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Virtual Reality Therapy in Mental Health

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Abstract

Initially designed for the treatment of phobias, the use of virtual reality in phobic disorders has expanded to other mental health disorders such as posttraumatic stress disorder, substance-related disorders, eating disorders, psychosis, and autism spectrum disorder. The goal of this review is to provide an accessible understanding of why this approach is important for future practice, given its potential to provide clinically relevant information associated with the assessment and treatment of people suffering from mental illness. Most of the evidence is available for the use of virtual reality exposure therapy in anxiety disorders and posttraumatic stress disorder. There is hardly any evidence that virtual reality therapy is effective in generalized anxiety disorder and obsessive-compulsive disorder. There is increasing evidence that cue exposure therapy is effective in addiction and eating disorders. Studies into the use of virtual reality therapy in psychosis, autism spectrum disorder, and attention deficit hyperactivity disorder (ADHD) are promising.

Contents

1. INTRODUCTION

Virtual reality (VR) is a computer-generated three-dimensional (3D) simulation, such as a set of images and sounds of real-life situations, with which one can interact in a seemingly realistic way by using special electronic equipment. The current standard VR systems use VR headsets with head-mounted display. VR provides not only visual and auditory stimuli but also tactile and olfactory stimuli. The subjective feeling that a user experiences in VR as "being there" is termed presence.

By presenting VR worlds in therapy, the patients' typical experiences in real life are evoked to improve their behavior and overcome their problems. Patients can enter anxious situations or difficult social situations in VR in which situations can be graded in difficulty and repeatedly rehearsed in the presence of a therapist before the patients try out these new therapeutic strategies in real life. The most common modes of VR application are exposure-based therapy, behavioral skills training, and cognitive skills training. This review discusses the available evidence on clinical applications of VR therapies for a number of psychiatric disorders, i.e., anxiety disorders, posttraumatic stress disorder (PTSD), obsessive-compulsive disorder (OCD), substance use disorders (SUDs), eating disorders, psychotic disorders, and the neurodevelopmental disorders autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD).

VR is used for not only treatment but also assessment purposes. VR enables researchers to design scenarios that can be used to assess real-time behavioral, emotional, cognitive, and physiological responses to a virtual environment. Below we discuss studies that have addressed issues that are relevant for a better understanding of a number of psychiatric symptoms by manipulation of VR worlds.

2. ASSESSMENT USING VIRTUAL REALITY

The main conditions investigated in Section 2 are social anxiety disorder (SAD), PTSD, OCD, substance-related disorders, eating disorders, psychosis, and ADHD.

2.1. Assessment in Social Anxiety Disorder

Research has investigated whether VR can be used to reliably and validly assess social anxiety and public speaking anxiety, but results are inconclusive. Until recently, the technology was limited so that the preprogrammed avatars used in conversation could not be controlled to interact and converse with the patient in real time. Powers et al. (2013) investigated a new technology allowing the operator to directly control the avatar's behavior and speaking during VR conversations. Results showed that VR conversation successfully enhanced fear ($d = 2.29$). Actually, participants rated their fear higher during VR conversation than during in vivo conversation. Kampmann et al. (2018) investigated whether a VR behavioral assessment task (BAT) predicted social anxiety in daily life. The virtual situations used in the BAT consisted of engaging in a conversation with a stranger at a bus stop and attending a foreign language class in which the teacher asked the participant a number of questions. Participants were also instructed to give an impromptu 5-min speech (in vivo BAT) in front of a camera. Individuals with high anxiety during the VR BAT reported higher social anxiety on the Daily Event Survey, which they completed daily at home for 1 week. The in vivo BAT did not prove to be a significant predictor of everyday social anxiety. Other studies have investigated physiological differences between subjects undergoing a VR BAT and those undergoing an in vivo BAT. Generally, a VR BAT (e.g., giving a speech to a virtual audience) and an in vivo BAT resulted in comparable changes in salivary cortisol levels, cardiovascular activity, electrodermal activity, respiratory sinus arrhythmia, and eye movements (fixation duration of faces) (see Emmelkamp et al. 2020).

2.2. Assessment in Posttraumatic Stress Disorder

Given that some soldiers may overreport PTSD symptoms to get benefits or may underreport PTSD symptoms because of shame, it has been suggested that VR can be used for assessment of PTSD in active duty soldiers and veterans. A few studies have investigated whether psychophysiological responses when soldiers and veterans are confronted with realistic VR worlds would be more informative than self-reported symptoms, but results so far are inconclusive (see Myers et al. 2016, Rizzo & Shilling 2017).

To investigate mechanisms underlying the development of trauma symptoms, VR worlds have been investigated as an analog to real trauma. Up to now, the trauma film paradigm has been used as an analog for posttraumatic stress. Such analog trauma VR worlds proved to be as effective in inducing intrusive memories in a normal population as traumatic film (Cuperus et al. 2017, Dibbets & Schulte-Osterman 2015) and more effective than after script-driven imagery (Schweitzer et al. 2018). Taken together, the results show that VR is a promising technology for research into trauma-related processes.

2.3. Assessment in Obsessive-Compulsive Disorder

A number of studies are relevant with respect to the use of VR for assessment purposes. To examine OCD using objective behavioral indices, Kim et al. (2010) used VR to simulate realistic environments (house and office) in which individuals are asked to engage in OCD-relevant tasks (e.g., locking doors). This VR task includes measures of checking (frequency and duration) inside

the virtual environment, as well as time spent gazing at OCD-relevant stimuli. Kim et al. (2010) found that behavioral measures obtained from this task differentiated individuals with OCD from healthy controls. In another study, the same group (Kim et al. 2012) used the virtual environment as a diagnostic tool to discriminate patients with checking behavior from those without. These researchers developed a virtual environment with a house and office for the assessment of anxiety and compulsions in patients with OCD. A high level of anxiety was found in patients with OCD with checking behavior relative to OCD patients without checking behavior and healthy controls. Patients with checking behavior showed a higher checking frequency and spent more time on checking and more time on gazing during checking behavior. This finding is in line with more experimental research (van den Hout et al. 2019), in which individuals with obsessive checking behavior experience greater uncertainty in uncertain situations, which in turn leads them to engage in checking behavior: Feelings of uncertainty provoke checking behavior, and checking behavior preserves feelings of uncertainty.

Results of the Kim et al. (2012) study are in line with a pilot study done by another group, wherein a virtual video game environment was used to provoke more OCD symptoms in OCD patients relative to healthy controls (van Bennekom et al. 2017). The authors conclude that the VR game has the potential to be a valuable tool to objectify and standardize an OCD diagnosis. However, in contrast to the studies by Kim and colleagues (2010, 2012), here it concerned a virtual game environment: No 3D goggles to immerse the patient in a 3D perspective were used. Participants navigated through the OCD house looking at a computer screen.

Laforest et al. (2016b) investigated whether a VR world could be used to trigger anxiety in OCD patients with contamination. The primary goal of this research was to assess how effectively a virtual environment could induce anxiety in individuals with contamination-subtype OCD. After a training, VR world participants (OCD patients and adults without OCD) were immersed in VR for approximately 5 min. Participants had to go through the restroom with various degrees of cleanliness (e.g., the first stall was relatively clean, and the last presented filthy walls and an unflushed toilet). Participants were asked to "touch" the walls and the toilet seat each time with their hands. Results revealed that exposure to a "contaminated" virtual environment induced a higher anxiety level, not only on state anxiety as assessed with the State-Trait Anxiety Inventory (STAI; Spielberger et al. 1970) but also on heart rate, in the OCD group relative to the control group.

2.4. Assessment in Substance Use Disorder

Craving in response to alcohol- and drug-related cues is presumed to play a role in the continuation of SUDs (Emmelkamp & Vedel 2006). A number of recent studies have addressed the issue of whether VR can be used to investigate whether substance-related situations lead to craving in substance-abusing individuals. Most studies have been conducted with individuals with nicotine dependence. In nearly all studies, cue exposure to VR cues (e.g., cigarettes, ashtray, smokers in a pub) led to craving, and there is some evidence that peer pressure by virtual avatars is highly effective in triggering craving. Moreover, in alcohol-abusing patients and in cocaine- and cannabis-using patients, VR has proven to be effective in inducing craving (see Segawa et al. 2020). Regarding alcohol abuse, social pressure by virtual avatars led to greater craving than did virtual alcohol cues (Ghiţă & Gutiérrez Maldonado 2018). Taken together, the results of these studies indicate that immersing individuals in virtual environments related to their specific addiction can enhance the reliability of craving assessment and suggest that virtual induced craving can also be used in cue exposure therapy (see below).

2.5. Assessment in Eating Disorders

Various studies revealed that patients with eating disorders show higher anxiety when exposed to virtual environments with high-calorie food and certain social situations (e.g., kitchen, swimming pool). These studies with patients with anorexia and bulimia nervosa showed that exposure to virtual food cues induces similar emotional, cognitive, and behavioral reactions as does exposure to real food: High-calorie foods presented in VR worlds can provoke body dissatisfaction and craving for food. Generally, the higher presence experienced in VR situations, the higher is the anxiety experienced (see De Carvalho et al. 2017).

2.6. Assessment in Psychosis

A number of studies have used VR worlds to investigate memory deficits and executive functioning in patients with schizophrenia. Generally, results showed that the VR tasks enabled researchers to distinguish between patients with schizophrenia spectrum disorders and controls (e.g., Fajnerová et al. 2014, Josman et al. 2009).

Other studies have focused on the assessment of social cognition and social competence. The use of real-life assessment of social cognition and social competence is limited by the complexity of real-life observation by a clinician. In contrast, VR assessment of these functions may provide more readily implemented functional capacity measurement and has been investigated in the areas of medication management, social competence, anxiety, and thinking patterns, using a variety of VR environments such as a VR street, train, library, park, and supermarket to assess function in different clinical groups. As an example, Greenwood et al. (2016) investigated whether virtual supermarket shopping was a viable alternative to direct assessment of real-life function in patients with schizophrenia. Patients with schizophrenia were asked to shop for items, using a self-directed search in a VR supermarket and in a real-life supermarket. Multiple regression analyses indicated that VR efficiency measures contributed significant unique variance to real-life efficiency outcomes. Greenwood et al. (2016) conclude, "VR functional shopping measures may enhance predictions of real life performance, over and above existing cognitive test procedures, and provide a more time-efficient method for evaluating real life outcomes" (p. 206).

Finally, a recent systematic review (Rus-Calafell et al. 2018) included 18 studies that investigated the use of VR for the assessment of paranoid ideation in nonclinical and clinical participants, including patients with psychosis or with ultrahigh risk of psychosis, in a variety of virtual environments, including a library, the London Underground train, a walk in a street, and a pub. The results of these studies together give clear evidence that paranoid ideation can be readily triggered by avatars, even avatars who are programmed to behave neutrally.

In sum, the use of VR for neurocognitive assessment and social cognition and social competence is promising. Studies into the assessment of paranoid ideation are certainly of interest, but most studies have used nonclinical samples, which limits the generalizability to clinical practice.

2.7. Assessment in Attention Deficit Hyperactivity Disorder

Studies have investigated whether VR can be used for some neuropsychological tests assessing attention, executive function, and memory, such as the continuous performance test (CPT). Results of these studies have shown that CPT when applied in VR may be as reliable as the classic CPT but may be preferred by children (Díaz-Orueta et al. 2014, Pollak et al. 2009). At least one study (Neguţ et al. 2017) suggests that assessment through VR offers a more ecological assessment that better captures the real level of the development of attention processes than does the CPT. Areces et al. (2018) investigated the diagnostic usability of the 3D VR video game Nesplora Aula, which

creates a virtual environment to evaluate attention, impulsivity, and processing speed in children. Nesplora Aula discriminated between children diagnosed with ADHD and controls.

3. VIRTUAL REALITY TREATMENT: STATE OF THE ART

3.1. Anxiety Disorders

In this section, we give an overview of randomized controlled trials (RCTs) that have been done to investigate the efficacy of virtual reality exposure therapy (VRET) in the treatment of anxiety disorders.

3.1.1. Specific phobias. Specific phobias can be subdivided into different categories such as situational phobias (e.g., fear of flying) or fear of small animals (e.g., spider phobia). Specific phobias are some of the most prevalent psychiatric disorders, with chronic and adverse effects on everyday life and a 12-month prevalence of 6.4% (Kessler et al. 2012). Comorbidity is high, especially with other anxiety disorders, depression, and somatoform disorders (Trumpf et al. 2010). The treatment recommended by international guidelines (Natl. Inst. Health Clin. Excell. 2011) is exposure therapy. The dominant theory in explaining the effects of exposure therapy was previously the emotional processing theory (Foa & Kozak 1986), but in recent years the inhibitory learning theory has become the preferred theory to explain the powerful effects of exposure (Craske et al. 2014). For an extensive overview of the efficacy of exposure therapy in specific phobias, see a review about different aspects concerning the success of exposure therapy (Böhnlein et al. 2020). VRET can be viewed as a modern variant of exposure therapy, wherein patients are exposed in VR to their idiosyncratic fear and learn that their most feared scenario does not occur. In this review, we limit ourselves to the clinically relevant specific phobias of acrophobia, dental phobia, and fear of flying.

3.1.1.1. Acrophobia. In a first pilot study, a within-groups design was used to evaluate the effectiveness of low-budget VR in acrophobia (Emmelkamp et al. 2001). Individuals suffering from acrophobia were exposed to two sessions of virtual heights, followed by two sessions of exposure in vivo. VRET was found to be as effective as exposure in vivo on anxiety and avoidance measures. In a first RCT, 33 patients with acrophobia were randomized to either VRET or exposure in vivo to heights (Emmelkamp et al. 2002). The virtual environments used in treatment were copied from the real world used during exposure in vivo. VRET was found to be as effective as exposure in vivo on anxiety and avoidance measures and a behavioral avoidance test. The results were maintained at 6-month follow-up.

A randomized crossover design ($n = 26$) study investigated whether cognitive coping self-statements would have an additional value above VRET (Krijn et al. 2007b). Patients with acrophobia were randomly assigned to receive either (*a*) two sessions of VRET followed by two sessions of VRET plus coping self-statements or (*b*) two sessions of VRET plus coping self-statements followed by two sessions of VRET. Results showed that VRET, regardless of whether coping self-statements were added, decreased anxiety of heights and avoidance behavior. In another RCT (Meyerbröker et al. 2018), patients with acrophobia or fear of flying were treated with VRET. Patients were randomly assigned to either VRET plus yohimbine hydrochloride, VRET plus propranolol, or VRET plus a placebo. While all three conditions improved on the anxiety symptoms, no differences were found between conditions, indicating that VRET with a nonactive placebo is a powerful intervention in the treatment of acrophobia.

In a more recent trial, a smartphone application for the use of VRET was investigated (Donker et al. 2019). In a single-blind RCT, individuals with acrophobia were randomly assigned either to

a fully self-guided app-based VR cognitive behavioral therapy (VR CBT) group using cardboard VR goggles or to a waiting-list control group. Six animated VR CBT modules and a gamified VR environment were made accessible during a 3-week period. In total, 193 participants were randomly assigned to the intervention group ($n = 96$) or a control group ($n = 97$). Intent-to-treat analyses revealed significant reduction of acrophobia symptoms after treatment and at 3-month follow-up. Donker et al. (2019) conclude that this is the first study wherein VRET is used as a stand-alone treatment without the guidance of a therapist.

3.1.1.2. Fear of flying. Research into the efficacy of VRET in fear of flying has been done with different control conditions. The use of VRET alone has been compared to cognitive therapy (Krijn et al. 2007a), exposure in vivo (Rothbaum et al. 2000, 2006), and the enhancement of VRET with yohimbine hydrochloride (Meyerbröker et al. 2011, 2018). VRET was as effective as exposure in vivo, and the results generalized to real-life situations (Morina et al. 2015b). Cognitive restructuring did not enhance the effects of VRET (Krijn et al. 2007a). Results of other RCTs showed that VRET is more effective than bibliotherapy, relaxation training, and exposure in vitro (Maltby et al. 2002, Mühlberger et al. 2001). The long-term effects of VRET in fear of flying are stable for up to 3 years after treatment termination (Mühlberger et al. 2006, Wiederhold & Wiederhold 2003). The advantages of VRET over exposure in vivo are enormous, given that virtual flights are a lot less expensive and more sustainable from an ecological perspective (Meyerbröker 2014). A more recent study investigated the effectiveness of an Internet-based exposure treatment for fear of flying (NO-FEAR Airlines), with and without therapeutic guidance, including exposure scenarios composed of images and sounds, versus a waiting-list control group (Campos et al. 2019). NO-FEAR Airlines (with and without therapist guidance) was significantly more effective than the waiting-list control group on primary outcomes measures. No significant differences were found between the two ways of delivering the intervention.

3.1.1.3. Dental phobia. In dental phobia, much research into different VR interventions has been done (for an overview, see Gujjar et al. 2019a). In general, VR is an effective intervention method that uses distraction to reduce pain and anxiety in patients undergoing different dental treatments.

In a recent study, the effect of VR was used to relieve anxiety during a mandibular third molar extraction in 51 participants; in contrast, 49 participants did not receive the VR intervention (Yamashita et al. 2020). Anxiety decreased among patients who had received the VR intervention relative to the 49 patients who had not received VR. In another study with 50 patients, VR was also used as a distraction intervention (Ougradar & Ahmed 2019). This study found that 35% of the patients rated the VR intervention as extremely beneficial, 30% as quite beneficial, 25% as of some benefit, and 10% as of little benefit. In another study, the effect of VR was used not as a distraction method during treatment but as exposure therapy prior to dental treatment (Gujjar et al. 2019b). A single-blind RCT was conducted, wherein 30 patients with dental phobia were randomly assigned to receive either VRET or an informational pamphlet. Intention-to-treat analysis showed an interaction effect between time and condition, meaning that patients in the VRET condition showed a significant reduction in anxiety scores whereas the patients in the control group did not.

In another recent trial, VR was used to reduce preoperative dental anxiety with 255 participants (Lahti et al. 2020). Patients were randomly assigned to either the VR relaxation training group or the treatment-as-usual (TAU) group. The VR intervention consisted of approximately 3.5 min of a 360° immersion into a peaceful landscape. Total and anticipatory dental anxiety decreased more in the VR group than in the TAU group. Lahti et al. (2020) conclude that even a short VR application can reduce preoperative dental anxiety.

In sum, in specific phobias VRET can play an important role in helping patients to overcome their avoidance behavior. In dental phobia, approaches different from exposure have been investigated as well. One example is distraction and relaxation techniques, the rationale of which is not in line with the assumed theoretical background of exposure therapy.

3.1.2. Agoraphobia and panic disorder. In panic disorder and agoraphobia, CBT consisting mainly of exposure to anxiety-provoking situations and bodily sensations is the first-choice treatment (Natl. Inst. Health Clin. Excell. 2011). While exposure to different social situations can be a challenge in vivo, VR provides an excellent opportunity to mimic different daily situations for panic disorder and agoraphobia. Although this prospect seems obvious, existing research into the efficacy of VR exposure therapy in panic disorder and agoraphobia has been limited, and dissemination into clinical practice is going slowly.

In total, five reported RCTs have investigated the effects of VRET in patients with panic disorder and agoraphobia (Botella et al. 2007, Malbos et al. 2013, Meyerbröker et al. 2013, Pelissolo et al. 2012, Penate et al. 2008). In a first study, VRET ($n = 12$) was compared with both a waiting-list control group ($n = 13$) and an exposure in vivo group ($n = 12$) in a weekly 9-session treatment (Botella et al. 2007). The results showed that VRET was superior to waiting-list control, and comparable effects were found for VRET in comparison with in vivo treatment. The findings were maintained at 12-month follow-up. In another study, VRET ($n = 15$) was compared with standard CBT ($n = 13$) in an 11-session lasting treatment (Penate et al. 2008). Posttreatment, in a behavioral avoidance test, patients were asked to walk on an average street. The results showed that the effects of standard CBT and VRET were comparable posttreatment, showing a significant decrease in panic measures. In another RCT, CBT plus VRET ($n = 19$) was compared with a waiting-list control group ($n = 18$) and to CBT with exposure in vivo ($n = 18$) (Meyerbröker et al. 2013). Results showed that both CBT plus exposure in vivo and CBT plus VRET were superior to the waiting-list control condition. On three of the four outcomes measures, CBT plus VRET was equally effective as CBT plus exposure in vivo. However, on panic disorder severity, a significant interaction was found, favoring CBT plus exposure in vivo above CBT plus VRET. In another RCT, 92 patients with panic disorder and agoraphobia were randomized to receive either CBT or VRET (Pelissolo et al. 2012). In both groups, moderate response rates to treatment were found, and no between-groups differences were found. The results were stable at 9-month follow-up. In a small study, the additional effect of cognitive therapy added to VRET was investigated (Malbos et al. 2013), and no additional value of cognitive therapy was found.

In sum, VRET is a viable treatment for patients with panic disorder and agoraphobia, demonstrating effects comparable to those of state-of-the-art CBT, which recent meta-analyses on VRET in anxiety disorders confirm (Carl et al. 2019, Wechsler et al. 2019). With respect to RCTs on panic disorder and agoraphobia, research indicates that VR and exposure in vivo show similar efficacy.

3.1.3. Social anxiety disorder. SAD is characterized by an excessive fear of negative evaluation and rejection by other people and a consistent fear of embarrassment or humiliation. A central component of CBT for SAD is exposure to feared stimuli while eliminating safety behaviors so that patients learn that feared negative consequences are unlikely to occur. Given that social situations to practice in CBT in real life are often scarce, VRET has become an important instrument to reproduce social situations, and it has been shown to have the potential to elicit the social distress that patients experience (Emmelkamp et al. 2020).

A number of studies revealed that virtual social environments can be effectively manipulated for therapeutic purposes. Our research team (Morina et al. 2015a) investigated, in participants with

high levels of social anxiety, the use of verbal interactions between clients and virtual humans. We applied a VR system specifically designed to expose clients with social anxiety complaints to anxiety-provoking social situations. Two sessions of virtual exposure involving several free speech dialogues with virtual humans (avatars) with simultaneous monitoring by a therapist were associated with significantly lower levels of social anxiety and higher self-efficacy 3 months after exposure. Taken together, these studies suggest that virtual social environments can be successfully used for therapeutic purposes.

So far four RCTs have investigated VRET in socially anxious patients, including those with speech anxiety. Bouchard et al. (2011) compared two variants of CBT plus exposure with waiting-list controls: (*a*) CBT plus exposure in vivo and (*b*) CBT plus VRET. Both variants of CBT were clearly more effective than the control condition, and no differences were found in the effects of CBT plus exposure in vivo and the effects of CBT plus VRET. The results are difficult to interpret, however, given that the exposure variants were mixed with other CBT exercises. In an RCT by Anderson et al. (2013), VRET was equally effective as exposure group therapy up to 1 year follow-up. Both treatments involved cognitive components addressing self-focused attention, negative perception of self and others, perception of negative emotion regulation, ruminations, and unrealistic goal settings in social situations that make results with respect to the efficacy of VRET as a stand-alone treatment difficult to evaluate. Bouchard et al. (2017) compared three conditions: CBT plus VRET, CBT plus in vivo exposure, and waiting list. Both active treatments were more effective than waiting list, and CBT plus VRET was more effective than CBT plus in vivo exposure. Again, given the combination of cognitive restructuring and VRET, the effects of VRET are difficult to evaluate.

The RCT by Kampmann et al. (2016a) is the only study so far with patients with generalized SAD in which pure VRET without any cognitive intervention was investigated. Pure individual VRET was compared with individual exposure in vivo without any cognitive intervention and with a waiting-list control group. This study was the first attempt to develop and apply a variety of complex virtual social interactions. The virtual situations consisted of the following: giving a talk in front of an audience of people who asked questions, buying and returning clothes, talking to a stranger, attending a job interview, dining in a restaurant, being interviewed by a journalist, and having a blind date. Semistructured dialogues were controlled by the therapist, who was in a separate room. The therapist could vary the dialogue style, avatar's gender, avatar's gestures, number of avatars present, and dialogue topic's degree of personal relevance. Exposure in vivo consisted of exposure exercises that could be implemented in the therapist's office or in supermarkets, cafes, shops, or subway stations in the neighborhood of the office. Both active treatments were more effective than waiting-list control for social anxiety symptoms, BAT, stress, and avoidant personality disorder–related beliefs. However, in vivo exposure was more effective than VRET in reducing social anxiety and avoidant personality disorder–related beliefs at 3-month follow-up. Thus, although VRET as a stand-alone therapy containing extensive verbal interaction without any cognitive restructuring was effective in reducing complaints of generalized SAD, it was still less effective than exposure in vivo.

Finally, two meta-analyses regarding the effects of VRET in SAD have been published. Kampmann et al. (2016b) reported that, when VRET for SAD was compared with passive control conditions at postassessment, the effect size was large (Hedges' $g = 0.82$); when compared with active control conditions, the effect size was not significant ($g = -0.24$). A meta-analysis of Chesham et al. (2018) confirmed this finding.

3.1.4. Generalized anxiety disorder. Generalized anxiety disorder (GAD) typically starts before the age of 20 years (Mohammadi et al. 2020) and is usually known to have a chronic or

recurring course (Angst et al. 2009). Only a few studies have investigated VR applications for the treatment of GAD. These applications differ in focus and in how VR is involved in treatment. In one of the first studies of GAD ($n = 20$), VRET was combined with a mobile device giving biofeedback, and this treatment was compared with a waiting-list control group (Gorini & Riva 2008). In VRET, patients were immersed in a peaceful virtual environment (e.g., a beach or a park), helping them to relax. After relaxation, participants were confronted with an idiosyncratic stressor in words. Results showed no differences between groups; both groups improved compared to baseline.

In another study using VR as a relaxation method, the effects of mindfulness skills training to reduce GAD symptoms were investigated (Navarro-Haro et al. 2019). In this study ($n = 42$), mindfulness group training was compared with mindfulness training plus a VR training in mindfulness in reducing GAD symptoms. Both groups improved significantly on GAD measures, and the group that received additional VR training was more treatment adherent than the group receiving only mindfulness group training.

The aim of a recent study of Guitard et al. (2019) was to examine whether standardized VR scenarios could elicit sufficient anxiety to expose patients to a catastrophic scenario depicting their most feared worry. In this study, 28 patients with GAD were exposed first to a neutral noncatastrophic scenario and then to a personalized scenario in imagination or a standardized virtual scenario that was presented in a counterbalanced order. This study found that the standardized virtual scenarios induced as much anxiety as personalized scenarios in imagination, suggesting that standardized VR scenarios can be used in therapy. Guitard et al. (2019) conclude that the findings are specific to anxiety, and not to negative affect in general.

Repetto et al. (2013) investigated a clinical protocol for the treatment of GAD based on the use of a biofeedback-enhanced VR system. The VR consisted of an eight-session treatment wherein relaxation and exposure techniques were used. In the first six sessions, patients explored relaxing VR environments (e.g., a tropical island) that were accompanied by progressive muscle relaxation. In the last two sessions, the patients explored the island again but were exposed to preselected words or images related to their personal stressful events. To increase the effects of relaxation, patients could access, from home using a mobile phone, the same VR environment experienced during the therapy. In a small RCT, 24 patients with GAD were randomized to (*a*) the VR and mobile group, including a biofeedback-assisted relaxation program; (*b*) the VR and mobile group without biofeedback; or (*c*) a waiting-list control group. Although both active treatment groups experienced a significant decrease on the Beck Anxiety Inventory (BAI; Beck et al. 1988), no significant differences were found between the three conditions.

Different strategies have been applied to use VR techniques in the treatment of GAD (see also Wang et al. 2019). Not all of these treatment approaches are in line with international treatment guidelines (Natl. Inst. Health Clin. Excell. 2011), nor do they make use of standardized research procedures or relevant clinical measures. In sum, there are interesting approaches, but none of these studies has proven the additional value of VR in the treatment of GAD.

3.2. Posttraumatic Stress Disorder

A number of studies have investigated whether VRET can be used in individuals with PTSD. Prolonged exposure to imaginal stimuli related to traumatic situations involves elaboration and processing of the trauma memories and is generally considered the treatment for PTSD for which the most evidence is available (Foa et al. 2008). Although prolonged exposure involving emotional processing of traumatic situations and habituation of anxiety is an evidence-based therapy for PTSD, a number of patients are unwilling to undergo this treatment or are unable to

visualize the traumatic stimuli due to avoidance of anxiety, and as a result such patients may drop out of treatment. Given this situation, clinicians have developed alternative exposure strategies based on exposure to VR environments. Such VR-based improvements to emotional engagement could overcome barriers in activation of the fear structure because of avoidance. In addition, controllable fictitious virtual environments may be more acceptable for PTSD patients than exposure in imagination. A few RCTs have compared VRET versus prolonged imaginal exposure in active duty soldiers and veterans in the United States. Such VR sessions involved imaginal exposure to traumatic war memories along with a simultaneous computer-generated viewing of virtual worlds of Iraq or Afghanistan with multisensory stimulus options to adapt to the patient's description of the specific trauma. Generally, VRET was as effective as prolonged exposure (Rizzo & Shilling 2017), but in the largest RCT comparing prolonged imaginal exposure with VRET with active duty soldiers, prolonged exposure was more effective than VRET at 3- and 6-month follow-up (Reger et al. 2016). Additional analyses (Norr et al. 2018b) revealed that both prolonged exposure and VRET had a lower risk of posttreatment suicidal ideation relative to the waiting-list control, thus supporting the use of VRET (and prolonged exposure) in addressing thoughts of suicide among soldiers with PTSD. Soldiers who had greater PTSD symptom reduction after VRET were less likely to be taking antidepressant medication, had greater PTSD hyperarousal symptoms, and were younger. Soldiers who did best in terms of PTSD symptom reduction in prolonged exposure were more likely to be taking antidepressant medication, had lower PTSD hyperarousal symptoms, and were older (Norr et al. 2018a). Whether these results will also apply to other populations with PTSD needs to be studied.

Beidel et al. (2019) compared, in soldiers with combat-related PTSD, the efficacy of VRET plus a group treatment for anger, depression, and social isolation (trauma management therapy) with a psychoeducation control condition involving only VRET. Although VRET resulted in clinically significant decreases in PTSD symptoms, anger, and depression, decreases in social isolation occurred only for participants who received trauma management therapy as well.

In sum, VRET in veterans and active duty soldiers with PTSD results in a clinically significant decrease in PTSD symptoms. There is no evidence, however, that patients in VRET are more emotionally engaged than patients in prolonged exposure therapy. Although trauma-relevant visuals, sounds, vibrations, or smells are induced in VRET to increase the patient's emotional engagement with the traumatic memory and hence activate emotional processing, a study of Reger et al. (2019) found that soldiers with war trauma in VRET did not report significantly higher average or peak scores on the Subjective Units of Distress Scale or an increased reduction of distress over time relative to participants in prolonged exposure.

In Europe, another, more flexible type of VR environment termed EMMA's World was developed for the treatment of PTSD. In this environment, any traumatic event can be represented in VR by using, for example, pictures, video, music, and sounds. In two small trials, this VR therapy was compared with CBT in victims of robbery, (domestic) violence, abuse, and motor vehicle accidents. VR therapy led to a reduction of PTSD complaints comparable to reductions due to CBT (Botella et al. 2015).

A limited number of studies have investigated whether the efficacy of VRET could be enhanced by using pharmaceutical agents such as dexamethasone and D-cycloserine to augment extinction in VRET with patients with PTSD. Dexamethasone did not enhance the effects of VRET in an RCT with veterans but increased dropout substantially (Maples-Keller et al. 2019). Results of the effects for D-cycloserine augmentation of VRET for PTSD are mixed. In a pilot RCT (Difede et al. 2014) in victims of the World Trade Center, VRET plus D-cycloserine was more effective than VRET plus placebo. This finding was, however, not replicated in an RCT with Iraq and Afghanistan war veterans with PTSD (Rothbaum et al. 2014). Patients who received VRET plus

D-cycloserine had, however, greater reductions in cortisol and startle responses posttest relative to patients who received VRET plus placebo.

A number of clinicians are reluctant to use trauma-focused therapies as prolonged exposure and VRET in individuals with PTSD because such clinicians are afraid that the reexperience of trauma may increase the likelihood of becoming psychotic, although there is no evidence to support this idea. Although hallucinations and persecutory ideation may temporarily increase in the course of trauma-focused therapy, there is some support for the notion that trauma-focused therapy, including VRET, reduces persecutory ideation and psychosis-like experiences (Buck et al. 2019).

Finally, a recent meta-analysis (Wenrui et al. 2019) of 10 RCTs found that VRET had a moderate, significant effect ($g = 0.327$) on PTSD symptoms and was equally effective as trauma-focused CBT. More sessions of VRET enhanced the effects of treatment.

3.3. Obsessive-Compulsive Disorder and Hoarding

Very few studies have investigated the efficacy of VR in the treatment of OCD and hoarding. Below, we discuss these studies separately for OCD and hoarding.

3.3.1. Obsessive-compulsive disorder. OCD is a severe disorder that often has a chronic course in patients, putting a lifetime burden on them (Stein et al. 2019). Treatment according to international guidelines (Natl. Inst. Health Clin. Excell. 2011) consists of exposure and response prevention (ERP), which shows remission rates of up to more than 50%, leaving room for improvement (Sharma et al. 2014). However, it is assumed that ERP often provokes a lot of distress in patients, and less than 40% of patients receive an adequate amount of CBT (Mancebo et al. 2006). VR exposure therapy has the potential to encourage patients to experience first exposure steps in a safe environment. Although VRET offers large potential for OCD treatment, very few studies have been conducted with VR and OCD patients.

Most studies have investigated VR as a diagnostic device with the potential to trigger anxiety during VR exposure, but research into the role of VR ERP has been scarce. In a nonclinical trial with participants ($n = 21$) with high fear of contamination, after three sessions of virtual ERP, participants experienced less anxiety and disgust and a reduced urge to wash their hands in comparison with healthy controls (Inozu et al. 2020). In an earlier pilot study with patients with OCD-subtype fear of contamination, a 12-session ERP treatment was given (Laforest et al. 2016a). Three patients were exposed to two virtual environments: one to train them (neutral) and one OCD (contaminated) environment. Exposure included touching dirty and filthy walls and toilet seats wherein the degree of difficulty could be gradually increased. A single-case design was used. Data of the time series revealed statistically significant symptom reductions in all three patients. Given the limited number of patients, larger studies are needed before this approach can be recommended for clinical practice.

Furthermore, interesting focus points for treatment, e.g., the use of rubber hands to simulate contamination with a patient's own hands, have been assessed (Jalal et al. 2020). In this study, OCD patients ($n = 29$) watched a visible fake hand that was stroked together with their invisible real hand such that the real hand became contaminated with fake feces, simulating exposure. The manipulation occurred either synchronously ($n = 16$; experimental condition) or asynchronously ($n = 13$; control condition). Interestingly, after 5 min of tactile stimulation of the hand, no differences between conditions were found: Both groups indicated increased facial disgust, anxiety,

handwashing urges, and discontinuation of the exposure. These findings indicate the potential for VR in the treatment of fear of contamination.

It is remarkable that, despite the high prevalence of OCD and lifetime burden (Ruscio et al. 2010), almost no VR environments have been created to focus on exposure targets. Although different OCD themes often complicate the focus of treatment for VRET, these themes seem to be universal (Hunt 2020), and the question remains whether virtual environments need to specifically meet all idiosyncratic fears to be successful (Meyerbröker 2014). Yet the potential value of VRET for treatment of OCD has yet to be demonstrated.

3.3.2. Hoarding. In hoarding, VR is used with different focuses for treatment. In a first small pilot study in patients with compulsive hoarding, a VR exposure environment was used (O'Connor et al. 2011). Patients could organize their idiosyncratically hoarded things, and such organization occurred in the virtual environment via photographs. In the first phase of the study, patients could hoard their own things in the virtual environment; in the second phase, they could sort their things in the virtual environment; and in the third phase, they could delete items from the virtual environment. The overall objective was to help patients learn how to more efficiently organize and categorize or eventually throw away hoarded items. The authors conclude that VR is a suitable instrument for the treatment of hoarding.

On the basis of the abovementioned pilot study, a small RCT investigated the efficacy of 24 inference-based therapy group sessions of 1.5 h and five sessions of VR for hoarding (St-Pierre-Delorme & O'Connor 2016). While the inference-based approach addresses doubts in a broader sense, the VR environments were used to help patients sort their belongings. In the virtual environments, 30 photographs of the individual patients were set into the environment. In the active control condition, images of objects that were not personal to patients were used and pasted into the patients' VR environment.

In the experimental condition, patients could alter their virtual environment so that it looked similar to their actual home, and they then developed a plan for sorting objects. Afterward, patients could discard items in the virtual environment in a virtual 3D garbage can and rerate their anxiety. At the start of each session, the therapist assessed whether the patient sorted and discarded the same items at home. Clutter levels in the bedroom were found to decrease in the experimental condition while increasing in the control condition. No effects were found for the living room and the kitchen. St-Pierre-Delorme & O'Connor (2016) conclude that the VR task may have facilitated the process of letting go more objects.

To sum up, only a few studies with VR and hoarding disorder have been done, and the rationale for treatment often differs. Given the complexity of hoarding disorder and its consequences (Frost et al. 2000, Tolin et al. 2008), we assume that more than a virtual environment is needed to successfully treat these patients.

3.4. Addiction

Addictive behaviors are viewed as learned habits that are reinforced by rewards according to operant learning principles. Addictive substances stimulate the pleasure centers in the brain, thus providing positive reinforcement for substance abuse. In many cases, however, substance abuse is also negatively reinforced by amelioration of negative feelings. Many addiction theories assume that craving plays a central role in the acquisition and maintenance of substance dependence (see Emmelkamp & Vedel 2006). In some CBT protocols, patients are treated with cue exposure, consisting of repeated exposure to the sights or smells of substances (e.g., the sight and smell of a glass of beer or the sight of white powder on a mirror) until the cravings elicited by these cues substantially weaken.

3.4.1. Substance abuse. Cue exposure therapy in substance abuse has led to mixed results (Emmelkamp & Vedel 2006, Mellentin et al. 2017), which has inspired researchers to investigate the effects of cue exposure therapy delivered through VR. Cue exposure through VR (10 sessions in 5 weeks) was more effective than standard CBT in reducing alcohol craving in alcohol-dependent patients (Lee et al. 2009). Alcohol cue reactivity led to a reduction in frontal alpha activity in the VR cue exposure condition. VR cue exposure was also effective in social drinkers after one session (Choi & Lee 2015). Although certainly of interest, these studies are clinically less relevant since reduction in alcohol dependence was not studied (Segawa et al. 2020).

3.4.2. Smoking. Some studies have investigated whether VR cue exposure therapy is effective in the treatment of smoking, but few of these studies were controlled, and the results of these controlled studies were mixed. In a study of Park et al. (2014) with moderately dependent individuals, VR cue exposure was as effective as CBT in reducing the number of cigarettes smoked. In an RCT of Pericot-Valverde et al. (2019), however, the addition of VR cue exposure to CBT was not more effective than CBT as a stand-alone therapy. The relapse rate 1 year after treatment in the combined condition was actually higher than in the stand-alone CBT condition.

In sum, although VR cue exposure has proven to be effective in triggering craving, the results of clinical trials are mixed. The effectiveness of VR cue exposure in nicotine- and alcohol-dependent patients is limited.

3.5. Eating Disorders

VR is used primarily in a therapeutic context to investigate two main aspects of eating disorders: body image distortions (relevant for anorexia and bulimia nervosa) and uncontrolled eating (binge eating and bulimia). To assess body image distortions, 3D figures of the patient's body are created and presented to the patient, thus enabling the patient to become aware of the body image distortion and to get a more realistic view of the body. To address uncontrolled eating, cue exposure to eating-related stimuli is used. VR environments simulate real-life situations and food cues that trigger disordered eating behavior. Clus et al. (2018) and De Carvalho et al. (2017) summarize the available information with respect to the usefulness of VR for the treatment of eating disorders, and both reviews are supportive of the potential usefulness of the realistic VR designs that have been developed for eating disorders.

3.5.1. Body image disturbance. VR worlds in therapy are used for two main goals: changing body image disturbance and binge eating. Riva et al. (2002) found, in females with binge eating disorder, that VR exposure for body image disturbance resulted in increased body satisfaction relative to CBT with an emphasis on psychonutrition. In a study by the same group (Cesa et al. 2013) in obese patients with binge eating disorders, the clinical efficacy of an enhanced CBT protocol, including a VR protocol, aimed at unlocking the negative memory of the body (VR-based CBT) was compared with the clinical efficacy of standard CBT and with standard inpatient usual care. In this VR-based body image protocol, changes to the perception of one's body are stimulated. This therapy involves reliving past experience in VR in the presence of a psychotherapist, thus enabling the patient to recognize cognitive errors in their perception of various situations and to interpret these situations in a different way. Only VR-based CBT was effective at improving weight loss at 1-year follow-up. Both VR-based CBT and standard CBT led to a reduction of monthly binge eating episodes up to 1 year follow-up. Thus, although the VR-based treatment was able to better prevent weight regain than did standard CBT, it did not succeed in better managing binge eating episodes. Marco et al. (2013) compared standard CBT with CBT plus VR to teach

patients the difference between actual body size and perceived body weight. The VR-augmented CBT was superior to standard CBT posttreatment and at 1-year follow-up with respect to bulimia symptoms and attitudes toward the body.

3.5.2. Cue exposure. In vivo cue exposure is an evidence-based treatment for eating disorders (Butler & Heimberg 2020). In VR cue exposure, therapy patients are repeatedly exposed to emotionally provoking eating-related situations. VR cue exposure may offer several advantages to in vivo exposure, including improved acceptance of treatment, more realistic VR eating environments than the therapist's office, and the gradual presentation of VR environments tailored to the anxiety hierarchy of the patient.

A study of Ferrer-García et al. (2017) investigated whether VR cue exposure therapy was effective in adults with bulimia nervosa and binge eating disorder who had insufficiently profited from structured evidence-based CBT for eating disorders. In this RCT, two conditions were compared after the unsuccessful CBT: (*a*) 6 sessions of additional CBT for eating disorders and (*b*) 6 sessions of VR cue exposure that aimed to habituate craving and anxiety responses to food-related cues to diminish the risk of overeating. Both treatments (VR cue exposure and additional CBT) improved with respect to episodes of binge eating and episodes of uncontrollable overeating, drive for thinness and body dissatisfaction, and food craving, but the VR cue exposure group reported significantly higher reductions in the number of binge eating episodes, in the number of overeating episodes, and in food craving than the additional-CBT group. These positive outcomes were maintained at 6-month follow-up (Ferrer-Garcia et al. 2019). Thus, the results of VR-based treatments are promising for patients with eating disorders. There is, however, a clear need to compare VR-based cue exposure with exposure in vivo to feared foods or body image.

3.6. Psychosis

The use of VR treatment in psychotic disorders is still in an early stage, and few RCTs have been conducted. We limit our discussion to RCTs that used 3D VR with an immersive head-mounted display in the VR group. Park et al. (2011) compared 10 sessions of social skills training using VR role-playing with social skills training using traditional role-playing in an RCT with 91 inpatients with schizophrenia between 18 and 45 years old. In the VR role-playing condition, participants engaged in role-play with virtual persons (avatars). Only VR social skills training enhanced the patients' motivation. Furthermore, both social skills trainings were effective, but the VR condition profited more from conversational skills, whereas the classical social skills training group showed a benefit in nonverbal skills.

Most people with psychotic disorders have paranoid ideation and are inclined to avoid people. CBT, including exposure to social situations, is an evidence-based psychological treatment for people with psychotic disorders, but the effects are limited. Moreover, exposure to social situations in real life cannot be controlled by the therapist, and a number of patients are unwilling to undergo exposure because of strong paranoid fears. Pot-Kolder et al. (2018) investigated whether these limitations could be overcome through VR CBT. They conducted an RCT with patients with a psychotic disorder to establish the effectiveness of 16 sessions of VR CBT ($n = 58$) compared with TAU ($n = 58$). On the basis of an individualized case formulation, VR exposure was conducted to social cues that elicited anxiety; paranoid thoughts; and avoidance (safety behaviors), including refraining from communication and avoiding eye contact with avatars. Interestingly, posttest and at 6-month follow-up, a large reduction was found in paranoid thoughts in the VR CBT group, whereas a slight increase was noted in the control group. Furthermore, use of safety behaviors decreased significantly in the VR CBT group up to 6 months follow-up, but not in the control

group. This is the first study in patients with a psychotic disorder that demonstrates that VR CBT strongly reduces paranoid ideation and avoidance in real-life social situations. There is a clear need for studies that compare the effectiveness of VR CBT with that of standard CBT.

A small pilot RCT was reported by Du Sert et al. (2018) in patients with schizophrenia with refractory auditory verbal hallucinations. Nineteen patients were randomly allocated to either a VR-assisted therapy (VRT) group or a TAU group whose treatment consisted of antipsychotic medication and regular meetings with clinicians. VRT consisted of seven sessions with dialogues with an idiosyncratic avatar that was created by the patient, thus enabling the patient to directly enter into dialogue with a virtual representation of their persecutory voices. The patient was encouraged by the therapist to enter into a dialogue with the avatar to improve emotional regulation and assertiveness. Over the course of therapy, the avatar's interaction with the patient became gradually less abusive. The results revealed that symptoms did not change in the TAU condition but that VRT produced significant improvements in the severity of auditory verbal hallucinations, depressive symptoms, and quality of life that lasted up to 3 months follow-up. Four patients, however, dropped out in the VRT condition, which renders the results difficult to interpret.

Although the results of the Du Sert et al. (2018) study suggest that VRT is a promising treatment for patients with schizophrenia with refractory auditory verbal hallucinations, RCTs involving larger samples of patients are needed to compare VRT with evidence-based CBT before this treatment can be implemented in clinical practice.

3.7. Autism Spectrum Disorders

ASD is a neurodevelopmental disorder characterized by impairment in social communication, social interaction, and cognitive functions (APA 2013). For two decades, researchers have investigated whether VR technology can help rehabilitate young people with ASD. A number of studies have investigated the usability and efficacy of various VR skills training interventions in the rehabilitation of individuals with ASD, including training of emotional skills, a variety of cognitive skills (e.g., attention, problem solving), social adaptation and communication skills, and daily living skills (e.g., shopping and street crossing), but the results are inconclusive (Mesa-Gresa et al. 2018). In a recent meta-analysis of Karami et al. (2020) based on 26 uncontrolled and 9 controlled studies, VR-based skills training was moderately effective. Training of daily living skills, however, was more effective than training of emotional skills, cognitive skills, and social and communication skills. Generally, the results of VR training were better for high-functioning ASD patients than for low-functioning ASD patients and for patients older than 8 years than for younger patients. The number of training sessions did not affect treatment effectiveness.

VR social cognition training in young adults with high-functioning autism led to improved emotion perception, attribution, and theory of mind (e.g., Didehbani et al. 2016, Kandalaft et al. 2013). One study examined whether VR-based social cognition training of young adults with high-functioning ASD led to a convergence between brain changes and behavioral changes (Yang et al. 2018). The results revealed brain-behavior changes in three specific brain regions linked to social perception, emotion recognition, and theory of mind: the right posterior superior temporal sulcus, the left inferior frontal gyrus, and the left superior parietal lobule. If replicated, this finding would provide evidence for the neuroplasticity of brain areas in patients with ASD as a result of VR social cognition training.

3.8. Attention Deficit Hyperactivity Disorder

The treatment of ADHD is primarily based on pharmacotherapy (e.g., methylphenidate, dextroamphetamine), as well as CBT or a combination of medication and CBT. CBT consists of

social skills training and cognitive rehabilitation. Cognitive remediation attempts to reduce the daily impact of cognitive deficits by improving cognitive functioning and has been found to be effective in children with ADHD (e.g., Van der Oord et al. 2014).

Many studies have investigated VR technology for improving behavioral and cognitive skills in children with ADHD, but few clinical RCTs have been reported (see Bashiri et al. 2017). Bioulac et al. (2020) investigated whether a VR-based cognitive remediation program was effective in children with ADHD. In an RCT, children with ADHD were assigned to cognitive remediation delivered in a virtual classroom ($n = 16$), to pharmacotherapy (methylphenidate) ($n = 16$), or to psychotherapy ($n = 19$). After therapy by cognitive remediation in VR, children exhibited significantly higher numbers of correct hits on the virtual classroom test and on the CPT, and the results were comparable to those from the pharmacotherapy condition. However, children in the virtual classroom cognitive remediation group did not improve on behavioral ratings for ADHD.

4. FUTURE DIRECTIONS

Initially designed for the treatment of specific phobias, VR worlds have also been designed for the treatment of other anxiety disorders, PTSD, substance-related disorders, eating disorders, psychosis, ADHD, and ASD. The central mechanism in the interventions for these various disorders is, for most of these disorders, exposure to relevant situations that trigger the specific problems related to these disorders. In some disorders (e.g., autism spectrum, ADHD, psychosis), social and cognitive skills training with avatars in VR environments is also a common element.

An important aspect of VR research is the acceptability of VR assessment and treatment by both clinicians and patients. Many clinicians are reluctant to use VR in treating patients; specifically, such clinicians are afraid that the working alliance may be impaired in VR therapy because patients wear head-mounted displays, thus preventing eye contact (Meyerbröker & Emmelkamp 2008). A few studies, however, found that VR therapy does not necessarily negatively affect the therapeutic relationship. In a study of Ngai et al. (2015), no difference was found in the level of the working alliance between VRET and exposure group therapy. In a study by Wrzesien et al. (2013), the therapeutic alliance was not negatively influenced by the use of VR technology.

Other concerns of clinicians are that patients in VR therapy will drop out because the VR worlds may be experienced as unrealistic and not relevant for the patients' problems and that their problems may become even worse. In a recent meta-analysis of attrition in VRET for anxiety disorders, Benbow & Anderson (2019) compared attrition in VRET and in exposure in vivo for anxiety disorders. The authors concluded that the results of these trials suggest that attrition rates are not lower in VRET than in exposure in vivo. Future studies should investigate whether attrition in VR treatment is a problem in other disorders.

But what about the negative effects of VR treatment? A recent study (Fernandez-Alvarez et al. 2019) investigated the deterioration rates of VR in retrieved data sets from 15 published RCTs for anxiety disorders. Deterioration was established with the Reliable Change Index (Jacobson et al. 1984). The overall results showed that deterioration rates for VR therapy were comparable to other therapeutic approaches and that the deterioration rate was lower for patients treated with VR therapy than for patients in waiting-list control groups. The results for deterioration after VR therapy in other mental disorders have not been systematically reviewed, so there is a clear need for studies into potential deterioration in disorders other than anxiety disorders.

A few studies have addressed the acceptability of VR for patients. Garcia-Palacios et al. (2007) tested the willingness to undergo either virtual exposure or exposure in vivo. The acceptability of VR exposure was comparable to that of traditional exposure therapy. In a study of Quero et al. (2014), the acceptability of VR interoceptive exposure was compared with traditional interoceptive exposure. The VR intervention was evaluated as positively as the traditional interoceptive

exposure condition. However, at 3-month follow-up, participants who had received the traditional interoceptive exposure reported being more satisfied than the participants who had received the virtual interoceptive exposure.

One criticism that can be applied to all of the studies discussed in this review is that none of the studies adapted the virtual environments to the sociocultural context of more diverse groups. Despite the success of various VR treatments in mental health, the question remains, how effective is the use of these scenarios when they do not resemble the sociocultural context? This is an important limitation for therapists in less developed countries, as such therapists are often forced to use generic foreign environments that do not resemble local settings. The inclusion of culturally relevant elements in virtual environments can increase the effectiveness of these procedures since such elements are more familiar and offer the patient a greater sensation of presence. As a first step, in a study in the Dominican Republic, 300 participants with symptoms of agoraphobia were interviewed, and VR scenarios were created on the basis of the information obtained (Garcia-Batista et al. 2020). The result was four scenarios with anxiety-increasing parameters relevant for the population of the Dominican Republic. While this is a first step into more socioculturally diverse environments, their efficacy has yet to be demonstrated, and future studies should address this issue in other cultures.

One limitation related to the lack of dissemination of VR in clinical practice is the economic cost of VR (Segal et al. 2011). VR devices are becoming increasingly available, and the rapid development of VR technologies significantly reduces the cost of VR hardware, thus enabling the use of VR applications in the public mental health care sector. Unlike the case 20 years ago, a full set of VR equipment (one computer, one head-mounted display, and one motion-sensing input set) can be bought for less than $1,500 (Riboni et al. 2020). In addition, however, there are considerable costs involved in creating new 3D VR worlds. For most disorders discussed in this article, VR worlds are available on the market, but the prices for use by individual therapists are high.

Most studies of assessment and treatment of the mental health problems discussed in this review employ VR systems with immersive headsets. An increasing number of studies use computer-generated 3D scenes. For the technical differences between immersive VR and computer-generated 3D scenes, see Cipresso et al. (2018). There is a clear need to compare the effectiveness of VRET using immersive headsets with that of VRET using computer-generated 3D scenes in patients with mental disorders. One issue to be investigated is whether the presence in the VR world, defined as the feeling of "being there," is comparable in VRET using headsets and VRET using 3D images. If VRET using 3D scenes is as effective as VRET using headsets, VRET using 3D scenes will likely be more used by clinicians since that setup is easier to use in the office.

SUMMARY POINTS

1. The most evidence regarding the use of virtual reality exposure therapy is available for specific phobias, social anxiety disorder, and panic disorder with agoraphobia. Head-to-head comparisons of virtual reality exposure therapy with evidence-based cognitive behavioral interventions rarely reveal one approach to be superior to any other.
2. There is hardly any research published into the effects of virtual reality therapy in generalized anxiety disorder and obsessive-compulsive disorder.
3. Research into virtual reality exposure therapy and posttraumatic stress disorder (PTSD) is limited to veterans and active duty soldiers with PTSD; very few studies have been

published regarding the effects of virtual reality exposure on individuals with PTSD from other traumas.

4. There is increasing evidence that virtual reality cue exposure therapy is effective in addiction and eating disorders.
5. Studies into the use of virtual reality therapy in autism spectrum disorder, attention deficit hyperactivity disorder, and paranoid psychosis are promising.

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Errata

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