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VIRTUAL REALITY EXPOSURE THERAPY FOR ACROPHOBIA: A SYSTEMATIC REVIEW OF CLINICAL EVIDENCE

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Abstract: Acrophobia, or fear of heights, is a common and impairing specific phobia. Virtual reality exposure therapy (VRET) offers controlled, immersive height simulations that may overcome practical and acceptability barriers of in vivo exposure. This review synthesizes randomized controlled trials, controlled comparative studies, pilot studies, case reports, and meta-analyses evaluating VRET for acrophobia. Across these studies, VRET reliably reduces height-related anxiety, behavioral avoidance, and catastrophic cognitions, with effects that are large relative to no-treatment or waitlist controls. In head-to-head comparisons, outcomes for VRET are generally comparable to traditional in vivo exposure, with no significant differences observed on standard acrophobia outcome measures (e.g., Acrophobia Questionnaire, Attitude Towards Heights Questionnaire, Behavioral Avoidance Test). Adverse effects are uncommon and typically mild. Short-term follow-ups suggest maintenance of gains after treatment. Taken together, the evidence indicates that VRET is an effective, acceptable, and scalable option for acrophobia, suitable for clinical settings where real-world height exposures are difficult to deliver. Future work should clarify the durability of benefits over longer intervals and identify patient and treatment factors (e.g., sense of presence, guidance format) that optimize outcomes.

Keywords: exposure-based therapy, cognitive behavioral intervention, anxiety disorders, phobia treatment, inhibitory learning, immersive technology

1. INTRODUCTION

About 2–5% of people suffer from acrophobia, or the pathological fear of heights, which is a prevalent specific phobia [1]. Significant anxiety and fear of commonplace height-related situations such as bridges, balconies, and tall buildings can result from this condition. Crucially, the effects of acrophobia extend beyond discomfort; they can actually be dangerous. When in high places, people with severe acrophobia may experience panic and become so anxious that they are unable to descend safely. Most individuals with acrophobia do not receive treatment, instead relying on avoidance; thus, the phobia often persists untreated. This highlights the need for treatments that are both acceptable and accessible [2].

Acrophobia is typically treated with exposure-based cognitive-behavioral therapy (CBT), particularly in vivo (real-life) exposure. In vivo exposure entails a systematic or gradual confrontation with actual height situations under therapeutic supervision. Exposure therapy is highly effective; in many cases, it can completely eliminate or significantly reduce phobias [3, 4]. For instance, Öst's seminal one-session exposure therapy demonstrated about 90% improvement rates in specific phobias [5], and this approach has shown similarly promising outcomes in younger populations [6]. However, both patients and therapists may find in vivo exposure uncomfortable or impractical. Setting up real-world height exposures (e.g., repeatedly finding increasingly tall buildings or bridges) can be challenging and costly. Moreover, many patients are unwilling to attempt in vivo exposure at all due to intense fear; such exposure has low acceptability for some individuals. Indeed, acrophobic patients often refuse or drop out of in vivo therapy because the prospect of confronting actual heights is too distressing. In vivo sessions can also be cumbersome or uncontrollable by therapists. Subsequently, the prevalence of acrophobia and the number of individuals who undergo successful exposure therapy is widely apart.

The gap can be addressed by virtual reality (VR) technology. VR facilitates height simulations through controlled and immersive simulation within a safe environment. Patients are able to feel the sensation of being at a great distance by the use of VR headsets or Cave Automatic Virtual Environment (CAVE) systems such as standing on a virtual ledge or glass elevator yet stay physically secure in the therapy room [35]. This will render exposure therapy more palatable; on the side of the patient, VRET can be a better therapy choice with a reduced refusal rate in comparison to in vivo exposure [7]. The other characteristic of VR is the ability to exert fine control over stimulus intensity (the therapist can raise the virtual height or challenge in the situation progressively) and repeatability. The potential of VRET had been shown early in the 1990s: Rothbaum et al. (1995) reported that VR exposure could drastically decrease fear of heights in acrophobic individuals [9], and in a study about phobia therapy around the same time North et al. (1996) showed another successful use of VR [10] which further spoke of the promise of the technology. Many experiments have been carried out since the pioneers of the research, confirming the wide possibilities of VR in phobia treatment [7, 8, 38, 40-45, 48]. Indicatively, VR has been applied to fear of flying with positive results [12, 13], and even in other studies VRET has been as effective as live exposure therapy [14, 15]. These achievements are the driving factors behind its application in acrophobia. Another study by Garcia-Palacios et al. (2001) particularly redefined the criteria of success in the therapeutic approach with VR exposure where some acrophobic patients only attain any meaningful improvement without confronting any height in the real world [16]. Due to the high prevalence rate and disability of acrophobia, the logistical and emotional burden of exposure in vivo, researchers are keen to consider VRET a safe, effective and scalable alternative [1, 34].

The paper is a systematic review of the clinical evidence of VRET in acrophobia. We narrow on research that has tested the results of treatment, incorporating a variety of RCTs and other studies in the last twenty years. The important studies are summarized in tables with the design features, key results, and the effect sizes reported. The methodology of search and inclusion is described based on the PRISMA recommendations, and the flow diagram of the study selection is included. We also write about meta-analytic implications, the physiological processes that are likely to mediate the effects of VRET, patient acceptability and feedback, and some practical considerations to real-life implementation (cost and device needs). We would like to thoroughly evaluate the effectiveness of VRET as a fear of heights treatment method and provide factors that impact its effectiveness and application.

2. METHODS

We conducted a systematic search for peer-reviewed studies of VR interventions for acrophobia across multiple databases (PubMed, PsycINFO, Scopus, Web of Science) and Google Scholar. The search spanned publications from inception through December 2025. Keywords included combinations of "acrophobia" or "fear of heights" with "virtual reality", "VR exposure", and "virtual reality exposure therapy". Reference lists of relevant articles and prior reviews were also scanned for additional sources. Studies were included if they (1) involved an intervention using VR exposure to treat acrophobia, and (2) reported outcomes related to fear of heights (e.g. self-reported fear/anxiety, avoidance behavior, or physiological responses). We imposed an English-language requirement but no other language or date restrictions.

Eligible study designs encompassed randomized controlled trials (RCTs), non-randomized controlled trials, open pilots, case series, and relevant meta-analyses. We excluded papers that did not involve a VR treatment for acrophobia (for instance, studies only validating VR simulations or addressing other phobias without acrophobia-specific data). We also excluded purely conceptual/theoretical papers and non-peer-reviewed abstracts. Our search and screening process is summarized in the PRISMA flow diagram in Fig. 1.

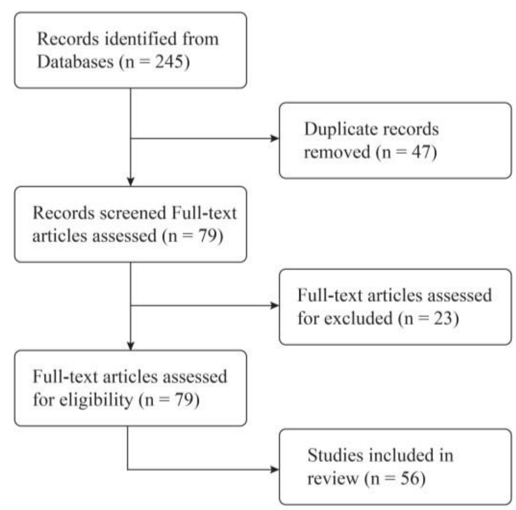

Fig 1. PRISMA flow diagram of study selection for the systematic review of VRET for acrophobia.

Data from included studies were extracted into summary tables. For each study, we recorded the sample characteristics, VR hardware and software used, comparison group or condition (e.g. in vivo exposure or waitlist control), outcome measures (such as the Acrophobia Questionnaire (AQ), Attitude Towards Heights Questionnaire (ATHQ), Behavioral Avoidance Test (BAT), and Heights Interpretation Questionnaire (HIQ)) [17], number of sessions, follow-up duration, and main results including effect sizes when reported. Tables 1–4 present the key characteristics and outcomes of the primary studies. In synthesizing findings, special attention was paid to comparisons of VRET with no-exposure control conditions and with traditional in vivo exposure.

In total, we identified 10 primary studies meeting the inclusion criteria. Of these, 6 were controlled trials (5 of which were randomized) and 4 were smaller-scale reports (open pilots or detailed case studies). Also, we took into account the findings of various meta-analyses and wider reviews as background. The studies incorporated may be classified as: (a) those clinical trials that directly compare VRET to a control or alternative intervention, (b) single-arm pilot studies and case report studies that involve VRET to acrophobia, and (c) relevant systematic reviews or meta-analytic studies. Most of the controlled studies were RCT. The sources of meta-analytic data incorporated helped to support the results on efficacy and present the combined estimates of the effect size.

3. DISCUSSION AND FINDINGS

According to the literature on VRET to treat acrophobia, it is clear that there is great evidence in favor of the practice, including self-administered VR programs and automated ones. The findings were organized in broad themes such as efficacy versus no treatment, in vivo exposure comparison, long lasting outcomes, technology and cost-effectiveness.

3.1 Overview of Evidence and Efficacy Findings

The VRET literature on treating acrophobia is a solid foundation that it is an effective therapy, both in an individual study and in a meta-analysis. Broadly, the results can be organized into several themes: (1) effectiveness of VRET relative to no-treatment controls, (2) effectiveness relative to traditional in vivo exposure therapy, (3) durability of treatment effects at follow-up, (4) technical aspects (e.g. VR system type) influencing outcomes, and (5) acceptability and practical implementation considerations such as cost-effectiveness.

Early research showed that exposure to VR can significantly lessen fear of heights. Notably, controlled studies conducted by Emmelkamp et al. (2001, 2002) demonstrated that, in the short term, VRET's effectiveness is comparable to that of in vivo exposure [18, 19]. With results that often last for at least 6 to 12 months (although some relapse in self-reported fear was noted without continuing practice), these pioneering investigations confirmed VR as an effective therapy technique for acrophobia [21]. A significant discovery regarding cost-effectiveness was made in the early 2000s: expensive immersive setups (CAVE systems) do not clearly outperform basic VR headsets in terms of results [20].

The more recent wave of studies (2015–2025) expanded VRET to novel formats and larger samples. Notably, Freeman et al. (2018) tested an automated VR coach in a sample of 100 patients [24], and Donker et al. (2019) evaluated a fully self-guided smartphone VR app in nearly 200 participants [25] (see Table 3). These landmark trials, summarized in Table 4, provided high-quality data showing that VRET not only reduces fear but can do so with very large effect sizes. Freeman et al. observed that a VR program administered without a human therapist led to dramatically greater improvements on the HIQ (Heights Interpretation Questionnaire) [17] compared to a usual-care control (Cohen's d ≈ 2.0). Donker et al. found that a self-administered VR CBT app led to substantial reductions in AQ (Acrophobia Questionnaire) scores relative to a waitlist, with an effect size of d ≈ 1.14. Gains were maintained well in the follow-up in both studies (4 weeks in case of Freeman et al., 3 months in case of Donker et al.). These experiments demonstrate that VRET could be administered in scalable forms (optimizable or at-home) without compromising effectiveness. In comparison, a small pilot study by Levy et al. (2015) proposed that VRET generates equivalent fear reduction to traditional cognitive treatment even in the simplest form (single-session remote implementation) [22, 48]. Celik et al. (2020) have published another innovative study, which involved using VRET and Acceptance and Commitment Therapy (ACT) methods and reported significant fear improvements that were also sustainable at a 6-month follow-up [27]. A study by Suyanto et al. (2017) indicated that a cheap VR system built on Kinect was capable of producing the right amount of fear and a feeling of presence on the participants who were acrophobic [23]. In these recent studies, there were no significant negative outcomes reported; VR was widely tolerated except that some experienced cybersickness or technical failures resulting in some drop-outs [32]. The participants were frequently found to have high engagement and even enjoyment in VR sessions (some of them referred to the therapy as a game like challenge to beat the game of their phobia).

Table 1. Early VR Acrophobia Studies — Characteristics (1995–2006)

Study (Year)	Sample & VR	Comparator
Rothbaum (1995)	20 students;	Wait-list

	low-res HMD	
Emmelkamp (2001)	10 patients; PC-CAVE	In vivo exposure
Emmelkamp (2002)	33 patients; HMD (3 sessions)	In vivo exposure
Krijn (2004)	33 patients; HMD vs CAVE	No-treatment / In vivo
Coelho (2006)	10 patients; HMD (3 sessions)	None

Table 2. Early VR Acrophobia Studies — Outcomes

Study (Year)	Key Outcomes
Rothbaum (1995)	VR reduced fear/avoidance vs wait-list.
Emmelkamp (2001)	VR ≥ in vivo on AQ; stronger ATHQ improvement.
Emmelkamp (2002)	Both VR and in vivo improved; maintained for 6 months.
Krijn (2004)	VR reduced fear; HMD = CAVE; stable at 6 months.
Coelho (2006)	Fear reduction maintained at 1 year (BAT, ATHQ).

Table 3. Recent VR Acrophobia Studies — Characteristics (2015–2025)

Study (Year)	Sample & VR	Comparator
Donker (2019)	193 adults; smartphone app + cardboard HMD	Wait-list
Freeman (2018)	100 adults; Valve HMD, 6 automated sessions	Usual care
Levy (2015)	6 adults; PC-HMD	Cognitive therapy (no VR exposure)
Suyanto (2017)	20 adults; Kinect VR	None
Celik (2020)	2 case reports; PC-HMD + Acceptance and Commitment Therapy (ACT)	None
Hui (2024)	61 college students; PC-HMD VRET + tDCS (mPFC)	Sham tDCS (with VRET)
Bohmeier (2025)	43 adults; PC-HMD VRET + iTBS (left DLPFC)	Sham iTBS (with VRET)
Francová (2025)	43 adults; PC-HMD VRET (3 sessions)	Wait-list + psychoeducation
Guo (2025)	50 adults; PC-HMD VRET (6 sessions)	Imaginal exposure therapy (IET)

Table 4. Recent VR Acrophobia Studies — Outcomes

Study (Year)	Key Outcomes
Donker (2019)	Large AQ reduction at 3 months (d≈1.14); some attrition from device issues.
Freeman (2018)	Automated VR control on HIQ
Levy (2015)	VR reduced fear; similar to cognitive therapy (small sample).
Suyanto (2017)	VR induced anxiety appropriately; strong presence; feasible.
Celik (2020)	VR + ACT produced marked fear reduction.
Hui (2024)	Active tDCS
Bohmeier (2025)	Two VRET sessions yielded ~79% remission
Francová (2025)	presence predicted greater improvement
Guo (2025)	Both VRET and imaginal exposure improved acrophobia symptoms

These studies hold that VRET shows a significant decrease in acrophobic symptoms of different delivery modes (e.g., therapist-guided in clinic, automated virtual coach or self-directed at home). The large trials by Freeman et al. (2018) and Donker et al. (2019) provide high-quality data, which proves that VRET can not only decrease fear, but also produce extremely large effects. In one trial by Freeman, e.g. the HIQ scores of the VR-treated group were on average worse by a margin of about 25 points as compared to the control (adjusted d ≈ 2.0). The VR app group in the trial of Donker achieved a greater increase in the AQ by comparison with the controls by a margin of 27 points higher (d = 1.14, CI = 0.84 to 1.44). In both studies, approximately 70-80 percent of VR participants recorded a 50 percent reduction of fear, which was virtually nonexistent of the control states. Such effects are exceedingly high clinical impacts. These results were further established in a more recent randomized trial by Francova et al. (2025): the participants who were administered three sessions of VRET experienced considerably more reductions of height-related fear and avoidance than the participants in the control treatment through psychoeducation, and the improvements were observed to be maintained at two months of follow-up [53]. In comparison, the results of VRET on fear were not dramatically different as observed in Levy et al. (2015), which was probably because the authors used a rather small sample but still reported statistically significant differences between the VRET and an active psychotherapy (cognitive therapy). An example of qualitative reporting was carried out by Celik et al (2020) wherein the authors reported that the combination of ACT principles and VR resulted in improved value-oriented behaviors and decreased avoidance that lasted 6 months.

To conclude, there is a growing amount of reliable evidence that VRET can be utilized as an effective intervention in acrophobia treatment. VRET has always shown better than no-treatment controls, with very high effect sizes in the diminution of height-related fear and avoidance. As a typical illustration, on RCTs, Cohen d values between VRET and waitlist tend to fall in the 1.0 to 2.0 range, suggesting extremely significant benefits (traditionally, d = 0.8 is a very large effect). The summary of Table 5 of the key studies will show the results of effect size. Unlike the significant increase compared to no-treatment, VRET and classic in vivo exposure yield similar results to a great extent. The trials that are mostly conducted are head to head and minimal differences are not statistically significant. As an example, Emmelkamp et al. (2002) found no significant difference in the efficacy of VR and real exposure because both groups showed improvement in questionnaires and behavioral tests [19]. Meta-analyses support this correspondence: Carl et al. (2019) have identified an overall effect size difference of g = -0.07 (with VR having a slight advantage) in the combination of RCTs on different phobias, and an earlier meta-analysis has made the same conclusion [29, 30, 31]. That is, patients are likely to gain more or less regardless of whether a therapist exposes them to heights using VR or exposes them to real heights. Separately, VRET has been eligible to make an important influence in comparison with control conditions in anxieties disorders in general, with pooled impacts generally falling within the large range [28]. These findings, in a practical sense, have significant implications: VRET seems to be a very attractive alternative or a complement to in vivo therapy, as it is of equal efficacy with a higher acceptability and a lower level of harm. VR can also be used in a proxy in an environment where exposure to real-height is impractical or unacceptable.

Table 5. Key Outcome Effect Sizes in VRET for Acrophobia

Study (Year)	**Outcome Measure(s)**	**Comparison**	**Effect Size**
Rothbaum et al. (1995)	Fear & avoidance (questionnaires, BAT)	VR vs. waitlist	*d* ≈ 0.9 (VR > control)
Freeman et al. (2018)	Heights Interpretation Questionnaire (HIQ)	VR vs. usual care	*d* ≈ 2.0 (very large)
Donker et al. (2019)	Acrophobia Questionnaire (AQ)	VR vs. waitlist	*d* = 1.14 (large)
Emmelkamp et al. (2002)	AQ, BAT, ATHQ	VR vs. in vivo exposure	*d* ≈ 0 (n.s. difference)

In addition to the efficacy on repeated measures, VRET research has covered mechanisms and auxiliary outcomes. The subjective presence of participants (sense of being there in the virtual height) becomes one of the central factors: the increased presence is likely to be associated with a greater level of fear activation and eventually with a greater level of fear reduction. In fact, it seems to be important to experience some physiological arousal when engaging in VR sessions in order to gain therapeutic benefits. Virtual height research has demonstrated that acrophobic individuals have high heart rate and anxiety in virtual height conditions comparable to actual heights which leads to the hypothesis that VR actually induces genuine fear response which can be habituated or extinguished. Fear activation, habituation and cognitive reprocessing following numerous VR exposures result in quantifiable reductions in anxiety and avoidance behavior. The tangible results of this process are improvements of behavioral avoidance tests and self-report scales (e.g. AQ, ATHQ). It is interesting to note that the therapeutic changes realized through VRET are very similar to those of an in vivo exposure, implying that they are based on the same essential mechanism: inhibitory learning to suppress fear associations.

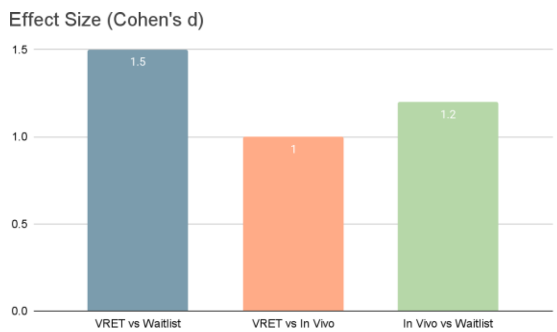

Fig 2. Effect Sizes Across Treatment Types

The VR exposure and conventional in vivo exposure result in significant changes over no treatment (Cohen 1.1 d of VR and 0.8 d of the in vivo on average). Direct comparisons show that VRET and in vivo are similar in the difference (d 0.0-0.2 in one way or the other) which implies that they are the same. To be more specific, small, medium and large are d = 0.2, d = 0.5 and d = 0.8, respectively. Therefore, d > 1 in the acrophobia trials is an indication of extremely large, clinically significant improvement.)

3.2 Follow-up and Durability of Improvements

The issue of lasting therapeutic gains is also among the most significant issues of phobia treatment. Follow-ups done within a short time have positive outcomes: Freeman et al. (2018) and Donker et al. (2019) observed enduring improvements at the 4-week and 3-month-follow-up, respectively, with a substantial reduction in fear being sustained [24, 25]. Gains were maintained at 6 months in medium-term reports by Krijn et al. (2004) and Emmelkamp et al. (2002) [20, 19]. According to Coelho et al. (2006), behavioral improvement persisted at 12 months yet there was some subjective fear relapse and this suggested that booster sessions are required [21]. Celik et al. (2020) also reported continued improvements at 6 months with VR + ACT, so there was potential to continue with long-term results with integrated methods [27].

In general, there is some evidence indicating that VRET can have lasting effects at least several months after treatment, but the real long-term efficacy (more than one year) is somewhat less understandable, since there is not much data. It is evidence that when practice is not continued, some apprehension may be renewed with time (e.g. say after about a year). Such a trend does not occur in isolation to VR - even in traditional exposure therapy, discontinuation of exposure may gradually undermine the progress. According to Arroll et al. (2017), in a systematic review, numerous phobia treatments have been reported to possess great short-term efficacy but questionable long-term efficacy, with booster exposures aiding in avoiding relapse [1]. With acrophobia, a judicious approach could be to suggest that the client undergoes VR refresher therapy or direct practice of height after the intensive treatment as a means of reinforcers.

Table 6. Follow-up Outcomes in Selected VRET Trials

Study (Year)	Follow-up	Main Findings at Follow-up
Krijn et al. (2004)	6 months	Effects maintained; AQ and BAT improvements stable; VR group similar to in vivo group.
Emmelkamp et al. (2002)	6 months	Both VR and in vivo groups maintained gains; majority of patients still at much lower fear levels than baseline.
Coelho et al. (2006)	1 year	Partial maintenance: BAT/ATHQ improvements persisted, but AQ fear ratings rose toward baseline (return of some subjective fear).
Freeman et al. (2018)	4 weeks	HIQ scores remained greatly improved from baseline (minimal decay from immediate post-test).
Donker et al. (2019)	3 months	Large effect maintained at follow-up

In sum, VRET appears capable of producing lasting fear reductions for many individuals, at least in the medium term. However, like any phobia treatment, periodic reinforcement may be beneficial to ensure that gains do not diminish over longer periods.

3.3 Moderator Variables and Technological Considerations

Over the evolution of acrophobia VRET, the diversity of VR platforms has expanded. Early studies in the 1990s used what were then state-of-the-art systems that are primitive by today's standards. For example, Rothbaum's initial 1995 study employed a low-resolution head-mounted display tethered to a desktop computer. Emmelkamp's early-2000s work often utilized CAVE-like multi-wall projection setups or heavy wired HMDs with limited graphics. As technology advanced, later researchers adopted more sophisticated PC-based HMDs (with better graphics and tracking) and even smartphone-based VR.

However, as of 2026, standalone six degrees-of-freedom (6DoF) VR systems—such as Meta Quest 3, Apple Vision Pro, and Pico 4—have become the new clinical standard. These devices offer full positional tracking, wireless operation, and built-in computing capabilities, making them highly suited for therapy and research alike [53]. Most recent trials now employ these standalone HMDs due to their portability, high fidelity, and ease of setup in both clinical and home environments. Legacy systems like smartphone VR (e.g., Google Cardboard) have become obsolete due to limited immersion and interactivity, and are no longer used in modern trials. CAVE systems and Kinect-based hybrids still appear occasionally in the literature but primarily as historical or experimental platforms [20, 23].

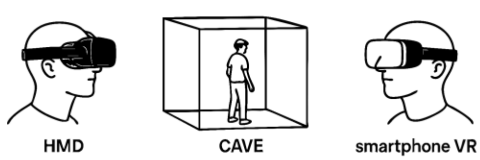

Fig. 3. Types of Virtual Reality Systems Used in Acrophobia

Most studies used consumer head-mounted displays (HMDs) tethered to PCs or consoles (e.g., Oculus Rift, HTC Vive), especially in recent years. A minority used CAVE systems (multi-wall VR rooms) in early research. Some of them experimented with less mobile solutions such as smartphone VR (e.g., Google Cardboard) or motion-tracking hybrids (Kinetic-based VR) to make access more universal. Interestingly, there were no significant differences in the results of sophisticated CAVE systems and simple HMDs - even simple and cheap VR may be used as an effective treatment of acrophobia.

Positively, it looks like more sophisticated VR systems do not have better clinical outcomes. A direct comparison showed no difference in the outcome of an immersive CAVE and a standard HMD [20]. This would imply that in a real-world perspective, the consumer VR devices are easily accessible and that this alone to the therapy would suffice a very important consideration to scalability. Therapist involvement is another technological factor. The conventional guidelines involved the presence of a live therapist to facilitate the exposure but Freeman et al. (2018) demonstrated that even a fully automated VR coach could produce a substantial effect [24], and Donker et al. (2019) demonstrated that a self-guided app could be very effective [25]. The implications of these findings are scalable models in which time spent with therapists is minimized, which may make them less expensive.

The newest research has also investigated the potential of the neuromodulatory methods to improve the efficiency of VRET. Hui et al. (2024) reported that VRET combined with anodal transcranial direct current stimulation (tDCS) of the medial prefrontal cortex proved to be faster in the early reduction of fear, yet the long-term results were similar to standard VRET [55]. Conversely, there was no additional benefit of providing intermittent TMS with theta-burst stimulation prior to VRET sessions, and both active and sham stimulation groups had the same high response rates [56]. Nevertheless, support provided by therapists may also be of benefit to some patients (e.g., patients who should be encouraged or reframe cognitions during exposure) which can be investigated in the future.

Outcomes may also be moderated by patient characteristics. To provide an example, there may be people who have very high levels of baseline fear, which may take more sessions to experience the same amount of improvement. Donker et al. observed that those with more severe initial acrophobia took longer to complete the VR modules, suggesting they proceeded at a slower pace [25]. Presence tendency (how easily a person feels "present" in virtual environments) could influence how strongly they respond to VR; some evidence suggests those who experience greater presence have more anxiety activation and thus more opportunity for extinction [36, 37]. Francová et al. (2025) provided additional empirical support for this, showing that presence levels significantly predicted symptom improvement in a recent randomized trial [53]. Such individual differences have not been studied in depth and remain an important research direction [49].

3.4 Acceptability, Safety, and Patient Feedback

In the literature, VRET has been well-accepted by patients. A number of participants who refused or felt apprehensive about in vivo heights accepted to be exposed to VR. Most trials have recorded low dropout rates in VRET conditions. As an illustration, Freeman et al. (2018) showed a low rate of attrition in the VR treatment (4-week program was completed by all 49 VR-assigned patients) [24]. Donker et al. (2019) also observed some loss of participants mainly because of technical issues, approximately 23 percent of those who enrolled failed to begin the VR application because their smartphones could not operate with it, and a portion (approximately 10-15 percent) of those who had begun dropped out because of hardware or cybersickness problems. These technical dropouts demonstrate the need to make certain of easy to use technology that has been thoroughly tested. However, satisfaction was reported among individuals who have participated in VR. In qualitative feedback, patients frequently wrote that VR exposure was not as terrifying as they expected and even fun or game-like when they were immersed in it. Freeman et al. reported that the participants were keen on the completion of all VR levels and overcoming challenges of a virtual world [24]. Some of the studies have directly evaluated side effects and reported no severe negative incidents [32]. Motion sickness or dizziness are the most frequent minor side effects, which are reported by a small part of the users, particularly in case of laggy graphics in the VR or when the individual is likely to get simulator sickness. In the trial of Donker, some users noted the presence of nausea or headache which caused them to pause or slow the training, but these were only temporary and disappeared after changing the pace. Notably, none of the participants have been reported to have any accidents or any long-term negative impacts of VR therapy. As a matter of fact, several research papers focus on the safety of VRET: it enables them to perform extreme exposure exercises without risking an individual to get into real danger.

There are also comparative studies that have used VR and in vivo to report a positive feedback on patients. Indicatively, in the studies by Emmelkamp et al. [18, 19], part of the respondents explicitly indicated that they would prefer VR sessions over actual exposures, noting the presence of less anticipatory anxiety and more readiness to experiment with something in VR that they would not have dared in reality (because they knew that they were actually safe). This leads to the possibility of VR to enhance the aspect of acceptability, which is very crucial as a treatment that patients are willing to undergo has more chances of working in real life. Even therapists have reported benefits of VR: it is possible to do therapy in the office, repeatable situations and no travel logistics involved.

To sum up, VRET is not only effective but also tolerable to patients, and its safety profile is high. In cases where technical problems are not a major concern, most patients go through VR treatment and many of them are entertained. Rarely there are serious problems but mild cybersickness may occur in a minority. These attributes justify the practical nature of the application of VRET in a practical clinical environment.

4. INTERPRETIVE MODEL OF VRET MECHANISMS

These studies as a group indicate that there are a series of processes which are interrelated and which explain the therapeutic effects of VRET in acrophobia. The synthesis of these mechanisms is shown in a conceptual model in figure 4. The major factors contributing to it may include: (a) VR environment characteristics (e.g. level of immersion, realism, multisensory feedback) that can influence the strength of patient response; (b) VR treatment format (therapist-guided vs. self-guided, frequency of sessions) which may influence patient engagement and adherence; and (c) patient factors (degree of fear at baseline, tendency to experience presence, anxiety sensitivity) that might moderate the effect. These variables affect the degree of presence that a patient will feel in VR i.e. the realness of the virtual heights to a patient. Presence: the increasing presence results in more emotional involvement and fear arousal during VR sessions. This high fear activation is in fact wanted as it gives a chance to undergo the extinction learning. The repeated VR exposure, with or without coaching or self-directed coping, causes the patient to gradually habituate to the feared stimuli and develop new non-threatening associations with heights. This type of learning is inhibited and is manifested by the decreases in fear and avoidance behaviors in the long run. In line with this model, physiological evidence indicates that VR height conditions provoke actual fear (e.g. increased heart rate, sweat) like actual heights, particularly high presence. With repetitions, such responses decline, which signifies habituation. It also involves cognitive changes: patients indicate the change in their catastrophic thinking (such as that the overestimation of falling or panicking has decreased).

This mechanistic pathway is further supported by neuroimaging data: the VRET causes a reduction in the functional connectivity of fear-related brain regions, such as the visual cortex and default mode network, and the neural alterations are strongly associated with the improvement of symptoms [54] [54]. In the end, such processes result in measurable improvements in acrophobia symptoms: on both behavioral (the individual is now able to climb higher in a real or virtual structure than he used to) and self-report scales such as the AQ and ATHQ. The model in Fig. 4 does not rely on an entirely theoretical suggestion instead of the empirical findings presented in the reviewed literature; it illustrates the way VRET promotes therapeutic change in acrophobia by connecting the independent variables through the mediator of presence to the consequence of the reduction of fear.

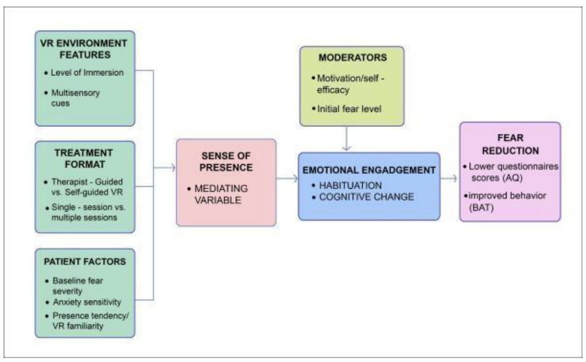

Fig. 4. Interpretive model of VRET mechanisms in acrophobia based on the reviewed studies.

The diagram demonstrates the effect of individual (e.g. initial level of fear, anxiety sensitivity) and treatment (VR immersion, type of guidance) factors on the perception of presence in virtual environments of height, which subsequently causes fear activation. Extinction (inhibitory learning) is achieved through repeated exposure as the stimulus (a fear-inducing stimulus) is activated and a successful coping mechanism produced resulting in reduced fear response. However, this leads to improvement in outcomes with time the reduction of anxiety, avoidance, and distress associated with heights. Having high presence will result in greater fear activation (which is good until the tolerable level of a person) and having low presence may restrain it and finally slack development. Sufficient fear activation is necessary to engage the fear structure and allow new learning, consistent with the emotional processing theory and inhibitory learning framework. Factors like multi-sensory cues in VR (looking down, hearing wind) can heighten presence and emotional arousal, thereby potentially enhancing outcomes, as long as the patient can gradually habituate. On the other hand, individual resilience and coping skills (which can be enhanced via therapist or automated coaching) help translate the fear activation into extinction learning rather than overwhelming panic. The net result is a decrease in the pathological fear of heights.

5. LIMITATIONS OF THE CURRENT REVIEW

Several limitations in the current body of evidence, as well as limitations of this review, should be noted. First, although we performed a comprehensive search, it is possible that some unpublished trials or the very latest studies (as of 2025) were not captured. The field of VR therapy is advancing rapidly, with new studies on acrophobia VRET and related technologies (such as augmented reality exposure for heights, e.g., Tsai et al. 2018) continuing to emerge. We limited our scope to English-language research published in scholarly journals, which could introduce language or publication bias.

Moreover, as a formal meta-analysis was not conducted in this review, all references to effect sizes rely on values reported in individual studies or prior narrative reviews. A quantitative synthesis (meta-analysis) would be useful to more precisely estimate the average effect of VRET and to statistically test equivalence with in vivo exposure. Encouragingly, existing meta-analyses support our qualitative findings—for example, Carl et al. (2019) and Freitas et al. (2021) both conclude that VR exposure is highly effective and not significantly different from in vivo exposure in treating phobias. Nonetheless, the current meta-analytic updates (which include the most recent trials) are justified to ensure the reinforcement of such conclusions.

The danger of bias on most individual studies is another consideration. To enhance the level of analytical rigor, we enhanced the methodological critique through Cochrane ROB-2. This has been appraised in three summary tables to make it clear. A domain-level assessment of randomization process and implementation of deviations of planned interventions is presented in Table 7. Table 8 reports on missing outcome data and risks associated with outcome measurement. Table 9 summarizes the selection of reported results and provides the overall risk of bias rating for each trial.

Table 7. Randomization and Intervention Deviations in VRET RCTs

Study (Year)	Randomization Process	Deviations from Intended Interventions
Rothbaum et al. (1995)	Some concerns – unclear method, small N	Low risk – protocol followed
Emmelkamp et al. (2001)	Some concerns – method not described	Low risk
Emmelkamp et al. (2002)	Low risk – allocation described	Low risk
Freeman et al. (2018)	Low risk – robust, concealed allocation	Low risk – protocol followed
Donker et al. (2019)	Low risk – randomization described	Low risk
Francová et al. (2025)	Low risk – balanced allocation	Low risk
Guo et al. (2025)	Low risk – computerized assignment	Low risk – parallel interventions
Hui et al. (2024)	Low risk – sham-controlled double-blind	Low risk
Bohmeier et al. (2025)	Low risk – double-blind randomized	Low risk

As shown in Table 7, early trials like Rothbaum (1995) and Emmelkamp et al. (2001) had small samples and did not report details of allocation concealment, contributing to potential selection bias. None of the trials could blind participants given the nature of the comparisons (VR vs. real exposure or vs. no exposure), and outcome assessors were usually not blinded either—though Freeman et al. (2018) did implement single-blind assessments.

Table 8. Missing Outcome Data and Measurement Bias

Study (Year)	Missing Outcome Data	Measurement of Outcome
Rothbaum et al. (1995)	Some concerns – attrition noted	Some concerns – unblinded self-report
Emmelkamp et al. (2001)	Low risk	Some concerns – no blinding
Emmelkamp et al. (2002)	Low risk	Some concerns – unblinded data collection
Freeman et al. (2018)	Low risk – complete data	Low risk – single-blind assessors
Donker et al. (2019)	Some concerns – dropout due to tech	Some concerns – self-report only
Francová et al. (2025)	Low risk	Some concerns – self-report only
Guo et al. (2025)	Low risk	Some concerns – fMRI + unblinded questionnaires
Hui et al. (2024)	Some concerns – mild attrition	Low risk – blinded assessors
Bohmeier et al. (2025)	Low risk – completers analyzed	Low risk – fully blinded

Table 8 indicates that attrition bias was minimal in most studies. Freeman had 0% outcome attrition, while Donker had some pre-treatment dropouts due to technical issues, but the trial applied an intent-to-treat analysis to mitigate this. Some recent studies, such as Hui (2024) and Bohmeier (2025), achieved low risk in outcome measurement through blinded assessments.

Table 9. Reporting Bias and Overall Risk of Bias

Study (Year)	Selection of Reported Results	Overall Risk of Bias
Rothbaum et al. (1995)	Low risk	High
Emmelkamp et al. (2001)	Low risk	Moderate
Emmelkamp et al. (2002)	Low risk	Moderate
Freeman et al. (2018)	Low risk – pre-registered trial	Low
Donker et al. (2019)	Low risk – outcomes matched protocol	Moderate
Francová et al. (2025)	Low risk	Moderate
Guo et al. (2025)	Low risk	Moderate
Hui et al. (2024)	Low risk	Moderate
Bohmeier et al. (2025)	Low risk	Low

As summarized in Table 9, the overall risk of bias varied across studies. Early trials tended to show higher risk, while more recent trials such as Freeman (2018) and Bohmeier (2025) were judged as low risk across most domains. The wider body of evidence of the RCTs can thus be described as being moderate in their quality- there is some risk of bias, but the bigger and more recent trials were reasonably of good quality. Further interference with the credibility of findings is possible in the future as VRET research continues to be blinding (where possible) and the pre-registration of trials.

Lastly we agree that this review did not produce any new empirical information but instead synthesized previous research. Although we made an attempt to be comprehensive and up to date, the findings reached are necessarily constrained by the existence of research and its quality. The literature has some gaps including a paucity of long-term (>1 year) outcome data and a poor awareness of which patient subgroups are most benefited. These are the valuable avenues to study further.

6. CONCLUSION

Finally, VRET has evolved into an empirically supported acrophobia treatment out of an experimental concept of the state of the art. The existing body of evidence (over 20 years of research with the majority of RCTs) supports more than just the idea that VRET is a reliable fear of heights reducing strategy, but also the fact that a significant proportion of patients receiving VR treatment should record significant, clinically meaningful improvement (in many cases, to the point of not satisfying acrophobia criteria of diagnostic) [32]. Moreover, VR exposure has also been demonstrated to yield similar results to conventional in vivo exposure therapy and as such VR can be used as a viable direct replacement or complement to in vivo exposure [19, 30]. The exposure in VR has certain practical advantages that are not previously found in clinical trials: it is tolerated without serious adverse reactions, can be implemented in a convenient setting at a clinic or even at the home of a patient, and is repeatable and adaptable on-demand. These factors make VR a highly eligible as a first-line or adjunctive intervention in patients reluctant to use real-height exposure or who otherwise have no access to in vivo exposure therapy.

Nevertheless, to fully implement VRET into the routine practice of clinical care, some of these gaps are to be addressed. The durability of VR treatment gains in the long term (to make sure that the fear can be reduced in the long run) and how the relapse can be prevented (through booster VR sessions or even mixed reality measures spaced out) need to be researched further. It will be more convincing to conduct bigger trials with more people (different ages, cultural backgrounds) to enable the generalizability of the findings. With technology changing, research bringing the latest advances such as augmented reality (AR) or mixed reality exposing height may widen the treatment kit (an initial study indicates that AR is also able to generate height anxiety, so it could be employed alongside VR) [50]. Besides, further research in mechanisms is justified, e.g., in quantifying physiological arousal or neural activations during VR sessions (some studies, e.g. Diemer et al. 2016, have already started it) to better see how VR leads to fear extinction [51]. It is worth mentioning that a novel study by Herrmann et al. (2017) discovered that exposure therapy was faster when the medial prefrontal cortex was stimulated in acrophobia [52]. These directions give hints to the possible methods of making VRET more effective by integrating it with neuromodulation or other methods.

In terms of implementation, the results of this review will promote the use of VR by clinicians and healthcare systems in the context of anxiety disorders [46]. It will be significant to train clinicians to use VR equipment and software as well as to develop clinical guidelines (such as how VR can be incorporated into the current CBT protocols and how to manage any cybersickness). Positively, VR hardware is now becoming considerably cheaper and consumer VR is now ubiquitous, which reduces obstacles to implementing the technology in clinics. The upkeep of the equipment (e.g. cleaning of devices, keeping them charged, updated etc.) can be handled by any regular procedure, and the technical help can guarantee an efficient work.In terms of implementation, the results of this review will promote the use of VR by clinicians and healthcare systems in the context of anxiety disorders [46]. It will be significant to train clinicians to use VR equipment and software as well as to develop clinical guidelines (such as how VR can be incorporated into the current CBT protocols and how to manage any cybersickness). Positively, VR hardware is now becoming considerably cheaper and consumer VR is now ubiquitous, which reduces obstacles to implementing the technology in clinics. The upkeep of the equipment (e.g. cleaning of devices, keeping them charged, updated etc.) can be handled by any regular procedure, and the technical help can guarantee an efficient work. Self-help VR applications like ZeroPhobia demonstrate that entirely self-administered therapy is feasible [26]; such tools could dramatically increase reach by allowing people to overcome fear of heights on their own schedules [47]. Of course, appropriate oversight and safety screening (to ensure someone is a suitable candidate for self-guided VR) will be needed. Overall, the convergence of evidence indicates that VRET is a powerful and practical treatment for acrophobia, with the potential to close the gap for the many individuals who need help for fear of heights but have struggled to receive effective therapy in traditional formats.

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