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COMPREHENSIVE REVIEW

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The use of virtual reality in assessment and treatment of anxiety and related disorders

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Abstract

In recent years the development of new virtual environments has been qualitatively high and fast at the same time, but the dissemination of virtual reality (VR) in clinical practice is still scarce. The aim of this review is to give an insight into the state of the art of the use of VR as an assessment tool and treatment intervention in anxiety and related disorders as posttraumatic stress disorder and obsessive–compulsive disorders.

Besides an overview into the efficacy of VR, a summary will be given on assumed working mechanisms in virtual reality exposure therapy and how this aligns with current theoretical models. Further, it will be discussed how VR is accepted by patients and research into the reluctance of therapist to use this technology during treatment with focus on the therapeutic alliance and how it may be influenced by the use of VR. Finally, we discuss clinical and future issues as, for example, dissemination into clinical practice and what VR has to offer therapists in future. This not only in adult population but as well in younger patients, as young adolescents VR has a great potential as it connects easily with its playful elements to this population and might be a low threshold step to offer treatment or preventive interventions.

KEYWORDS
anxiety disorders, OCD, PTSD, virtual reality, virtual reality exposure

1 | INTRODUCTION

Exposure therapy involves exposing the patient to feared stimuli and is the treatment of choice in the majority of anxiety and related disorders (National Institute for Health and Clinical Excellence, 2011). Virtual reality exposure therapy (VRET) can be categorized as a modern variant of exposure therapy designed to simulate naturalistic environments wherein patients are exposed to their idiosyncratic fear. Given its unlimited technological possibilities, VRET offers the therapist a pallet of options to provide individual tailored exposure treatment. The use of VRET in anxiety and related disorders has been one of first technological agents introduced in the therapist's office. Its efficacy has been studied extensively (e.g., Carl et al., 2019; Wechsler et al., 2019), including its generalizability to the real world (Morina, Ijntema, et al., 2015).

The dominant theory in explaining the effects of exposure therapy has been the Emotional Processing Theory (Foa & Kozak, 1986). However, in recent years the effects of exposure therapy have been explained in terms of the inhibitory learning model (Craske et al., 2014). Although underlying mechanisms of VRET are still not

well understood (Scheveneels et al., 2019), parallels in temporal precedence between VRET and exposure in vivo have been found (Meyerbroeker et al., 2013).

The aim of this literature overview is to provide the reader with the current evidence for VR as an assessment and treatment tool in anxiety and related disorders. We will further focus on implications for future research and clinical practice.

Key Practitioner Message

- Virtual reality exposure therapy is effective in most anxiety disorders
- Virtual reality as an assessment tool offers potential as a research paradigm
- Virtual reality exposure working mechanisms are not yet investigated well
- Cost-effectiveness of VR in clinical practice is not well established yet

2 | ASSESSMENT

VR offers a high potential in ecological validity and controlled real life experiences (Bell et al., 2020). Furthermore, consumer and commercial VR has been available for a long time now (Riva & Serino, 2020). Nonetheless, empirical findings about VR as an assessment tool are still scarce. Most of the available research into the assessment of anxiety disorders with VR has been conducted with social anxiety disorder (SAD), posttraumatic stress disorder (PTSD) and obsessive–compulsive disorder (OCD). For a more extensive overview in other disorders see Emmelkamp and Meyerbröker (2021).

2.1 | Social anxiety disorder

Research investigating whether VR can be used as a reliable and valid assessment tool in SAD and fear of public speaking has produced rather inconclusive results. This might be due to the racing technological development in recent years. While in earlier years spontaneous interaction between the patient and an avatar (virtual person in VR) were not possible due to pre-programmed speech sequences of the avatars, more recently spontaneous interaction in VR were made possible by developing interactive avatars.

Several studies have concluded that virtual social environments can be effectively modified for therapeutic purposes (Felnhofer et al., 2019; Hartanto et al., 2014; H. Kim et al., 2018; Kishimoto & Ding, 2019; Lange & Pauli, 2019). For example, Kim et al. (2018) instructed 79 individuals with SAD and 51 healthy control participant to give impromptu speeches on self-related topics to a virtual audience and reported that participants with SAD showed less eye gaze towards the audience than healthy controls. Lange and Pauli (2019) examined avoidance behaviour in 50 individuals with high versus low social anxiety and concluded that avoidance behaviour when bypassing virtual humans with neutral and angry facial expressions is modulated by the emotional facial expressions of virtual bystanders and that social anxiety generally amplifies avoidance.

Research has also investigated the use of verbal interactions between individuals with high anxiety levels and virtual humans. In a pilot study with healthy participants, it was found that real time conversations operated by the therapist in VR can elicit fear (Powers et al., 2013). Our group has applied a virtual reality system specifically designed to expose clients with social anxiety to anxiety provoking verbal social situations. In a study, we found that two sessions of virtual exposure involving several free speech dialogues with avatars prearranged by the therapist could induce significant levels of social anxiety in university students with elevated social anxiety (Morina, Brinkman, et al., 2015). In a more recent study, we investigated whether a VR behavioural avoidance test (BAT) would predict social anxiety in daily life (Kampmann et al., 2018). In particular, we investigated the value of maximum anxiety levels during in vivo and virtual reality behavioural assessment tasks (BATs) in predicting daily social anxiety relative to self-report measures. It was found that neither in vivo nor VR BATs better predicted complaints of social anxiety than self-report questionnaires.

Other studies have investigated potential physiological differences between virtual reality BAT and in vivo BAT (Dechant et al., 2017; Kothgassner et al., 2016; Owens & Beidel, 2015; Scheveneels et al., 2019). The findings indicate that asking individuals with and without SAD to give a presentation in front of a virtual audience versus a real audience leads to similar significant increases in physiological outcomes, such as salivary cortisol, cardiovascular or electrodermal activity (Kothgassner et al., 2016; Owens & Beidel, 2015). This applied both to normal participants and individuals with SAD. There is some preliminary evidence that assessing physiological outcomes while being confronted with feared virtual environments may have diagnostic validity (Scheveneels et al., 2019).

In sum, VR has the potential to function as an ecological valid assessment instrument. However, future research needs to further examine its potential additional value above self-report questionnaires.

2.2 | Posttraumatic stress disorder

Even though patients with PTSD are known to be highly avoidant of trauma related stimuli, research into VR as an assessment tool is scarce. In one study conducted with veterans, it was investigated whether avoidant behaviour on an avatar task predicts PTSD severity (Myers et al., 2016). In this study, the patient directed an avatar confronted with elements potentially triggering his symptoms. A strong correlation between PTSD symptom burden and the ability to predict PTSD symptom burden based on demographic variables (age, sex and combat exposure) was significantly improved by adding the task score as a predictor. The authors concluded that virtual environments have the potential for more objective assessment of PTSD symptoms, compared with symptom self-report which have been associated with over- or underreport of

symptoms in veterans. In PTSD research, VR has been used as a prediction tool for the development of PTSD symptoms in veterans as well, for an overview see Bourla et al. (2018). Furthermore, VR has also been applied as an experimental psychopathology model to study trauma-related symptoms among healthy participants. Several studies provide evidence that VR can successfully elicit negative affect and induction-related symptoms (e.g., Cuperus et al., 2017; Dibbets, 2020; Dibbets & Schulte-Ostermann, 2015; Meyer et al., n.d.). The aim in these studies is to assess relevant cognitive, behavioural and physiological processes involved in stress-related symptoms, aiming at increasing our knowledge about PTSD by modelling processes related to trauma exposure.

2.3 | Obsessive–compulsive disorder

In OCD, several studies have investigated the feasibility of VR as an assessment instrument, mainly focusing on evoking fear of contamination and control behaviours. Objective behavioural indices have been used to study OCD behaviour in a daily environment (e.g., house and office) to assess how individuals engage in OCD relevant tasks (Kim et al., 2010). The VR task included measures of checking behaviour (i.e., frequency and gaze duration) and time spent gazing at relevant OCD stimuli. It was found that these measures differentiated well between healthy individuals and those with OCD. A study elaborating on these findings by the same group (Kim et al., 2012) investigated whether the VR environment could discriminate OCD patients with checking behaviours from those without checking behaviours. The authors concluded that patients with checking behaviour showed a higher checking frequency and spent more time on checking and more time on gazing in the VR environment. This is in line with a pilot study done by another group, wherein a virtual video game environment (i.e., a house with different OCD provoking situations as, e.g., a burning gas stove) was used to provoke more OCD symptoms in OCD patients in comparison to healthy controls (van Bennekom et al., 2017). The study was replicated in another small sample by the same group (van Bennekom et al., 2021). No relation was found between arousal and emotions during the VR game and the severity measure of OCD. The authors concluded that their gaming environment has the potential to objectify and standardize OCD diagnosis. In a study focusing more on individuals with fear of contamination, a subtype of OCD, it was investigated whether the VR environment could evoke anxiety symptoms (Laforest, Bouchard, Crétu, et al., 2016). 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 virtually 'touch' walls and the toilet seat each time with their hands. It was found that exposure to a more contaminated virtual environment resulted in higher levels of anxiety on self-report and physiological measures in the OCD group relative to individuals without fear of contamination.

In sum, it has been found that VR has potential in diagnostic validity, including discrimination between subtypes of OCD (e.g., fear of contamination). Yet, future research needs to further examine several basic assessment criteria: usability; utility (i.e., what us the additional value of a technological contribution), and satisfaction and reliability (including accuracy, effectiveness, and efficiency) (for an overview see Ferreri et al., 2019). Other relevant developmental possibilities concern for example enhancing the sense of presence by using rubber hands in fear of contamination (Jalal et al., 2020).

3 | TREATMENT

Several clinical trials have assessed the efficacy of VRET for patients with specific phobias, SAD, agoraphobia and panic disorder, generalized anxiety disorder (GAD), and PTSD, and OCD.

3.1 | Specific phobias

Specific phobias can be subdivided into different categories such as situational phobias (e.g. fear of flying) or small animals (e.g., spider phobia) (American Psychiatric Association, (APA), 2013). We will limit this overview to the clinically most relevant phobias as acrophobia and fear of flying for which several RCT's have been conducted. 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 were an exact copy of the surroundings for the exposure in vivo (i.e., fire escape stairs). VRET was found to be as effective as exposure in vivo on anxiety and avoidance self-report measures and a behavioural avoidance test. Results were maintained at 6-month follow-up. In another study, a randomized crossover design was used to investigate whether cognitive coping statements would enhance the effects of VRET (Krijn, Emmelkamp, Ólafsson, Schuemie, & Van Der Mast, 2007). Twenty-six patients with acrophobia were randomly assigned to either two sessions of VRET followed by two sessions of VRET + coping statements or two sessions of VRET + coping statements followed by two sessions of VRET. The authors concluded that coping statements had no additional value above VRET.

In a more recent trial that combined VR with a smartphone application (Donker et al., 2019), participants with acrophobia were randomly assigned to either a self-guided app-based VR intervention using cardboard VR goggles or a waiting list control condition. A total of six animated VR CBT modules and a gamified VR environment were made accessible during a 3-week period. A total of 193 participants were randomly assigned to either the intervention group ($n = 96$) or a control group ($n = 97$). Intent-to-treat analyses showed a significant reduction of acrophobia symptoms after treatment and at 3-month follow-up.

Another RCT was investigated whether effects of VRET in patients with acrophobia or fear of flying could be enhanced by pharmacological agents (Meyerbröker et al., 2018). Patients were randomly assigned to either VRET plus yohimbine hydrochloride, VRET plus propranolol, or VRET plus a placebo. It was found that 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.

Research into the efficacy of VRET in fear of flying has been done in comparison with different control conditions. In the first trials, it was found that VRET for fear of flying was more effective than bibliotherapy, relaxation and exposure in vitro (Maltby et al., 2002; Mühlberger et al., 2001). The long-term effects were maintained up to 3 years after treatment (Mühlberger et al., 2006; Wiederhold & Wiederhold, 2003). In other trials, VRET was compared to cognitive therapy (Krijn, Emmelkamp, Ólafsson, Bouwman, et al., 2007) and exposure in vivo (Rothbaum et al., 2000; Rothbaum et al., 2006). It was found across studies that VRET was as effective as exposure in vivo and that its effects generalized to the real world (Morina, Ijntema, et al., 2015). VRET for fear of flying offers some advantages over exposure in vivo. Along treatment efficacy VRET for fear of flying represents a more sustainable therapy as it can be conducted without having to actually fly (Meyerbröker, 2014).

3.2 | Social anxiety disorder

Several controlled trials have examined treatment efficacy in SAD (see Emmelkamp et al., 2020 for an overview of research into different aspects of SAD). The first trial was conducted by Klinger et al. (2005) who divided and matched 36 patients with SAD into two groups based on gender, age, duration, SAD severity and ability to use computers. The examination of a 12 sessions virtual exposure to diverse social situations relative to a 12 sessions group cognitive behaviour therapy revealed both treatments were similarly effective. More recently, four RCTS have investigated VRET in socially anxious patients, including speech anxiety. Bouchard et al. (2011) compared two variants of CBT plus exposure with waiting list control: (a) CBT plus exposure in vivo and (b) CBT plus exposure in virtuo. Both variants of CBT were clearly more effective than the control condition and no differences were found in effects of CBT plus exposure in vivo and CBT plus exposure in virtuo. However, results are difficult to interpret, given that the exposure variants were mixed with other CBT exercises. Since then, three RCTs applying VRET alone or in combination with cognitive components have been conducted (Anderson et al., 2013; Bouchard et al., 2011; Kampmann et al., 2016).

Bouchard et al. (2011) compared CBT plus VRET ($n = 17$) and CBT plus in vivo exposure ($n = 22$) to a wait-list condition ($n = 20$). Both active treatments were more effective than wait-list and results indicated that CBT plus VRET was more effective than CBT plus in vivo exposure. The results were similar at the 6-month follow-up. It must be noted, however, that in this trial the therapist discussed exposure exercises with the patient while being in the same room, which may have confounded the results. Furthermore, given the combination of cognitive restructuring and VRET, the effects of pure VRET cannot be isolated. Anderson et al. (2013) randomly assigned patients with SAD to 8 weeks of VRET ($n = 30$) or exposure group therapy ($n = 39$) or wait-list control ($n = 28$). A substantial number of participants had fear of public speaking as their main complaint. Both treatments involved cognitive components addressing self-focused attention, negative perception of self and others, rumination, perception of negative emotion regulation and unrealistic goal settings in social situations. Treatment efficacy was re-assessed among 28 out of the original sample of 65 patients 4 to 6 years after treatment and the majority of patients reported significant improvements (Anderson et al., 2017; Richards et al., 2016).

Our group (Kampmann et al., 2016) conducted the first trial with patients with generalized SAD using pure VRET without any cognitive intervention ($n = 20$) and compared this to individual exposure in vivo without any cognitive intervention ($n = 20$) and a wait-list control group ($n = 20$). Furthermore, this was the first trial to apply a variety of complex virtual social interactions (e.g., buying and returning clothes, talking to a stranger or attending a job interview), which were controlled by the therapist sitting in a separate room. Both active treatments were more effective than the wait-list control group on 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, VRET as a standalone therapy consisting of extensive verbal interaction only was effective in reducing complaints of generalized SAD, yet it was less effective than exposure in vivo.

Altogether, existing trials suggest that VRET for SAD is effective. However, more clinical trials on the efficacy of VRET for SAD are clearly needed.

3.3 | Agoraphobia and panic disorder

In the treatment of panic disorder and agoraphobia, VR provides an excellent opportunity to mimic different daily life situations. Although this prospect seems obvious, existing research into the efficacy of VRET in panic disorder and agoraphobia has been limited, and dissemination into clinical practice is not seen often.

In a first study with patients with panic disorder VRET was compared to exposure in vivo in weekly treatment consisting of nine sessions (Botella et al., 2007). It was found that VRET was superior to the waiting list control group, but that effects for VRET were comparable to those in exposure in vivo and were maintained at 12-month follow up. In another study VRET was compared to CBT in an 11 session treatment (Penate et al., 2008). At post-treatment participants were asked to do a behavioural avoidance test, wherein patients were asked to walk on a common street. Results showed that effects of CBT and VRET were comparable, showing a significant decrease on panic measures. In another RCT, 92 patients with panic disorder and agoraphobia were randomized to receive either CBT or VRET (Pelissolo et al., 2012). Moderate response rates to treatment were found in both groups, without any significant difference between-groups. The results were stable at 9-month follow-up. In another RCT, our group combined VRET with cognitive interventions and compared to cognitive interventions and exposure in vivo or a waiting list control condition (Meyerbroeker et al., 2013). It was found that cognitive interventions plus VRET or exposure in vivo were superior to waiting list control condition, but on three of the four outcome measures effects found were equally effective between in vivo or VRET. In a small RCT, the additional effect of cognitive therapy added to VRET

was investigated (Malbos et al., 2013) and no additional value of cognitive therapy was found.

Taken together, VRET seems to be a suitable treatment for patients with panic disorder and agoraphobia (Wechsler et al., 2019), but dissemination is not easy in times that generalization and distribution of virtual environments remains a costly issue.

3.4 | Generalized anxiety disorder

Different strategies have been applied to use VR techniques in the treatment of GAD (see e.g., Wang et al., 2019). Not all of these treatment approaches are in line with international treatment guidelines (NICE, 2013), nor do they make use of standardized research procedures or relevant clinical measures.

In a first study VRET was combined with a mobile device giving biofeedback in comparison with a waiting list control group (Gorini & Riva, 2008). In this small trial participants entered a relaxing and peaceful virtual environment (e.g., a beach or a park), where they could relax. After the relaxation phase participants were exposed to their idiosyncratic stressor in words and had to rate their anxiety. It was found that both groups improved compared to baseline, but no differences between the groups were found. These results are in line with another study wherein VR was used as a relaxation method in combination with a mindfulness skills training (Navarro-Haro et al., 2019). In this study mindfulness group training was compared with mindfulness training plus VR training in mindfulness in reducing GAD symptoms. It was found that both groups improved significantly on GAD measures, but only the VR group showed a better treatment adherence.

In a small pilot study, 24 patients with GAD were randomized to (a) the VR and mobile group, including a biofeedback-assisted relaxation programme; (b) the VR and mobile group without biofeedback; or (c) a waiting-list control group (Repetto et al., 2013). A clinical protocol for the treatment of GAD based on the use of a biofeedback-enhanced VR system was investigated. 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 idiosyncratic stressful fears. Although both active treatment groups experienced a significant decrease on general anxiety symptoms, no difference was found between conditions.

In a different approach to treat GAD, it was investigated whether the engagement in aerobic exercise would lead to stress reduction and therefore to the presence of less GAD symptoms (Wang et al., 2020). In this study 77 patients with GAD were randomly assigned to either to virtual nature group or a virtual abstract painting group. In the virtual nature a 20-min moderate to high intensity aerobic exercise was done. Results on psychophysiological and self-report measures showed that the virtual nature group compared to the virtual abstract painting group showed higher levels of stress reduction and personal satisfaction. The authors conclude that a virtual exercise is more effective in inducing relaxing effects in patients with GAD.

In within-subjects design it was investigated whether patients with GAD, who were first exposed to a neutral non-catastrophic scenario and then to a personalized scenario in imagination or a standardized virtual scenario, all presented in a counter-balanced order (Guitard et al., 2019). It was found that the standardized virtual reality scenario evoked as much anxiety as the personalized scenario in imagination. The authors conclude that the standardized VR scenario can be used in therapy and that the findings were not attributable to general negative effect but GAD anxiety specific.

In sum, there are interesting approaches into the treatment of GAD, but none of these studies has proven the additional value of VR in the treatment of GAD. The last study (Guitard et al., 2019) seems to be a promising approach, but further efficacy trials are needed.

3.5 | Posttraumatic stress disorder

Rothbaum et al. (2001) conducted the first examination of the efficacy of VRET for PTSD in an open clinical trial with 16 male Vietnam veterans in the US. VRET consisted of an average of 13 exposure therapy sessions, following which patients reported a significant reduction in PTSD. Since then, several RCTs have compared the efficacy of VRET for PTSD, with most of them using exposure therapy as an active control condition (McLay et al., 2011, McLay et al., 2017; Reger et al., 2016; Roy et al., 2014), whereas one RCT compared VRET to present-centred therapy. All of the trials comparing VRET to an active condition were conducted with military personnel. The findings do not suggest any significant differences between VRET and exposure therapy (McLay et al., 2011, McLay et al., 2017; Reger et al., 2016; Roy et al., 2014). The comparison of VRET to present-centred therapy also indicated that VRET is effective in treating PTSD, without any significant difference between the two active conditions (Ready et al., 2010).

A number of RCTs compared the efficacy of VRET to wait-list among military personnel (Gamito et al., 2010; Miyahira et al., 2012; Reger et al., 2016) or civilians and disaster workers exposed to 9/11 terrorist attacks (Difede et al., 2007). These trials revealed that VRET is significantly more effective in reducing PTSD symptoms than wait-list control conditions.

Altogether, current research on VRET for PTSD suggests that VRET can successfully reduce PTSD symptoms. It must be noted, however, that the findings must be interpreted with great caution because only two of the trials included more than 10 participants in the VRET condition (McLay et al., 2017; Reger et al., 2016, with 36 and 30 participants in the VRET condition at post-treatment, respectively). To that effect, more trials with larger samples are needed. Furthermore, future research needs to investigate potential benefits of VRET over other available efficacious treatments.

3.6 | Obsessive–compulsive disorder

In a pilot study with OCD patients with fear of contamination, a 12 session VR exposure and response prevention (ERP) treatment was given (Laforest, Bouchard, Bossé, et al., 2016). A single-case design was used to analyse the data of three patients exposed to two different virtual environments (one neutral training environment and a contaminated OCD environment). Data of a time series analyses showed significant symptom reduction in all patients.

After this first promising pilot study, only two other trials into the efficacy of VR ERP have been published. The first concerns a nonclinical trial with participants ($n = 21$) with high fear of contamination, who received three sessions of VR ERP (Inozu et al., 2020). It was shown that participants experienced less anxiety and disgust and a reduced urge to wash their hands in comparison with healthy controls. In another study with OCD patients, the use of rubber hands to simulate contamination with a patient's own hands were investigated (Jalal et al., 2020). In this trial participants watched a visible fake hand that was mimicked with their invisible real hand, simulation exposure to that their hand was contaminated with fake faeces. Patients ($n = 29$) were randomly assigned to either synchronously manipulation or asynchronously. It was found that after 5 min of tactile stimulation of the hand no differences between groups were found, indicating an increased facial disgust, increased anxiety and handwashing urges.

To sum up, it is surprising that despite a chronic course of the disorder, almost no studies into the efficacy of VR ERP can be found. Although, different OCD themes (e.g., control, contamination, etc.) make different environments necessary to apply broad ERP, these themes seem to be universal (Hunt, 2020). Whether virtual environments specifically need to incorporate all idiosyncratic fears of patients remains unclear (Meyerbröker, 2014), however, the efficacy of VR ERP still needs to be demonstrated.

4 | WORKING MECHANISMS OF VIRTUAL REALITY EXPOSURE THERAPY

In this section, the theoretical assumptions of exposure therapy and how they align with findings within VR research will be discussed. In general, research into the working mechanisms of change underlying VRET has been scarce.

It has been assumed that the effects of VRET are driven by the same underlying cognitive and emotional mechanisms as exposure in vivo. Currently, the most influential theoretical model on explaining the effects of exposure therapy for anxiety disorders is the inhibitory learning model (Craske et al., 2014). However, according to the inhibitory learning model, patients learn in exposure therapy that their feared negative outcomes cannot occur or will not have the same consequences as in real life. For instance, a patient with OCD will know that touching a virtual contaminated toilet can lead to disgust, but not to actual contamination. In fact, a large number of feared negative outcomes often reported by patients with anxiety disorders cannot occur in VRET. Therefore, it can be questioned if the effects found in VRET can be fully explained by the inhibitory learning model.

In a recent study into the working mechanisms of VRET, it was found that treatment effects were not predicted by the extent to which participants could test and evaluate their expectancies of an exposure task (Scheveneels et al., 2019). This remains the only study to date, which investigated the effects of VRET and how these align to the inhibitory learning model.

In earlier studies, the effects of VRET were investigated in terms of the Emotional Processing Theory (EPT), which posits three basic assumptions (Foa & Kozak, 1986). According to the EPT, first activation of the anxiety network has to take place, before within- and between session habituation can occur. In VRET results with patients with fear of heights (Emmelkamp et al., 2002), panic disorder and agoraphobia (Meyerbroeker et al., 2013), and PTSD (Reger et al., 2019) have been compared to exposure in vivo and prolonged exposure. In fear of heights, the authors found that subjective units of distress (SUDS) during VR exposure and exposure in vivo showed that patients were basically experiencing the same reactions: anxiety first increased during exposure and then steadily decreased across sessions. The authors concluded that generally the overall anxiety level experienced during VR exposure, was lower than the anxiety experienced during exposure in vivo, but this did not affect efficacy. This is comparable with the results found in panic disorder and agoraphobia and PTSD and prolonged exposure. No differences between the VRET and (prolonged) exposure (in vivo) group were found on average and peak SUDS and relevant outcome measures.

Besides the EPT and the inhibitory learning model, other cognitive and emotional processes such as self-efficacy have been investigated. Self-efficacy refers to the concept of trust into one's own capacity to successful execute a relevant behaviour (Bandura, 1977). Several studies have investigated cognitive and emotional mechanisms involved in VRET. Both in SAD (Kampmann et al., 2019) and in specific phobias (Meyerbröker & Emmelkamp, 2008) it was found that self-efficacy increases during VRET. Self-efficacy was significantly associated with treatment outcome, but these changes did not significantly predict symptom improvement (Kampmann et al., 2019).

In a study using VRET as exposure method in 28 patients with spider phobia, it was found that changes in perceived self-efficacy and dysfunctional beliefs were the best predictor of change in general outcome measures (Côté & Bouchard, 2009). Findings indicate that eventually a sense of mastery is an important element accounting for the effects of VRET. A study done by the same group (Tardif et al., 2019) revealed that among patients with spider phobia changes in their beliefs about spiders and in perceived self-efficacy significantly predicted the reduction in fear after VR treatment.

In sum, it can be concluded that self-efficacy plays an important role in VRET, possibly by breaking an avoidance behaviour pattern and increasing the belief about one's own capacity and maybe thereby the motivation in patients to go further in the process of exposure.

However, more research into the mechanisms of change in VRET is clearly warranted, given that the effects of VRET do not align with theoretical models.

5 | CLINICAL PRACTICE

With respect to clinical practice, there are some reoccurring issues concerning both the patients and the therapists. Difficulties on how to engage patients to use VR for therapeutic reasons relate to patients' distrust in technology or avoidance tendencies. On the other hand, some therapists are concerned that the use of VR might diminish the therapeutic relationship. In our experience, most patients are willing to at least give VRET a try. This helps them to get familiar with the advantages of VR therapy. In recent years, the equipment for VR treatment has become much lighter and easily applicable. In a first study done already in 2007 (Garcia-Palacios et al., 2007) patients willingness to undergo VRET or exposure in vivo was compared in patients with specific phobias. The authors conclude that the acceptability of VRET was comparable to exposure in vivo. In another study the acceptability of VR interoceptive exposure was compared to traditional interoceptive exposure in patients with panic disorder (Quero et al., 2014). Although the VR interoceptive exposure was evaluated as positively as traditional interoceptive exposure at post-treatment, at 3 month follow-up patients who had received VR interoceptive exposure were less satisfied than patients who had received traditional interoceptive exposure.

While in the past decennia there have been enormous improvements of virtual environments, it has not been observed that patients experienced significantly more emotional involvement by a higher sense of presence. As a consequence, it can be concluded that making virtual environments more realistic does not necessarily increase the sense of presence and emotional involvement. Altogether, it seems sufficient that a virtual environment generally contains the anxiety specific triggers for a disorder to enhance the sense of presence in patients. This is often enhanced when a certain level of interaction is possible in the virtual environment. Comparing attrition rates between VRET and exposure in vivo, it has been found in a meta-analysis (Benbow & Anderson, 2019) that in anxiety disorders these attrition rates are comparable.

With respect to the concern raised by some therapists that VRET might interfere with the therapeutic alliance, we would like to point out that VR therapy can of course be only partially used. This enables the therapist to test the extent to which VR therapy interferes with the therapeutic alliance. More importantly, several studies have investigated the working alliance during VRET. In a study by Wrzesien and colleagues (Wrzesien et al., 2013) no negative influence of VR was found on the therapeutic alliance. In another study, a direct comparison between VRET and exposure in vivo was made and no differences in evaluation of the therapeutic alliance were found (Ngai et al., 2015).

In conclusion, there is evidence that restraint in using VR in a therapeutic context, is not supported by empirical evidence. In fact, there is evidence that it produces comparable therapeutic effects when adequately personalized to a patient's anxiety.

6 | FUTURE DIRECTIONS

Virtual reality provides clinicians with an enormous potential of possibilities for therapeutic use and researchers with the option to make use of highly standardized exposure procedures. There are a few important aspects concerning the use of VR in the future. One aspect that has been barely investigated is the use of VR in children and adolescents within the therapeutic context. VRET is a potentially fruitful approach to exposure, and particularly in adolescents, given its low barriers and playful elements. Connecting with the technological driven environment of adolescents, VRET is assumed to have a high potential to improve treatment, early intervention and prevention in this population. However, despite its potential in adolescents, high-quality research on the effectiveness of VRET in this group is scarce (Kothgassner & Felnhofer, 2020). There is only one study in adolescents (13–16 years) with fear of public speaking (Kahlon et al., 2019), that found that symptoms decreased significantly and that treatment effects were maintained at 1 and 3 month follow up. One of the limitations of the study is that it did not include an adequate control condition. In conclusion, whereas VRET seems a promising treatment for adolescents with SAD, there is a compelling need for high-quality research into its efficacy this younger population.

One of the potentials but also pitfalls of VR is the proliferation of different health technology companies offering different functionalities within their commercial packages. Often these packages have been developed by technicians and they miss the important functionality as interaction or specific anxiety triggers. Large differences in quality of therapeutical use and functionality are all presented as virtual reality. Often it only concerns 360° video's with no potential for the therapist to give direction to the intervention and no potential for the patient to interact. When applications are provided with functionalities like these, developmental and economic costs increase enormously and this is not always evident for clinicians as is always indicated that the economic costs of VR hardware are being significantly reduced. This is one of the potential obstacles concerning the slow going dissemination of VR in clinical practice. Although the costs for the hardware have been significantly reduced in the past decennia and a VR computer set and VR goggles and one motion-sensing device are available for less than $1.500 (Vailati Riboni et al., 2020) the costs are mainly in developing and creating adequate VR environments and functionality. These costs may be one of reasons why dissemination of VR in clinical practice is still going slow (Segal et al., 2011).

CONFLICT OF INTEREST

Both authors declare to have no conflict of interest by the publication of this manuscript.

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REFERENCES

American Psychiatric Association, (APA), (2013). Diagnostic and statistical manual of mental disorders: DSM-5.

Anderson, P. L., Edwards, S. M., & Goodnight, J. R. (2017). Virtual reality and exposure group therapy for social anxiety disorder: Results from a 4–6 year follow-up. *Cognitive Therapy and Research*, *41*(2), 230–236. https://doi.org/10.1007/s10608-016-9820-y

Anderson, P. L., Price, M., Edwards, S. M., Obasaju, M. A., Schmertz, S. K., Zimand, E., & Calamaras, M. R. (2013). Virtual reality exposure therapy for social anxiety disorder: A randomized controlled trial. *Journal of Consulting and Clinical Psychology*, *81*(5), 751–760. https://doi.org/10.1037/a0033559

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*, 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Bell, I. H., Nicholas, J., Alvarez-Jimenez, M., Thompson, A., & Valmaggia, L. (2020). Virtual reality as a clinical tool in mental health research and practice. *Dialogues in Clinical Neuroscience*, *22*(2), 169–177. https://doi.org/10.31887/DCNS.2020.22.2/lvalmaggia

Benbow, A. A., & Anderson, P. L. (2019). A meta-analytic examination of attrition in virtual reality exposure therapy for anxiety disorders. *Journal of Anxiety Disorders*, *61*, 18–26. https://doi.org/10.1016/j.janxdis.2018.06.006

Botella, C., Gracía-Palacios, A., Villa, H., Baños, R. M., Quero, S., Alcañiz, M., & Riva, G. (2007). Virtual reality exposure in the treatment of panic disorder and agoraphobia: A controlled study. *Clinical Psychology and Psychotherapy*, *14*(3), 164–175. https://doi.org/10.1002/cpp.524

Bouchard, S., Dumoulin, S., Robillard, G., Guitard, T., Klinger, E., Forget, H., & Roucaut, F. X. (2011). A randomized control trial for the use of in virtuo exposure in the treatment of social phobia: Final results. *Journal of Cyber Therapy and Rehabilitation*, *4*, 197–199.

Bourla, A., Mouchabac, S., el Hage, W., & Ferreri, F. (2018). E-PTSD: An overview on how new technologies can improve prediction and assessment of posttraumatic stress disorder (PTSD). *European Journal of Psychotraumatology*, *9*(sup1, 1424448. https://doi.org/10.1080/20008198.2018.1424448

Carl, E., Stein, A. T., Levihn-Coon, A., Pogue, J. R., Rothbaum, B., Emmelkamp, P., Asmundson, G. J. G., Carlbring, P., & Powers, M. B. (2019). Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials. *Journal of Anxiety Disorders*, *61*, 27–36. https://doi.org/10.1016/j.janxdis.2018.08.003

Côté, S., & Bouchard, S. (2009). Cognitive mechanisms underlying virtual reality exposure. *Cyberpsychology & Behavior*, *12*(2), 121–129. https://doi.org/10.1089/cpb.2008.0008

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy*, *58*, 10–23. https://doi.org/10.1016/j.brat.2014.04.006

Cuperus, A. A., Klaassen, F., Hagenaars, M. A., & Engelhard, I. M. (2017). A virtual reality paradigm as an analogue to real-life trauma: Its effectiveness compared with the trauma film paradigm. *European Journal of Psychotraumatology*, *8*(sup1, 1338106. https://doi.org/10.1080/20008198.2017.1338106

Dechant, M., Trimpl, S., Wolff, C., Mühlberger, A., & Shiban, Y. (2017). Potential of virtual reality as a diagnostic tool for social anxiety: A pilot study. *Computers in Human Behavior*, *76*, 128–134. https://doi.org/10.1016/j.chb.2017.07.005

Dibbets, P. (2020). A novel virtual reality paradigm: Predictors for stress-related intrusions and avoidance behavior. *Journal of Behavior Therapy and Experimental Psychiatry*, *67*, 101449. https://doi.org/10.1016/j.jbtep.2019.01.001

Dibbets, P., & Schulte-Ostermann, M. A. (2015). Virtual reality, real emotions: A novel analogue for the assessment of risk factors of post-traumatic stress disorder. *Frontiers in Psychology*, *6*, 681. https://doi.org/10.3389/fpsyg.2015.00681

Difede, J., Cukor, J., Jayasinghe, N., Patt, I., Jedel, S., Spielman, L., … Hoffman, H. G. (2007). Virtual reality exposure therapy for the treatment of posttraumatic stress disorder following. *The Journal of Clinical Psychiatry*, *68*, 1682–1689. https://doi.org/10.4088/JCP.v68n1102

Donker, T., Cornelisz, I., van Klaveren, C., van Straten, A., Carlbring, P., Cuijpers, P., & van Gelder, J.-L. (2019). Effectiveness of self-guided app-based virtual reality cognitive behavior therapy for acrophobia: A randomized clinical trial. *JAMA Psychiatry*, *76*(7), 682–690. https://doi.org/10.1001/jamapsychiatry.2019.0219

Emmelkamp, P. M. G., Krijn, M., Hulsbosch, A. M., De Vries, S., Schuemie, M. J., & Van der Mast, C. A. P. G. (2002). Virtual reality treatment versus exposure in vivo: A comparative evaluation in acrophobia. *Behaviour Research and Therapy*, *40*(5), 509–516. https://doi.org/10.1016/S0005-7967(01)00023-7

Emmelkamp, P. M. G., & Meyerbröker, K. (2021). Virtual reality therapy in mental health. *Annual Review of Clinical Psychology*, *17*, 495–519. https://doi.org/10.1146/annurev-clinpsy-081219-115923

Emmelkamp, P. M. G., Meyerbröker, K., & Morina, N. (2020). Virtual reality therapy in social anxiety disorder. *Current Psychiatry Reports*, *22*(7), 32. https://doi.org/10.1007/s11920-020-01156-1

Felnhofer, A., Kryspin-Exner, I., Kothgassner, O., Hlavacs, H., & Beutl, L. (2019). Physical presence, social presence, and anxiety in participants with social anxiety disorder during virtual Cue exposure. *J*, *22*(1), 46–50. https://doi.org/10.1089/cyber.2018.0221

Ferreri, F., Bourla, A., Peretti, C.-S., Segawa, T., Jaafari, N., & Mouchabac, S. (2019). How new technologies can improve prediction, assessment, and intervention in obsessive-compulsive disorder (e-OCD): Review. *JMIR Mental Health*, *6*(12), e11643. https://doi.org/10.2196/11643

Foa, E. B., & Kozak, M. J. (1986, January). Emotional processing of fear. Exposure to corrective information. *Psychological Bulletin*, *99*, 20–35. https://doi.org/10.1037/0033-2909.99.1.20

Gamito, P., Oliveira, J., Rosa, P., Morais, D., Duarte, N., Oliveira, S., & Saraiva, T. (2010). PTSD elderly war veterans: A clinical controlled pilot study. *Cyberpsychology, Behavior and Social Networking*, *13*(1), 43–48. https://doi.org/10.1089/cyber.2009.0237

Garcia-Palacios, A., Botella, C., Hoffman, H., & Fabregat, S. (2007). Comparing acceptance and refusal rates of virtual reality exposure vs. in vivo exposure by patients with specific phobias. *Cyberpsychology & Behavior*, *10*(5), 722–724. https://doi.org/10.1089/cpb.2007.9962

Gorini, A., & Riva, G. (2008). The potential of virtual reality as anxiety management tool: A randomized controlled study in a sample of patients affected by generalized anxiety disorder. *Trials*, *9*. https://doi.org/10.1186/1745-6215-9-25

Guitard, T., Bouchard, S., Belanger, C., & Berthiaume, M. (2019). Exposure to a standardized catastrophic scenario in virtual reality or a personalized scenario in imagination for generalized anxiety disorder. *Journal of Clinical Medicine*, *8*(3). https://doi.org/10.3390/jcm8030309

Hartanto, D., Kampmann, I. L., Morina, N., Emmelkamp, P. G. M., Neerincx, M. A., & Brinkman, W.-P. (2014). Controlling social stress in virtual reality environments. *PLoS ONE*, *9*(3), 1–17. https://doi.org/10.1371/journal.pone.0092804

Hunt, C. (2020). Differences in OCD symptom presentations across age, culture, and gender: A quantitative review of studies using the Y-BOCS symptom checklist. *Journal of Obsessive-Compulsive and Related Disorders*, *26*, 100533. https://doi.org/10.1016/j.jocrd.2020.100533

Inozu, M., Celikcan, U., Akin, B., & Mustafaoğlu Cicek, N. (2020). The use of virtual reality (VR) exposure for reducing contamination fear and disgust: Can VR be an effective alternative exposure technique to in vivo? *Journal of Obsessive-Compulsive and Related Disorders*, *25*, 100518. https://doi.org/10.1016/j.jocrd.2020.100518

Jalal, B., McNally, R. J., Elias, J. A., Potluri, S., & Ramachandran, V. S. (2020). "Fake it till you make it!" Contaminating rubber hands ("multisensory stimulation therapy") to treat obsessive-compulsive disorder. *Frontiers in Human Neuroscience* 13. https://doi.org/10.3389/fnhum.2019.00414

Kahlon, S., Lindner, P., & Nordgreen, T. (2019). Virtual reality exposure therapy for adolescents with fear of public speaking: A non-randomized feasibility and pilot study. *Child and Adolescent Psychiatry and Mental Health*, *13*(1), 47. https://doi.org/10.1186/s13034-019-0307-y

Kampmann, I. L., Emmelkamp, P. M. G., Hartanto, D., Brinkman, W.-P., Zijlstra, B. J. H., & Morina, N. (2016). Exposure to virtual social interactions in the treatment of social anxiety disorder: A randomized controlled trial. *Behaviour Research and Therapy*, *77*, 147–156. https://doi.org/10.1016/j.brat.2015.12.016

Kampmann, I. L., Emmelkamp, P. M., & Morina, N. (2018). Self-report questionnaires, behavioral assessment tasks, and an implicit behavior measure: Do they predict social anxiety in everyday life? *PeerJ*, *2018*(8), e5441. https://doi.org/10.7717/peerj.5441

Kampmann, I. L., Emmelkamp, P. M. G., & Morina, N. (2019). Cognitive predictors of treatment outcome for exposure therapy: Do changes in self-efficacy, self-focused attention, and estimated social costs predict symptom improvement in social anxiety disorder? *BMC Psychiatry*, *19*(1), 80. https://doi.org/10.1186/s12888-019-2054-2

Kim, H., Shin, J. E., Hong, Y.-J., Shin, Y.-B., Shin, Y. S., Han, K., Kim, J. J., & Choi, S.-H. (2018). Aversive eye gaze during a speech in virtual environment in patients with social anxiety disorder. *Australian & New Zealand Journal of Psychiatry*, *52*(3), 279–285. https://doi.org/10.1177/0004867417714335

Kim, K., Roh, D., Kim, C.-H., Cha, K. R., Rosenthal, M. Z., & Kim, S. I. (2012). Comparison of checking behavior in adults with or without checking symptom of obsessive-compulsive disorder using a novel computer-based measure. *Computer Methods and Programs in Biomedicine*, *108*(1), 434–441. https://doi.org/10.1016/j.cmpb.2012.03.014

Kim, K., Kim, S. I., Cha, K. R., Park, J., Rosenthal, M. Z., Kim, J.-J., Han, K., Kim, I. Y., & Kim, C.-H. (2010). Development of a computer-based behavioral assessment of checking behavior in obsessive-compulsive disorder. *Comprehensive Psychiatry*, *51*(1), 86–93. https://doi.org/10.1016/j.comppsych.2008.12.001

Kishimoto, T., & Ding, X. (2019). The influences of virtual social feedback on social anxiety disorders. *Behavioural and Cognitive Psychotherapy*, *47*(6), 726–735. https://doi.org/10.1017/S1352465819000377

Klinger, E., Bouchard, S., Légeron, P., Roy, S., Lauer, F., Chemin, I., & Nugues, P. (2005). Virtual reality therapy versus cognitive behavior therapy for social phobia: A preliminary controlled study. *CyberPsychology and Behavior*, *8*(1), 76–88. https://doi.org/10.1089/cpb.2005.8.76

Kothgassner, O. D., & Felnhofer, A. (2020). Lack of research on efficacy of virtual reality exposure therapy (VRET) for anxiety disorders in children and adolescents. *Neuropsychiatrie*. https://doi.org/10.1007/s40211-020-00349-7

Kothgassner, O. D., Felnhofer, A., Hlavacs, H., Beutl, L., Palme, R., Kryspin-Exner, I., & Glenk, L. M. (2016). Salivary cortisol and cardiovascular reactivity to a public speaking task in a virtual and real-life environment. *Computers in Human Behavior*, *62*(C), 124–135. https://doi.org/10.1016/j.chb.2016.03.081

Krijn, M., Emmelkamp, P. M. G., Ólafsson, R. P., Bouwman, M., Van Gerwen, L. J., Spinhoven, P., … Van Der Mast, C. A. P. G. (2007). Fear of flying treatment methods: Virtual reality exposure vs. cognitive behavioral therapy. *Aviation Space and Environmental Medicine*, *78*(2), 121–128.

Krijn, M., Emmelkamp, P. M. G., Ólafsson, R. P., Schuemie, M. J., & Van Der Mast, C. A. P. G. (2007). Do self-statements enhance the effectiveness of virtual reality exposure therapy? A comparative evaluation in acrophobia. *CyberPsychology and Behavior*, *10*(3), 362–370. https://doi.org/10.1089/cpb.2006.9943

Laforest, M., Bouchard, S., Crétu, A.-M., & Mesly, O. (2016). Inducing an anxiety response using a contaminated virtual environment: Validation of a therapeutic tool for obsessive-compulsive disorder. *Frontiers in ICT*, *3*. https://doi.org/10.3389/fict.2016.00018

Laforest, M., Bouchard, S., Bossé, J., & Mesly, O. (2016). Effectiveness of in virtuo exposure and response prevention treatment using cognitive-behavioral therapy for obsessive-compulsive disorder: A study based on a single-case study protocol. *Frontiers in Psychiatry*, *7*. https://doi.org/10.3389/fpsyt.2016.00099

Lange, B., & Pauli, P. (2019). Social anxiety changes the way we move—A social approach-avoidance task in a virtual reality CAVE system. *PLoS ONE*, *14*(12), 1–19. https://doi.org/10.1371/journal.pone.0226805

Malbos, E., Rapee, R. M., & Kavakli, M. (2013). A controlled study of agoraphobia and the independent effect of virtual reality exposure therapy. *Australian and New Zealand Journal of Psychiatry*, *47*(2), 160–168. https://doi.org/10.1177/0004867412453626

Maltby, N., Kirsch, I., Mayers, M., & Allen, G. J. (2002). Virtual reality exposure therapy for the treatment of fear of flying: A controlled investigation. *Journal of Consulting and Clinical Psychology*, *70*(5), 1112–1118. https://doi.org/10.1037/0022-006X.70.5.1112

McLay, R. N., Wood, D. P., Webb-Murphy, J. A., Spira, J. L., Wiederhold, M. D., Pyne, J. M., & Wiederhold, B. K. (2011). A randomized, controlled trial of virtual reality-graded exposure therapy for post-traumatic stress disorder in active duty service members with combat-related post-traumatic stress disorder. *Cyberpsychology, Behavior and Social Networking*, *14*(4), 223–229. https://doi.org/10.1089/cyber.2011.0003

McLay, R. N., Baird, A., Webb-Murphy, J., Deal, W., Tran, L., Anson, H., Klam, W., & Johnston, S. (2017). A randomized, head-to-head study of virtual reality exposure therapy for posttraumatic stress disorder. *Cyberpsychology, Behavior and Social Networking*, *20*(4), 218–224. https://doi.org/10.1089/cyber.2016.0554

Meyer, T., Nelson, J., & Morina, N. (n.d.). *Time for a walk through time: Re-experiencing of aversive memories is inversely linked to spatio-temporal distance*.

Meyerbroeker, K., Morina, N., Kerkhof, G. A., & Emmelkamp, P. M. G. (2013). Virtual reality exposure therapy does not provide any additional value in agoraphobic patients: A randomized controlled trial. *Psychotherapy and Psychosomatics*, *82*, 170–176. https://doi.org/10.1159/000342715

Meyerbröker, K., & Emmelkamp, P. M. G. (2008). Therapeutic processes in virtual reality exposure therapy: The role of cognitions and the therapeutic alliance. *Journal of Cyber Therapy and Rehabilitation*, *1*(3).

Meyerbröker, K., Morina, N., & Emmelkamp, P. M. G. (2018). Enhancement of exposure therapy in participants with specific phobia: A randomized controlled trial comparing yohimbine, propranolol and placebo. *Journal of Anxiety Disorders*, *57*, 48–56. https://doi.org/10.1016/j.janxdis.2018.05.001

Meyerbröker, K. (2014). Virtual Reality Exposure Therapy. In P. M. G. Emmelkamp & T. Ehring (Eds.), *The Wiley handbook of anxiety disorders (pp. 1310–1324)*. Wiley & Blackwell. https://doi.org/10.1002/9781118775349.ch63

Miyahira, S. D., Folen, R. A., Hoffman, H. G., Garcia-Palacios, A., Spira, J. L., & Kawasaki, M. (2012). The effectiveness of VR exposure therapy for PTSD in returning warfighters. *Annual Review of Cybertherapy and Telemedicine*, *10*, 128–132.

Morina, N., Ijntema, H., Meyerbröker, K., & Emmelkamp, P. M. G. (2015). Can virtual reality exposure therapy gains be generalized to real-life? A

meta-analysis of studies applying behavioral assessments. *Behaviour Research and Therapy*, *74*, 18–24. https://doi.org/10.1016/j.brat.2015.08.010

Morina, N., Brinkman, W.-P., Hartanto, D., Kampmann, I. L., & Emmelkamp, P. M. G. (2015). Social interactions in virtual reality exposure therapy: A proof-of-concept pilot study. *Technology and Health Care*, *23*(5), 581–589. https://doi.org/10.3233/THC-151014

Mühlberger, A., Herrmann, M. J., Wiedemann, G., Ellgring, H., & Pauli, P. (2001). Repeated exposure of flight phobics to flights in virtual reality. *Behaviour Research and Therapy*, *39*(9), 1033–1050. https://doi.org/10.1016/S0005-7967(00)00076-0

Mühlberger, A., Weik, A., Pauli, P., & Wiedemann, G. (2006). One-session virtual reality exposure treatment for fear of flying: 1-year follow-up and graduation flight accompaniment effects. *Psychotherapy Research*, *16*(1), 26–40. https://doi.org/10.1080/10503300500090944

Myers, C. E., Radell, M. L., Shind, C., Ebanks-Williams, Y., Beck, K. D., & Gilbertson, M. W. (2016). Beyond symptom self-report: Use of a computer "avatar" to assess post-traumatic stress disorder (PTSD) symptoms. *Stress*, *19*(6), 593–598. https://doi.org/10.1080/10253890.2016.1232385

National Institute for Health and Clinical Excellence. (2011). Common mental health problems: Identification and pathways to care.

National Institute for Health and Clinical Excellence. (2013). Common mental health problems: Identification and pathways to care. NICE Guideline (CG123).

Navarro-Haro, M. V., Modrego-Alarcón, M., Hoffman, H. G., López-Montoyo, A., Navarro-Gil, M., Montero-Marin, J., … García-Campayo, J. (2019). Evaluation of a mindfulness-based intervention with and without virtual reality dialectical behavior therapy® mindfulness skills training for the treatment of generalized anxiety disorder in primary care: A pilot study. *Frontiers in Psychology*, *10*, 55. https://doi.org/10.3389/fpsyg.2019.00055

Ngai, I., Tully, E. C., & Anderson, P. L. (2015). The course of the working alliance during virtual reality and exposure group therapy for social anxiety disorder. *Behavioural and Cognitive Psychotherapy*, *43*(2), 167–181. https://doi.org/10.1017/S135246581300088X

Owens, M. E., & Beidel, D. C. (2015). Can virtual reality effectively elicit distress associated with social anxiety disorder? *Journal of Psychopathology and Behavioral Assessment*, *37*(2), 296–305. https://doi.org/10.1007/s10862-014-9454-x

Pelissolo, A., Zaoui, M., Aguayo, G., Yao, S. N., Roche, S., & Ecochard, R. (2012). Virtual reality exposure therapy versus cognitive behavior therapy for panic disorder with agoraphobia: A randomized comparison study. *Journal of CyberTherapy & Rehabilitation*, *5*(1), 34–43.

Penate, W., Pitti, C. T., Manuel Bethencourt, J., de la Fuente, J., & Gracia, R. (2008). The effects of a treatment based on the use of virtual reality exposure and cognitive-behavioral therapy applied to patients with agoraphobia. *International Journal of Clinical and Health Psychology*, *8*(1), 5–22.

Powers, M. B., Briceno, N. F., Gresham, R., Jouriles, E. N., Emmelkamp, P. M. G., & Smits, J. A. J. (2013). Do conversations with virtual avatars increase feelings of social anxiety? *Journal of Anxiety Disorders*, *27*(4), 398–403. https://doi.org/10.1016/j.janxdis.2013.03.003

Quero, S., Angeles Perez-Ara, M., Breton-Lopez, J., Garcia-Palacios, A., Banos, R. M., & Botella, C. (2014). Acceptability of virtual reality interoceptive exposure for the treatment of panic disorder with agoraphobia. *British Journal of Guidance & Counselling*, *42*(2), 123–137. https://doi.org/10.1080/03069885.2013.852159

Ready, D. J., Gerardi, R. J., Backscheider, A. G., Mascaro, N., & Rothbaum, B. O. (2010). Comparing virtual reality exposure therapy to present-centered therapy with 11 U.S. Vietnam veterans with PTSD. *Cyberpsychology, Behavior and Social Networking*, *13*(1), 49–54. https://doi.org/10.1089/cyber.2009.0239

Reger, G. M., Koenen-Woods, P., Zetocha, K., Smolenski, D. J., Holloway, K. M., Rothbaum, B. O., Difede, J. A., Rizzo, A. A., Edwards-Stewart, A., Skopp, N. A., Mishkind, M., Reger, M. A., & Gahm, G. A. (2016). Randomized controlled trial of prolonged exposure using imaginal exposure vs. virtual reality exposure in active duty soldiers with deployment-related posttraumatic stress disorder (PTSD). *Journal of Consulting and Clinical Psychology*, *84*(11), 946–959. https://doi.org/10.1037/ccp0000134

Reger, G. M., Smolenski, D., Norr, A., Katz, A., Buck, B., & Rothbaum, B. O. (2019). Does virtual reality increase emotional engagement during exposure for PTSD? Subjective distress during prolonged and virtual reality exposure therapy. *Journal of Anxiety Disorders*, *61*, 75–81. https://doi.org/10.1016/j.janxdis.2018.06.001

Repetto, C., Gaggioli, A., Pallavicini, F., Cipresso, P., Raspelli, S., & Riva, G. (2013). Virtual reality and mobile phones in the treatment of generalized anxiety disorders: A phase-2 clinical trial. *Personal and Ubiquitous Computing*, *17*(2), 253–260. https://doi.org/10.1007/s00779-011-0467-0

Richards, S. H., Dickens, C., Anderson, R., Richards, D. A., Taylor, R. S., Ukoumunne, O. C., Kessler, D., Turner, K., Kuyken, W., Gandhi, M., Knight, L., Gibson, A., Davey, A., Warren, F., Winder, R., Wright, C., & Campbell, J. (2016). Assessing the effectiveness of enhanced psychological care for patients with depressive symptoms attending cardiac rehabilitation compared with treatment as usual (CADENCE): Study protocol for a pilot cluster randomised controlled trial. *Trials*, *17*, *17*, 59. https://doi.org/10.1186/s13063-016-1184-9

Riva, G., & Serino, S. (2020). Virtual reality in the assessment, understanding and treatment of mental health disorders. *Journal of Clinical Medicine*, *9*(11). https://doi.org/10.3390/jcm9113434

Rothbaum, B. O., Anderson, P., Zimand, E., Hodges, L., Lang, D., & Wilson, J. (2006). Virtual reality exposure therapy and standard (in vivo) exposure therapy in the treatment of fear of flying. *Behavior Therapy*, *37*(1), 80–90. https://doi.org/10.1016/j.beth.2005.04.004

Rothbaum, B. O., Hodges, L. F., Ready, D., Graap, K., & Alarcon, R. D. (2001). Virtual reality exposure therapy for Vietnam veterans with posttraumatic stress disorder. *The Journal of Clinical Psychiatry*, *62*(8), 617–622. https://doi.org/10.4088/jcp.v62n0808

Rothbaum, B. O., Hodges, L., Smith, S., Lee, J. H., & Price, L. (2000). A controlled study of virtual reality exposure therapy for the fear of flying. *Journal of Consulting and Clinical Psychology*, *68*(6), 1020–1026. https://doi.org/10.1037/0022-006X.68.6.1020

Roy, M. J., Constanzo, M. E., Blair, J. R., & Rizzo, A. A. (2014). Compelling evidence that exposure therapy for PTSD normalizes brain function. *Studies in Health Technology and Informatics*, *199*, 61–65.

Scheveneels, S., Boddez, Y., Van Daele, T., & Hermans, D. (2019). Virtually unexpected: No role for expectancy violation in virtual reality exposure for public speaking anxiety. *Frontiers in Psychology*, *10*, 2849. https://doi.org/10.3389/fpsyg.2019.02849

Segal, R., Bhatia, M., & Drapeau, M. (2011). Therapists' perception of benefits and costs of using virtual reality treatments. *Cyberpsychology, Behavior and Social Networking*, *14*(1–2), 29–34. https://doi.org/10.1089/cyber.2009.0398

Tardif, N., Therrien, C.-E., & Bouchard, S. (2019). Re-examining psychological mechanisms underlying virtual reality-based exposure for spider phobia. *Cyberpsychology, Behavior and Social Networking*, *22*(1), 39–45. https://doi.org/10.1089/cyber.2017.0711

Vailati Riboni, F., Comazzi, B., Bercovitz, K., Castelnuovo, G., Molinari, E., & Pagnini, F. (2020). Technologically-enhanced psychological interventions for older adults: A scoping review. *BMC Geriatrics*, *20*(1), 191. https://doi.org/10.1186/s12877-020-01594-9

van Bennekom, M. J., de Koning, P. P., Gevonden, M. J., Kasanmoentalib, M. S., & Denys, D. (2021). A virtual reality game to assess OCD symptoms. *Frontiers in Psychiatry*, *11*, 1640. https://doi.org/10.3389/fpsyt.2020.550165

van Bennekom, M. J., Kasanmoentalib, M. S., de Koning, P. P., & Denys, D. (2017). A virtual reality game to assess obsessive-compulsive disorder. *Cyberpsychology, Behavior and Social Networking*, *20*(11), 718–722. https://doi.org/10.1089/cyber.2017.0107

Wang, T.-C., Sit, C. H.-P., Tang, T.-W., & Tsai, C.-L. (2020). Psychological and physiological responses in patients with generalized anxiety disorder: The use of acute exercise and virtual reality environment. *International Journal of Environmental Research and Public Health*, *17* (13), 1–15. https://doi.org/10.3390/ijerph17134855

Wang, T.-C., Tsai, C.-L., Tang, T.-W., Wang, W.-L., & Lee, K.-T. (2019). The effect of cycling through a projection-based virtual environment system on generalized anxiety disorder. *Journal of Clinical Medicine*, *8* (7), 973. https://doi.org/10.3390/jcm8070973

Wechsler, T. F., Kuempers, F., & Muehlberger, A. (2019). Inferiority or even superiority of virtual reality exposure therapy in phobias?—A systematic review and quantitative meta-analysis on randomized controlled trials specifically comparing the efficacy of virtual reality exposure to gold standard in vivo Exp. *Frontiers in Psychology*, *10*, *10*. https://doi.org/10.3389/fpsyg.2019.01758

Wiederhold, B. K., & Wiederhold, M. D. (2003). Three-year follow-up for virtual reality exposure for fear of flying. *Cyberpsychology & Behavior*, *6* (4), 441–445. https://doi.org/10.1089/109493103322278844

Wrzesien, M., Bretón-López, J., Botella, C., Burkhardt, J.-M., Alcañiz, M., Pérez-Ara, M. Á., & del Amo, A. R. (2013). How technology influences the therapeutic process: Evaluation of the patient-therapist relationship in augmented reality exposure therapy and in vivo exposure therapy. *Behavioural and Cognitive Psychotherapy*, *41*(4), 505–509. https://doi.org/10.1017/S1352465813000088

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