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Virtual Reality Exposure Therapy for Post-Traumatic Stress Disorder and Other Anxiety Disorders

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Abstract Anxiety disorders, including phobias and post-traumatic stress disorder, are common and disabling disorders that often involve avoidance behavior. Cognitive-behavioral treatments, specifically imaginal and in vivo forms of exposure therapy, have been accepted and successful forms of treatment for these disorders. Virtual reality exposure therapy, an alternative to more traditional exposure-based therapies, involves immersion in a computer-generated virtual environment that minimizes avoidance and facilitates emotional processing. In this article, we review evidence on the application of virtual reality exposure therapy to the treatment of specific phobias and post-traumatic stress disorder and discuss its advantages and cautions.

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Introduction

Anxiety disorders are among the most common and disabling disorders among Americans, with 18% of adults suffering from one in a given year [1]. Phobias are a category of anxiety disorders that involve intense fear occurring in the presence of or in anticipation of a specific object or situation. Post-traumatic stress disorder (PTSD) involves strong physiologic and psychological responses to cues associated with the traumatic event. A hallmark of these disorders is avoidance behavior.

Cognitive-behavioral therapy (CBT), specifically exposure therapy, has garnered a great deal of empirical support in the literature for the treatment of anxiety disorders [2]. Exposure therapy typically involves the patient repeatedly confronting the feared stimulus in a graded manner, either in imagination or in vivo. Emotional processing is an essential component of exposure therapy, involving activation of emotional networks with information about the feared stimulus, including its meaning [3]. Virtual reality exposure (VRE) therapy is an alternative to more traditional exposure-based therapies that has been used in the treatment of acrophobia, claustrophobia, arachnophobia, driving phobia, fear of flying, social phobia (fear of public speaking), and PTSD. Exposure therapy in the virtual environment allows the participant to experience a sense of presence in an immersive, computer-generated, three-dimensional, interactive environment that minimizes avoidance behavior and facilitates emotional involvement. The VRE participant is outfitted with a head-mounted display with separate screens for each eye, stereo earphones, and a device that tracks head movements so

that sounds and images change in a natural way with head motion. The environment allows controlled delivery of sensory stimulation via the therapist, including visual, auditory, olfactory, and tactile cues. The patient confronts the feared stimuli, and through the processes of habituation and extinction, anxiety decreases with prolonged and repeated therapeutic exposures. VRE is administered in the traditional and confidential therapeutic setting. Thus, it is convenient and cost-effective (eg, as compared with in vivo exposure for fear of flying) and may be a preferable mode of treatment for individuals who are unable or unwilling to participate in other forms of exposure therapy. Garcia-Palacios and colleagues [4] surveyed 150 individuals with specific phobias and fear of public speaking regarding the acceptability of VRE and in vivo exposure treatments. A total of 76% chose VRE over in vivo exposure, with only a 3% refusal rate for VRE, compared with a 27% refusal rate for in vivo exposure. The availability of VRE thus may increase the number of individuals willing to be treated for these anxiety disorders. Additionally, recent literature reviews indicated that VRE demonstrated large treatment effect sizes (average, 0.96) across studies and that VRE outperformed standard in vivo treatments for various anxiety disorders, including specific phobias, fear of flying, and social phobia [5•, 6•].

In this article, we review the development and progression of treatment studies on the application of VRE therapy to the treatment of phobias and panic disorder, with a focus on recent data relevant to the treatment of PTSD.

Specific Phobias

Acrophobia

In a pioneering study, Rothbaum et al. [7] examined the use of VRE in the treatment of acrophobia. Twenty college students were assigned to 8-week VRE treatment or wait-list control. The virtual environments included footbridges, outdoor balconies, and a glass elevator. On measures of anxiety, avoidance, attitudes, and distress associated with exposure to heights, the treatment group showed significant improvement, whereas the control group was unchanged.

The effectiveness of VRE compared with in vivo exposure in 10 participants with acrophobia was evaluated by Emmelkamp et al. [8]. Participants received a pretest followed by two sessions of VRE, an intermediate test, and two sessions of in vivo exposure, followed by a post-test. Virtual environments included a diving tower with pool and a tower building with elevator. VRE was found to be at least as effective as in vivo exposure on measures of anxiety and avoidance and more effective on attitudes toward heights. Emmelkamp et al. [9] then evaluated VRE compared with in vivo exposure in 33 participants with acrophobia. VRE was again found to be superior to in vivo exposure on measures of anxiety, avoidance, attitudes toward heights, and on the behavioral avoidance test. These results were maintained at 6-month follow-up.

Arachnophobia

With a patient dubbed "Miss Moffett," Carlin et al. [10] pioneered the use of VRE therapy, augmented with tactile stimulation, for the treatment of arachnophobia. In this case report, the 12-session VRE treatment that led to Miss Moffett's cure is described. Garcia-Palacios et al. [11] subsequently found that given a choice of one 3-hour session of in vivo exposure or three 1-hour sessions of VRE to treat arachnophobia, 89.2% of phobic individuals (n=75) would be willing to participate in VRE, and 10.8% would be willing to participate in the in vivo exposure. Garcia-Palacios et al. [12] examined the effectiveness of four 1-hour sessions of VRE compared with a wait-list condition in the treatment of arachnophobia in 23 participants. The virtual environment involved participants visualizing and touching a virtual spider with their cyber hands. A total of 83% of participants in the VRE condition evidenced clinically significant improvement, compared with 0% in the control group, as measured by self-report, clinician ratings, and behavioral avoidance test. A virtual world was created by Bouchard et al. [13] by editing a three-dimensional computer game modified to offer gradual hierarchies of spiders. The 11 participants showed significant improvement before to after VRE treatment on the behavioral avoidance test and on measures of self-efficacy and related beliefs.

Hoffman et al. [14] randomly assigned eight spider phobic students to one of three groups: no treatment, three 1-hour sessions of VRE with no tactile cues, or three 1-hour sessions of VRE with a physically touchable virtual spider. Although both VRE conditions significantly reduced their fear of spiders from before to after treatment, improvement was higher in the VRE plus tactile augmentation group than in the ordinary VRE group on the behavioral avoidance test.

Aviophobia

In a randomized controlled study of VRE for fear of flying, Rothbaum et al. [15] compared VRE with standard exposure therapy and a wait-list control group. Forty-five patients were randomly assigned to one of the three groups. Both treatment conditions consisted of four sessions of anxiety management (breathing retraining, cognitive restructuring, thought stopping) followed by four sessions of exposure, either to the virtual flight environment while seated in a virtual aircraft cabin, or a combination of in vivo exposure to an airport/aircraft and imaginal exposure to flying while seated in the aircraft. On the post-treatment test

flight, average in-flight anxiety ratings were almost identical for the two treatment groups—33.19 (SD, 15.6) for VRE and 33.88 (SD, 16.3) for standard treatment—and equally superior to wait list; effect size improvements on standard questionnaires were significantly improved with treatment but not significantly different between treatment groups. Twelve-month follow-up data were obtained from 24 of the 30 treatment completers. A total of 92% of the VRE group and 91% of the standard treatment group had flown since the post-treatment flight, and self-report measures indicated that treatment gains were maintained for both groups [16]. In a second randomized controlled treatment study, Rothbaum et al. [17] assigned 83 fear-of-flying participants to VRE, standard exposure therapy, or a wait-list control group. Seventy-five participants completed treatment (n=25 for each group). Both treatment groups received four sessions of anxiety management training and then participated in four sessions of VRE or standard exposure therapy over 6 weeks. VRE and standard exposure were essentially equivalent on all measures, including willingness to fly on the post-treatment flight, anxiety ratings during the flight, self-ratings of improvement, and satisfaction with treatment. Follow-up assessments at 6 and 12 months indicated that treatment gains had been maintained.

Mühlberger et al. [18] randomly assigned 30 flight phobic individuals to complete one virtual reality (VR) test flight followed by four VRE flights in one lengthy session, or one VR test flight followed by a lengthy deep-muscle relaxation session. Both groups completed a VR test flight at the end of the session. Test flights consisted of the first 6 min of the VR flight, whereas exposure flights included 16 min of all VR flight phases, auditory stimulation, and air turbulence (Fig. 1). As measured by fear ratings and heart rate changes, fear responses decreased with repetition of VRE flights. Repeated exposure to VR flights was more effective in reducing physiologic and subjective fear responses than relaxation training.

Fig. 1 Virtual airplane for the fear of flying (*Courtesy of* Virtually Better)

Forty-five fear-of-flying participants were randomly assigned by Maltby and colleagues [19] to five sessions of VRE, which included one session of anxiety management skills (progressive muscle relaxation, cognitive restructuring), or to an attention placebo group treatment consisting of education about the safety and mechanics of flight and elicitation of flying history and fears that were discussed in a group format. A total of 65% of VRE and 57% of attention placebo group participants flew during the post-treatment test flight, and at 6-month follow-up, 47% and 36%, respectively, reported having flown in the 6 months following treatment. Neither of these group differences was significant. Although both conditions yielded significant improvements on standardized measures of flight anxiety, VRE yielded significantly greater improvement on four of five standardized measures of flight anxiety. However, these differences were not maintained at 6-month follow-up.

Krijn et al. [20] compared the effectiveness of VRE to that of CBT (four weekly sessions) and bibliotherapy in 86 fear-of-flying participants. The VRE condition involved aircraft and airport virtual environments for all, and environments for fear of heights and claustrophobia were used if indicated in graded exposure. The CBT condition included muscle relaxation and challenging of irrational beliefs. Bibliotherapy involved no therapist contact and reading materials on the topics of flying, aircrafts, relaxation, and cognitive-behavioral coping skills. On the two major outcome measure anxiety questionnaires, no significant difference was noted between VRE and CBT, and the effects of both conditions were small. The authors cited the small number of sessions and the fact that their virtual environment did not elicit anxiety in a substantial number of patients (16 of 50) as factors. Both treatment conditions were followed up with group cognitive-behavioral training, which consisted of psychoeducation, education by a pilot about aircraft safety and flying, two simulation flights, and a real flight. Results indicated that CBT plus group cognitive behavioral training showed the largest decrease in subjective anxiety.

Claustrophobia

Botella et al. [21] used a multiple baseline design to evaluate the effectiveness of VRE in the treatment of four participants with claustrophobic fear. The virtual environment included a house and an elevator, each with different scenarios, such as presence or absence of windows, closed or open doors, and walls that could be moved to further confine the space. Following eight graded VRE sessions, a decrease in all self-report anxiety measures was observed, and a clear improvement in all behavioral avoidance test measures was obtained. These results were maintained at 3-month follow-up.

Driving Phobia

A multiple baseline design was also used by Wald and Taylor [22] to evaluate the effectiveness of VRE in the treatment of five patients with driving phobia. Treatment included eight weekly sessions of graded exposure to a range of scenarios in the VR driving simulator. After treatment, three participants no longer met criteria for driving phobia; however, none of the participants evidenced a change in their actual driving frequency at post-treatment assessment, suggesting that VRE may not be sufficient to successfully treat fear of driving.

Data on treatment of simple phobias with VRE are promising and indicate that across multiple applications, VRE successfully elicits phobic responses and leads to statistical and clinically meaningful improvements on measures of anxiety and avoidance behaviors.

Social Phobia and Fear of Public Speaking

North et al. [23] examined the effectiveness of 5 weeks of VRE in the treatment of 16 student participants with a fear of public speaking. The treatment group was exposed to a virtual public speaking scene that included an auditorium with an audience and a speaking podium (Fig. 2), and the control group was exposed to a trivial virtual reality scene. The VRE group showed significant improvement on measures of anxiety, avoidance, attitudes, and disturbance associated with fear of public speaking, whereas the control group did not show meaningful changes. Harris et al. [24] found that four VRE sessions seemed to be effective in reducing public speaking anxiety in university students, as measured by self-report and heart rate measures. In a study carried out by Klinger et al. [25], 36 participants were assigned to 12 weeks of VRE or group CBT (control condition) for the treatment of social phobia. Virtual environments included situations involving performance, scrutiny, intimacy, and assertiveness. Statistical and clinical improvements were noted in both groups, with no significant difference between groups on outcome measures.

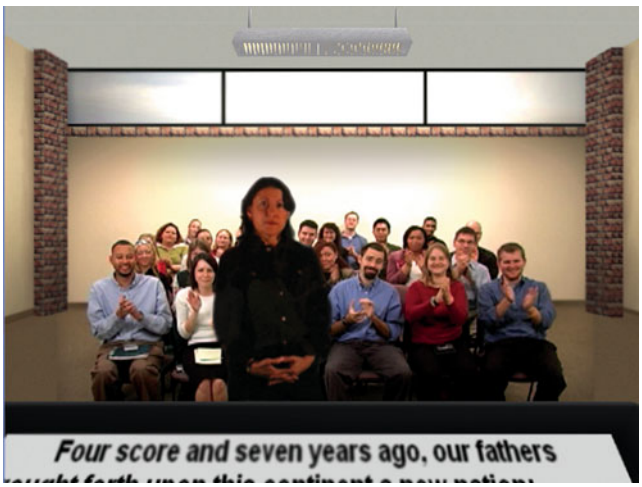

Fig. 2 Virtual classroom for the fear of public speaking (*Courtesy of* Virtually Better)

In the context of a private practice setting, Anderson et al. [26] examined the use of VRE in the treatment of social phobia with prominent fear of public speaking. One individual was treated with weekly sessions, whereas the other was treated in an intensive 3-day format. The virtual environment involved a video of actual people embedded in a virtual classroom, and the therapist controlled the virtual audience reactions: interested, bored, neutral, or applauding. Both individuals successfully completed a behavioral avoidance test (giving a speech to a group of individuals) and evidenced decreased scores on all measures of public speaking anxiety from before to after treatment. Follow-up data completed by one participant indicated maintenance of treatment gains.

Panic Disorder With/Without Agoraphobia

Botella et al. [27] randomly assigned 37 participants diagnosed with panic disorder with and without agoraphobia to one of three conditions: VRE, in vivo exposure, or wait-list control. Nine weekly sessions included psychoeducation, cognitive restructuring, breathing retraining, exposure to internal and external stimuli, and relapse prevention. Depending on treatment condition, exposure occurred in vivo or in the VR environment. The VR program consisted of six environments: training room, house, subway, bus, shopping mall, and tunnel. Using 50% reduction in panic frequency as the criterion for clinical improvement, 100% of in vivo participants and 90% of VRE participants met criteria at the end of treatment (wait list, 28.6%). At 12-month follow-up, 90% in vivo and 91.6% VRE participants met the criteria for panic-free status.

The results of these studies indicate that in addition to its utility in the treatment of simple phobias, VRE is a viable alternative for treatment of more complex anxiety disorders, including social phobia and panic disorder.

Virtual Reality Exposure Treatment of Post-Traumatic Stress Disorder

The past three years have seen a proliferation in reports of the use of VR in treating PTSD. VR is a promising enhancement to empirically validated exposure treatment for PTSD. Imaginal exposure entails the patient repeatedly telling of the traumatic experience with his/her eyes closed to enhance presence in the memory. However, the numbing and avoidance inherent in PTSD can serve as an obstacle to

emotional engagement in the memory, which is an essential ingredient for treatment success. According to Foa and Kozak [3], it is necessary for fear-relevant information associated with the trauma to be activated through emotional engagement. Accessing these fear structures repeatedly leads to decreased anxiety through habituation and extinction and, subsequently, the incorporation of new information.

The first trauma-relevant virtual environment was designed to treat PTSD related to combat in the Vietnam War. Two virtual environments were available in this treatment. One was a virtual jungle clearing with jungle sounds, gunfire, helicopters, screams, and explosions (Fig. 3). The second was the interior of a Huey helicopter with views to the outside that flew over different terrains, including a jungle, rice paddies, and a river. A case study described the treatment of a 50-year-old combat veteran with PTSD related to his service in Vietnam 26 years earlier [28]. Following 14 90-minute sessions occurring over 7 weeks, symptoms of PTSD decreased by 34% according to clinician measures and 45% according to self-report, with gains maintained at 6-month follow-up. Similar results were reported in a larger sample of nine Vietnam veterans who received treatment twice weekly over 5 to 7 weeks [29]. Clinician ratings of PTSD symptoms showed a significant decrease between baseline Clinician-Administered PTSD Scale (CAPS) scores (mean, 68) and CAPS scores at 6-month follow-up (mean, 47). Decreases in individual CAPS scores ranged from 15% to 67%. Data from two open trials totaling 21 patients found statistically significant reductions in PTSD symptoms that were maintained at 6-month follow-up [30].

Anticipating that substantial numbers of the thousands of people at risk for PTSD following the World Trade Center attack of September 11, 2001, would not respond to imaginal exposure therapy, Difede and Hoffman [31] developed a simulation of the attack to facilitate emotional engagement in exposure therapy. The virtual environment opened with a view of the towers and a plane flying past and gradually progressed through sequences at the rate determined collaboratively by the therapist and patient to show the planes flying into the towers and each tower collapsing with accompanying sounds of explosions, people screaming, and sirens. A case study described the treatment of a 26-year-old woman with PTSD and major depression related to her witnessing of the attacks from right outside the buildings [32]. Despite the failure of her symptoms to improve with standard imaginal exposure, at the conclusion of six treatment sessions using VR, an 83% reduction in depressive symptomatology and a 90% reduction in PTSD symptomatology were achieved. An outcome study in this population compared a 14-session VRE treatment (n=9) with a wait-list group (n=8) [33]. Results showed a significant time by group interaction (P<0.01) with a large effect size of 1.53. The VR group showed a significantly greater reduction in clinician-rated PTSD scores than the wait-list control group.

Fig. 3 Virtual Vietnam scenarios (*Courtesy of* Virtually Better)

Since these initial studies, environments have been created for a range of trauma experiences. The development of a virtual simulation of a terror bus bombing in Israel was described by Josman and colleagues [34] in 2006. The environment starts out as a quiet city street in Israel near an outdoor café. At the therapist's command, a bus pulls up to a bus stop across the street. Subsequent steps add the visual components of a bus explosion with fire, smoke, and shattered glass on the street. The final scene adds the audio components of the explosion: people screaming and sirens wailing. A study of healthy volunteers found significant differences in distress scores between scene 1 and scene 2, scene 2 and scene 4, and scene 3 and scene 4, setting the stage for a treatment study of individuals with PTSD using the virtual bus bombing scenario [35].

Beck and colleagues [36] used a driving environment to treat individuals with PTSD or severe subsyndromal PTSD related to a motor vehicle accident. The environment simulated a highway, urban, suburban, or rural setting. Amount of traffic, time of day, and weather conditions were set by the therapist, who was also able to introduce specific driving scenarios such as tailgating, although the motor vehicle accident was not simulated. Participants were able to navigate the driving, including direction of driving and turns. Eight sessions of VR-enhanced treatment were included in a 10-session protocol of exposure without cognitive techniques. An uncontrolled trial of eight enrolled patients yielded six who completed treatment. CAPS and Impact of Events Scale (IES) total scores were significantly lower upon assessment 1 month after treatment compared with pretreatment scores, as were all cluster scores, with the exception of the hyperarousal cluster on the CAPS; CAPS scores were an average of 40% lower after treatment, with

greater reductions reported on self-report measures. Beck Anxiety Inventory and Beck Depression Inventory scores did not show significant change, although moderate effect sizes were noted.

The greatest concentration of VR-enhanced PTSD literature has emerged in the treatment of military personnel returning from Operation Iraqi Freedom/Operation Enduring Freedom. Two case studies were published describing exposure treatment enhanced by the Virtual Iraq environment [37, 38]. Virtual Iraq is a platform made up of a city scenario and a Humvee scenario. The city incorporates scenes such as marketplaces, security checkpoints, mosques, apartment buildings that can be entered, and rooftops that can be accessed. The Humvee scenario includes a desert setting with overpasses, checkpoints, debris, broken-down structures, and ambushes that can be introduced (Fig. 4). As the patient navigates through the environment with the use of a gamepad (mounted on a rifle replica for the city scenario), the therapist can manipulate the environment to match the time of day, weather conditions, and background noise of the patient's traumatic experience. Many elements can be added to the environment. Pedestrians and vehicles, including Humvees, planes, and helicopters, can be introduced or removed. Combat elements that can be introduced include gunfire, improvised explosive devices, rocket-propelled grenades, car bombs, and insurgent attacks. Vibrations beneath the patient's chair accompany car rumblings and explosions, and olfactory cues, including Middle Eastern spices, burning rubber, and garbage (among others), may be dispersed at the therapist's selection.

Gerardi and colleagues [37] described the treatment of an Operation Iraqi Freedom veteran diagnosed with combat-related PTSD. Treatment consisted of four 90-minute sessions with VR treatment incorporated for an average of 50 min in each of the last three sessions. Treatment incorporated elements of psychoeducation, relaxation, and cognitive processing of the exposure. CAPS score decreased by 56% during treatment, changing from a score of 106 to a score of 47. Reliable change was evidenced on both the CAPS and the self-report measured of depression.

Fig. 4 Virtual Iraq Humvee scenario from user perspective (*Courtesy of* Virtually Better)

Reger and Gahm [38] described the treatment of an active duty army soldier diagnosed with combat-related PTSD. He was treated with six 90-minute sessions over 4 weeks incorporating elements of relaxation, psychoeducation, in vivo exposure, and VR-enhanced exposure (which lasted on average 35 min). PTSD symptoms as measured by the PTSD Checklist-Military Version showed significant improvement over the course of treatment, changing from a pretreatment score of 58 to a post-treatment score of 29, with significant functional improvement reported subjectively by the patient.

Although uncontrolled and preliminary, a recent report offers encouraging results from using exposure therapy in theater [39]. Although only four patients were treated with traditional exposure therapy and six with VRE therapy, patients reported an improvement of 74% with traditional exposure therapy and 67% with VRE. These results give us preliminary evidence that exposure therapy, specifically VRE therapy, can be successfully and safely administered in a war zone.

Virtual Reality Exposure Therapy in Clinical Practice: Issues in Optimal Care

Multiple resources are available to train clinicians to deliver exposure-based therapy (eg, the Foa et al. manual [40]), and the Veterans Administration and Department of Defense have made considerable advances in training their mental health clinicians in the delivery of evidence-based treatment. However, troubling evidence indicates that therapists often do not use exposure therapy, even after receiving training. This has implications for the delivery of competent VR-based exposure therapy.

Becker et al. [41] found that only 17% of 217 licensed psychologists surveyed reported using exposure therapy to treat PTSD. Inadequate training was the most common reason for not using exposure. However, even among those with training, more than one third (38%–46%) did not use exposure therapy. In addition to disinclination to use manualized treatments, clinicians expressed the concern that patients would decompensate, despite there being equivocal evidence for any lasting symptom exacerbation from exposure therapy [42, 43]. These results were confirmed by Cahill and colleagues [44], who trained a large cohort of psychologists to use traditional exposure therapy for PTSD related to the World Trade Center attacks of September 11, 2001. They found that implementation of treatment was hindered by a discomfort using exposure and

cognitive restructuring techniques, concerns about decompensation, and a disinclination to use manualized treatments.

VRE should only be used by clinicians who are trained and competent in exposure therapy; bad VRE therapy is simply bad therapy. Cahill and colleagues [44] propose based on their findings that experts in PTSD treatment outcomes train people who will supervise the implementation of exposure treatments in their community clinics. We have undertaken a "train-the-trainer" model in an effort to develop an optimal standard of care for the implementation of VRE for the treatment of PTSD (Rothbaum et al., unpublished manual). In this model, clinicians participate in an intensive 2-day, "hands-on" workshop in the clinical practice of VRE followed by 6 months of group supervision. During the supervision period, each clinician is expected to treat two patients and discuss the treatment implementation during the supervision/consultation group.

Conclusions

The evidence is compelling that VR-assisted exposure therapy is effective and efficient in the treatment of patients with anxiety disorders. VRE has several advantages, primarily focusing on the ease of delivery as compared with in vivo exposure and the control over exposure stimuli. The treatment of patients with anxiety disorders usually calls for exposure to the feared stimuli, but this is often difficult to arrange or costly and time consuming to conduct in vivo. VRE has been demonstrated to be as effective as in vivo exposure for several disorders but more convenient and efficient (eg, being able to conduct exposure for the fear of flying that includes several flights within the typical 45-minute therapy hour, or exposure to speaking in front of virtual audiences without leaving the therapist's office). Although the VR equipment is more expensive than using imaginal exposure therapy, which requires no hardware or software, this may be offset in part by the cost of the therapist's time for the delivery of in vivo exposure therapy.

VRE also has been shown to be effective in treating PTSD, although the strength of the available evidence is still preliminary as compared with other anxiety disorders, as most of the data do not come from controlled trials. Nevertheless, it has been shown to be effective across trauma populations, across laboratories, and across the world, even when delivered in a war zone. VRE for PTSD has the advantages of delivering controlled trauma-relevant stimuli in several sensory modalities (visual, auditory, kinesthetic, and olfactory) to create an evocative exposure that is more difficult to avoid. It may be more attractive than traditional therapy to a video-savvy generation [38].

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