Review

Retracted: Implementations of Virtual Reality for Anxiety-Related Disorders: Systematic Review

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Abstract

Background: Although traditional forms of therapy for anxiety-related disorders (eg, cognitive behavioral therapy, CBT) have been effective, there have been long-standing issues with these therapies that largely center 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 (eg, weather and bystander behavior) or additional expenses such as travel to reach a destination. To address these issues, past studies have implemented virtual reality (VR) technologies for virtual reality exposure therapy (VRET) to provide an immersive, interactive experience that can be conducted privately and inexpensively. The versatility of VR allows various environments and scenarios to be generated while giving therapists control over variables that would otherwise be impossible in a natural setting. 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 can and should improve to treat disorders in which anxiety is a key symptom, including specific phobias, posttraumatic stress disorder and acute stress disorder, generalized anxiety disorder, and paranoid ideations.

Objective: The aim of this review was to establish the efficacy of VR-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 before August 31, 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 2419 studies. These studies were a mix of case studies focused solely on VRET, experimental studies comparing the efficacy of VRET with various forms of CBT (eg, 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 favor 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 to provide a completely immersive and interactive experience that is capable of blurring the lines between the real and virtual world.

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KEYWORDS

virtual reality; virtual reality exposure therapy; phobic disorders; anxiety disorders

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Introduction

Background

Anxiety-related disorders such as specific phobias, posttraumatic stress disorder (PTSD), and general or specific anxiety (eg, public speaking or social anxiety) disorders stand as 1 of the most common, growing mental health disorders worldwide [1]. In 2014, 19.5% of individuals above the age of 16 years 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, 1 of the most effective treatment methods has been exposure therapy, which stems from the broader practice of cognitive behavioral 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 behavior toward 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 (eg, behavior of living organisms and 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 or 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-1990s, 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 (eg, display resolution, tracking accuracy, and 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 that immerses the user with sensory stimuli. These stimuli are often limited to the user's visual and auditory senses but may sometimes incorporate tactile stimuli through an apparatus (eg, force feedback gloves, toy spiders) to allow VR users to feel objects with their hands. By utilizing a customizable virtual environment, 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, uncomfortable, and required special training to operate. The computers used to run VR were barely able to do so, leading to low-quality VR experiences (eg, jagged graphics and inconsistent and low frame rates) that could lead to simulator sickness, characterized by symptoms of nausea, headaches, and dizziness [6]. In addition to simulator sickness, early HMDs were also 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 therapists' needs. These limitations ultimately restricted the use and research of VR-based psychotherapy to well-funded or specialized institutions [14].

Although 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 small, independent developers and large, 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 modern mobile phones (e.g. iPhone, Google Pixel, etc.).

Objective

The aim of this systematic review was 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 treatment, its uses as a diagnostic or assessment tool, and innovations in the pursuit of greater VR experiences in relation to psychological disorders in which anxiety is a key symptom, including specific phobias, PTSD and acute stress disorder (ASD), specific and general anxiety disorder, and paranoid ideations.

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Methods

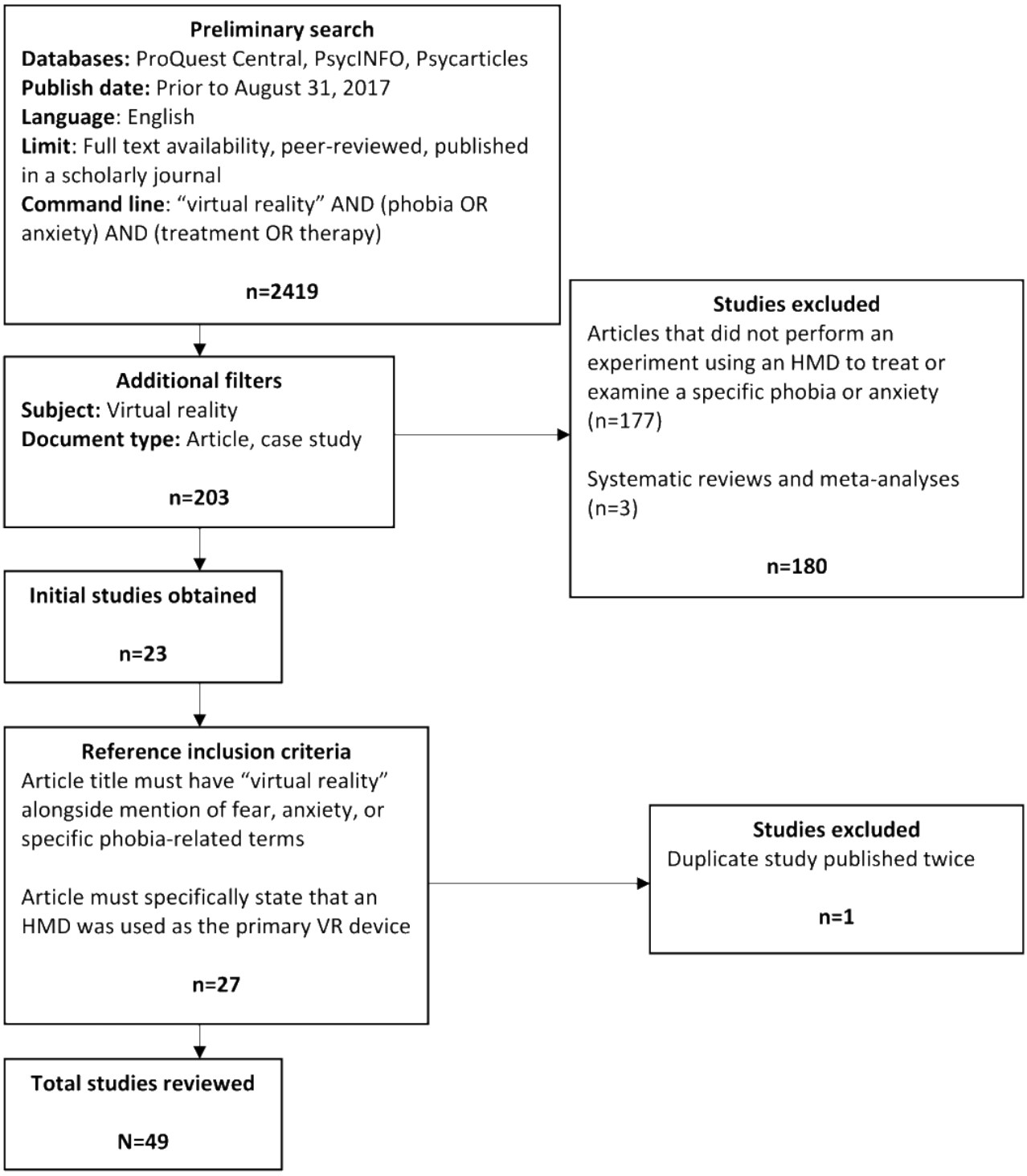
Databases Searched

ProQuest Central, PsycINFO, and PsycARTICLES were the databases used to conduct a comprehensive search of the past literature. Studies must have been published before August 31, 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). Although VR is a common referential acronym for virtual reality, the full term was exclusively used during the search to streamline the search process and avoid any other terms that may use the VR acronym (eg, variable reward and voice recognition). An initial 2419 studies were collected from the 3 databases used to conduct this search.

Figure 1. Systematic Review Search Prisma. HMD: head-mounted display; VR: virtual reality.



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Table 1. Specific phobia treatments.

Author	Phobia type	Methodology	Sessions, n	Session length	Follow-up	Intervention (patients, n)
Botella et al [17]	Claustrophobia	Case	8	35-45 min	1 month	VRET[a] (n=1)
Botella et al [18]	Agoraphobia	Controlled	9	1 hour	12 months	VRET (n=12); IVE[b] (n=12); WL[c] (n=13)
Carlin et al [9]	Arachnophobia	Case	12	50 min	None	VRET (n=1)
Emmelkamp et al [19]	Acrophobia	Controlled	3	1 hour	6 months	VRET (n=17); IVE (n=16)
Garcia-Palacios et al [7]	Arachnophobia	Controlled	3-10 (4)[d]	1 hour	None	VRET (n=12); WL (n=11)
Maltby et al [13]	Aviophobia	Controlled	5	50 min	6 months	VRET (n=20); EGT[e] (n=23)
Moldovan and David [20]	Multiple	Controlled	1	60 min	None	VRET (n=16); WL (n=16)
Muhlberger et al [8]	Aviophobia	Controlled	1	180 min	None	VRET (n=15); RT[f] (n=13)
Rothbaum et al [21]	Acrophobia	Controlled	7	35-45 min	None	VRET (n=12); WL (n=8)
Rothbaum et al [22]	Acrophobia	Case	5	35-45 min	None	VRET (n=1)
Rothbaum et al [23]	Aviophobia	Case	6	35-45 min	1 month	VRET (n=1)
Rothbaum et al [24]	Aviophobia	Controlled	8	1 hour	6 months	VRET (n=15); IVE (n=15); WL (n=15)
Rothbaum et al [25]	Aviophobia	Controlled	8	1 hour	12 months	VRET (n=13); IVE (n=11)
Rothbaum et al [26]	Aviophobia	Controlled	8	N/A[g]	6 and 12 months	VRET (n=25); IVE (n=25); WL (n=25)
Shiban et al [27]	Arachnophobia	Controlled	2	N/A	None	MCE[h] VRET (n=15); SCE[i] VRET (n=15)
Whitney et al [28]	Acrophobia	Case	8	N/A	None	VRET+VPT[j] (n=1)

[a]VRET: virtual reality exposure therapy.

[b]IVE: in vivo exposure.

[c]WL: waiting list.

[d]Mean value.

[e]EGT: exposure group therapy.

[f]RT: relaxation therapy.

[g]N/A: not applicable.

[h]MCE: multiple context exposure.

[i]SCE: single context exposure.

[j]VPT: vestibular physical therapy.

Inclusion and Exclusion Criteria

For the initial 2419 studies collected, the following inclusion and exclusion criteria were implemented. Parameters were set to limit the studies only to those whose subject was on VR (n=217) and whose document type was either an article or a 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 with 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 having explicitly used an HMD within the study itself. A total of 27 additional studies were collected through these criteria, although 1 study appeared to have been published twice in 2 years with some minor differences; therefore, the most recent version of that study was kept [15], whereas 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.

Studies were also placed into 1 of the 5 categories for the purposes of this review: phobia treatments (see Table 1), PTSD treatments (see Table 2), anxiety treatments (see Table 3),

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paranoia evaluation (see Table 4), and innovations and evaluation (see Table 5).

Quality Assessment

Quality assessment of the collected studies was examined by both authors using the inclusion and exclusion criteria. The quality of each of the 49 studies was also appraised through the mixed methods appraisal tool (2011), which was designed to assess the methodological quality of quantitative (randomized, nonrandomized, and descriptive), qualitative, and mixed-methods studies used within systematic reviews [60].

Table 2. Posttraumatic stress disorder and acute stress disorder treatments.

Author	Study type	Trauma type	Follow-up	Interventions and patients, n
Gerardi et al [29]	Case	War	None	VRET[a] (n=1)
Cardenas-Lopez et al [30]	Uncontrolled	Assault	None	VRET (n=6)
McLay et al [31]	Controlled	War	None	VRET (n=10); TAU[b] (n=10)
Reger et al [32]	Uncontrolled	War	None	VRET (n=24)
Reger et al [33]	Controlled	War	3 and 6 months	VRET (n=54); IE[c] (n=54) ; MA[d] (n=54)
Cardenas Lopez and de la Rosa-Gomez [34]	Case	Assault	None	VRET (n=1)
Rothbaum et al [35]	Case	War	3 and 6 months	VRET (n=1)
Rothbaum et al [36]	Controlled	War	3, 6, and 12 months	VRET with D-cycloserine (n=53); VRET with alprazolam (n=50); VRET with placebo (n=53)

[a]VRET: virtual reality exposure therapy.

[b]TAU: treatment as usual.

[c]IE: imaginal exposure.

[d]MA: minimal attention.

Table 3. Anxiety treatments.

Author	Anxiety type	Study type	Sessions, n	Session length	Follow-up	Comparisons and patients, n
Alsina-Jurnet et al [37]	Performance	Uncontrolled	1	90 min	None	High test anxiety (n=11); Low test anxiety (n=10)
Anderson et al [38]	Social	Case study	6 to 10	Unknown	Unknown	VRET[a] (n=2)
Anderson et al [6]	Social	Controlled	8	Unknown	3 and 12 Months	VRET (n=25); EGT[b] (n=25); WL[c] (n=25)
Harris et al [39]	Social	Controlled	4	12-15 min/exposure	None	VRET (n=8); WL (n=6)
Padrino-Barrios et al [40]	Dental	Controlled	1	Unknown	Unknown	VR[d] exposure first half (n=15); VR exposure second half (n=15)
Repetto et al [41]	General	Controlled	8	Unknown	Unknown	VRET with biofeedback (n=9); VRET without biofeedback (n=8); WL (n=8)
Tanja-Dijkstra et al [42]	Dental	Controlled	1	Unknown	1 week	Active VR (n=22); Passive VR (n=23); No VR (n=24)
Wallach et al [43]	Social	Controlled	12	1 hour	None	VRET (n=28); CBT[e] (n=30); WL (n=30)

[a]VRET: virtual reality exposure therapy.

[b]EGT: exposure group therapy.

[c]WL: waiting list.

[d]VR: virtual reality.

[e]CBT: cognitive behavioral therapy.

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Table 4. Paranoia or paranoid ideations evaluation.

Author and population	Pateints, n	Age in years, mean (SD)	Analysis
Fornells-Ambrojo et al [44]			Qualitative
Early psychosis (clinical)	10	24.2 (2.3)	
Healthy (Nonclinical)	10	23.8 (2.3)	
Freeman et al [45]: Assaulted 1 month before	106	34.4 (11.6)	Quantitative
Freeman et al [46]: Local adult	200	37.5 (13.3)	Quantitative
Freeman et al [47]			Quantitative
Low nonclinical paranoia	30	44.2 (11.2)	
High nonclinical paranoia	30	36.0 (11.7)	
Persecutory delusions	30	44.2 (11.7)	

Table 5. Virtual reality evaluations and innovations.

Author	Disorder	Aim
Cornwell et al [48]	Social anxiety	Evaluating the relationship between trait social anxiety and startle reactivity
Geuss et al [49]	Acrophobia	Assessing perceptual estimates and actions of gaps within VR[a]
Hartanto et al [50]	Social anxiety	Evaluating the efficacy of various social stressors within VR
Orman [51]	Performance anxiety	Assessing effects of VR exposure on performing musicians
Owens and Beidel [52]	Social anxiety	Evaluating the efficacy of VR stimuli for social anxiety VRET[b]
Park et al [53]	Social anxiety	Assess the virtual interactions of patients with schizophrenia with digital avatars
Pertaub et al [15]	Public speaking anxiety	Evaluate participant responses toward positive, negative, and static virtual audiences
Powers et al [54]	Social anxiety	Evaluate a VR-based interactive dialogue system to elicit the same level of fear from an in vivo conversation
Price et al [55]	Social phobia	Evaluate the importance of presence within VR as a predictor of treatment response for social anxiety VRET
Qu et al [56]	Social phobia	Evaluate the influence of virtual bystanders on the participant's self-efficacy, anxiety, social evaluation, vicarious experience, and cognitive consistency
Regenbrecht et al [57]	Acrophobia	Assessing the relationship between presence and fear of heights within VR
Slater et al [58]	Social anxiety	Assessing the efficacy of low-fidelity VR on social anxiety VRET
Veling et al [59]	Social anxiety	Evaluate the effects of childhood trauma on social stress reactivity and psychopathology within VR

[a]VR: virtual reality.

[b]VRET: virtual reality exposure theory.

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 nonrandomized, and 3 studies as quantitative descriptive based on the parameters set by the mixed methods appraisal tool [60].

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 before the patient'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 [19,21,22], whereas aviophobia patients would experience the next stage of a flight (eg, stationary and take-off) [8,23,24,26]. 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 with that of a pre-established treatment including standard IVE [18,19,24], relaxation therapy [8], or exposure group therapy [13]. In 1

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study comparing treatment outcomes of VRET, IVE, and a waiting list condition for participants with agoraphobia, no significant differences were observed at the posttreatment 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 [18]. The comparison for VRET and relaxation therapy yielded similar results; however, it was found that although VRET was more effective in reducing flying avoidance in participants, it was only marginally better at reducing the participants' fear of flying ratings compared with relaxation therapy [8]. Finally, in a comparison of VRET and exposure group therapy, more VRET participants experienced clinically significant change compared with exposure group therapy participants based on posttreatment assessments, but the significant difference disappeared between the 2 groups during the 6-month follow-up [13].

Posttraumatic Stress Disorder and Acute Stress Disorder

Studies investigating the efficacy of VRET on PTSD and 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 used for specific phobias, but VRET sessions were more personalized for each patient. For example, veterans were given a virtual environment that matched the war environment that they had participated in, which included a jungle for the Vietnam War [35] and a desert city for Middle Eastern wars [29,31-33,36]; victims of physical abuse unrelated to war were placed in an urban environment [30,34].

A comparison of VRET, IE, and waiting list conditions found that, although VRET and IE both led to significant improvements in PTSD symptoms compared with the waiting list, IE was superior based on the Clinician-Administered PTSD Scale (CAPS), a structured interview performed by the clinician to gauge the severity of PTSD-related symptoms [61]. Follow-up assessments conducted at 3 and 6 months also indicated that those who underwent IE experienced continual improvement, whereas those who underwent VRET did not [33].

Another study sought to compare VRET with 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. A posttreatment assessment using CAPS indicated that 70% (7/10) of patients that underwent VRET showed at least a 30% improvement, whereas only 11% (1/9) of treatment-as-usual patients showed the same level of improvement. Although 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 [31].

Finally, 1 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 D-cycloserine, 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 based on CAPS scores; 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 [36].

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. Although 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. Although VRET aims to address problematic behaviors 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 [40].

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 posttreatment assessments [43]. A similar finding was reported when VRET was compared with EGT as an intervention for public-speaking anxiety across posttreatment, 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 general anxiety disorder incorporated biofeedback and a mobile, rather than a computer-based, VR system. The virtual environments for the biofeedback group, which depicted various scenes associated with relaxation, could change based on the patient's heart rate and physiological activation; a reduction in either results in a reduced intensity for certain stimuli within the virtual environment. Virtual environments 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 behavioral avoidance and state anxiety, whereas the VR without biofeedback group only experienced a significant decrease in behavioral avoidance, and the waiting list group experienced no significant changes [41].

VR distraction was utilized for both dental anxiety studies in this review, which were conducted during either a simulated [40] or live [42] 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 virtual environment, whereas 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 with those that completed the procedure without VR [40]. Similar findings were reported for the live procedure study in which an oral prophylaxis (teeth cleaning) was performed. Participants were randomly assigned to 1 group that received VR distraction during the first half of the procedure and another group that received the VR distraction

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during the second half. Participants in both groups experienced significantly greater calmness during the portion of the procedure when they received VR distraction compared with the portion when they did not [42].

Paranoia or 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 the therapist has more control over the virtual stimuli, environment, and situational factors; avatars in the virtual environment cannot physically harm nor be harmed by the patient, and paranoid beliefs that surface during VR exposure can be verified [47]. As there were not a lot of studies dedicated to this topic, each study employed the same task within the same virtual environment: participants rode a London Underground train for a few minutes surrounded by avatars with neutral expressions and mannerisms.

In 1 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 [46]. This finding provided support toward 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 nonclinical paranoia, and low nonclinical paranoia groups [47].

Innovations and Evaluations

Although 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. Although 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 for 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 [54].

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 [50]. Other studies aimed to evaluate changes in audience behaviors and other social stressors (eg, number of avatars present and ethnic diversity) and demonstrated similar levels of efficacy in manipulating the patient's anxiety levels [52,59].

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; although a study on acrophobia found evidence that participants experienced real fear when exposed to a virtual cliff [57], a study on woodwind performance anxiety found inconsistencies in subjective anxiety ratings during a performance in a virtual concert hall [51]. 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 psychologically calming rather than anxiety-inducing.

Discussion

Principal Findings

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 toward 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 posttreatment. Although 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 [33]. Regardless, those who underwent VRET consistently showed significant improvement over those in the waiting list groups in the specific phobia, specific anxiety, and PTSD and ASD studies that compared the 2 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 virtual environment to study or differentiate between individuals with varying levels of paranoia. Although 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.

Finally, there have been many innovations to bolster the user's sense of immersion, or the feeling of being present, within an environment 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 behaviors of multiple avatars that comprise a virtual audience. In general, these innovations achieved their purpose by eliciting a greater amount of fear within the participant [54] or providing a dynamic manipulation of participant anxiety levels [50,52,59]. As for the evaluation of VR elements, simply recreating an object that the participant fears, such as a virtual cliff for those with acrophobia [57], is enough to generate real fear, although testing VR's efficacy on some tasks, such as performing on a woodwind instrument [51], may prove to be difficult due to the nature of the task itself and how it may conflict with common psychological or biometric measures.

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Limitations

Although a large number of studies were 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 virtual environments and procedures, the results may have been strengthened with more variety in the types of virtual environments used beyond the London Underground.

This issue also persists for the specific anxiety and PTSD and ASD studies in this review, where there was 1 clear subject that dominated, whereas 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 with the VR systems used in most of the studies included in this review. Although 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. Although the most powerful VR systems available today are mostly geared toward gaming, the same systems can provide some use toward 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 toward the efficacy of VRET, at least in relation to specific phobias and anxieties, the next step toward 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 virtual environment. Self-directed interventions provide patients with care in areas with limited to no access to therapists as well as to 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 toward anxiety-based treatments. These studies provided generally positive evidence toward 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.

Conflicts of Interest

None declared.

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Abbreviations

ASD: acute stress disorder
CBT: cognitive behavioral therapy
CAPS: Clinician-Administered PTSD Scale
EGT: exposure group therapy
HMD: head-mounted display
IE: imaginal exposure
IVE: in vivo exposure
MA: minimal attention
MCE: multiple context exposure
PTSD: posttraumatic stress disorder
RT: relaxation therapy
SCE: single context exposure
TAU: treatment as usual
VPT: vestibular physical therapy
VR: virtual reality
VRET: virtual reality exposure therapy
WL: waiting list

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