli. Both HMDs were also integrated with major digital distribution services such as Steam, which has attracted both indie and professional developers alike to create high quality VR programs. Renewed interest in VR also led to a push for mobile VR, a less powerful yet inexpensive version of computer-based VR that could run on most smartphones.

The aim of this systematic review is to explore previously established VR studies within psychotherapy to inform future VR research. Although modern VR HMDs are still relatively new, evaluating how past studies have utilized the VR technologies of their era can serve as a comprehensive guide as to how VR-based psychotherapy programs can improve in the future, as well as whether the limitations observed in past studies are still relevant with the current iteration of VR systems. Topics covered in this review will mainly cover the efficacy of VRET across multiple anxiety-based disorders, its uses as a diagnostic or assessment tool, and innovations in the pursuit of greater VR experiences.

Methods

Databases searched
ProQuest Central, PsycINFO, and PsycARTICLES were the databases used to conduct a comprehensive search of the past literature. Studies must have been published prior to 31-August-2017, peer reviewed, published in a scholarly journal, written in English, and have full text availability.
Search Terms
The command line used for the search was as follows: “virtual reality” AND (phobia OR anxiety) AND (treatment OR therapy). An initial 2,419 studies were collected from the three databases used to conduct this search.

Inclusion and Exclusion Criteria
For the initial 2,419 studies collected, the following inclusion and exclusion criteria were implemented. Parameters were set to limit the studies only to those whose subject was on virtual reality (n=217) and whose document type was either an article or case study (n=203). Studies that did not perform an experiment using an HMD for treating or examining a specific phobia or anxiety were excluded (n=177), as were other systematic reviews or meta analyses (n=3). HMDs were chosen as the VR system of choice for this review as the systems were the most accessible compared to CAVE and simulator-type systems, alongside the notion that the most prominent modern VR systems are HMDs. In total, 23 eligible studies met the inclusion criteria.

Another search was conducted based on the references detailed in each of the initial 23 eligible studies. Inclusion criteria for this search were that the reference title must have mentioned “virtual reality” alongside terms related to fear, anxiety, or a specific phobia, as well as adhering to the HMD requirement from the initial inclusion criteria. 27 additional studies were collected through these criteria, although one study appeared to have been published twice in two years with some minor differences, therefore the most recent version of that study was kept [15] while the older version was excluded [16], resulting in only 26 additional studies. In total, 49 studies were examined for this review.

Information found in Figure 1 exhibits the process in which the studies in this review were obtained based on the inclusion criteria, as well as the number of studies excluded based on the initial exclusion criteria.

(Figure 1)

Studies were also placed into one of five categories for the purposes of this review: Phobia Treatments (See Table 1), PTSD Treatments (See Table 2), Anxiety Treatments (See Table 3), Paranoia Evaluation (See Table 4), and Innovations and Evaluation (See Table 5).

(Table 1)

(Table 2)

(Table 3)

(Table 4)
Quality Assessment
Quality assessment of the collected studies were examined by both authors using the inclusion and exclusion criteria. The quality of each of the 49 studies were also appraised through the Mixed Methods Appraisal Tool (MMAT, 2011), which was designed to assess the methodological quality of quantitative (Randomized, Non-Randomized, and Descriptive), qualitative, and mixed method studies used within systematic reviews [17].

Results

Quality assessment outcomes
The 49 studies received an average rating of 86.73% and a modal rating of 100% (n=30). A total of 10 studies were classified as qualitative, 21 studies as quantitative randomized, 15 studies as quantitative non-randomized, and 3 studies as quantitative descriptive based on the parameters set by the MMAT [17].

Summary of Papers

Specific Phobias
The implementation of VRET for the treatment of specific phobias typically mirrors traditional phobia treatment protocols; treatment rationale was explained upon or prior to participant’s arrival, information gathering procedures were used to assess the patient’s phobic level, and a stimulus hierarchy would be established based on the information gathered. Levels of the stimulus hierarchy would vary based on the phobia being treated, but generally would incorporate a new level or factors as the patient progresses. For example, acrophobia patients undergoing VRET would often progress through greater heights [20,22,23], while aviophobia patients would experience the next stage of a flight (e.g. stationary, take-off, etc.) [8,24,25,27]. In short, regardless of the research methodology used or the specific phobia examined, treatment procedures were consistent across the 16 specific phobia studies.

A few studies compared the efficacy of VRET to a pre-established treatment, including standard IVE [19,20,25], relaxation therapy [8], or exposure group therapy [13]. In one study comparing treatment outcomes of VRET, IVE, and a waiting list condition for participants with agoraphobia, no significant differences were observed at the post-treatment and 12-month follow-up assessments between those that underwent VRET or IVE, but both groups did demonstrate significant improvements over those in the waiting list condition [19]. The comparison for VRET and relaxation therapy yielded similar results,
however, found that while VRET was more effective in reducing flying avoidance in participants, it was only marginally better at reducing the participants’ fear of flying ratings compared to relaxation therapy [8]. Lastly, in a comparison of VRET and exposure group therapy, more VRET participants experienced clinically significant change compared to exposure group therapy participants based on post-treatment assessments, but the significant difference disappeared between the two groups during the 6-month follow-up [13].

PTSD and ASD
Studies investigating the efficacy of VRET on PTSD and acute stress disorder (ASD) typically focused on patients who developed the disorder due to wartime combat or physical assault. Initial sessions followed the same format and components as the ones done for specific phobias, but VRET sessions were more personalized for each patient. For example, veterans were given a VE that matched the war environment that they had participated in, which included a jungle for the Vietnam War [36], and a desert city for Middle Eastern wars [30,32-34,37]; victims of physical abuse unrelated to war were placed in an urban environment [31,35].

A comparison of VRET, IE, and waiting list conditions found that, while VRET and IE both led to significant improvements in PTSD symptoms compared to the waiting list, IE was superior based on post-treatment assessments. Follow-up assessments conducted at 3 and 6-months also indicated that those who underwent IE experienced continual improvement, while those in VRET did not [34].

Another study sought to compare VRET to a treatment-as-usual condition, which consisted of patients performing their pre-established treatments, which included or was a combination of prolonged exposure, Eye Movement Desensitization and Reprocessing, and group therapy. Post-treatment assessments would indicate that 70% of patients that underwent VRET showed at least a 30% improvement on CAPS [61] scores, while only 11.1% of treatment-as-usual patients showed the same level of improvement. While this difference was deemed as significant, the authors noted that a small sample size and wide variability in the treatment-as-usual condition limited the interpretations of the study’s outcomes [32].

Lastly, one study investigated whether augmenting VRET with D-cycloserine, a glutamate receptor that had been demonstrated to improve the efficacy of exposure therapy for severe anxiety disorders, would also benefit VRET. All participants in the study underwent VRET, but were given either 50 mg of D-cycloserine, 0.25 mg of alprazolam (used primarily as a pharmacological treatment for anxiety), or a placebo pill. The study reported no significant differences in treatment outcomes for any of the groups, however, participants who were dosed with D-cycloserine experienced significant extinction learning that was not observed
in the alprazolam and placebo groups, suggesting that the use of D-cycloserine helped to enhance learning effects during VRET [37].

**Anxiety**

Studies that focused on general or specific (social, public speaking, dental, or test) anxiety utilized VR as a method to deliver VRET or VR distraction interventions. While VRET for general and specific anxiety largely mirrored the same procedural format as the VRET done for specific phobias, PTSD, and ASD, VR distraction was used to comfort patients during a dental procedure. Whereas VRET aims to address problematic behaviours and cognitions by exposing patients to a virtual simulation, VR distraction serves to give patients a more positive experience during an otherwise anxiety-inducing situation [41].

A comparison was conducted for the efficacy of VRET to CBT and waiting list conditions for the treatment of public speaking anxiety, and findings were largely concurrent with the specific phobia studies; both treatment groups experienced significant improvements over the waiting list, but did not significantly differ with each other based on post-treatment assessments [44]. A similar finding was reported when VRET was compared against EGT as an intervention for public speaking anxiety across post-treatment, 3-month, and 12-month follow-up assessments, however, the study had a small sample size that limited the findings [6].

A study that evaluated VRET for the treatment of GAD incorporated biofeedback and a mobile, rather than computer-based, VR system. The VEs for the biofeedback group, which depicted various scenes associated with relaxation, could change based on the participant’s heart rate and physiological activation; a reduction in either results in a reduced intensity for certain stimuli within the VE. VEs for the VRET without biofeedback and waiting list groups experienced the same scenes, but without the additional biofeedback features. Those who were in the biofeedback group were reported to have a significant decrease in behavioural avoidance and state anxiety, while the VR without biofeedback group only experienced a significant decrease in behavioural avoidance, and the waiting list group experienced no significant changes [42].

VR distraction was utilized for both dental anxiety studies in this review, which were carried out during either a simulated [41] or live [43] procedure. The stimulated dental procedure study compared active VR, passive VR, and no VR; those in the active VR condition could freely navigate around the VE while those in the passive VR condition could not. Those with higher levels of dental anxiety in both the active and passive VR conditions were reported to have less vivid memories of the procedure compared to those that completed the procedure without VR [41]. Similar findings were reported for the live procedure study in which an oral prophylaxis (teeth cleaning) was performed. Participants were randomly assigned to one group that received VR distraction during the first half of the procedure, and another group that received the VR distraction during the second half.
Participants in both groups experienced significantly greater calmness during the portion of the procedure when they received VR distraction compared to the portion when they did not [43].

Paranoia/Paranoid Ideations
The process of diagnosing paranoia has been difficult to do in real settings, as therapists must be able to discern whether an individual’s claims are legitimate or based on true paranoid beliefs. Through the use of VR, the diagnostic process for paranoia can be more reliable as more control is afforded to the therapist; avatars in the VE cannot physically harm nor be harmed by the patient, and paranoid beliefs that surface during VR exposure can be verified [48]. As there were not a lot of studies dedicated to this topic, each study employed the same task within the same VE: participants rode a London Underground train for a few minutes surrounded by avatars with neutral expressions and mannerisms.

In one study, individuals were found to be twice as likely to experience some form of persecutory thoughts during VR exposure if they reported paranoid ideations in day-to-day life [47]. This finding provided support towards the notion that neutral avatars were capable of eliciting paranoid thoughts, which was further confirmed in another study that compared the reactions of individuals belonging to clinical paranoia, high non-clinical paranoia, and low non-clinical paranoia groups [48].

Innovations and Evaluations
While previous sections covered how VR has been used to treat or study certain anxiety-based disorders, it is worth noting the studies that have sought to either study VR-specific features or create innovative programs to enhance VR-based treatment. For example, an interactive dialogue system for a study on social anxiety was developed to elicit fear responses during VR exposure to match the fear response levels observed in in-vivo conversations. While the study reported that participants believed in-vivo conversations were more realistic than the ones held in VR, fear ratings were found to be significantly higher for VR conversations than in-vivo ones. Although realism is an important factor, the authors considered that fear was a more important factor in the context of treating symptoms of social anxiety [55].

Another study sought to use dynamic social dialogue systems to manipulate the participant’s feelings of anxiety in real time, and effectively demonstrated that different ratios of positive and negative responses could serve as effective anxiety stressors to manipulate the participant’s anxiety level in any direction (low to high) at any time [51]. Other studies aimed to evaluate changes in audience behaviours and other social stressors (e.g. number of avatars present, ethnic diversity, etc.), and demonstrated similar levels of efficacy in manipulating the patient’s anxiety levels [53,60].
Several studies were also conducted to evaluate whether VR stimuli were capable of eliciting real emotions, a crucial factor for the treatment and assessment of specific phobias and other anxiety disorders. There are some mixed findings; while a study on acrophobia found evidence that participants experienced real fear when exposed to a virtual cliff [58], a study on woodwind performance anxiety found inconsistencies in subjective anxiety ratings during a performance in a virtual concert hall [52]. For the latter, the authors speculated that an increase in heart rate during VR exposure may have been due to the nature of performing on a wind instrument rather than due to the VR exposure, and the inconsistent subjective anxiety ratings could have been due to performers finding the act of performing to be psychological calming rather than anxiety-inducing.

Discussion

Principal Results
In relation to VRET, there appears to be an overwhelming amount of positive evidence that the VR-based treatment has an equal or greater efficacy towards the treatment of specific phobias and anxiety, but not as much for PTSD and ASD. This evidence comes from a mix of experimental designs, including case studies, controlled randomized trials, and within-group designs, with some studies also offering follow-up results as evidence of VRET’s effects beyond post-treatment. While the use of VRET for PTSD and ASD was effective, it appeared that some patients seemed to gain continual improvement when treated with another treatment option such as IE [34]. Regardless, those who underwent VRET consistently showed significant improvement over those in the waiting list groups in the specific phobia, specific anxiety, PTSD and ASD studies that compared the two together.

The use of VR to aid in the diagnosis of paranoia was also largely shown to be effective, and was further reinforced due to every study related to the topic in this review using the same procedures and VE to study or differentiate between individuals with varying levels of paranoia. While VR was not used as a treatment tool for paranoia, it does provide a safe environment for the patient while simultaneously giving therapists and researchers a way to accurately identify any paranoid ideations that may arise due to VR exposure.

Lastly, there have been many innovations towards better systems within a VE to bolster the immersion afforded by VR technology, at least for programs focused on treating social anxiety disorders. These innovations were largely focused on making VR avatars more realistic and sociable, ranging from increasing the realism of a person-to-avatar conversation, to the manipulative behaviours of multiple avatars that comprise a virtual audience. In general, these innovations achieved their purpose by eliciting greater amount of fear within the participant [55] or providing a dynamic manipulation of participant anxiety levels [51,53,60]. As for the evaluation of VR elements, simply recreating an object that the participant fears, such as a virtual cliff for those with acrophobia [58], is enough to
generate real fear, although testing VR’s efficacy on some tasks, such as performing on a
woodwind instrument [52], may prove to be difficult due to the nature of the task itself and
how it may conflict with common psychological or biometric measures.

Limitations
While there was an extensive amount of studies included in this review, some topics
appeared to be more researched than others, thus providing varying levels of quality and
quantity. In particular, there were a small number of studies dedicated to paranoia, and
although every study included in this review related to paranoia utilized the same VEs and
procedures, the results may have been strengthened with more variety in the types of VEs
used beyond the London Underground.

This issue also persists for the specific anxiety and PTSD and ASD studies in this review,
where there was one clear subject that dominated while there were only a few studies that
ventured beyond what was commonly researched. For specific anxiety, there were more
studies focused on social or public speaking anxiety, with only a couple of studies focused
on dental anxiety, and the PTSD and ASD studies largely focused on war-induced trauma
rather than physical assault-induced trauma.

Future Research
The landscape of modern VR has changed drastically compared to the VR systems used in
most of the studies included in this review. Whereas legacy VR systems were expensive,
required users to receive special training to operate or create VR programs, and were
limited to facilities that could invest in the technology, modern VR has provided cheaper
entry points, a vast library accessible through popular digital storefronts such as Steam or
Google Play and Apple App Store, and user-friendly experiences. While the most powerful
VR systems available today are mostly geared towards gaming, the same systems can
provide some use towards the study, diagnosis, or treatment of various anxiety-based
disorders.

One area of research that would be worth pursuing is a self-directed rendition of VRET that
can be done within a patient’s home with little to no therapist interaction. As there is an
overwhelming amount of positive evidence towards the efficacy of VRET, at least in relation
to specific phobias and anxieties, the next step towards evolving VRET may be to evaluate
whether those with mild to moderate anxiety-based systems may benefit from merely
exposing themselves to anxiety-inducing stimuli within a VE. Self-directed interventions
provide patients with care in areas with limited to no access to therapists, as well as those
who may be reluctant to see a therapist [62]. By utilizing a self-directed approach to VRET,
it may be possible to allow individuals with low anxiety severity to treat themselves at their
own pace, within their own home, and without the need for a therapist.
Conclusions
This review evaluated a variety of topics related to the use of VR for anxiety-based disorders, including VRET for specific phobias, specific anxieties, PTSD and ASD, and paranoia, while also outlining various innovations and evaluations conducted by studies to either improve the experiences afforded by VR or investigate the various factors that contribute to its efficacy towards anxiety-based treatments. These studies provided generally positive evidence towards the diagnostic and treatment capabilities of VR for anxiety-based disorders, however, research into VR has generally been limited to institutions that had the resources to invest in it. With the advent of more affordable, user friendly, and supported commercial VR systems, more VR research can finally be done by building on the foundation laid out by the early studies to both replicate past findings and establish new uses for VR within psychotherapy.
References


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