Journal of Anxiety Disorders 61 (2019) 55–63

Contents lists available at ScienceDirect

Journal of Anxiety Disorders

journal homepage: www.elsevier.com/locate/janxdis

You can do that?!: Feasibility of virtual reality exposure therapy in the treatment of PTSD due to military sexual trauma

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ARTICLE INFO

Keywords:
Military sexual trauma
Posttraumatic stress disorder
Virtual reality therapy

ABSTRACT

This initial feasibility study examined the use of virtual reality exposure therapy (VRE) in the treatment of MST-related PTSD, with newly developed content tailored to MST. Participants included 15 veterans (26% male) with MST-related PTSD. Assessment of PTSD, depression, and psychophysiological indicators of distress occurred at pre-treatment, post-treatment, and 3-month follow-up. Treatment included 6–12 VRE sessions. There were significant reductions in pre- to post-treatment PTSD (CAPS severity: $t(10) = 3.69$, $p = .004$; PCL-5: $t(10) = 3.79$, $p = .004$) and depressive symptoms, (PHQ-9: $t(8) = 2.83$, $p = .022$), which were maintained at follow-up. There also was a significant pre- to post-treatment reduction in heart rate response to a trauma cue. Cohen's d effect sizes were large (CAPS: $d = 1.11$; PCL-5: $d = 1.14$, PHQ-9: $d = .94$), and the percentage of participants meeting PTSD criteria continued to decline from post-treatment (53%) to follow-up (33%). Findings indicate VRE can be safely delivered and is a promising treatment for MST-related PTSD.

1. Introduction

Military sexual trauma (MST) is defined by the Veterans Health Administration (VHA) and Department of Defense (DoD) as any experience of sexual assault or repeated, threatening sexual harassment experienced by a veteran or service member during his or her military service (National Center for PTSD, 2017). A recent meta-analysis of MST prevalence studies estimated that 13.9% of service members and veterans report sexual assault (1.9% of men and 23.6% of women; Wilson, 2016). While these numbers are already high, they likely underestimate the true prevalence of MST as many survivors may not report their traumas.

MST is associated with a variety of negative mental health outcomes, including increased risk of depression, posttraumatic stress disorder (PTSD) substance abuse, and somatic symptoms with the most frequently reported being PTSD (Kimerling et al., 2010; Street, Gradus, Stafford, & Kelly, 2007; Street, Stafford, Mahan & Hendricks, 2008; Surís, Lind, Kashner, Borman, & Petty, 2004). MST is more highly associated with PTSD than civilian sexual trauma (Himmelfarb, Yaeger, & Mintz, 2006). Compared to other types of trauma, MST is related to higher depressive symptoms in men and women (Sexton, Raggio, McSweeney, Authier, & Rauch, 2017) and more associated with PTSD in women (Yaeger, Himmelfarb, Cammack, & Mintz, 2006). MST survivors face a number of barriers to accessing adequate mental health care including stigma, shame, fear of reprisal, retaliation, or social isolation (particularly if they are still serving), and underutilization of evidence-based treatments for PTSD both within and outside VA medical centers (Becker, Zayfert, & Anderson, 2004; IOM, 2012). Furthermore, a large study on implementation of evidence-based treatments for PTSD in the VA indicated that veterans with MST were less likely to complete treatment than those with combat trauma, although those who did complete experienced similar to larger average reductions in symptomatology (Eftekhari et al., 2013). These findings indicate that novel approaches towards engaging and retaining veterans and service members who have experienced MST in treatment are needed.

Prolonged exposure therapy (PE, Foa, Hembree, & Rothbaum, 2007) is a highly effective treatment for PTSD (Powers, Halpern, Ferenschak, Gillihan, & Foa, 2010) and multiple studies have demonstrated its efficacy with victims of sexual assault (Foa, Rothbaum, Riggs, & Murdock, 1991; Rothbaum, Astin, & Marsteller, 2005). Several trials have demonstrated large reductions in symptoms for veterans or service members following PE regardless of trauma type (Goodson, Lefkowitz,

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https://doi.org/10.1016/j.janxdis.2018.06.004
Received 7 October 2017; Received in revised form 30 March 2018; Accepted 14 June 2018
Available online 18 June 2018

Helstrom, & Gawrysiak, 2013; Mouilso, Tuerk, Schnurr, & Rauch, 2016), including a large randomized control trial that provided female veterans and active-duty personnel with PE (72.3% with MST; Schnurr et al., 2007), suggesting PE is an effective treatment within this population.

PE includes imaginal revisiting of a traumatic memory (imaginal exposure) and approaching feared but objectively safe stimuli in the real world (*in vivo* exposure). Both of these procedures are meant to activate pathological fear structures and provide corrective information leading to new, more adaptive associations and beliefs (Foa & Kozak, 1986; Foa & McLean, 2016). Indeed, studies have found that greater fear activation and reactivity both before and during treatment to be associated with improved outcomes in PE (Foa, Riggs, Massie, & Yarczower, 1997; Jaycox, Foa, & Morral, 1998; Norrhom et al., 2016; Rauch et al., 2015; Wangelin & Tuerk, 2015). Despite PE's efficacy, many patients are unable or unwilling to visualize effectively traumatic events and memories, whether due to avoidance or difficulty with mental imagery (Difede et al., 2007; Kosslyn et al., 2002). The use of VRE to deliver exposure therapy for MST-related PTSD may address this barrier by allowing clinicians to immerse patients in trauma-relevant environments that can be precisely controlled by the therapist. VRE provides multisensory and context-relevant cues that may increase the likelihood that the patient's fear structure is activated. Younger veterans and service members who have grown up with digital gaming technology may be more attracted to and comfortable with such an approach, which could increase treatment acceptability (Reger, Gahm, Rizzo, Swanson, & Duma, 2009; Wilson, Onorati, Mishkind, Reger, & Gahm, 2008). Additionally, as some clinicians have been hesitant to adopt PE (Becker et al., 2004; IOM, 2012), VRE technology that is user friendly and customizable for each patient may empower clinicians and increase their comfort level with exposure therapy.

Thus far, VRE has demonstrated efficacy across multiple anxiety disorders (Opriş et al., 2012; Powers & Emmelkamp, 2008) and in PTSD across multiple trauma types (Difede et al., 2007; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001). Studies suggest that patients with PTSD find VRE to be an acceptable treatment, and report high satisfaction with this approach (Botella, Serrano, Baños, & Garcia-Palacios, 2015; Reger et al., 2013). Recently, a system created specifically for those with combat-related PTSD from Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF) has demonstrated efficacy similar to that of PE (McLay et al., 2017; Reger et al., 2016; Rothbaum et al., 2014) at post-treatment, with one study reporting lower response rates than PE at follow-up, although VRE still led to significant reductions in PTSD symptoms compared to waitlist (Reger et al., 2016).

The current study aims to expand the use of VRE to veterans with PTSD due to MST through an initial feasibility study that includes newly built virtual environments tailored to MST. A primary goal is to determine the feasibility of VRE for MST, and we hypothesize that VRE will be safely delivered as a treatment for MST-related PTSD, as evidenced by dropout rates consistent with other PE treatment studies (20–40%) and the absence of critical incidents or adverse effects. A secondary goal is to assess clinical and psychophysiological outcomes of VRE for MST-related PTSD. We hypothesize that participants completing VRE will demonstrate clinically and statistically significant pre- to post-treatment reductions in PTSD and depressive symptoms on self-reported and clinician-assessed symptoms as well as psychophysiological indicators of distress (e.g., heart rate, skin conductance, acoustic startle response), which are objective indices of arousal and extinction learning (see Norrhom et al., 2016; Rothbaum et al., 2014). It is expected that gains will be maintained at the 3-month follow-up assessment.

2. Method

2.1. Participants

Military veterans from all military service eras were self-referred from advertisements (e.g., flyers, social media, webpages, on-hold messaging) and military outreach events (e.g., job fairs, yellow ribbon) or referred by professionals (e.g., community providers, VA, university medical centers). Interested veterans completed an initial phone screen to identify probable diagnosis of PTSD due to MST as well as other inclusion criteria, including veteran status of any era, age range from 18 to 80, medical stability, literacy in English, and ability to comprehend his or her role in the study as well as risks. Participants were excluded for a history of mania, psychosis, or schizophrenia; active suicidal risk; alcohol or drug dependence; inability to tolerate virtual reality helmet; and unstable psychotropic medication (less than 3 months on medication regimen). Twenty-seven veterans completed the phone screen, with five not meeting criteria for the study and two declining to participate in the study. Twenty participants agreed to schedule a pre-treatment assessment, with 15 completing the assessment.

Participants included 15 military veterans who experienced MST during their time in service. Participants ranged in age from 32 to 72 years, with an average age of 46. The majority of participants identified as female (n = 11, 73.4%), African American (66.7%), and were either never married or divorced (n = 9, 60.1%). Participants represented all military branches and the majority served pre-9/11 (n = 8, 53.1%) with an average of two deployments. Rates of total childhood maltreatment (CTQ total: M = 49.67, SD = 24.75) were relatively consistent with another study including veterans (Aversa, Lemmer, Nunnink, McLay, & Baker, 2014). Cutoff scores revealed reports of maltreatment experiences as follows: 40% (n = 6) endorsed physical abuse, 33% (n = 5) endorsed sexual abuse, and 47% (n = 7) endorsed emotional abuse. The most common secondary diagnosis to PTSD was major depressive disorder (n = 9, 60%). Four (27%) of the participants previously completed an adequate dose of trauma-focused treatment (i.e., three completed cognitive processing therapy, one completed cognitive behavioral conjoint therapy for PTSD); however, none of the treatment protocols included exposure as the primary emphasis. See Table 1 for demographic information on all study participants.

Of the 15 participants, nine (60%) completed an adequate dose of treatment (i.e., completed greater than 6 sessions) and two participants (13%) completed the study but not a full course of treatment (i.e., completed fewer than 6 sessions and completed post and/or 3-month follow-up assessment), four participants (27%) discontinued the study (2 before initiating treatment, 2 during treatment). There were no significant differences between treatment completers and non-completers on any demographic or pre-treatment assessment variable.

2.2. Measures

2.2.1. Clinician-Administered PTSD scale for DSM-5 (CAPS-5; Weathers et al., 2013)

The CAPS-5 is a 30-item structured interview that corresponds to the DSM-5 criteria for PTSD. The CAPS provides a measure of PTSD severity and diagnosis, and was administered at all assessment time points: pre-treatment, post-treatment assignment, post-treatment, and 3-month follow-up.

2.2.2. The MINI International neuropsychiatric interview (MINI; Sheehan et al., 1998)

The MINI is a semi-structured interview that screens for DSM-5 Axis 1 disorders. The MINI was administered during the pre-treatment assessment to screen and diagnose comorbid axis 1 disorders.

2.2.3. PTSD checklist for DSM-5 (PCL-5)

The PCL-5 is a 20-item self-report measure designed to assess the

Table 1
Participant Demographic Information.

	Intent to Treat $n = 15$	IOP $n = 4$	OP $n = 11$
Education			
HS Graduate	1 (6.7)	1 (25.0)	0 (0.0)
Some College	3 (20.0)	1 (25.0)	2 (18.2)
2-Year College Degree	5 (33.3)	2 (50.0)	3 (27.3)
4-Year College Degree	4 (26.7)	0 (0.0)	4 (36.4)
Completed Graduate/Professional School	2 (13.3)	0 (0.0)	2 (18.2)
Employment Status			
Unemployed	3 (20.0)	2 (50.0)	1 (9.1)
Student	1 (6.7)	0 (0.0)	1 (9.1)
Part-Time	2 (13.3)	0 (0.0)	2 (18.2)
Full-Time	5 (33.3)	0 (0.0)	5 (45.2)
Retired	2 (13.3)	0 (0.0)	2 (18.2)
On Disability	2 (13.3)	2 (50.0)	0 (0.0)
Military Branch			
US Army	4 (26.7)	1 (25.0)	3 (27.3)
US Marine Corps	1 (6.7)	1 (25.0)	0 (0.0)
US Navy	6 (40.0)	0 (0.0)	6 (54.6)
US Air Force	3 (20.0)	1 (25.0)	2 (18.2)
US Marine Corps Reserves	1 (6.7)	1 (25.0)	0 (0.0)
Military Pay Grade			
E1	1 (6.7)	1 (25.0)	0 (0.0)
E2	2 (13.3)	1 (25.0)	1 (9.1)
E3	2 (13.3)	0 (0.0)	2 (18.2)
E4	4 (26.7)	1 (25.0)	3 (27.3)
E5	2 (13.3)	0 (0.0)	2 (18.2)
E6	2 (13.3)	1 (25.0)	1 (9.1)
O3	1 (6.7)	0 (0.0)	1 (9.1)
Deployed			
Yes	8 (53.3)	3 (75.0)	5 (45.5)
No	5 (33.3)	1 (25.0)	4 (36.4)
Military Service Era			
Vietnam	1 (6.7)	0 (0.0)	1 (9.1)
Pre Persian Gulf War (1974-1991)	2 (13.3)	0 (0.0)	2 (18.2)
Persian Gulf War (1991)	1 (6.7)	1 (25.0)	0 (0.0)
Pre OEF/OIF/OND (1992-2001)	4 (26.7)	1 (25.0)	3 (27.3)
OEF/OIF/OND (post 9/11/2001)	7 (46.9)	2 (50.0)	5 (45.5)
Comorbid Diagnoses			
Major Depressive Disorder	9 (60.3)	3 (75.0)	6 (54.6)
Panic Disorder	3 (20.0)	1 (25.0)	2 (18.2)
Agoraphobia	6 (40.2)	1 (25.0)	5 (45.5)
Social Anxiety Disorder	2 (13.3)	0 (0.0)	2 (18.2)
Generalized Anxiety Disorder	3 (20.0)	1 (25.0)	2 (18.2)
Obsessive-Compulsive Disorder	2 (13.3)	1 (25.0)	1 (9.1)
Substance Use Disorder, past 12 months	1 (6.7)	0 (0.0)	1 (9.1)
Participants on psychotropic medications	6 (40.2)	3 (75.0)	3(27.3)

Note: Values presented as *n*(%).

DSM-5 symptoms of PTSD (Weathers, Litz, et al., 2013). The PCL-5 was administered at all assessment time points (i.e., pre-treatment, 6-week post-treatment assignment, post-treatment, 3-month follow-up) as well as across treatment sessions. Internal consistency was adequate in the current sample (α = .90)

2.2.4. Patient health questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001)

The PHQ-9 is a nine item self-report of general depression and distress. Participants rate frequency of depressive symptoms over the past two weeks as 0 (not at all), 1 (several days), 2 (more than half the days), or 3 (nearly every day). Total scores range from 0 to 27. Several studies support its validity, feasibility, and its capacity to detect changes of depressive symptoms over time. The PHQ-9 was administered at all assessment time points: pre-treatment, 6-week post-treatment assignment, post-treatment, and 3-month follow-up. Internal consistency was adequate in the current sample (α = .88)

2.2.5. Childhood trauma questionnaire-short form (CTQ-SF; Bernstein et al., 2003)

The CTQ-SF is 28-item retrospective self-report measure of childhood experience of maltreatment, including physical abuse, physical neglect, emotional abuse, emotional neglect, and sexual abuse. Item scores range from 1 (never true) to 5 (very often true). Total scores range from 25 (no maltreatment) to 125 (severe maltreatment). Internal consistency was adequate in the current sample (α = .95)

2.3. Psychophysiological assessment

Psychophysiological assessments were completed after the interviews at pre- and post-treatment, and at 3-month follow-up visits. Psychophysiological reactivity, consisting of heart rate, acoustic startle, and skin conductance responses, was measured using the Biopac MP150 data acquisition system (Biopac Systems, Inc., Goleta, CA) and analyzed using the Mindware software suite (Mindware Technologies, Gahanna, OH) according to previously published methods from our group (e.g., Norrholm et al., 2011; Norrhom et al., 2016). In short, heart rate, startle, and skin conductance responses were acquired through Ag/AgCl electrodes placed on the torso and wrist, under the eye over the *orbicularis oculi* muscle, and on the middle fingers of the non-dominant hand, respectively. Peak startle amplitude within 20–200 ms after acoustic probe onset was used as the startle response measurement as in previous VR studies coupled to psychophysiology (e.g., Norrhom et al., 2016; Rothbaum et al., 2014). The mean heart rate, mean peak startle amplitude, and mean skin conductance response for each condition (Blue Square control or VR clip) were calculated according to previously published methods (Norrhom et al., 2016; Rothbaum et al., 2014). Pre-treatment to post-treatment analyses are based only on the mean raw response scores obtained during the VR clip.

Participants viewed identical standardized VR clips using an eMagin Z800 head mounted display and audio stimuli were presented binaurally with headphones. Stimulus presentation occurred though the use of SuperLab 4.0 for Windows (Cedrus Corp., San Pedro, CA). The psychophysiology assessment sessions consisted of three 2-minute VR scenes (Rothbaum et al., 2014) separated by presentation of a 30-sec blank blue screen (Blue Square). Two scenes were presented from the perspective of a service member navigating her/his way through a Forward Operating Base (FOB) or through an urban American city environment that included a hotel room with bathroom, an alley adjacent to a bar, and the rear of a parked vehicle. The trauma neutral scene was based on previously used virtual environments depicting the inside of a public space similar to that seen in an American shopping mall. The blank screen and VR scenes were not counterbalanced, but alternated through the session. Two startle probes were presented prior to the onset of VR scenes and during each blank screen. Five startle probes were presented during each VR scene, during periods of low-level background sounds. A total of 25 startle probes were delivered. The time between startle probes was between 9 and 22 s, consistent with previous research (e.g., Norrholm et al., 2006).

2.4. Apparatus

The BRAVEMIND virtual reality system used in the current project was developed at the University of Southern California Institute for Creative Technologies and the equipment and technical specifications (e.g., computer, software, VR headset, interface devices, etc.) are detailed in Rizzo et al. (2017). The VR MST-specific stimulus content was built into the BRAVEMIND VR exposure system previously developed for use in treating combat-related PTSD. MST-relevant scenarios and features were designed and developed leveraging expert clinician feedback and existing literature, which specified the types of environments where the occurrence of MST has been commonly reported. This led to the creation of an Afghanistan-themed forward operating base that included barracks, tents, other living and work quarters, latrines, and showers. Additionally, a set of US civilian and military base contexts were constructed that included barracks, offices, apartments, a small town bar area, vacant lots, motel rooms, bathrooms, and

Fig. 1. Examples of content in the BRAVEMIND Military Sexual Trauma (MST) scenarios.

Fig. 2. US Base and Town Scenario Clinician Interface. The clinician interface includes options to adjust the following: 1) time of day (e.g., morning, sunset, night), 2) starting location (e.g., bar, apartment, alleyway, office), 3) setting details including doors open or closed (e.g., women's restroom, apartment bedroom) and lights on or off (e.g., men's restroom, office), 4) looping sounds (e.g., road traffic, bar noise, breathing, shower), and single sounds (e.g., pants zipper, cell phone vibrating, remove clothes, revolver cocking).

automobile interiors (see Fig. 1 for sample images). Patients can be immersed in relevant locations within the virtual scenarios and clinicians can provide real time customization of the ambient settings (e.g., time of day, room lighting, ambient sounds, etc.) and trigger stimuli (e.g., breathing of a perpetrator, etc.) via a separate "Wizard of Oz"-type clinician interface (see Fig. 2). This interface is a key feature that allows clinicians to customize the therapy experience to match the patients' trauma narrative. The system does not attempt to recreate visually a sexual assault as the patient describes the assault details (for example, no assailant avatar is used), but rather, attempts to match context and setting cues, including sounds and lighting, that the patient describes in accordance with the established protocol that implements PE within the VR simulations (Rothbaum, Difede, & Rizzo, 2008).

2.5. Procedure

Following the phone screen, eligible participants were scheduled for a pre-treatment assessment and were asked to provide a copy of their DD214 to confirm military service record. All assessment and treatment procedures took place in an established outpatient psychiatric and behavioral healthcare clinic setting. During the pre-treatment assessment, assessors informed participants of study details, participants signed consent forms, and the assessor administered the CAPS-5 to confirm a PTSD diagnosis due to MST. All other interview, self-report, and psychophysiological assessment were conducted at this time.

The feasibility study was initially conceived of as a small 6-week waitlist control randomized design; however, due to an imbalance in randomization and commensurate imbalance in dropout between the arms, the design was converted to an open trial midway through to safeguard recruitment resources for the main study goal. Thus, the first 9 of 15 participants were randomly assigned to either immediate VRE ($n = 6$) or waitlist control ($n = 3$). Randomized participants completed a 6-week post-treatment assignment assessment, which served as an additional baseline assessment for participants randomized to the waitlist control and as a post-treatment assessment for those in the treatment condition who completed treatment within the first 6-weeks. Participants who were randomized to the treatment condition and completed treatment sessions beyond the 6-week post-treatment assignment date completed a post-treatment assessment at the conclusion of therapy. Three months following the final treatment session, all randomized participants completed the 3-month follow-up assessment. Randomized participants were reimbursed $50 each for the pre-treatment, 6-week post-treatment assignment, and 3-month follow-up assessments, and $20 for the post-treatment assessment.

When the RCT was converted to an open clinical trial, the 6-week post-treatment assignment assessment was discontinued due to the majority of participants requiring greater than 6 weeks of treatment. Open clinical trial participants were given the option to complete the study as part of a 2-week intensive outpatient program (IOP; Harvey et al., 2017). Six additional participants were enrolled in the open clinical trial (IOP $n = 4$), resulting in a total of 15 veterans enrolled in the study. After the phone screen, all open clinical trial participants completed the pre-treatment assessment, post-treatment assessment, and 3-month follow-up assessment. Participants were reimbursed $50 for all onsite assessments and $20 for assessments conducted via phone.

2.6. Treatment

The BraveMind VRE therapy structure was consistent with PE, and included VRE in place of traditional imaginal exposure. Rather than imagining details of the traumatic event in one's mind and sharing them aloud with eyes closed, during VRE the patient recalls the events of the assault aloud while the therapist matches context and sensory details of the events in the virtual environment (e.g., location, sites, sounds) without showing an assailant in the VR. Therapists were trained in both PE and VRE and participated in weekly supervision meetings to ensure fidelity and effective implementation of treatment. VRE treatment included a minimum of 6 and maximum of 12, 90-minute VRE therapy sessions, with the final session number based on reaching a criterion of 70% symptom improvement as indicated on the PCL-5 from baseline or agreement between the clinician and participant that maximum benefit had been achieved. Sessions were once weekly for the first six sessions and once or twice weekly beyond the sixth session in the RCT. In the open clinical trial, if participants received treatment as part of a two-week intensive outpatient program, they received VRE therapy daily for two business weeks.

During the first treatment session, the clinician provided a rationale for VRE therapy, reviewed trauma history, introduced breathing retraining, and oriented the participant to the virtual reality apparatus. Session 2 included a discussion of common reactions to trauma, rationale for in vivo exposure and construction of the in vivo hierarchy. Session 3 included a rationale for VRE, identification of starting and ending points for the VRE, 30–45 minutes of VRE, and processing of the VRE session. Subsequent sessions included homework review, 30–45 minutes of VRE, and processing of events. The final session included rerating SUDS on the in vivo hierarchy. Outpatient participants were reimbursed $20 for time and travel associated with each treatment session (not if they completed the study as part of the IOP). Please refer to the case vignette below for an illustrative example of a veteran's engagement in VRE, including VR cues and individual outcomes.

3. Results

3.1. Feasibility outcomes

Of the 15 participants enrolled in the study, 2 (13%) dropped out of the study after the pre-treatment assessment and before initiating treatment, 4 (27%) discontinued treatment early (i.e., less than 6 sessions), and 9 (60%) completed treatment, resulting in a total dropout rate of 40%, as a most conservative estimate, and a dropout rate of 31% when including only participants who dropped out of the study after initiating treatment (i.e., 4 of the 13 treatment initiators). No critical incidents occurred or were reported during the course of the study. See Table 2 for means and standard deviations for all outcome measures of PTSD, depression, and psychophysiological indicators of distress. Of note, *t*-test analyses revealed no significant differences between IOP and

Table 2
Means and standard deviations for assessment of PTSD, Depression, and Psychophysiological indicators of distress.

	Intent to Treat		IOP Participants		OP Participants	
	n	*M(SD)*	*n*	*M(SD)*	*N*	*M(SD)*
CAPS						
Pre	15	41.53 (10.08)	4	40.25 (10.21)	11	42.00 (10.49)
Post	11	28.91 (15.51)	4	31.50 (8.19)	7	27.43 (18.98)
3mth	9	27.89 (14.63)	2	29.50 (7.78)	7	27.43 (16.56)
PCL-5						
Pre	14	48.35 (13.48)	4	54.25 (4.11)	10	46.00 (15.34)
Post	11	26.81 (19.83)	4	19.00 (8.29)	7	31.29 (23.60)
3mth	9	35.00 (18.37)	2	40.00 (7.07)	7	33.57 (20.76)
PHQ-9						
Pre	13	16.45 (5.70)	4	20.00 (4.40)	9	14.89 (5.69)
Post	9	11.78 (6.08)	4	11.75 (4.72)	5	11.80 (7.56)
3mth	9	14.00 (6.12)	2	16.50 (2.12)	7	13.29 (6.82)
Heart Rate						
Pre	13	73.43 (9.66)	4	73.85 (5.86)	9	73.24 (11.27)
Post	7	66.12 (3.92)	3	64.09 (5.62)	4	67.65 (1.56)
Skin Conductance						
Pre	13	4.78 (6.00)	4	6.80 (7.15)	9	3.89 (5.65)
Post	7	1.92 (2.30)	3	3.61 (2.80)	4	0.65 (0.58)
EMG Startle						
Pre	6	5.85 (4.62)	3	2.85 (2.20)	3	8.85 (4.65)
Post	4	1.06 (0.44)	3	1.03 (0.53)	1	1.14 (n/a)

Table 3
Paired t-tests examining change in PTSD, depression, and psychophysiological indicators of distress.

Outcome	*n*	*M*	*SD*	*M* Difference	*SD* Difference	*t*-Test	Cohen's *d*
CAPS							
Pre/Post	11	42.55/28.91	9.92/15.51	13.64	12.27	3.69**	1.11
Post/3mth	9	29.56/27.89	17.00/14.63	1.67	11.16	0.45	
PCL-5							
Pre/Post	11	47.09/26.82	14.67/19.83	20.27	17.75	3.79**	1.14
Post/3mth	9	29.78/35.00	20.84/18.37	−5.22	10.51	−1.491	
PHQ-9							
Pre/Post	9	16.56/11.78	6.64/6.08	4.78	5.07	2.83*	0.94
Post/3mth	7	12.57/13.00	6.37/5.89	−0.43	3.99	−0.28	
Heart Rate							
Pre/Post	6	78.38/65.80	5.96/4.19	12.58	3.89	7.92**	3.23
Skin Conductance							
Pre/Post	4	5.06/1.99	6.24/2.51	3.07	3.86	1.95	0.80
EMG Startle							
Pre/Post	6	5.31/1.06	5.23/0.44	4.25	5.28	1.61	0.80

* $p < .05$.
** $p < .01$.

OP participants on pre-treatment PTSD, depressive symptoms, or demographic variables. Therefore, due to lack of pre-treatment differences and small treatment cell sizes, further analyses included all participants. One of the four IOP participants discontinued VRE therapy but remained in treatment and completed prolonged exposure therapy. The overall IOP treatment retention rate was 100% with no reported critical incidents.

3.2. VRE treatment outcomes for PTSD and depressive symptoms

As shown in Table 3, paired samples t-tests were conducted for the intent-to-treat sample ($n = 15$) to examine 1) the average change in PTSD and depressive symptoms between pre- and post-treatment assessments, and 2) the maintenance of treatment gains between post-treatment and 3-month follow-up assessments. There was a significant reduction in pre-treatment to post-treatment clinician-assessed PTSD symptoms (CAPS severity: $t(10) = 3.69$, $p = .004$), self-reported PTSD symptoms (PCL-5: $t(10) = 3.79$, $p = .004$), and self-reported depressive symptoms, ($t(8) = 2.83$, $p = .022$). There were no significant differences between post-treatment to 3-month follow-up assessments of PTSD (CAPS severity: $t(8) = 0.45$, $p = .666$; PCL-5: $t(8) = -1.49$, $p = .174$) or depressive symptoms ($t(6) = -0.28$, $p = .786$), indicating a maintenance of treatment gains from post-treatment to 3-month follow-up. Pre- to post-treatment Cohen's d effect sizes were large for measures of PTSD and depressive symptoms (CAPS: $d = 1.11$; PCL-5: $d = 1.14$, PHQ-9: $d = .94$). Using established criteria for clinically significant pre to post-treatment score differences, 64% ($n = 7$) of study completers demonstrated a clinically significant reduction in PCL-5 scores (i.e., 10^+ reduction: Wortmann et al., 2016) and 54% ($n = 6$) demonstrated a clinically significant reduction in PHQ-9 scores (i.e., 5^+; McMillan, Gilbody, & Richards, 2010). Notably, the percentage of participants who met diagnostic criteria for PTSD declined across assessment points, decreasing to 53% meeting criteria for PTSD immediately post-treatment and 33% meeting criteria for PTSD at the 3-month follow-up assessment.

3.3. VRE treatment outcomes for psychophysiological indicators of distress

With respect to psychophysiological assessment, the range of missing data was 53% to 73% due to software malfunction, noise in data interfering with interpretation, or participant incompletion. Data from the RCT and open trial were combined such that available psychophysiological data at post-treatment ($n = 4$) or 3-month follow-up ($n = 3$) were combined as a single post-treatment data point, resulting in seven participants having a pre-treatment and post-treatment data point.

Paired t-test analyses revealed a significant reduction in pre-treatment to post-treatment mean heart rate ($t(5) = 7.92$, $p = .001$), as measured during the standardized VR simulation of common MST contexts (e.g., barracks, apartment). The reduction in mean peak startle amplitude ($t(3) = 1.61$, $p = .206$) and mean skin conductance response ($t(5) = 1.94$, $p = .109$) during VR simulation was not statistically significant.

4. Case vignette

The participant was a 38-year-old, male Navy veteran who deployed in support of OIF and was honorably discharged at a pay grade of E4. The participant completed the study through the IOP as part of the open clinical trial. At the time of the study, he was in a committed relationship with a man. He reported repeated sexual assault by a superior noncommissioned male officer. He endorsed childhood sexual abuse, physical abuse, and physical neglect as well as a history of substance use disorder. In addition to PTSD, he met DSM-5 criteria for major depressive disorder, panic disorder, agoraphobia, and obsessive-compulsive disorder at the pre-treatment assessment. Prior to this study, the participant completed cognitive processing therapy to address MST. He completed an equivalent of 11 treatment sessions in the current study to address MST; thus, he completed a full dose of treatment.

For VR exposures, the hotel room setting was used. During the first retelling of the sexual assault, the therapist identified relevant contextual and sensory details to incorporate in subsequent sessions. For example, as the participant described clothes being removed and hearing heavy breathing, the therapist selected the looping sound "male breathing" and the sound of "remove clothes" to match the participant's words and experience (see Fig. 2 for the VR interface). Additional effects used in this case included dimmed lights and orientation towards the open hotel bathroom door, which was lighted. Regarding outcomes, the participant was engaged in VRE therapy sessions and demonstrated high initial emotional activation and significant and relatively quick habituation. His peak SUDS were 100/100 on the first session, reducing to 60/100 during the second session, and 5/100 by the final session. He showed a similar pattern with *in vivo* exposure. The participant described the VR as activating and instrumental in helping him process the trauma and reach his goal of sleeping with a bathroom door open. His maladaptive beliefs related to the event greatly declined over the course of treatment. At the beginning of treatment the veteran reported high levels of guilt and shame for being raped, but by the end he denied any guilt or shame regarding his actions.

Consistent with overall study findings, the participant showed significant reductions in self-reported and clinician-assessed PTSD

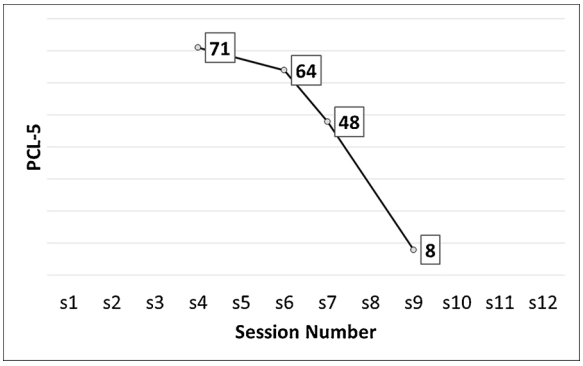

Fig. 3. Case vignette participant PCL-5 scores across treatment sessions. During the IOP, the PCL-5 was administered after the 3rd, 5th, 6th, and 8th treatment sessions.

symptoms, and depressive symptoms declined from the moderately severe to moderate range. Self-reported PTSD symptoms declined across treatment sessions (see Fig. 3). Psychophysiological indicators of distress, including heart rate, peak startle amplitude, and skin conductance assessed during the standardized VR clips declined from pre-treatment to post-treatment assessment (see Fig. 4). The participant continued to meet diagnostic criteria for PTSD at the post-treatment assessment, yet his symptoms declined from the severe to moderate range. This participant was not local and did not complete the 3-month follow-up assessment.

5. Discussion

In this first study to test VRE for MST, utilizing newly developed virtual reality content for MST, this initial feasibility study suggests that VRE can be safely implemented in the treatment of MST-related PTSD. Results indicated dropout rates consistent with other PE treatment studies with military samples, and there were no reports of adverse effects or critical incidents in response to VRE implementation. Importantly, each of the four participants who initiated treatment in the intensive outpatient format completed treatment. Overall, our findings provide initial evidence that VRE for MST-related PTSD can be feasibly implemented and that patients are able to tolerate this approach similarly to traditional exposure therapy for PTSD.

Second, it was hypothesized that VRE therapy would result in statistically and clinically meaningful reductions in PTSD and depression symptoms as well as psychophysiological indicators of distress following treatment. In support of the second hypothesis, this small sample evidenced statistically significant pre- to post-treatment reductions in clinician-assessed and self-reported PTSD symptoms as well as self-reported depressive symptoms which were maintained at the 3-month follow-up. Notably, the majority of participants no longer met diagnostic criteria for PTSD at the 3-month follow-up. Cohen's *d* effect sizes in the current study were consistent with or higher than those found in other treatment studies examining the application of established evidence-based therapy for PTSD within military samples, which range from 0.80 (Schnurr et al., 2007) to 1.02 (Surís, Link-Malcolm, Chard, Ahn, & North, 2013) for both clinician and self-reported PTSD symptoms and .59 (Schnurr et al., 2007) to 0.67 (Surís et al., 2013) for depressive symptoms. Therefore, there is promising initial evidence VRE therapy for MST-related PTSD may be effective in reducing PTSD and depressive symptoms. With regard to objective psychophysiological indicators of distress, there were significant reductions in heart rate at post-treatment compared to pre-treatment. The pre- to post-treatment reductions in skin conductance and EMG/startle were notable but were not statistically significant.

The current study included both an outpatient and intensive outpatient format for delivery of VRE. The lower dropout rate of participants in the IOP format suggests that veterans might be more likely to engage and complete an adequate dose of VRE therapy when treatment is condensed rather than spaced, consistent with recent research on IOP for combat trauma (Beidel, Frueh, Neer, & Lejuez, 2017; Harvey et al., 2017) As dropout from trauma-focused treatment is a significant clinical and health concern among veterans, IOP formats may provide an efficient and innovative way to improve retention.

Findings in the current study must be considered within the context of several study limitations. A primary limitation was the small sample

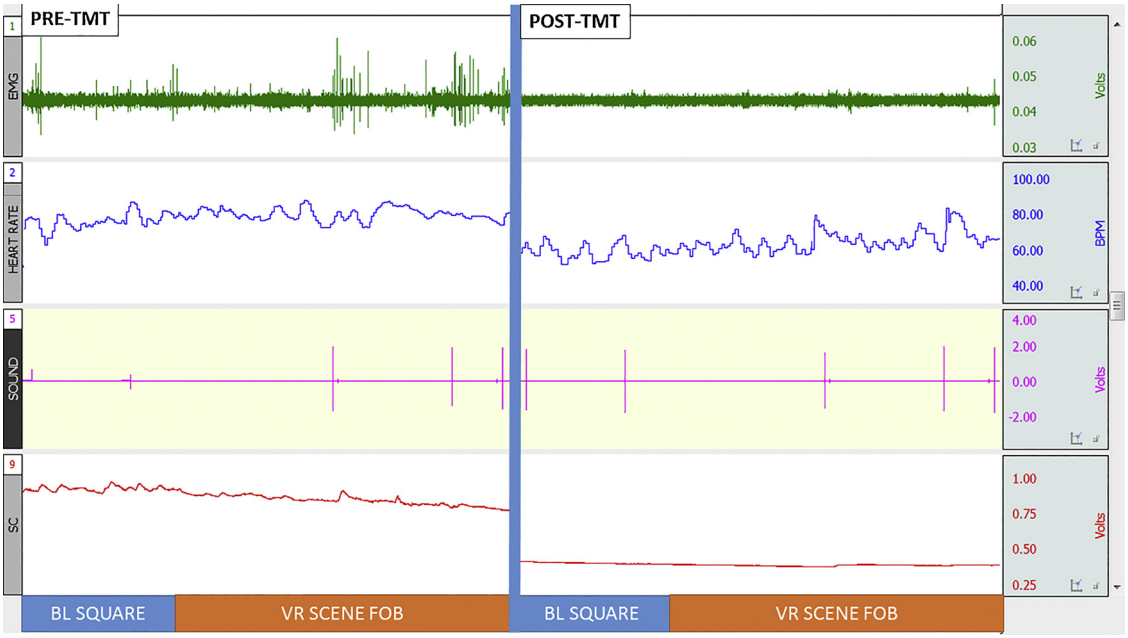

Fig. 4. Case vignette participant pre-treatment and post-treatment psychophysiological indicators of distress. From the top row to bottom row: EMG startle, heart-rate, startle probe, skin conductance. Vertical lines in the startle probe row represent the introduction of the sound probe. For the case example participant, the figure shows EMG reactivity in response to the startle probe during the pre-treatment but not post-treatment assessment. As shown in the figure, reductions in skin conductance and heart rate were notable.

size, and therefore study findings should be interpreted with caution. With avoidance as a hallmark symptom of PTSD, low enrollment likely is related to the difficulty in confronting trauma memories as well as the potential fear of reprisal, shame, and stigma commonly associated with MST-related PTSD. The waitlist condition likely posed an additional, unexpected barrier for engagement, with two out of three waitlist participants dropping from the study before treatment. The potential of being randomized to a waitlist condition might have further hindered study enrollment, particularly among veterans with PTSD who already were ambivalent and avoidant of confronting trauma memories. Another limitation of the current study was the lack of a control group after eliminating the waitlist condition. Future studies will benefit from examining the use of VRE in treating MST-related PTSD with a larger sample and with an active control group to establish treatment efficacy.

Several strengths are noteworthy for this study. First, the sample included a diverse group of military veterans who had served during multiple service eras, presented with varied types and frequencies of comorbid diagnoses, and experienced numerous social stressors. Despite the variability in presentation and background, there were no significant differences between those who did and did not complete the study, and, overall, participants demonstrated benefit from treatment. A second strength was the assessment of treatment gains maintenance at a 3-month follow-up. Lastly, the use of standardized and multi-method assessment of psychological indicators of distress, including self-reports, clinician assessment, and psychophysiological assessment was also a strength.

Overall, VRE has the potential to increase attractive and effective treatment options for veterans and service members with MST-related PTSD. The use of VRE therapy to reduce emotional avoidance and enhance emotional processing can further enhance traditional prolonged exposure. Some clinicians might be reluctant to utilize VRE to address PTSD for concern about worsening patient symptoms, fear the patient is unable to tolerate distress, or a belief the patient is too high risk; however, research does not support an iatrogenic effect of VRE therapy (Arens et al., 2018), and the current study's results are consistent with this finding. With significant mental health difficulties for veterans with a history of MST and the impact of MST on public health, VRE therapy may increase access to care and provide relief to veterans with MST-related PTSD. This study provides initial support for the feasibility and safe application of VRE therapy in treating PTSD related to even highly personal and sensitive traumas, such as sexual assault. Yes, you can do that.

Disclosure statement

Dr. Rothbaum owns equity in Virtually Better, Inc. that creates virtual reality products. The terms of this arrangement have been reviewed and approved by Emory University in accordance with its conflict of interest policies. However, the Bravemind software described in this paper was created by Dr. Skip Rizzo and the Institute for Creative Technologies at USC.

Acknowledgements

This work was supported by DOD grant Number W81XWH-14-C-0091(Rizzo, PI).

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