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Author manuscript

*Harv Rev Psychiatry*. Author manuscript; available in PMC 2018 May 01.

Published in final edited form as:

*Harv Rev Psychiatry*. 2017 ; 25(3): 103–113. doi:10.1097/HRP.000000000000138.

## The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders

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### Abstract

Virtual reality, or VR, allows users to experience a sense of presence in a computer-generated three-dimensional environment. Sensory information is delivered through a head mounted display and specialized interface devices. These devices track head movements so that the movements and images change in a natural way with head motion, allowing for a sense of immersion. VR allows for controlled delivery of sensory stimulation via the therapist and is a convenient and cost-effective treatment. The primary focus of this article is to review the available literature regarding the effectiveness of incorporating VR within the psychiatric treatment of a wide range of psychiatric disorders, with a specific focus on exposure-based intervention for anxiety disorders. A systematic literature search was conducted in order to identify studies implementing VR based treatment for anxiety or other psychiatric disorders. This review will provide an overview of the history of the development of VR based technology and its use within psychiatric treatment, an overview of the empirical evidence for VR based treatment, the benefits for using VR for psychiatric research and treatment, recommendations for how to incorporate VR into psychiatric care, and future directions for VR based treatment and clinical research.

### Keywords

Technology; virtual reality; anxiety disorders; exposure therapy; psychiatric treatment

### The history of the development of VR based technology

Virtual Reality (VR) is a technological interface that allows users to experience computer-generated environments within a controlled setting. This technology has been increasingly used in the context of mental health treatment and within clinical research. The primary focus of this article is to review the available literature regarding the effectiveness of VR within psychiatric treatment with a specific emphasis on anxiety disorders, as VR is particularly well-suited for use within exposure based treatment for anxiety disorders as it provides the opportunity for a sense of present and immersion in the feared environment.

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Conflicts of Interest: Dr. Rothbaum owns equity in Virtually Better, Inc. that creates virtual reality products. The terms of this arrangement have been reviewed and approved by Emory University in accordance with its conflict of interest policies.

Potential advantages and disadvantages for the use of VR within psychiatric research and treatment and practical recommendations for incorporating VR into psychiatric care will be presented.

VR aims to parallel reality and create a world that is both immersive and interactive.<sup>1</sup> Users fully experience VR when they believe that the paradigm accurately simulates the real-world experience that it attempts to recreate. The sense of presence, or “being there” in VR, is facilitated through the use of technology such as head-mounted displays, gesture-sensing gloves, synthesized sounds, and vibrotactile platforms, which allow for the stimulation of multiple senses and active exploration of the virtual environment.<sup>1-3</sup> Furthermore, some VR paradigms are programmed to react to the actions of the user. This dynamic interaction enables the participant to engage with the VR environment in a more naturalistic and intuitive way.<sup>1,4</sup> In all, VR is potentially a powerful tool for the psychiatric community because the user experience can be consistently replicated, tested, and modified within a safe environment without compromising real-world applicability. VR’s precise control of sensory cues, particularly for auditory, tactile, and olfactory systems, increases the sense of realism and memory of the virtual environment.<sup>1,4,5</sup>

Early development of what is now VR began in the 1950’s and 60’s with several key inventions. In 1957, Morton Heilig invented the Sensorama, which aimed to engage all of the user’s senses via specific components like smell generators and vibrating chairs to provide a complete multi-sensory experience.<sup>5</sup> In 1961, the Philco Corporation created Headsight, the first head-mounted displays to incorporate motion tracking and dual monitor displays, for military training purposes.<sup>6</sup> In 1965, Ivan Sutherland developed the Ultimate display, which employed the first computer-generated interface, thereby allowing users greater real time interaction with VR.<sup>7</sup> The concept of VR was eventually formalized in 1989 when Jaron Lanier coined the term “virtual reality,” at which point VR began to gain greater presence in research and psychiatric treatment.<sup>8,9</sup> During the 1990’s and early 2000’s, psychologists began to utilize VR with prolonged exposure therapy. The first study to formally investigate the efficacy of VR-based exposure therapy (VRE) focused on the treatment of acrophobia and results suggested that VRE was effective,<sup>10</sup> leading to additional studies on the use of VR-based therapy for anxiety disorders and other psychiatric conditions.

## Anxiety Disorders

A wide body of research has suggested large treatment effects for exposure-based therapy for anxiety disorders.<sup>11</sup> Modern exposure therapy is based on emotional processing theory, which posits that fear memories are structures that contain information regarding fear stimuli, responses, and meaning. As such, the goal of intervention is to activate and modify these fear structures by presenting novel incompatible information and facilitating emotional processing. VR-based techniques are ideal for exposure therapy, as the sense of presence experienced in VR provides the opportunity to immerse the patient in the feared environment that is tailored to match specific aspects of their fear structures in order to activate and modify these structures. As such, the bulk of VR treatment research has been conducted for anxiety disorders, and broadly, results suggest the VRE is related to large

declines in anxiety symptoms,<sup>12</sup> demonstrates similar efficacy compared to traditional exposure interventions, has a powerful real-life impact, and demonstrates good stability of results over time.<sup>13</sup> Meta-analytic results for VRE for anxiety disorders even suggest a small effect size favoring VRE over in-vivo conditions, despite most studies not demonstrating an advantage when considered in isolation.<sup>14</sup> There is evidence that treatment gains made in VRE generalize to real life, as meta-analytic results suggest that VRE patients, compared to wait-list patients, perform significantly better on behavioral assessments post-treatment, and found no significant differences between VRE and in-vivo exposure at post-treatment and follow up.<sup>15</sup> As such, VRE is a promising treatment approach, and evidence for VRE for specific anxiety disorders will be reviewed. Given the application of VR to a wide range of psychiatric disorders, this literature will also be reviewed.

### **Advantages for using VR for psychiatric research and treatment**

Within traditional exposure therapy, imaginal exposures are dependent on patients being able to imagine effectively specific feared stimuli. VR eliminates a potential barrier for patients who may experience difficulty with imagining or visualization. In-vivo exposures can be costly (e.g., an actual flight), or impractical to conduct (e.g., combat in Iraq or Afghanistan), whereas VR approaches allow for an inexpensive approach and the possibility of constructing exposures that may be difficult to implement in-vivo. VRE provides the opportunity to manipulate exposures in ways that might not be possible in-vivo, such as repeating a virtual flight landing multiple times. VRE also affords complete control, as the provider can control the dose and specific aspects of the exposure environment to match the specific patient's feared stimuli and optimize individualized pacing through exposures. For instance, if a patient with the fear of flying is not ready for turbulence, the therapist can guarantee no turbulence. VR approaches allow for confidentiality to remain intact while conducting exposures, which may not be the case for in-vivo exposures.

Findings suggest that patients report satisfaction with VR based therapy and may find it more acceptable than traditional approaches. An early study on VRE with patients with PTSD due to motor vehicle crashes suggested that patients reported very high satisfaction with VRE.<sup>16</sup> In a sample of 150 patients with specific phobias, the refusal rate for VR exposure (3%) was lower than for in-vivo exposure (27%),<sup>17</sup> providing preliminary evidence that VR-based exposure may be more acceptable to patients. One study in a PTSD sample found equivalent satisfaction between VRE and imaginal exposure,<sup>18</sup> while another found increased satisfaction for VRE.<sup>19</sup> In a sample of 352 post 9/11 US soldiers, the majority reported that they would be willing to use most of the technology-based approaches for mental health care included in the survey (e.g., VR).<sup>20</sup> Additionally, 19% of those who reported that they would not be willing to talk to a counselor in person reported being willing to use VR approaches to access mental health care, suggesting VR may potentially address some barriers to treatment.

VR offers several advantages for conducting psychiatric research. The ability to control the exposure dose and stimulus presents the opportunity to conduct exquisitely controlled clinical and experimental research. For example, in the first human study examining the efficacy of combining D-cycloserine with exposure therapy,<sup>21</sup> each research participant

received exactly the same exposure to virtual heights. It is also feasible to collect other sources of data relevant to treatment process within VRE, such as psychophysiological assessment and data specific to the exposure (e.g., stimuli used, time in exposure). For example, for VR approaches with substance use disorders, the exact timing of craving and decision to use can be monitored in a VR environment. Additionally, testing of a skill or medication designed to reduce cravings can be tested in a VR environment rather than in the more dangerous “real world”.

While VR provides many advantages, there are also disadvantages to consider in its use. In the past, technology and costs were significant disadvantages to the dissemination of VR in clinical settings. VR was expensive, difficult to set-up, and would malfunction or “glitch” on occasion.<sup>1,2,4,22</sup> While initial cost to begin VR continues to be a potential disadvantage, prices have decreased over time, and vendors have recently begun selling smartphone-based VR therapy systems which currently start at \$600. While the technology has improved and thus there is diminished likelihood of malfunctions and the programs are more user-friendly than in the past,<sup>4,23</sup> the possibility of “glitches” remain a consideration and potential disadvantage in clinical practice. As such, another potential disadvantage is the need for in-depth training and practice with VR prior to clinical use, to ensure the ability to effectively trouble-shoot glitches while still maintaining competent clinical care.

### Treatment course for VRE

A treatment course for VRE follows a typical treatment course, merely substituting VR for some other exposures or practices. VRE typically begins with 2–3 initial sessions in which psychoeducation regarding the specific disorder, psychosocial history, an overview of avoidance and the rationale for exposures, and the process of VR based exposures is discussed. Many VRE treatments also include some relaxation and/or coping strategies during this introductory period, such as breathing relaxation or cognitive restructuring. Typically, all subsequent sessions include conducting a VR exposure in which the patient progresses at an individualized pace through a graded exposure hierarchy.

Quality VRE is individualized to the patient. For instance, each step on the hierarchy can be repeated until the patient’s anxiety decreases significantly, as noted by their subjective units of distress ratings and therapist’s behavioral observation. Progressing through the hierarchy should be a collaborative approach in which the therapist discusses with the patient before they move on to the next step in the graded exposure. The content available for a fear hierarchy are often preselected for VR exposures, as specific VR system content is developed for specific disorders and specific traumatic experiences or fears. Thorough assessment of the patient’s fear or specific traumatic experience should occur prior to exposure in order to individualize how they progress through the steps of the hierarchy and the time spent with different content. For instance, the fear of flying hierarchy includes eight steps, from walking through an airport terminal to flying during a thunderstorm with turbulence. For a patient with panic and agoraphobia, taxiing and take-off may be an important focus of treatment, with a focus on specific stimuli linked to these symptoms (i.e., the sound of the cabin door closing), whereas for a patient with specific phobia of flying due to an underlying fear of the plane crashing, flying through a thunderstorm and turbulence

may be an important focus. For patients with PTSD, a thorough assessment of the patient's index trauma will facilitate the therapist being able to prepare in advance what VR program to utilize (e.g., Virtual Iraq) and the specific setting and stimuli (e.g., time of day, specific weapon noises) that may be used.

A quality VR exposure will also involve the therapist being skillful in effectively engaging the patient in activating the fear structure. Therapists are encouraged to be mindful of encouraging and facilitating emotional engagement within VR and discussing response prevention of any safety behaviors as necessary. Specifically, patients may attempt to engage in safety behaviors (e.g., repeating a specific mantra during take-off in virtual flight), distraction, or active coping strategies during VR based exposures, so therapist should review the rationale for exposure and importance of not engaging in such behaviors and help the patient to emotionally engage during the exposures.

## Method

We now turn to a review of the available literature regarding the effectiveness of incorporating VR within the treatment of a wide range of psychiatric disorders with a specific focus on exposure-based intervention for anxiety disorders. Systematic searches were conducted using PsycINFO, MEDLINE, EMBASE, and Google Scholar. Search terms included virtual reality, virtual reality exposure therapy, computer-generated exposure, virtual reality with psychiatric, therapy, psychological, anxiety, disorder, specific phobia, social anxiety disorder, post-traumatic stress disorder, panic, agoraphobia, generalized anxiety disorder, obsessive compulsive disorder, schizophrenia, psychotic, pain, addiction, eating disorder, bulimia, anorexia, binge eating, and autism. We identified studies mentioning virtual reality based psychiatric treatment in the title, abstract, or keywords. The most recent search was in September 2016. Inclusion criteria included studies that enrolled patients with a psychiatric condition who received virtual reality based intervention. Exclusion criteria included not presenting measurement of outcome for the treatment. Given that many VR based approaches are relatively novel and/or preliminary, randomized or quasirandomized controlled trials was not an inclusion criterion.

## Specific phobias

Specific phobia (SP) is characterized by marked fear/anxiety relating to a specific object or situation (e.g., flying, heights, animals, needles, or blood).<sup>24</sup> SPs, particularly flight phobia, are among the most researched disorders within the scope of VR-based interventions. Two studies on fear of flying using a within-group design have demonstrated significant reductions in flight-related anxiety<sup>25</sup> as well as an increased likelihood to fly on an airplane following treatment.<sup>26</sup> Several RCTs have demonstrated symptom reduction and behavioral change (e.g., decreased avoidance) for VR-based exposure superior to control conditions and equivalent to that of CBT alone.<sup>23, 27–32</sup> Further investigation revealed that these treatment gains were maintained at one-<sup>33,34</sup> and 3-years<sup>35</sup> post-treatment. Additional studies have found that VRE for fear of flying may be enhanced by the inclusion of physiological feedback<sup>36</sup> and motion simulation.<sup>37</sup> VRE has shown acceptability and efficacy in the treatment of other SPs. Specifically, VR is effective for the treatment of acrophobia (fear of

heights) based on within-group<sup>38</sup> and controlled between-group data.<sup>10,39,40</sup> Similar effects have been observed in RCTs for the treatment of arachnophobia (fear of spiders)<sup>41–43</sup> and in one multiple-baseline study, fear of driving.<sup>44</sup>

In summary, there have been numerous studies showing efficacy for VR-based CBT for the treatment of SPs. Many of these studies have used RCTs with adequate sample sizes and have found large treatment effects both within and between treatment groups. Some have incorporated behavioral avoidance tests to the actual feared stimulus and have demonstrated meaningful behavioral change. Further, data suggest that treatment gains are maintained for years following treatment completion. The cumulating data showing efficacy for VRE for SPs is very promising, particularly for patients with fears pertaining to situations that may not be safe, cost effective, or feasible to conduct in-vivo.

## Social anxiety disorder

Social anxiety disorder (SAD) is a psychiatric condition in which the patient experiences anxiety in social interactions (e.g., conversations, meeting new people, public speaking) during which they might be judged or socially evaluated by others.<sup>24</sup> VR-based interventions for SAD typically involve the use of computer-generated social environments (e.g., classrooms, auditoriums, conference rooms) with virtual audiences. In examination of generalized SAD, two RCTs found VR-based CBT to be as effective as traditional CBT<sup>45</sup> and superior to control conditions<sup>46</sup>. VR-based CBT for fear of public speaking has demonstrated effects similar to traditional CBT and above that of controls<sup>47–49</sup> and effects were maintained at one-year post treatment.<sup>47,50</sup> Finally, preliminary data has begun to show efficacy for VR in the treatment of school-based anxiety, including test anxiety.<sup>51,52</sup>

Although there have been fewer studies examining the effects of VRE for SAD compared to SPs, the data thus far have been very encouraging. VR can be especially useful for this population as finding multiple confederates with whom a patient can interact can be costly and time consuming. Given these data and the potential cost savings of using VR-based social interactions, VR can be a particularly useful adjunct to CBT for SAD.

## Post-traumatic stress disorder

Post-traumatic stress disorder (PTSD) involves a history of exposure to a traumatic event as well as symptoms of intrusion, avoidance, negative alterations in cognitions and mood, and alterations in arousal and reactivity.<sup>24</sup> Across several studies, VRE for PTSD demonstrates a medium-to-large treatment effect size<sup>13</sup> and superior treatment outcomes compared to waitlist controls and comparable outcomes with standard exposure treatment.<sup>53</sup> Early investigations into VRE for PTSD suggested that this treatment approach held promise for PTSD treatment in case studies<sup>54–56</sup> and open trial designs across a broad range of traumatic experiences.<sup>16,57,58</sup> A preliminary study comparing VR based exposure therapy for PTSD following the World Trade Center Attacks (n=13) with a waitlist control (n=8) found that the VR group demonstrated a significant decline in PTSD scores compared to the waitlist group and that this improvement was maintained at a six-month follow-up assessment.<sup>59</sup> Results demonstrated statistical and clinical significance, as baseline scores in both groups fell



within the severe range, whereas at post-treatment the mean score for the VR group was in the mild range and 7 of the 10 VR completers did not meet PTSD diagnostic criteria. No significant effect was identified for depressive symptoms or general distress, but notably these scores were relatively low at baseline for both groups. The sample in this study was not demographically diverse (i.e., mostly middle aged men), but the participants' exposure to the attacks did vary (i.e., firefighters, disaster workers, and civilians), suggesting that the standardized virtual stimuli were able to effectively engage individuals with diverse experiences of the traumatic event.

The first investigation to compare VRE to another active treatment randomly assigned Vietnam veterans to VRE or present-centered therapy.<sup>60</sup> Results did not identify a significant difference post-treatment, but did identify a moderate advantage of VRE at 6 months post-treatment. Notably, the sample size was small (N=11), suggesting the need for larger trials with sufficient power to detect treatment differences. Open trials have provided further support for the use of VRE for PTSD for combat-related PTSD,<sup>61,62</sup> and results from a small RCT of VRE compared to treatment as usual for active duty personnel with combat-related PTSD found that VRE was more effective based on post-treatment PTSD symptoms.<sup>63</sup> A recent study investigated VRE augmented with D-cycloserine (DCS) or alprazolam compared to placebo for military related PTSD with 156 post 9/11 veterans.<sup>64</sup> Results suggested that there were no overall differences related to medication use, but six sessions of VRE was related to significantly improved PTSD symptoms and psychobiological measures of startle and cortisol reactivity at post-treatment as well as three, six, and twelve months post-treatment, suggesting that VRE for PTSD results in clinical improvement that is sustained over time. It is notable that VR has been used as standardized stimuli for psychophysiological assessment pre and post PTSD treatment.<sup>64</sup>

In another randomized double-blind trial, DCS or placebo were administered prior to VR exposure treatment sessions for patients with chronic PTSD (N=25).<sup>65</sup> Both groups demonstrated significant decreases in PTSD symptoms at post-treatment, and the group that received DCS demonstrated significantly higher remission rates at post-treatment and significantly higher remission rates and lower PTSD scores at a 6-month follow-up assessment. The VR-DCS group demonstrated greater improvement in depressive symptoms and state anger at 6-month follow-up. These findings suggest that VR exposure therapy for PTSD is effective and may be enhanced by DCS. One recent study randomly assigned 162 active duty soldiers to either 10 sessions of prolonged exposure, VRE, or minimal attention waitlist.<sup>66</sup> At post-treatment, both VRE and prolonged exposure resulted in greater improvement, but there were no significant differences when comparing the treatment groups. Contrary to hypotheses, prolonged exposure demonstrated a greater improvement than VRE at three and six month follow-up assessments. This suggests that VRE treatment may result in less symptom recovery after treatment ends. Authors suggested that individual variability in how activating VR environments are may exist and that improved VRE content may assist in emotional engagement. While the extant literature on VR exposure treatment for PTSD suggests promise, it is notable that many of the studies utilize small sample sizes, do not employ randomization, and/or lack a comparison to an active treatment condition, suggesting that future research would benefit from more randomized clinical trials with

larger samples and comparison to standard of care treatment, such as traditional prolonged exposure therapy.

## **Panic disorder and agoraphobia**

Panic disorder and agoraphobia (PDA) are characterized by a sudden rush of anxiety manifested by physiological (e.g., heart palpitations, sweating, choking sensations) and cognitive (e.g., racing thoughts, fear of dying) symptoms, leading to fear and/or avoidance of specific places or situations.<sup>24</sup> VRE for PDA presents situations that commonly elicit panic attacks such as tunnels, parking lots, city squares, and highways. Early data making use of multiple-baseline designs found initial support for the use of VR in treating PDA.<sup>67</sup> Although RCTs generally have found positive effects for VR-based CBT for PDA, results have varied between studies with regard to differences between this and traditional CBT. Most studies have found VR-based CBT to be as effective as traditional CBT in ameliorating PDA symptoms. Findings from some investigations suggest that whereas VRE may result in better treatment response<sup>68,69</sup> and fewer required treatment sessions,<sup>70</sup> it may not differ from traditional CBT,<sup>71</sup> particularly when considering long-term outcome. This suggests that any incrementally better effects may appear early on in treatment.<sup>68</sup> These equivalent longer-term treatment effects have remained stable for three-,<sup>68</sup> six-,<sup>72</sup> nine-,<sup>73</sup> and 12-months<sup>74</sup> post-treatment. Altogether, investigations of VR-based exposure for PDA using rigorous study design and methodology support the efficacy of these tools for the treatment of PDA. Moreover, there appear to be several advantages to using VR-based CBT for PDA such as improved treatment response and decreased time required for treatment.

## **Generalized anxiety disorder**

Generalized anxiety disorder (GAD) is a condition in which the patient experiences persistent, excessive and intrusive worrying to the extent that daily functioning becomes difficult.<sup>24</sup> Gorini and colleagues<sup>75</sup> conducted a small-scale RCT (N=20) which used VR in conjunction with biofeedback for patients to practice relaxation exercises during treatment. Although the study did not have enough power to examine between group differences, it provides preliminary support for the feasibility of using VR for patients with GAD. Thus far, this has been the only investigation to examine the use of VR in the treatment of GAD. This is perhaps due to the difficulty associated with creating standardized VR scenarios that are able to capture the numerous, varying individualized worries patients with GAD tend to experience. Given this complication, VR-based treatment programs could focus on some of the more common worries among patients with GAD (e.g., health anxiety, something happening to a loved one). Alternatively, or if a patient's worries are not readily addressable with these scenarios, VR-based treatment could serve as a visual guide for practicing relaxation- or mindfulness-based approaches as well as breathing exercises.

## **Obsessive-compulsive disorder**

Obsessive-compulsive disorder (OCD) is marked by intrusive thoughts, images and/or impulses that cause anxiety (e.g., fear of contamination, need for symmetry) and lead to compensatory repetitive behaviors (e.g., excessive cleaning, arranging things in a specific



way) that reduce anxiety. Thus far, no RCTs have assessed the efficacy of VR in the treatment of OCD, although two studies have examined the ability of VR to elicit anxious responding in patients with OCD. Data from these studies suggest that VRE to feared stimuli was able to elicit anxiety in patients with OCD relative to controls with no diagnosis. Further, participants' level of anxiety was positively associated with their immersion, or the extent to which they felt that they were physically present in the virtual environment.<sup>76,77</sup> This suggests a need for VR scenarios to be realistic and relevant to the patient's concerns. Similar to GAD, the impetus for obsessions and compulsions varies across patients, making it difficult to develop all-encompassing VR programs that meet the needs of all patients. Further, many patients have numerous obsessions and associated compensatory behaviors, which adds to this barrier. VR may not be necessary for OCD, as many of their feared stimuli may be readily accessible in their environment (e.g., toilets) or imaginations (e.g., making a mistake). Despite these difficulties, using VR during the treatment of OCD may be advantageous for patients whose obsessions are not feasible or appropriate for traditional exposure therapy (e.g., exposure to public restrooms). As data for VR-based CBT for OCD are preliminary but promising, more research in this area is undoubtedly warranted.

## Schizophrenia

While the preponderance of research investigating the use of VR in psychiatric care has focused on anxiety disorders, this approach demonstrates promise in the treatment of other disorders. Schizophrenia is a severe mental illness which includes psychotic symptoms (e.g., hallucinations, delusions), disruptions to normal emotional/behavioral functioning (e.g., flat affect, reduced pleasurable experiences, isolation), and difficulty with cognitive processing.<sup>24</sup> Data examining VR as an adjunct to treatment in this population have been limited, but initial investigations have provided a promising avenue for the treatment of this population. When used in the treatment of schizophrenia, VR scenarios have included social situations during which patients have learned to cope with social distress associated with delusional convictions and practiced social skills. One small RCT found that combining VR-based social interactions with exposure and cognitive therapy led to decreases in persecutory delusions as well as distress during in-vivo social interactions.<sup>78</sup> Three studies have used VR as an adjunct to social skill training (SST) for schizophrenic patients, two of which were uncontrolled pilot investigations that provide preliminary support for the efficacy of this approach in improving social skills and interactivity.<sup>79,80</sup> Another RCT of 91 schizophrenic individuals found that in comparison to traditional SST, SST including VR components resulted in increased interest in SST and generalization of skills learned during treatment and an improvement in the ability to converse and be assertive, although patients receiving traditional SST demonstrated better nonverbal social skills.<sup>81</sup> Although the extant data are limited, these preliminary results are promising particularly given the previously reviewed barriers to providing exposure to social interactions with repeated practice.

## Acute and chronic pain

Given that the experience of pain requires conscious attention, cognitive distraction is often incorporated as part of pain management in an attempt to shift attention and focus away from painful medical procedures. VR has been studied as a way to facilitate distraction from

acute pain during painful procedures, such as burn-related pain or physical therapy. An initial investigation for a small sample of four burn patients found that subjective pain ratings were lower when patients were in VR during occupational therapy.<sup>82</sup> A subsequent case study in a pediatric cancer patient provided further support that VR distraction may be useful in decreasing pain during painful medical procedures.<sup>83</sup> A within-subjects randomized trial comparing routine analgesia and routine analgesia combined with a VR game found that VR combined with analgesics was significantly more effective in reducing pain responses for children undergoing burn treatment.<sup>84</sup> A controlled trial comparing VR with other distraction techniques found that VR was more effective than some distraction techniques (i.e., child care worker, music, TV with headphone) in reducing subjective pain severity, but VR was not significantly more effective than watching television. In an fMRI study investigating the impact of VR on pain-related brain activity, participants subjectively reported decreased time thinking about pain and decreased pain severity and demonstrated significantly reduced activity in brain regions related to both sensory and emotional pain processing, providing subjective and objective support that VR techniques can aid in pain reduction.<sup>85</sup>

VR has also been used to help individuals with chronic pain learn and practice pain management techniques in combination with existing cognitive and/or behavioral interventions, as VR may help non-responders to conventional treatment and can provide the ability to standardize instructions and stimuli.<sup>86</sup> A VR system for chronic pain populations has been developed in which patients take a virtual meditative walk to learn mindfulness-based stress reduction, and preliminary results suggest that this system is more effective in reducing subjective pain compared to a non-VR control mindfulness condition.<sup>87</sup> A study in a sample of patients with fibromyalgia found that the use of VR with activity management treatment, which included VR based sessions involving activity management instructions, motivation enhancement, overcoming activity-related barriers, and acknowledgement of personal strengths, led to significant improvements with regard to functional disability compared to treatment as usual.<sup>88</sup>

In sum, findings suggest that VR in addition to standard pharmacological pain management can be helpful in reducing subjective pain severity when compared to standard analgesia alone for short-term acute pain during medical procedures. While this presumably relates to cognitive distraction, specific mechanisms are currently unknown<sup>89</sup> and future research could investigate mechanisms underlying this effect. Preliminary evidence also suggests VR may be helpful in helping individuals with chronic pain learn and practice specific pain management techniques, such as mindfulness or activity management.

## Addiction

Conditioned reactivity to drug-related cues is an important maintenance factor in drug and alcohol addiction, as such repeated exposure to drug-related cues has been used to reduce cue reactivity craving in order to prevent relapse. VR cue exposure provides the opportunity to conduct repeated exposures to drug-related cues in a controlled therapeutic environment. An initial pilot study found that VR-based cue exposure (e.g., a virtual bar, syringe, needle) was effective at eliciting physiological arousal, subjective craving, and urges to use drugs in

men with opioid dependence.<sup>90</sup> Another investigation found that a VR “crack” cocaine environment was effective at eliciting craving and physiological arousal in a crack cocaine dependent sample.<sup>91</sup> A VR casino environment was shown to be effective in eliciting psychophysiological arousal and urges to gamble in a sample of recreational gamblers,<sup>92</sup> suggesting that VR based cue elicited craving is effective across different addiction populations. In a nicotine dependent sample, a VR-based smoking environment elicited increased psychophysiological arousal and craving compared to a neutral cue, and this response decreased over the course of a four week VR cue exposure treatment.<sup>93</sup> In a sample of nicotine-dependent cigarette smokers, self-reported withdrawal symptoms and craving prior to a VR cue exposure were predictive of craving experienced in VR and significant increases in heart rate were present for three of the four VR smoking cues, providing further support for the ability of VR stimuli to effectively elicit subjective craving and physiological arousal related to substance-related cues.<sup>94</sup> A double-blind placebo study investigated the effects of DCS in concurrent cocaine and nicotine-dependent participants (N=29) who engaged in VR based cue-exposure therapy in conjunction with brief cognitive-behavioral therapy for smoking. Results indicated no significant effect of DCS, however, overall significant decreases in smoking at mid and post-treatment compared to baseline and craving for cigarettes and cue-induced craving decreased over the course of the study.<sup>95</sup> Notably, approximately 90% of the treatment sessions were attended, suggesting that VR based cue exposure therapy is a tolerable treatment approach. A randomized trial of CBT plus either smoking VR cue exposure therapy or placebo VR cue exposure therapy found that the smoking VR participants had a higher quit rate and reported significantly fewer cigarettes smoked per day at the end of treatment.<sup>96</sup> As such, the extant literature suggests that VR-based environments are effective at eliciting cue reactivity and craving in different substance dependent populations and can be effectively incorporated within repeated cue exposure treatment.

## Eating pathology

VR approaches have been used with different forms of eating pathology to address body image disturbances and eating, shape, and weight concerns. VR has been used to explore and challenge body image distortions, to implement exposure to food cues in order to identify and challenge eating, shape, and weight concerns, and to practice more effective eating strategies. An early investigation used several different VR environments, including household rooms with food items, to explore patient’s eating, shape, and weight beliefs and concerns, and images of different body types to resolve discrepancies in their perception of their body, and found preliminary support that these approaches improved body awareness in binge eating-disordered patients and obese patients.<sup>97</sup> A follow-up controlled investigation of 28 obese patients randomized to VR treatment or CBT-based groups found that VR treatment resulted in significantly greater improvements with body satisfaction, anxiety level, and problematic eating.<sup>98</sup> No significant differences were found for self-efficacy or stages of change in psychotherapy across the two groups. In a randomized trial comparing VR-based CBT for body image disturbances with traditional CBT for 13 eating disordered patients, VR-based CBT was found to result in significantly greater symptom improvement with regard to body image disturbances; no differences were found for eating disorder

symptoms across the two groups.<sup>99</sup> In a controlled study comparing CBT for eating disorders with and without a component of VR based body image treatment, the VR group demonstrated greater improvement at post-treatment and one month follow-up, however, it is notable that they received additional treatment sessions.<sup>100</sup> As such, extant literature provides preliminary support for the efficacy of incorporating VR into the treatment of different types of eating pathology and weight problems, as results suggest that VR may result in comparable treatment effects to traditional CBT approaches and may result in greater improvement for some specific outcomes.

## Autism

Autism spectrum disorder (ASD) is a developmental disorder marked by repetitive or restrictive patterns of behavior and difficulties with social communication and interaction. Research on the effectiveness of VR in the treatment of ASD suggests preliminary support for social improvement. Lahiri and colleagues<sup>101</sup> found preliminary evidence for the use of a VR-based computer task in improving social communication performance in autistic teenagers. However, the applicability of the results is questionable due to the sample and proof-of-concept design of the study. Sample size was small (N=8) and the range of ASD severity was limited. The researchers only enrolled autistic teenagers with average or above average intelligence, because the task utilized a menu-driven communication system that required a certain level of reading ability, limiting the samples representativeness. There have also been intervention studies that have shown relative improvements with regard to theory of mind, emotion recognition, and communication skills.<sup>102,103</sup> All of the studies mentioned demonstrate low drop-out rates and suggest high acceptability of patients towards VR.<sup>101–103</sup> Overall, this provides preliminary evidence that VR could be feasibly and effectively incorporated into psychiatric treatment for ASD.

## Recommendations for how to incorporate VR into psychiatric care

VR is incorporated at the point in treatment when in vivo exposure would normally be administered. As an example, a typical protocol using VR for fear of flying teaches anxiety management techniques in the first four sessions and incorporates VR exposure to a virtual airport and airplane in the last four sessions.<sup>23</sup> Specific equipment and training is needed to integrate VR into psychiatric practice effectively. A VR system will typically consist of a computer with two monitors, one for the provider's interface in which they are constructing the exposure in real time, and another for the provider's view of the patient's position in the VR environment, and a head-mounted displays and a platform.

VR-specific training is an important consideration in integrating VR into psychiatric practice. VR vendors provide both internet-based training courses in VR therapy as well as on-site, structured training on VR use within therapy. Providers should be trained sufficiently to feel proficient with the VR technology before using it with patients through specific training as well as role-plays. Training for providers should include information and practice of trouble-shooting for glitches within session, as well as possible contact information for individuals from the VR vendor who may be able to help trouble-shoot. Additionally, providers should be well trained in the rationale for incorporating VR within

psychiatric care to ensure that they are able to effectively communicate this to patients in order to demonstrate credibility. Given that VR is most frequently used during exposure therapy for anxiety disorders, it is important to note that sufficient training in exposure therapy is a prerequisite to considering VR training and implementation; sufficient training and continued supervision and support in exposure therapy should be in place before VR is integrated into patient care; bad VR therapy is still just bad therapy.

## Future directions for VR-based treatment and clinical research

The empirical literature suggests that VR demonstrates promise in the treatment of psychiatric conditions as well as within clinical research. However, a recent review of VRE RCTs found that overall methodological rigor was low;<sup>104</sup> authors noted that recent research has focused on preliminary support for novel uses for VR as opposed to studies becoming more methodologically rigorous over time. Another review noted the continued use of small samples and no controls,<sup>105</sup> echoing the need for more well-powered and controlled studies comparing VR-based treatment to other treatment approaches.

Future research could identify factors relevant to who may or may not be a good candidate for VR-based treatment. Individual differences related to immersion or sense of presence may be relevant. More broadly, research focused on the therapeutic process within VR and not just outcome will be important.<sup>106</sup> Research testing hypothesized mediators and moderators of VR-based treatment will prove informative, for example, investigating factors such as emotional processing, psychophysiological markers during exposure, and the therapeutic alliance.

When designing a VR study, the use of a control condition and large enough sample sizes to be sufficiently powered to detect an effect while considering possible treatment drop-out rates and projected attrition over all follow up assessments is recommended. Additionally, suggestions on data collection within VR studies will be provided. At the initial assessment, a thorough clinical assessment involving standardized semi-structured diagnostic interview administered by a trained mental health professional should occur, including assessment of possible comorbid conditions. Additionally, it would be beneficial to assess patient outcome expectancy, baseline psychophysiological response to standardized relevant VR stimuli, and personality and other individual difference variables that could be hypothesized to relate to the ability to experience presence/immersion at baseline. Information on current psychoactive medications use should be collected, and participants would ideally agree to stay on the same dose throughout the course of the study and follow-up assessments. During treatment, it is recommended that patients subjective units of distress ratings during each VRE session, psychophysiological monitoring during exposure, therapist and patient ratings of therapeutic alliance, engagement during exposure, presence/immersion in VR, and global improvement are collected. The study therapist can also document the amount of time spent in VR, the repetitions of the exposure, and the specific VR environments and cues used. It is also recommended that therapy sessions are video or audio-recorded to facilitate investigation of process variables or behavioral coding. Post-treatment assessments should ideally occur over a long follow-up period of at least 12 months, to allow for the investigation of the treatment effects over time. Post-treatment assessment could include

multiple indicators of treatment outcome, including patient-report, blind assessor report, therapist-report, behavioral tasks, and quality of life assessment. Methodologically rigorous and controlled use of VR within clinical research can help improve as well as elucidate the treatment process, as well as processes related to anxiety and fear processes more broadly, and lead to personalized medicine.

## Conclusions and Summary

Conventional wisdom is that it takes about 20 years from the time the first research is published to become common use. The first study using virtual reality to treat a psychological disorder was published in 1995,<sup>10</sup> and here we are 20 years later! Virtual reality has emerged as a viable tool to help in a number of different disorders, with the most strength of evidence for use in exposure therapy for patients with anxiety disorders, cue exposure therapy for patients with substance use disorders, and distraction for patients with acute pain requiring painful procedures. Overall, meta-analyses have indicated that VR is an efficacious tool, compares favorably to comparison conditions, and has lasting effects that generalize to the real world. However, problems have been noted including small sample sizes, lack of methodological rigor, and lack of comparison groups. With the cost of head mounted displays coming down and smaller smart phone applications being developed, it is likely that virtual reality applications will proliferate. It will be important that these are treated as tools and therapists are properly trained in their applications.

## Acknowledgments

Source of Funding: Dr. Rothbaum has funding from Wounded Warrior Project, Department of Defense Clinical Trial Grant No. W81XWH-10-1-1045, “Enhancing Exposure Therapy for PTSD: Virtual Reality and Imaginal Exposure with a Cognitive Enhancer”, National Institute of Mental Health Grant No. 1R01MH094757-01, “Prospective Determination of Psychobiological Risk Factors for Posttraumatic Stress,” Brain and Behavior Research Foundation (NARSAD) Distinguished Investigator Grant, “Optimal Dose of early intervention to prevent PTSD”, and McCormick Foundation “Brave Heart: MLB’s Welcome Back Veterans SouthEast Initiative.” Dr. Rothbaum receives royalties from Oxford University Press, Guilford, APPL, and Emory University and received one advisory board payment from Genentech. For the remaining authors none were declared.

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