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Does virtual reality increase emotional engagement during exposure for PTSD? Subjective distress during prolonged and virtual reality exposure therapy

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ABSTRACT

Prolonged exposure (PE) is a treatment for posttraumatic stress disorder (PTSD) based on emotional processing theory. According to this theory, emotional engagement during imaginal exposure is critical to clinical outcome. One rationale for virtual reality exposure therapy (VRE) is the ability of trauma-relevant, multi-sensory stimuli to increase emotional engagement. This study compared the subjective distress of active duty soldiers ($N = 108$) during exposure via PE or VRE. Soldiers with higher mean or peak distress during the first imaginal exposure had higher baseline PTSD symptom severity. There was no difference between groups on average or peak distress during imaginal exposure at the first or final exposure session. There were no significant differences in between-session habituation observed between VRE and PE groups. However, each ten-point decrease in SUDS scores, either mean or peak, from the initiation of imaginal exposure to the end of treatment, was associated with a greater decrease in CAPS-W scores for both groups. There were no group differences in these trajectories or the magnitude of the association between distress/habituation, and PTSD symptoms. Future research on VRE should measure patient ratings of engagement during exposure to better understand which patients are aided by this innovative approach to treatment.

1. Introduction

Prolonged exposure (PE; Foa, Hembree, & Rothbaum, 2007) is a manualized psychotherapy for posttraumatic stress disorder (PTSD) that is based on emotional processing theory (Foa & Kozak, 1986). According to this theory, trauma results in the development of a memory network, or a fear structure. This fear structure includes information about the feared stimuli, physiological and other responses, and the meaning of these stimuli to the individual (Foa, Steeketee, & Rothbaum, 1989). Through the fear structure the survivor is provided with a program to escape danger, typically through avoidance. PE's demonstrated efficacy (Management of Posttraumatic Stress Disorder Workgroup, 2017; Powers, Halpern, Ferenschak, Gillihan, & Foa, 2010) is attributed to techniques that intentionally activate this memory network by approaching aspects of the fear structure in a manner that facilitates new learning. In PE, patients confront their trauma memories during imaginal exposure and approach safe but feared situations and circumstances in day-to-day life during *in vivo* exposure. According to the original theoretical conceptualization (Foa & Kozak, 1986), when exposure successfully activates the fear structure it allows for emotional processing, or the reorganization of the individual's fear structure though the incorporation of new information (e.g., new safe associations with previously feared stimuli). Thus, the successful activation of the fear structure, or "emotional engagement", is theorized to be a key component of emotional processing, and successful emotional processing should translate to the reduction of PTSD symptoms.

Despite the established efficacy of PE, a meaningful proportion of patients still meet diagnostic criteria for PTSD following treatment or do not achieve clinically meaningful change (Steenkamp, Litz, Hoge, & Marmar, 2015). One potential explanation for the variance in outcome is differences in emotional engagement during imaginal exposure. Within emotional processing theory, the persistence of trauma-related

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symptoms is due, in part, to inadequate activation and processing of the fear structure, often due to avoidance. Previous studies have demonstrated a relationship between emotional engagement during exposure and treatment outcomes such that greater emotional engagement is linked to better outcomes (Foa, Riggs, Massie, & Yarczower, 1995; Jaycox, Foa, & Morral, 1998) and inadequate emotional engagement during exposure has been proposed to decrease the efficacy of treatment (Foa, Huppert, & Cahill, 2006). Therefore, the therapist's primary task during imaginal exposure is to help the patient maintain an optimal level of emotional engagement. To address this, the PE treatment protocol (Foa et al., 2007) recommends various clinical techniques (e.g., present tense language and focus on emotion-producing content during imaginal exposure) in order to achieve a theoretically optimal level of engagement and adequate activation of the fear structure.

Clinically, activation of the fear structure can be inferred by patients' self-reported distress during imaginal exposure. These subjective units of discomfort (SUDS) are typically reported at the outset and conclusion of exposure, as well as every five minutes throughout. SUDS ratings serve as an efficient communication to the therapist regarding emotional engagement and allow the therapist to monitor the state-dependent level of emotional arousal during the exposure as an indicator of habituation. Indeed, higher SUDS ratings during exposures have been linked to better treatment outcomes (e.g., Jaycox et al., 1998).

Although both within session and between session habituation were initially purported to play a mechanistic role in PE and other exposure-based therapies (Foa & Kozak, 1986; McNally, 2007), recent research suggests that within session habituation is unrelated to treatment outcomes (see Cooper, Clifton, & Feeny, 2017 for a review)[1]. Regarding between session habituation, it is unclear whether between-session habituation plays a mechanistic role in PE, however, emotional processing theory certainly posits that between session habituation will occur over the course of treatment as the fear structure is modified (Rauch & Foa, 2006). Indeed, many studies have demonstrated associations among reductions in anxiety during exposure and reductions in PTSD symptoms (Jaycox et al., 1998; Rauch, Foa, Furr, & Filip, 2004; Sripada & Rauch, 2015; van Minnen & Hagenaars, 2002). However, recent research has called into question the importance of between-session reductions in distress during imaginal exposure. Many patients do not report between session habituation yet still demonstrate significant reductions in symptoms, which may be due to other factors such as increased distress tolerance (Craske et al., 2008; Bluett, Zoellner, & Feeny, 2014). Given the lack of consensus in the scientific literature as to the importance of between session habituation, it is imperative to examine patterns of habituation longitudinally, especially their relationship to treatment outcomes, as this will help clarify the role of habituation in PE.

More than two decades ago, multi-sensory virtual reality (VR) was proposed as a means to facilitate emotional processing in PTSD treatment (Rothbaum et al., 1995). Theoretically, VR systems that present relevant VR stimuli during exposure to the memory, such as trauma-relevant visuals, sounds, vibrations, or smells should increase emotional engagement and reduce the likelihood of inadequate activation. Indeed, studies have shown that VR is effective for the treatment of PTSD associated with combat traumas in Veterans from both Vietnam (Ready, Gerardi, Backscheider, Mascaro, & Rothbaum, 2010; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001)] and the wars in Iraq and Afghanistan (Reger et al., 2011; Rizzo et al., 2011; Rothbaum et al., 2014), as well as survivors of the September 11, 2001 attack on the World Trade Center (Difede et al., 2007, 2014).

Although there is substantial evidence for the effectiveness of VRE to reduce symptoms of PTSD, minimal research has addressed the mechanistic question of whether VR promotes emotional engagement. This study represents a secondary analysis of a previous clinical trial comparing VRE to PE for active duty soldiers with PTSD stemming from combat deployments to Iraq or Afghanistan (Reger et al., 2016). This trial found that both PE and VRE resulted in significant pre-post reductions in PTSD symptoms and that both treatments significantly reduced symptoms relative to a minimal attention waitlist condition. There were no differences in drop out or patient satisfaction. Although the clinical trial found no significant differences in PTSD symptoms between PE and VRE at post-treatment, it did not examine levels of emotional engagement in each treatment condition. As stated above, this is an important theoretical question as increased emotional engagement is the proposed mechanism by which VRE would improve treatment outcomes over PE. Therefore determining whether VRE was successful in manipulating this proposed mechanism allows for a deeper understanding as to why VRE did not produce superior treatment outcomes in this trial. This study, therefore, aims to explore: 1) whether VR increased emotional engagement during exposure as indexed by significantly higher levels of average distress and/or peak distress relative to PE; 2) whether VR resulted in increased between-session habituation compared to PE, and; 3) if emotional engagement and/or between session habituation predicted treatment outcome overall and differentially by treatment group.

2. Material and methods

2.1. Participants

The full methods used during the original clinical trial are available elsewhere (Reger et al., 2016). Participants were active duty U.S. Army soldiers who had developed PTSD during a military deployment to Iraq or Afghanistan. Index traumas had to have occurred during a military deployment to Iraq or Afghanistan. Soldiers with traumas involving sexual assault were excluded. Otherwise, events had to have occurred in environments similar to those available in the Virtual Iraq/Afghanistan system, though this was generously applied. For example, a soldier with a trauma that occurred inside a flying helicopter would have been excluded as the system did not provide such a simulation, whereas a soldier with an event inside a tent or building that was dissimilar to interiors in the VR system would have been included. Enrolled soldiers were randomized to 10 sessions of PE, 10 sessions of VRE, or a 5-week minimal attention waitlist. Given the purposes of this secondary analysis, we excluded participants assigned to the waitlist and included only the participants who were randomized to an active treatment. Imaginal exposure began at the third treatment session in the study. Of the 108 participants randomized to either PE or VRE, 12 (7 assigned to PE; 5 assigned to VRE) did not engage in treatment beyond the second session. These participants were excluded from the current analysis.

2.2. Measures and materials

2.2.1. Subjective units of discomfort (SUDS)

In PE, SUDS is a self-reported number from 0 to 100 that represents the patient's intensity of anxiety or discomfort (Foa et al., 2007). This rating indicates the patient's rating at that moment in time, and is a state-dependent snapshot. Zero represents no distress and 100 represents extreme distress. The patient "anchors" the meaning of varying levels of the SUDS to previous personal experiences and then rates their distress during exposure therapy by reporting any number from 0 to 100 to communicate their subjective experience.

2.2.2. Clinician administered PTSD scale (CAPS)

The CAPS (Blake et al., 1995) is a structured clinical interview that assesses the presence and severity of PTSD according to *DSM–IV*

[1] In contrast to this finding, note that many therapists still find it important to use within session habituation as a guide for achieving an adequate dose of imaginal exposure in order to avoid terminating exposure too early and unintentionally reinforcing avoidance (cf. Rosqvist, 2005).

criteria. The frequency and intensity of each symptom is coded on a scale ranging from 0 to 4 (0 = Never; None; 4 = Daily or almost every day; Extreme distress). For this study, we used the CAPS "last week" (CAPS-W) reference at all assessments.

2.2.3. Trauma similarity to virtual reality

Trauma events identified during patients' first assessments were rated for similarity to the stimuli available in the VR Iraq/Afghanistan system. Scores ranged from 1 (*Not at all Similar*; e.g., key audio and visual stimuli from the trauma were not available during VRE) to 4 (*Extremely Similar*; e.g., key stimuli in the trauma were available in the VR system). Trauma events were independently rated by two psychologists with extensive experience with the VR system. A weighted kappa with weights of 1.00, 0.67, 0.33, and 0.00 corresponding to 0, 1, 2, and 3 steps away from the diagonal, respectively, was used to evaluate interrater agreement. Raters agreed 82.30% of the time, Kw = .46; SE = .05, suggesting moderate agreement (Landis & Koch, 1977). A mean of the two ratings was used in the analysis.

2.2.4. Virtual Iraq/Afghanistan system

The virtual reality system included a Dell XPS desktop computer and an eMagin z800 head-mounted display (HMD), which is a headset with screens for each eye. To match the patient's head movements in the virtual environment, an inertia cube orientation tracker was attached to the HMD. Patients used a Logitech gaming joystick or a mini joystick attached to a mock M4 rifle to navigate through the environment. Over-the-ear headphones were used for audio stimuli, and therapists spoke with patients via a digital microphone that could be heard in the headphones. Participants stood or sat on a platform with bass shaker speakers, such that low frequency sounds were experienced as vibrations. An EnviroScent Scent Palette (Biopac Systems, 2013) provided simulated scents, when relevant to the memory being revisited during imaginal exposure. A wide range of scents were available including garbage, body odor, gunpowder, burnt rubber, etc.

The VR Iraq/Afghanistan system was developed by the Institute for Creative Technologies at the University of Southern California (Rizzo, Reger, Gahm, Difede, & Rothbaum, 2009). The system included a clinician's interface that allowed the therapist to customize the VR environment in real time to match characteristics of the patient's trauma memory. As the patient recounted their trauma memory during imaginal exposure, the therapist would match the environment. A wide range of audio/visual stimuli could be included. Examples of stimuli that could be customized included the time of day, weather, location of the vehicle in a convoy, presence of civilians or military personnel, small arms fire, mortar attacks, improvised explosive devices (IEDs), vehicle borne IEDs, rocket propelled grenades, and human remains. Two environments were available. One was a convoy scenario in which the view point was from within a military HUMVEE. The other allowed a first person walking simulation through a middle eastern city and marketplace. The city environment allowed for experiences outdoors or inside buildings and rooftops. Additional detail about the VR Iraq System is available elsewhere (Rizzo et al., 2009).

2.3. Procedure

2.3.1. Treatment

PE is a manualized psychotherapy (Foa et al., 2007) consisting of ten 90-120-minute sessions. Sessions 1 and 2 involve psychoeducation on breathing retraining, common reactions to traumatic events, and the rationale for conducting exposure therapy. After session 2, avoided situations, places, and circumstances were approached as *in vivo* exposure, which was planned as homework between sessions. In sessions 3 through 10, patients recount their trauma memory through repeated and prolonged imaginal exposure. These exposures can last from 30 to 60 minutes depending on the session number and the timing of an appropriate end based on the length of the patient's recounting of the event. Accordingly, this study included SUDS from the first 30 min of each imaginal exposure or virtual reality exposure trial. The purpose of this was to ensure that all session data was comparable, and is reasonable given evidence that 30 min imaginal exposures are just as effective as 60 min exposures (van Minnen & Foa, 2006). The VRE treatment protocol was identical to the PE treatment protocol with the exception of the use of virtual reality during imaginal exposure. As the patient revisited their trauma memory out loud, the clinician used the virtual Iraq/Afghanistan software to introduce relevant stimuli, in real-time, as the patient described the event. Following the exposure to the traumatic memory (imaginal or in virtual reality), the therapist and the patient processed the emotional material that emerged during the exposure. Details on therapist training, experience, and treatment fidelity are available elsewhere (Reger et al., 2016)

2.4. Data analytic plan

2.4.1. Aim 1

To test whether emotional engagement was higher in the VRE group than the PE group, we compared the differences in average SUDS between the VRE and PE groups, as well as the differences in peak SUDS between the VRE and PE groups, in sessions 3 and 10. These values were taken from contrasts conducted as part of the mixed-effects regression models described immediately below.

2.4.2. Aim 2

We used linear mixed-effects regression models (MRM) to compare between-session habituation between the two active treatment groups (Fitzmaurice, Laird, & Ware, 2004). Models for the mean and the peak SUDS at each imaginal-exposure-treatment session were specified using linear and quadratic terms for change over time. Choice of the time specification for the final models was based on the information criteria from the estimated models and examination of plots of the growth trajectories relative to the observed average values. Treatment assignment was included as a participant-level variable. The coefficient for the interaction between treatment assignment and session number was used to measure the difference between the treatment groups in the rate of change in the mean and peak SUDS over the course of treatment.

A secondary model specific to participants in the VRE group used the trauma similarity score in an interaction term to determine if change in the SUDS scores differed as a function of trauma similarity. For all analyses using linear mixed effects models, the regression coefficient and 95% confidence intervals are reported. Session number was rescaled by subtracting three from each value to have the first exposure session centered at zero.

2.4.3. Aim 3

To investigate the relationship between emotional engagement/between-session habituation and treatment outcomes, another set of models estimated the association between change in the SUDS scores and the primary outcome measure, the CAPS-W. A linear growth-curve model of the primary study outcome measure was specified to measure the amount of change between baseline, mid, and post treatment for the sample included in this study. Given only three time points of outcome assessment, the functional form of this model was restricted to linear change only. Random effects were included for the intercept and slope of the curve with an unstructured covariance matrix. Similar to the models for the mean and peak SUDS, an interaction term between the estimated amount of change (predicted difference between the last and first session-level observation, by participant from the models for aim two above) and study time was used to measure the amount and magnitude of difference in the rate of change in the outcome associated with between-session habituation.

All models included a random intercept and a random slope with an unstructured covariance matrix. Effect size estimates for longitudinal coefficients used the baseline standard deviation of the outcome

Table 1
Characteristics of the study sample, by treatment group.

	PE (n = 47) M (SD)	VRE (n = 49) M (SD)
Age	30.74 (6.97)	29.76 (6.50)
Baseline CAPS-W score	78.70 (17.17)	79.98 (15.57)
	%	%
Male	93.62	95.92
Race/ethnicity		
White, not Hispanic	57.45	73.47
Black, not Hispanic	6.38	4.08
Asian, not Hispanic	4.26	6.12
Native American, not Hispanic	2.13	0.00
Hispanic	23.40	14.29
Other	6.38	2.04
Marital status		
Single	10.64	12.24
Married	70.21	65.31
Separated/divorced	19.15	22.45
Rank/grade		
E1-E4	36.17	44.90
E5-E6	44.68	42.86
E7-E9	12.77	10.20
Officer	6.38	2.04

variable consistent with recommendation of Feingold (2009). Continuous explanatory variables were included in the model after centering at the baseline, study-population, arithmetic mean.

3. Results

Descriptive sample statistics by treatment group are provided in Table 1. Treatment groups did not differ on demographic variables, or on initial symptom severity (i.e., baseline CAPS score; Reger et al., 2016).

3.1. Aim 1

Analyses revealed that there were no significant differences between the VRE and PE groups on mean SUDS during in-session exposure at either session 3 (3.65, 95% CI [−4.22, 11.52]) or session 10 (−0.98 [95% CI = −14.84, 12.95]). Similarly, there were no significant differences between the VRE and PE groups on peak SUDS during imaginal exposure at either session 3 (2.48, 95% CI [−4.80, 9.77]) or session 10 (1.68 [95% CI = −14.63, 17.92]).

3.2. Aim 2

The group-average mean and peak SUDS scores decreased over time for both the PE and the VRE treatment groups (Table 2; Figs. 1 and 2). There was no statistically significant difference in the slope of the mean or peak SUDS decrease between treatment groups. There was no statistically significant difference in the amount of mean or peak SUDS reduction among participants in the VRE group as a function of trauma similarity (mean SUDS: b = −0.49, 95% CI = −2.20, 1.21; peak SUDS: b = −0.39, 95% CI = −2.46, 1.67).

Table 2
Linear mixed-effects model of mean and peak SUDS change from baseline to post-treatment by treatment group.

	Mean SUDS		Peak SUDS	
	b	95% CI	b	95% CI
Intercept	64.94	59.33, 70.55	80.97	75.78, 86.16
VRE	3.65	−4.22, 11.52	2.48	−4.80, 9.77
Slope	−4.14	−5.52, -0.28	−5.73	−7.34, -4.11
VRE	−0.14	−2.12, 1.85	0.24	−2.09, 2.56
Random effects				
σ_i	18.36	15.59, 21.61	16.40	13.77, 19.52
σ_s	4.00	3.28, 4.88	4.72	3.89, 5.72
Corr(σ_i, σ_s)	−0.06	−0.31, 0.19	−0.11	−0.35, 0.15

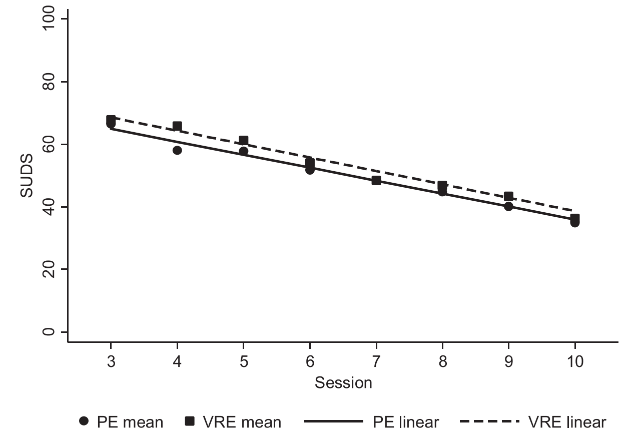

Fig. 1. Mean SUDS scores and linear change over time, by treatment assignment.

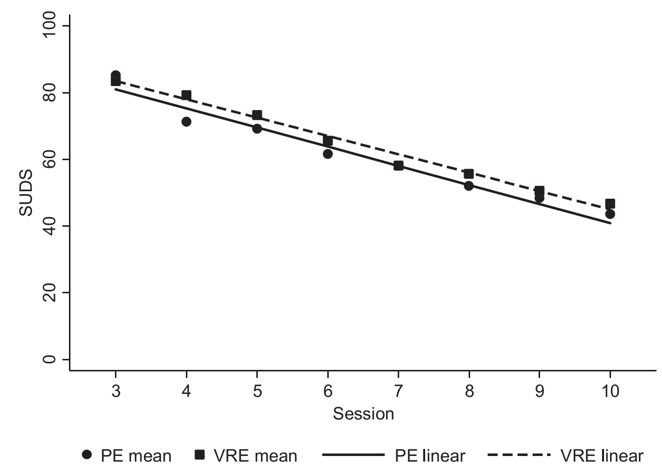

Fig. 2. Peak SUDS scores and linear change over time, by treatment assignment.

3.3. Aim 3

In Table 3, we present the coefficients for the model of the relationship between change in SUDS and change in CAPS-W over time.

Table 3
Association between change in the SUDS and the CAPS-W from baseline to post treatment from a linear mixed-effects model.

	Mean SUDS		Peak SUDS	
	b	95% CI	b	95% CI
Intercept	79.83	76.79, 82.87	79.85	76.83, 82.88
Session 3 score	0.35	0.17, 0.53	0.41	0.21, 0.61
10-point decrease in score	−1.07	−2.30, 0.16	−0.89	−1.90, 0.13
Slope	−11.36	−14.63, -8.10	−10.92	−14.22, -7.62
Session 3 score	0.14	−0.03, 0.32	0.16	−0.04, 0.36
10-point decrease in score	−2.93	−4.19, -1.67	−2.49	−3.55, -1.43
Random effects				
σ_i	9.81	6.51, 14.79		
σ_s	9.97	7.11, 13.97		
Corr(σ_i, σ_s)	0.37	−0.40, 0.84		

Participants in the study had, on average, a decrease of approximately 11 points at mid-treatment and 22 points at post-treatment on the CAPS-W relative to baseline. Session 3 is the SUDS score during the 1st imaginal exposure. Participants with higher baseline SUDS scores, either mean or peak, had higher baseline CAPS-W scores. There was not an association between baseline SUDS scores and the amount of change in the CAPS-W scores. Over time, from the initiation of imaginal exposure to the end of treatment, each ten-point decrease in SUDS score was associated with a significant decrease in CAPS-W scores (2.93 and 2.49 for mean and peak SUDS, respectively). There was no interaction between treatment assignment and change in either the mean or peak SUDS.

4. Discussion

The present study empirically tests a key theoretical rationale underlying VRE for combat-related PTSD. By providing trauma-relevant visuals, sounds, vibrations, or smells, VRE is theorized to potentially enhance treatment of combat-related PTSD by increasing the patient's emotional engagement with the traumatic memory and more effectively activating the relevant fear structure for emotional processing (Foa & Kozak, 1986; Foa et al., 2006). A recent randomized trial demonstrated that while effective in reducing PTSD symptoms relative to waitlist (Reger et al., 2016), VRE did not provide symptom reduction above and beyond standard PE. This study revisited those data to determine whether VRE was successful in enhancing emotional engagement (target mechanism of VRE), as measured by SUDS. Results found that participants in VRE did not report significantly higher average or peak SUDS or increased reduction of distress over time relative to participants in PE.

The present study does provide evidence for a relationship between reduction in subjective distress across sessions, or between session habituation, and reduction in PTSD symptoms for PE and VRE, overall. Each ten-point decrease in SUDS scores, either mean or peak, from the initiation of imaginal exposure to the end of treatment, was associated with a greater decrease in CAPS-W scores. This finding may be clinically relevant. Based on this scaling, 30-point reductions in SUDS were associated with a corresponding decrease in CAPS-W that may have been clinically meaningful. This pattern replicates some findings that suggest such habituation is one indicator of meaningful treatment benefit (Bluett et al., 2014; Sripada & Rauch, 2015; Cooper et al., 2017).

These results raise important and interesting questions for the future study of PTSD treatment. First, these findings suggest that the VR technology used in this study may not have increased emotional engagement over and above PE among the Iraq and Afghanistan deployed Army soldiers enrolled in this study. Participants were from a single war era (Iraq and Afghanistan), at a single military installation, and using a specific set of VR software/hardware. Additional research will help clarify the generalizability of these findings. Second, these results might invite questions related to the meaning of emotional engagement assessment during exposure sessions. One possible explanation for complicated findings in this area is that SUDS can both represent a mechanism (i.e. emotional engagement) through which treatment benefits are achieved as well as an indicator of PTSD severity. In this study, soldiers with higher mean or peak SUDS during their first exposure to the memory had higher baseline PTSD symptom severity. Thus, one might speculate that soldiers who presented to VRE or PE with heightened SUDS – rather than receiving a more potent dose of active treatment – might simply be presenting with more severe PTSD. Further, given the complex emotional experience that transpires during PE – e.g. fear, sadness, guilt, loss, frustration – these ratings might not isolate activation of emotions relevant to the fear structure. Continued basic research developing methods of assessing distress and emotional engagement during exposure may provide useful tools to better understand mechanisms of action in VRE therapy and other exposure treatments. Psychophysiological measurements of arousal during exposure therapy and assessments of physiological reactivity in response to PE and VRE therapy may be helpful.

According to emotional processing theory, poor emotional engagement can negatively impact outcome. Distractions and avoidance of emotion producing aspects of the memory during imaginal exposure risk interfering with treatment. For VR, the effectiveness of systems may be dependent on the ability of those systems to represent stimuli that are relevant and accurate. While clinicians and soldiers worked closely to identify and generate accurate and relevant stimuli, it is possible that the system available at the start of the study was not yet optimized for this purpose. To explore this matter further, the present study obtained expert VR system clinician alignment ratings evaluating the extent to which available VR stimuli aligned with each traumatic experience. Interestingly, emotional engagement during VRE could not be explained by the extent to which VR stimuli resembled the individual's trauma; alignment ratings were unrelated to ratings of distress. Thus, this might suggest that either alignment did not have an impact on SUDS ratings during exposures (e.g., due to the fear structure already being maximally activated), or VR stimuli were not sufficiently aligned in general such that they would differentially impact SUDS relative to PE.

On the other hand, this study used expert clinician ratings of the similarity between the VR system's capabilities and the trauma memories. This may be an inadequate proxy for patient self-reported ratings of the extent to which VR supported emotional engagement. Future research should examine alignment as rated by patients. As VR systems continue to update and advance, ongoing system improvements (e.g. stimuli tailoring, increased diversity of available scenarios, eye tracking) might also address previous limitations. Indeed, the VR Iraq/Afghanistan system used in this study was not updated after recruitment launched in 2009. Dramatic enhancements to the customization and capabilities of this system have occurred in the nearly 10-years since (Rizzo et al., 2017), which may well facilitate improved emotional engagement during VRE. Future studies could consider enrollment criteria that help ensure a fit between trauma memories and VR system capabilities. It is possible that specific sub-groups of patients can benefit from VRE over PE (Norr et al., 2018).

The finding that VRE did not result in significantly higher SUDS relative to PE may be comforting to some clinicians who are considering the adoption of VRE. Those who are new to VRE sometimes express concerns that the treatment may be too intense or may trigger excessive anxiety (Kramer, Savary, Pyne, Kimbrell, & Jegley, 2013). In this light, the findings of this study extend the findings of previous research. The VRE literature reflects the safe treatment of several hundred patients and this study suggests distress during VRE is not significantly higher than that experienced during imaginal exposure.

Conclusions from this study must be drawn carefully, with full consideration of limitations. First, the specific reason for no significant differences between the average and peak distress of participants receiving PE and VRE is not known. It may just indicate equivalence between the two modes of delivery for imaginal exposure therapy. A lack of significantly increased SUDS ratings in VRE might indicate deficiencies in the specific approach tested in the present study, or it could have implications for VR more broadly. Furthermore, power was not adequate to detect small differences between groups if they really did occur. Since the point estimates of the differences were small in magnitude, it is unclear if they would be meaningful even if they were statistically significant. Such answers can only be provided with continued research on VRE. The study is also limited in its lack of data regarding homework adherence. SUDS ratings in session may have been affected by imaginal exposure homework and this factor cannot be examined. Another limitation of the present study, as reported elsewhere (Reger et al., 2016) regards drop-out rates, which were high amongst both groups (44% and 41% for VRE and PE respectively). The study is limited regarding its generalizability; participants were active duty military personnel and all presented with PTSD related to combat experiences in Operation Iraqi and Enduring Freedom; the sample was also predominantly male. It is possible that these results would not generalize to female soldiers, non-combat traumas, or civilians. Finally, patients in this study were diagnosed using DSM-IV criteria, which do not reflect the changes made in the most recent edition.

Overall, the present study fails to provide support for the hypotheses that virtual reality exposure enhances emotional engagement as measured by SUDS with traumatic memories during the course of treatment. These results are important for clinical providers and agencies attempting to provide evidence-based interventions to soldiers experiencing combat-related PTSD. Prolonged exposure is a first line treatment for PTSD with a convincing evidence base (Bradley et al., 2005; Powers et al., 2010; Cahill, Rothbaum, Resick & Follette, 2009; Reger et al., 2016) and yet it is still underutilized in the soldier population (Hoge et al., 2014). Given these results, researchers might aim to improve the measurement of emotional engagement during exposure, patient ratings of the utility of VR systems to support engagement, and the customizability of VR systems to support enhanced activation of the fear structure. It is possible that available VR approaches might be provided in accordance with patient preferences when traditional exposure therapy proves ineffective, or when they might increase engagement. Given the effectiveness of these practices and their underutilization, clinicians should be encouraged to continue practices that maximize engagement and dissemination of trauma focused psychotherapies.

5. Disclosures

Dr. Barbara Rothbaum owns equity in Virtually Better, Inc., which is developing products related to virtual reality, and Dr. Rothbaum is a consultant for Virtually Better, Inc. The terms of this arrangement have been reviewed and approved by Emory University in accordance with its conflict of interest policies. However, the virtual reality used in this study was created by Dr. Skip Rizzo and the ICT lab at USC, not Virtually Better, Inc. Dr. Rothbaum receives royalties from Oxford University Press, Guilford, APPI, and Emory University and received one advisory board payment from Genentech.

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