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Trauma management therapy with virtual-reality augmented exposure therapy for combat-related PTSD: A randomized controlled trial

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ABSTRACT

Virtual reality exposure therapy (VRET) realistically incorporates traumatic cues into exposure therapy and holds promise in the treatment of combat-related posttraumatic stress disorder (PTSD). In a randomized controlled trial of 92 Iraq and Afghanistan veterans and active duty military personnel with combat-related PTSD, we compared the efficacy of Trauma Management Therapy (TMT; VRET plus a group treatment for anger, depression, and social isolation) to VRET plus a psychoeducation control condition. Efficacy was evaluated at mid- and post-treatment, and at 3- and 6-month follow-up. Consistent with our hypothesis, VRET resulted in significant decreases on the Clinician Administered PTSD Scale and the PTSD Checklist-Military version for both groups. Also consistent with our hypothesis, significant decreases in social isolation occurred only for those participants who received the TMT group component. There were significant decreases for depression and anger for both groups, although these occurred after VRET and before group treatment. All treatment gains were maintained six-months later. Although not part of the original hypotheses, sleep was not improved by either intervention and remained problematic. The results support the use of VRET as an efficacious treatment for combat-related PTSD, but suggest that VRET alone does not result in optimal treatment outcomes across domains associated with PTSD.

1. Introduction

The percentage of personnel returning from Operation Iraqi Freedom/Operation Enduring Freedom/Operation New Dawn (OIF/OEF/OND) who have been diagnosed with posttraumatic stress disorder (PTSD) ranges from 8 to 18% (Richardson, Frueh, & Acierno, 2010; Smith et al., 2008; Tanielian & Jaycox, 2008). Although PTSD as a result of military service may result from various types of traumatic events (e.g., combat, sexual assault, or other deployment related traumas), PTSD as a result of combat-trauma appears to be the most notoriously treatment-resistant (Watts et al., 2013). PTSD is characterized by intrusive symptoms that include unwanted memories, unpleasant dreams or nightmares, and flashbacks, as well as physiological and psychological distress in the response to trauma cues. The intrusions are met primarily with avoidance (i.e., effortful and/or passive) that theoretically reinforce symptoms of arousal (e.g., anger, sleep dysregulation, hypervigilance, anxiety). Additionally, combat-related PTSD is associated with emotional dysregulation, social maladjustment, poor quality of life, maladaptive cognitions, anger management difficulties, and impulsive or violent behavior (Frueh, Turner, Beidel, & Cahill, 2001). Given the complexity of the condition, it is logical that equally nuanced interventions are needed.

It has long been thought that exposure therapy is an appropriate treatment strategy for combat-related PTSD (Frueh, Turner, & Beidel, 1995). Interventions based on the core principles of exposure therapy (such as Prolonged Exposure [PE] and Cognitive Processing Therapy [CPT]) have well-established efficacy for civilian PTSD, but less support exists among veteran and active duty military populations with combat-related PTSD (Bradley, Greene, Russ, Dutra, & Westen, 2005; Frueh et al., 2007; Lee et al., 2016; Steenkamp, Litz, Hoge, & Marmar, 2015).

To our knowledge there are only six prospective RCTs that utilized exposure therapy (without VR) to treat US service members with combat-related PTSD (Monson et al., 2006; Morland et al., 2014; Rauch et al., 2015; Resick et al., 2015; Yehuda et al., 2014; Yuen et al., 2015). Recent reviews of the outcomes of exposure-based therapies for combat-related PTSD highlight the sizable percentage of individuals

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that still meet criteria for PTSD after completing treatment (Steenkamp, 2016) and generally, these interventions are associated with moderate effect sizes and high drop-out rates (Gros, Yoder, Tuerk, Lozano, & Acierno, 2011; Strachan, Gros, Ruggiero, Lejuez, & Acierno, 2012; Reger et al., 2011; Tuerk, Yoder, Ruggiero, Gros, & Acierno, 2010). A recent editorial (Hoge, Lee, & Castro, 2017) described current PTSD treatment as an "ongoing crisis" with high treatment attrition rates and a substantial number of participants retaining their PTSD diagnosis after a full course of treatment, and concluded that there is still considerable room for improving treatment efficacy.

Efficacious exposure therapy requires the patient to confront the traumatic event in as much detail and engaging as many sensory modalities as possible (Lang, 1968). The types of events that create combat-related PTSD cannot be reproduced in the clinic setting, thus in vivo exposure for the traumatic event is not feasible. Although imaginal exposure or written accounts of the trauma represent acceptable alternatives, they have several limitations. First, imaginal exposure is under the control of the participant; the therapist has limited ability to ensure that the patient is imagining the scene as described. Distraction or avoidance during imaginal exposure sessions has been demonstrated to attenuate treatment outcome. Second, imaginal or written exposures do not provide actual contact with the sights, sounds and smells that were present during the event and which are reported to serve as cues for flashbacks or other types of re-experiencing symptoms.

Virtual reality exposure therapy (VRET) represents a means of addressing the limitations of imaginal exposure therapy. It allows the presentation of traumatic events that cannot be recreated in vivo, allowing individuals to be in touch with traumatic cues that elicit arousal, and through repeated contact, decrease that arousal. Additionally, VRET overcomes a significant hurdle for imaginal exposure: an inability to engage in imagery of sufficient detail and affective magnitude to recreate the traumatic event (Beidel, Neer, Bowers, Frueh, & Rizzo, 2014). For combat-related PTSD, *Virtual Iraq,* and its successor *Bravemind* (Rizzo & Shilling, in press), presents visual, auditory, olfactory, and tactile cues, thereby engaging 4 out of 5 senses and offering the promise of optimizing exposure therapy.

Two recent randomized controlled trials (RCTs) of veterans or active duty personnel with deployment-related PTSD utilized VRET. Rothbaum et al. (2014) compared six sessions of VRET alone to VRET augmented either by d-cycloserine or alprazolam in a sample of Iraq and Afghanistan veterans. In this case, VRET used the prolonged exposure (PE; Foa, Hembree, & Rothbaum, 2007) model of exposure therapy. The results indicated that VRET alone was superior to VRET plus alprazolam, whereas augmentation with d-cycloserine was not different from either of the other groups. However, 73.5% to 78.6% of participants still met criteria for PTSD at post-treatment. One limitation of this trial is that six sessions may not be sufficient for the treatment of a disorder as severe and multifaceted as combat-related PTSD. Using 10 sessions and again delivering exposure therapy using the PE model, Reger et al. (2016) examined PE versus VRET (using PE) versus wait list control. The results indicated that both PE and VRET were significantly superior to wait list with respect to reducing PTSD symptoms, as measured by the Clinician Administered PTSD Scale (CAPS) − a 34-point reduction for PE and a 23-point reduction for VRET respectively, with no between group differences at post-treatment. Also at post-treatment, 65.63% of the PE group and 56.67% of the VRET group had a clinically significant change in PTSD symptoms, although the percentage no longer meeting diagnostic criteria was not reported.

Over the past 25 years, we have developed, evaluated and refined Trauma Management Therapy (TMT), a multi-component behavioral treatment for combat-related PTSD. TMT initially consisted of 14 sessions of individual imaginal exposure therapy followed by a group treatment designed to specifically treat depression, anger and social isolation (Frueh, Turner, Beidel, Mirabella, & Jones, 1996; Turner, Beidel, & Frueh, 2005). Initially positive results in a small RCT with Vietnam veterans (Beidel, Frueh, Uhde, Wong, & Mentrikoski, 2011) demonstrated that both TMT and an active control condition (individual exposure therapy and a psychoeducation group) significantly reduced PTSD symptoms as measured by the CAPS and PTSD Checklist-Military version (PCL-M). Also, both interventions reduced levels of physical anger outbursts, but only TMT reduced social isolation and enhanced social functioning. However, as with other interventions to date, symptoms remained elevated at post-treatment, suggesting the need for further development and refinement.

Given the less than optimal treatment outcomes reported in the literature, we revised the individual exposure therapy component of TMT by adding VR (Virtual Iraq/Bravemind; Rizzo & Schilling, in press). In a controlled pilot investigation using an intensive outpatient format (n = 112) examining the efficacy of this revision, we found that TMT significantly reduced symptoms of PTSD (Beidel, Frueh, Neer, & Lejuez, 2017). Scores on the CAPS dropped by 52.4 points, with 65.9% of participants no longer meeting diagnostic criteria for PTSD at post-treatment. There were also significant decreases in depression, anger and social isolation. Furthermore, all results maintained at six months follow-up. However, despite the overall positive results, this was a pilot investigation and randomized controlled trials are necessary.

In summary, the status of treatment for PTSD in veteran and active duty military populations indicates that although current treatments result in positive improvement, many individuals continue to display significant symptoms even after a full course of treatment (Hoge et al., 2017). Although TMT shows initial promise for OIF/OEF/OND veterans with combat-related PTSD, it is unclear whether VRET and/or group treatment specifically address the depression, anger, and social isolation that are part of this disorder. Furthermore, although two studies (Reger et al., 2016; Rothbaum et al., 2014) have added VR to one type of exposure paradigm (PE), the amount of exposure therapy was shorter than traditionally provided. Thus, the purpose of this study was to conduct a randomized controlled trial of TMT with OIF/OEF/OND veterans to (a) examine the utility of VRET for the treatment of combat-related PTSD and (b) examine how the group treatment of TMT specifically enhances treatment outcome for depression, anger, and social isolation in comparison to a psychoeducation control group. The specific hypotheses are as follows:

1) VRET (the first element of TMT and the control group) will significantly reduce the core symptoms of PTSD as assessed by the CAPS and PCL-M.
2) The group component of TMT will provide additional benefit in enhancing social and emotional functioning (e.g., increased social interactions, decreased anxiety and depression, decreased rage episodes) over the psychoeducation group alone.

2. Method

2.1. Participants

The RCT (NCT02809326) was approved by the US Army Medical Research and Materiel Command (USAMRMC), Office of Research Protections (ORP), Human Research Protection Office and the University of Central Florida Institutional Review Board, where the study took place. Informed consent was obtained from each participant. Participants were recruited through Yellow Ribbon events, clinician referrals, radio, television and social media ads, and presentations at (a) veterans support groups, (b) veteran-focused public events, and (c) local health and mental health fairs.

A telephone screen determined if the individual met basic study inclusion/exclusion criteria. Specifically, participants had to have experienced a combat-related traumatic event during military service in Operation Enduring Freedom, Operation Iraqi Freedom, and/or Operation New Dawn and believe that they were suffering from PTSD. Participants were excluded if they had:

1) acute cardiac difficulties (angina, myocardial infarction, and severe hypertension) because exposure therapy can be accompanied by temporary increases in heart rate and blood pressure. In the latter case, participants were included only after their physician's clearance.
2) comorbid psychotic disorders, antisocial personality disorder, or substance dependence. In the case of substance abuse, participants were included only after their substance abuse was under control for two weeks.

Participants with comorbid depressive disorders, anxiety disorders, and other personality disorders were included. Participants on benzodiazepines (less than 2% of the sample) had to eliminate their use (under psychiatrist supervision) before beginning the trial. No participant refused to discontinue those medications. With respect to other psychotropic medications, each participant had to be a stable medication regimen for 2–4 weeks prior to the trial (depending on the medication). They had to remain on that medication regimen throughout the trial and major medication changes resulted in administrative removal from the trial (see participant flow diagram).

One hundred seventy-nine (179) veterans and active duty personnel were formally screened for the program (see participant flow chart). Recruitment occurred from March 2010 through May 2016. Eighty-seven participants were excluded from the study. Forty-six (46) did not meet the study criteria, 3 were removed due to very high scores on a malingering scale (see below) and 38 declined to participate. Of the 92 who were eligible and agreed to participate, 49 were randomized to TMT and 43 were randomized to EXP. See flow chart for dropout rates and administrative removals by group and treatment phase. As indicated in Table 1, there was a significant difference in age between the two groups, but no other differences on demographic and clinical variables.

2.2. Assessment

Clinician—Administered PTSD Scale (CAPS; Blake et al., 1990; Weathers & Litz, 1994; Weathers et al., 1999). Designated a priori as the primary outcome measure, the CAPS (DSM-IV) is a 30-item semi-structured interview that assesses the frequency and severity of each of 17 diagnostic

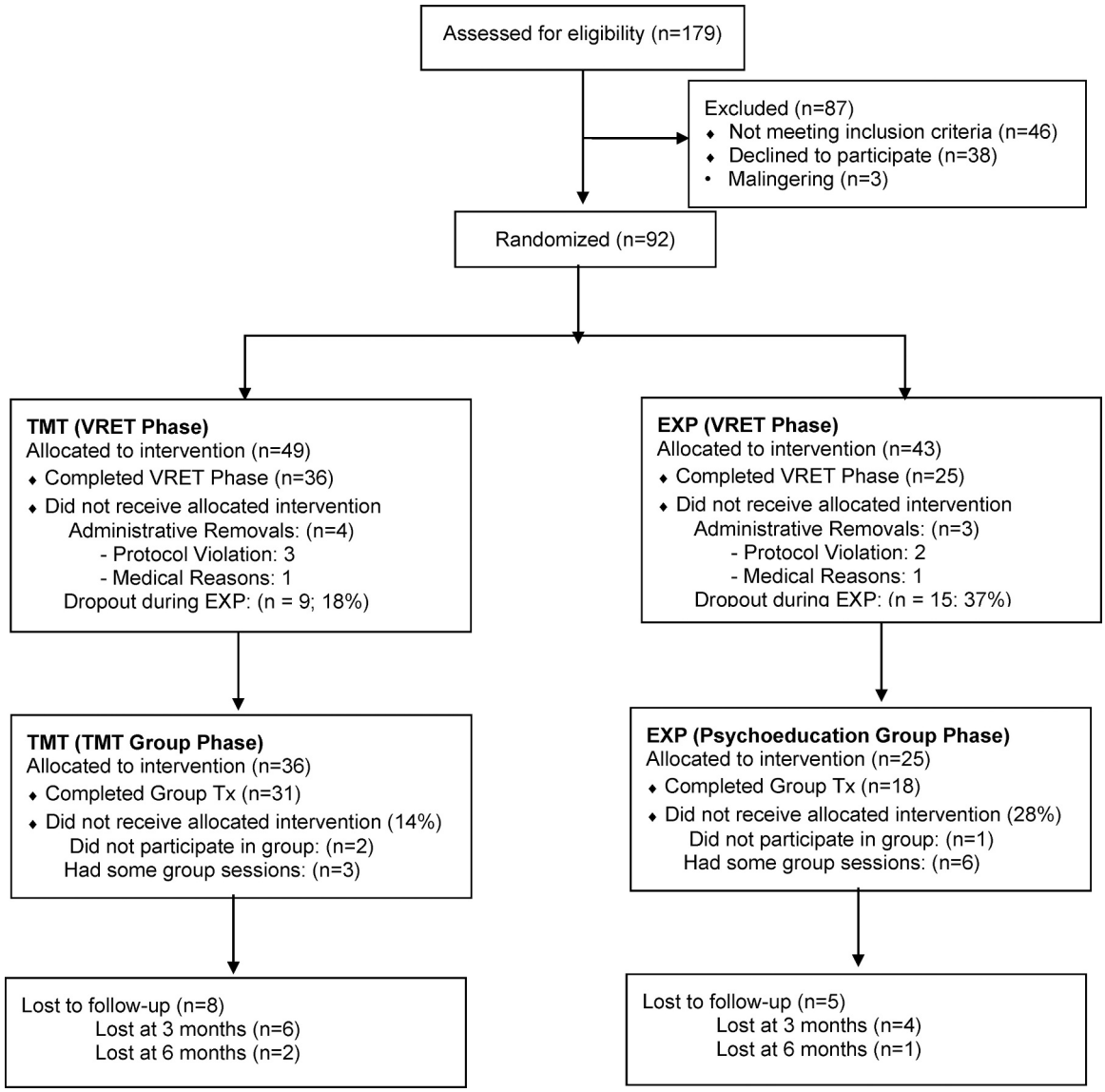

Table 1
Demographics.

Demographic Characteristics	TMT n = 49	EXP n = 43	(Test) p value
	Mean (sd) or n (%)	Mean (sd) or n (%)	
Age	37.67 (8.51)	33.26 (11.31)	(Wilcoxon) 0.002
Sex			(Fisher's) 0.681
Male	45 (91.8%)	41 (95.3%)	
Female	4 (8.2%)	2 (4.7%)	
Race/Ethnicity			(Fisher's) 0.721
Caucasian	32 (65.3%)	24 (55.8%)	
Hispanic/Latino(a)	14 (28.6%)	13 (30.2%)	
Black/African American	2 (4.1%)	4 (9.3%)	
Asian/Pacific Islander	0 (0.0%)	1 (2.3%)	
Other	1 (2.0%)	1 (2.3%)	
Education			(Fisher's) 0.250
High School Diploma	5 (10.2%)	9 (20.9%)	
Some College	29 (59.2%)	27 (62.8%)	
Bachelors	11 (22.4%	4 (9.0%)	
Graduate	4 (8.2)%	3 (7.0%)	
Marital Status			(Fisher's) 0.223
Single	10 (20.4%)	17 (39.5%)	
Married	28 (57.1%)	18 (41.9%)	
Separated	4 (8.2%)	4 (9.3%)	
Divorced	7 (14.3%)	4 (9.3%	
Military Branch			(Fisher's) 0.966
Army	36 (73.5%)	30 (69.8%)	
Marines	8 (16.3%)	9 (20.9%)	
Navy	1 (2.0%)	1 (2.3%)	
Air Force	3 (6.1%)	2 (4.7%)	
Civilian Contractor	1 (2.0%)	1 (2.3%)	
Active Duty			($\chi 2$) 0.964
Yes	9 (18.4%)	9 (20.9%)	
% Service Connected Disability	53.1%	53.5%	($\chi 2$) 0.999
Comorbidity			
HAM-A ≥ 18	38 (79.2%)	29 (67.4%)	($\chi 2$) 0.304
HAM-D ≥ 14	43 (89.6%)	38 (88.4%)	(Fisher's) 0.99
Mood Disorder	33 (67.3%)	27 (62.8%)	($\chi 2$) 0.812
Substance Use Disorder	3 (6.1%)	9 (20.9%)	(Fisher's) 0.06
Anxiety Disorders	7 (14.3%)	7 (16.3%)	(Fisher's) 0.99
Panic Disorder	4 (8.2%)	3 (7.0%)	(Fisher's) 0.99
Specific Phobia	2 (4.0%)	1 (2.3%)	(Fisher's) 0.99
Generalized Anx Dis	0 (0.0%)	2 (4.7%)	(Fisher's) 0.22
Social Anx Disorder	2 (4.0%)	1 (2.3%)	(Fisher's) 0.99
Obsessive Comp Dis	1 (2.0%)	2 (4.7%)	(Fisher's) 0.60

HAM-A (Hamilton Rating Scale for Anxiety).
HAM-D (Hamilton Rating Scale for Depression).

criteria. Additionally, the CAPS quantifies the impact of symptoms on social and occupational functioning. In addition to serving as the primary outcome measure, information on the CAPS was used to determine the presence of PTSD diagnosis at post-treatment and at all follow-up assessments. Licensed clinical psychologists or advanced doctoral students in clinical psychology conducted the interviews. All CAPS interviews were videotaped and 20% (across all assessment points) were rated by a second blinded clinician for the purpose of determining inter-rater reliability. The resultant intra-class correlation was 0.995. (Note: All study diagnoses were based on DSM-IV because the study was initiated prior to the publication of DSM-5).

PTSD Checklist – Military Version (PCL-M; Weathers, Huska, & Keane, 1991). The17-item DSM-IV version of this self-report military-specific questionnaire assessed PTSD symptom severity at pre, mid and post-treatment as well as 3- and 6-month follow-up. Given that the entire exposure phase of the treatment was conducted over 5 weeks, participants were asked to assess the severity of their symptoms "over the past week" rather than over the past month, so that mid treatment assessment was not confounded by pre-treatment status.

Structured Clinical Interview for DSM-IV (SCID I and II; First, Gibbon, Spitzer, Benjamin, & Williams, 1997; First, Spitzer, Gibbon, & Williams., 1997) was administered at pre-treatment to assess for the presence of other Axis I and II disorders.

Miller-Forensic Assessment of Symptoms Test (M-FAST; Miller, 2001). The M-FAST is a 25-item structured interview that is designed to detect malingered mental illness. The M-FAST consists of seven scales including Reported versus Observed, Extreme Symptomatology, Rare Combinations, Unusual Hallucinations, Unusual Symptom Course, Negative Image and Suggestibility. Items are scored yes-no based on the participant response as well as the clinician observation. The M-FAST was administered at pre-treatment.

Clinical Global Impressions Scale (CGI; Guy, 1976). The Severity and Global Improvement Subscales are each 7-point scales that were used to assess overall severity and improvement at all assessment points as well as weekly during treatment.

Hamilton Rating Scale for Depression (HAMD; Hamilton, 1960) and **Hamilton Rating Scale for Anxiety** (HAMA; Hamilton, 1959). These well-known clinical rating scales assess anxiety and depression and were administered at pre-, post-, 3-, and 6-month follow-up.

Self-Monitoring. Throughout treatment patients kept a log of daily behavioral ratings to monitor nightmares, total hours of sleep, and severity of anger (on a 10-point scale; 0 = no anger, 5 = moderate anger, 10 = extreme anger). For socialization, participants recorded the amount of time they spent in social activities (outside of family interactions at home). Participants monitored these behaviors daily throughout the course of treatment. Monitoring forms were turned in at each session and reviewed with the therapist for completion and accuracy.

2.3. Treatment credibility

Three treatment credibility scales (Borkovec & Nau, 1972) were used to assess for potential differences in outcome expectancy based on group assignment. Using a 10-point Likert scale, participants rated how logical the treatment seemed, how confident participants were about treatment, and their expectancy of success.

3. Treatment

3.1. Overview of the treatment program

Each treatment protocol was 17 weeks in length. The first phase of both protocols was identical and consisted of VRET, which was conducted 3 times per week for 5 weeks. Then the individuals participated in their randomly assigned group treatment (described below) which was conducted twice per week for the first two weeks and then once per week. The treatment program totaled 29 treatment sessions over 17 weeks for a total of 43.5 h of treatment for each patient. Participants were randomized to either TMT or EXP prior to initiating treatment. However, clinicians and participants were blinded to group assignment until VRET and the mid-treatment assessment were completed. Both treatments were manualized prior to study initiation.

3.2. Trauma management therapy

(TMT; Turner et al., 2005; Beidel, Frueh et al., 2017; Beidel, Stout et al., 2017). As noted, TMT consists of 29 treatment sessions administered over a period of 17 weeks. Individual treatment occurs first and consists of one psychoeducation/imaginal exposure therapy scene construction session, followed by 14 sessions of VRET.

3.2.1. Exposure

Exposure therapy in the TMT program does not follow the prolonged exposure (PE) treatment model, but does use the construction/

presentation of an imaginal scene that recreates the traumatic event. Unlike exposure in PE, which is administered for 45 min each session, exposure therapy in TMT continues until within sessions habituation (based on patient self-reported distress) is achieved. Therefore, within the TMT model, exposure therapy sessions may initially be 90–120 min in length and as within-session and between-session habituation is achieved, the final sessions may be 15–20 min in length (see further description below). In this study VRET used the *Virtual Iraq/Afghanistan System* (Rizzo & Schilling, in press), which consists of a set of virtual environments for the treatment of combat-related PTSD. The system is customizable and uses a Wizard of Oz interface to re-create the visual, auditory, olfactory, and tactile sensations that were part of the original traumatic event. Elements are delivered via head-mounted display (with a Sony HMZ-T3W head mounted display (HMD) with an InertiaCube 4 motion tracker), earphones, scent machine, and rumble platform (see Rizzo & Schilling, in press for a detailed explanation). In this investigation, the virtual environment (VE) was customized to the individual patient's traumatic scene. For example, if during the imaginal scene, the participant said, "and then I smelled diesel fuel," the therapist would deliver diesel fuel utilizing the Virtual Iraq software and a scent machine driven by an air compressor. If the participant did not recall the smell of diesel fuel, none was delivered.

VRET began in session 2. Anxiety was assessed using a 9-point (0–8) SUDS Likert scale, where 0 equaled no distress and 8 was extreme distress. Following assessment of baseline distress, the imaginal scene was presented by the clinician and SUDS were collected at 10-min intervals. As indicated above, sessions were not constrained by time, but continued until within session habituation (a 50% reduction from in session "peak SUDS") occurred. Thus, a participant who had a peak anxiety of "8" would continue exposure until reporting a level of 4. Overall, initial sessions lasted approximately 90–120 min, but later sessions lasted 15–20 min. If the participant achieved between session habituation (no increase in SUDS upon presentation of exposure scene), the clinician switched to in vivo exposure, using actual places and situations related to their traumatic scene (crowded places, sitting with one's back to a doorway, driving on roads resembling the location of the IED explosion, etc.).

3.2.2. Programmed practice

Programmed practice began at session 8 and continued through the end of the exposure component. Programmed practice was therapist–unaccompanied (i.e., "homework"). Consistent with the individual's unique traumatic event, assignments included watching movies (e.g., Black Hawk Down, Restrepo), visiting crowded places, or engaging with others in crowded social settings, providing additional opportunities to engage directly in feared activities, decreasing behavioral avoidance.

3.2.3. TMT group treatment

This highly structured group therapy component was developed to address elements of the PTSD symptom complex that, in preliminary studies (Frueh et al., 1995) did not appear to be addressed by exposure therapy. Three interventions were included in the group protocol; social reintegration, anger management/problem solving training, and brief behavioral activation for depression. Led by two therapists, the goal of the group component was skill acquisition, and specific training sequences included discussion, modeling, behavioral rehearsal, and feedback. Group sessions were 90 min in length. The three components are described below:

3.2.3.1. Social reintegration. Social reintegration focused on re-establishing and maintaining relationships with family members, friends, and co-workers (i.e., civilians) and engaging in/maintaining diverse social activities. Specific attention was given to communicating assertively, not aggressively.

3.2.3.2. Anger management/problem solving. This component focused on reducing temper outbursts and problematic expression of anger. Skill instruction included identifying high-risk situations and planning ahead, taking a break during a heated moment, reevaluating the situation, problem solving, and using assertive communication. Problem solving skills included defining the problem, brainstorming, evaluating solutions, and selecting/implementing a solution.

3.2.3.3. Brief behavioral activation (Lejuez, Hopko, Acierno, Daughters, & Pagoto, 2011). This component was included to specifically learn skills to deal with depression and guilt. Patients first identified areas of functioning where the participant wanted to make life changes (work, family, etc.). Next, they examined the values held within those areas. The participant then identified, planned, and carried out daily activities that were consistent with the important values identified.

3.3. Exposure treatment only

The EXP Only condition received an identical number of sessions (29) as those receiving TMT using an identical treatment format: one education session, 14 VRET sessions, and 14 sessions of group treatment. VRET was conducted identically as in the TMT condition. The group therapy condition was also led by two clinicians using the same number of treatment sessions. However, for this condition, the group treatment consisted of 7 sessions of psychoeducation regarding PTSD including (a) DSM criteria, demographics and prevalence, (b) risk factors, genetics and biological data, and conditioning models of PTSD, (c) PTSD comorbidity and common comorbid disorders, (d) pharmacological treatment of PTSD, (e) the impact of substance abuse, (f) impairment in interpersonal functioning among veterans with PTSD, and (g) issues related to anger control problems. These were didactic presentations with 15 min for discussion at the end of the presentations and no specific skills were taught or practiced. The remaining 7 sessions were unstructured discussion groups, providing participants the opportunity to share experiences related to their military service or other currently distressful experiences such as relationship issues, occupational or unemployment difficulties, or other topics introduced by the participants. The group leaders moderated, but did not lead, the discussion.

3.4. Treatment fidelity, treatment credibility, and treatment attrition

Therapists were licensed clinical psychologists (4) or advanced clinical psychology doctoral students (11) who received didactic training in the theory and implementation of all treatment components. This training was followed by conducting the treatment on a non-protocol patient, with close supervision by the first or third author. After demonstrating mastery of the treatment components for both protocols, therapists were assigned protocol patients. Therapists received weekly supervision from the first and third author. Twenty percent of the treatment sessions were randomly selected for treatment fidelity. Raters listened to each session and, using a form that included all the treatment elements for individual and group sessions, indicated which treatment elements they heard during that session. Furthermore, interventions that were not part of the overall treatment strategy (such as relaxation training) were also included on the rating form to identify whether extraneous interventions were included in the treatment session. There were no protocol deviations noted.

Treatment credibility ratings were completed after session 3. The average rating was 8.2 for TMT and 8.0 for EXP (on the 10-point scale) for the item "How logical does the treatment seem to you." For the item "How confident are you that this treatment will be successful in eliminating PTSD," the average rating was 7.6 for TMT and 6.9 for EXP. For the item, "How confident would you be in recommending this treatment to a friend who had PTSD," the average rating was 9.1 for TMT and 8.6 for EXP. There were no group differences on any of these

Table 2
Simplified Outputs of Linear Mixed-Effect Regressions (n = 49 for TMT and 43 for EXP).

	β	SE	t	p	Partial-R^2
CAPS					
Pre-Post: R^2 = 0.591					
time	−41.73	3.94	−10.59	0.000	0.383
group:time	−6.24	5.88	−1.06	0.293	0.006
Follow-Up: R^2 = 0.046					
time	−0.61	1.97	−0.31	0.756	0.000
group:time	−0.79	2.96	−0.27	0.790	0.000
PCL-M					
Pre-Mid: R^2 = 0.315					
time	−4.29	0.43	−10.02	0.000	0.174
group:time	0.14	0.63	0.23	0.822	0.000
Mid-Post: R^2 = 0.073					
time	−0.05	0.11	−0.46	0.649	0.000
group:time	−0.20	0.16	−1.24	0.215	0.001
Follow-Up: R^2 = 0.088					
time	−0.51	0.90	−0.57	0.572	0.001
group:time	−0.07	1.34	−0.05	0.960	0.000
CGI-Severity					
Pre-Mid: R^2 = 0.293					
Time	−0.13	0.01	−10.43	0.000	0.152
group:time	−0.01	0.02	−0.55	0.580	0.001
Mid-Post: R^2 = 0.013					
time	−0.02	0.01	−1.92	0.055	0.002
group:time	0.00	0.01	0.02	0.985	0.000
Follow-Up: R^2 = 0.037					
time	−0.16	0.12	−1.34	0.184	0.006
group:time	−0.06	0.18	−0.30	0.762	0.000
Daily Rating of Global Anger					
Pre-Mid: R^2 = 0.060					
time	−0.22	0.06	−3.55	0.001	0.019
group:time	0.02	0.09	0.25	0.805	0.000
Mid-Post: R^2 = 0.050					
time	−0.02	0.02	−0.85	0.396	0.004
group:time	0.00	0.03	0.07	0.944	0.001
Follow-Up: R^2 = 0.037					
time	0.09	0.27	0.33	0.742	0.001
group:time	−0.23	0.36	−0.63	0.535	0.002
Hamilton Depression Scale					
Pre-Mid: R^2 = 0.238					
time	−9.67	1.59	−6.07	0.000	0.129
group:time	0.53	2.35	0.23	0.822	0.000
Mid-Post: R^2 = 0.050					
time	−1.43	1.11	−1.29	0.204	0.004
group:time	−1.26	1.65	−0.76	0.450	0.003
Follow-Up: R^2 = 0.065					
time	−0.51	0.97	−0.53	0.597	0.002
group:time	0.58	1.42	0.41	0.687	0.001
Duration of Daily Social Interaction					
Pre-Mid: R^2 = 0.033					
time	1.67	2.21	0.76	0.449	0.001
group:time	1.77	3.28	0.54	0.589	0.000
Mid-Post: R^2 = 0.029					
time	2.45	0.99	2.47	0.014	0.009
group:time	−5.04	1.56	−3.24	0.001	0.017
Follow-Up: R^2 = 0.025					
time	−18.86	12.02	−1.57	0.124	0.010
group:time	27.65	16.68	1.66	0.105	0.010
Sleep Duration					
Pre-Mid: R^2 = 0.040					
time	0.04	0.04	1.16	0.248	0.002
group:time	0.08	0.06	1.40	0.162	0.003
Mid-Post: R^2 = 0.023					
time	0.00	0.02	0.01	0.989	0.000
group:time	0.05	0.02	2.10	0.036	0.004
Follow-Up: R^2 = 0.088					
time	0.00	0.25	0.01	0.990	0.000
group:time	−0.16	0.34	−0.48	0.635	0.002
Nightmares					
Pre-Mid: R^2 = 0.046					
time	−0.06	0.02	−2.97	0.003	0.007
group:time	0.01	0.03	0.50	0.618	0.000
Mid-Post: R^2 = 0.034					
time	−0.01	0.01	−1.00	0.318	0.000
group:time	0.00	0.01	0.18	0.858	0.000
Follow-Up: R^2 = 0.043					
time	−0.05	0.14	−0.38	0.708	0.001
group:time	−0.09	0.19	−0.47	0.642	0.002

ratings. Thus, the treatment had high credibility, participants were moderately to highly confident that it would eliminate their PTSD, and very confident in recommending the treatment to a friend.

The overall dropout rate was 39%, consistent with other clinical trials examining treatment for combat-related PTSD (Reger et al., 2016; Resick et al., 2015). The dropout rate was 28% for TMT and 50% for EXP, which was not significantly different ($\chi^2 = 2.14$, df = 91, $p < 0.14$).

4. Results

4.1. Intent to treat

We attempted to use multiple imputation (MI) to address dropouts during treatment and follow-up. However, we were unable to come up with a satisfactory model fit. Furthermore, as noted by von Hippel (in press), maximum-likelihood (ML) point estimates are "less biased and more efficient than multiple imputation point estimates in small samples of bivariate normal data… and with our new confidence intervals, ML should be preferred over MI, even in small samples, whenever both options are available." Thus, the intent to treat analysis used the preferred linear mixed-effects regression (LMER). All analyses were conducted using a random slope-intercept model, adjusted for age. Table 2 presents the results of the linear mixed-effect regressions for the intent to treat sample.

4.1.1. PTSD symptoms

4.1.1.1. CAPS. Examining changes on the CAPS from pre- to post-treatment (see Tables 3 and 4 and Fig. 1), the results revealed a statistically significant effect for time ($\beta = -41.73$, S.E. = 3.94, $t = -10.59$, $p < 0.001$, $R^2 = 0.383$). Both groups improved significantly from pre- to post-treatment. There were no main effects for group and no time x group interaction. Furthermore, an analysis of CAPS data from post-treatment to follow-up indicated there were no significant differences across group or time, and no time x group interaction, indicating that treatment gains were maintained at three- and six-month follow-up.

4.1.1.2. PCL-M. Consistent with the outcome for the CAPS, there was a statistically significant main effect for time on PCL-M scores (see Tables 3 and 4) from pre to mid treatment ($\beta = -4.29$, S.E. = 0.43, $t = -10.02$, $p < 0.001$, $R^2 = 0.174$) with no difference between groups and no time by group interaction. From mid- to post-treatment, there was no further significant decrease in PCL-M scores and no time by group interaction. Consistent with the CAPS, there were no significant changes from post-treatment to follow-up; scores indicated that treatment gains were maintained at three- and six-month follow-up.

4.1.1.3. CGI severity and improvement. At pre-treatment, the average CGI Severity rating was 5.0 for TMT and 5.1 for EXP, indicating markedly to severely ill. At post treatment, the average rating was 2.9

Table 3
Pre and Post Outcome on PTSD Measures (n = 49 for TMT and 43 for EXP).

Measure	TMT M and (sd)	EXP M and (sd)
CAPS		
Pre	85.5 (17.7)	82.7 (17.2)
Post	42.3 (22.0)	34.9 (18.0)
3-month follow-up	40.2 (22.6)	29.8 (21.2)
6-month follow-up	41.8 (24.5)	28.3 (18.0)
PCL-M		
Pre	63.4 (11.7)	59.4 (12.6)
Mid	38.9 (14.7)	34.6 (10.0)
Post	40.4 (14.8)	33.0 (9.7)
3-month follow-up	41.3 (15.2)	32.4 (10.5)
6-month follow-up	38.5 (13.6)	28.5 (8.4)
CGI- Severity		
Pre	5.0 (1.0)	5.1 (1.0)
Mid	3.1 (1.0)	2.8 (0.9)
Post	2.9 (1.3)	2.6 (1.1)
3-month follow-up	2.6 (1.3)	2.3 (1.3)
6-month follow-up	2.6 (1.3)	2.1 (1.0)
CGI-Improvement		
Mid	2.0 (0.7)	1.6 (0.6)
Post	2.0 (0.8)	1.7 (0.9)
3-month follow-up	1.8 (1.0)	1.7 (1.1)
6-month follow-up	2.0 (1.2)	1.3 (0.5)

for TMT and 2.6 for EXP, indicating mild illness. The results indicated a statistically significant main effect for time from pretreatment to mid-treatment ($\beta = -0.13$, S.E. = 0.01, $t = -10.05$, $p < 0.001$, $R^2 = 0.152$), with no further changes from mid-treatment to post-treatment. The results were maintained from post-treatment through follow-up, indicating no decline in functioning through follow-up. Consistently, the average improvement at post-treatment as assessed by the CGI Improvement scale was 2.0 for TMT and 1.7 for EXP,

Table 4
Pre, Post, And Follow-up Outcomes on Behavioral and Emotional Symptoms (n = 49 for TMT and 43 for EXP).

Measure	TMT M and (sd)	EXP M and (sd)
Daily Rating of Global Anger		
Pre	4.3 (2.3)	3.8 (2.3)
Post	2.9 (2.2)	2.3 (1.6)
3-month follow-up	2.9 (2.3)	1.8 (1.9)
6-month follow-up	2.1 (2.0)	2.2 (1.7)
Hamilton Depression Scale		
Pre	25.3 (9.6)	22.6 (9.3)
Mid	15.3 (8.4)	13.5 (7.0)
Post	13.8 (9.0)	10.7 (7.5)
3-month follow-up	14.0 (7.3)	9.6 (7.7)
6-month follow-up	13.2 (7.8)	11.6 (7.2)
Duration of Daily Social Interaction[a] (minutes per day)		
Pre	49.7 (54.3)	52.7 (61.9)
Mid	59. 4 (72.7)	66.2 (82.8)
Post	95.2 (124.6)	50.2 (48.6)
3-month follow-up	103.6 (189.8)	51.2 (47.5)
6-month follow-up	93.0 (114.5)	78.7 (74.9)
Sleep Duration (hours)		
Pre	5.14 (1.2)	5.16 (1.9)
Mid	5.43 (1.5)	5.52 (1.9)
Post	5.31 (1.2)	6.00 (1.3)
3-month follow-up	5.38 (1.2)	6.27 (1.8)
6-month follow-up	5.31 (1.7)	5.72 (2.3)
Nightmares (per night)		
Pre	0.82 (1.0)	0.69 (1.0)
Mid	0.59 (0.9)	0.48 (0.9)
Post	0.57 (1.0)	0.47 (1.1)
3-month follow-up	0.37 (0.6)	0.54 (1.2)
6-month follow-up	0.31 (0.5)	0.35 (0.9)

[a] Higher score on this variable represents better social functioning.

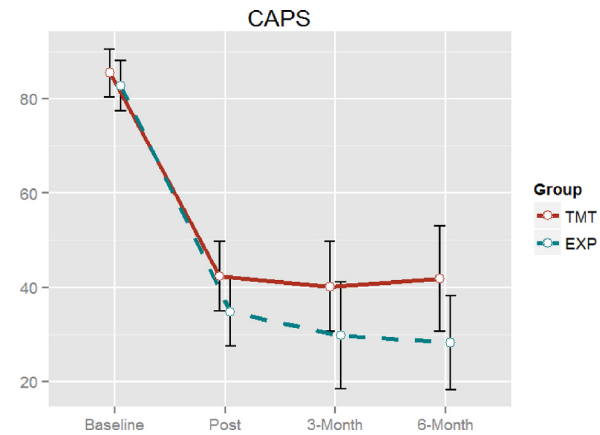

Fig. 1. CAPS scores for ITT sample at pre, post, three and six-month follow-up.

indicating that the average participant was "much" to "very much" improved. This improvement was maintained from post-treatment to follow-up.

4.1.2. Other behavioral and emotional symptoms

4.1.2.1. Anger. There was a statistically significant main effect for time on anger ratings (see Tables 3 and 4) from pre- to mid-treatment ($\beta = -0.22$, S.E. = 0.06, $t = -3.55$, $p = 0.001$, $R^2 = 0.019$) with no difference between groups and no time by group interaction. From mid- to post-treatment, there was no further significant decrease on anger ratings and no time by group interaction. Furthermore, there were no significant changes from post-treatment to follow-up; scores indicated that treatment gains were maintained at three- and six-month follow-up.

4.1.2.2. Depression. There was a statistically significant main effect for time on HAM-D scores (see Tables 3 and 4) from pre to mid treatment ($\beta = -9.67$, S.E. = 1.59, $t = -6.07$, $p < 0.001$, $R^2 = 0.129$) with no difference between groups and no time by group interaction. From mid to post, there was no further significant decrease on depression scores and no time by group interaction. Furthermore, there were no significant changes from post-treatment to follow-up; scores indicated that treatment gains were maintained at three- and six-month follow-up.

4.1.2.3. Social interaction. From pre-treatment to mid-treatment, there were no main effects for time or group, and no time x group interaction, for time spent socializing with others (see Tables 3 and 4). From mid-treatment to post-treatment, there was a significant main effect for time that was tempered by a significant time x group interaction ($\beta = -5.04$, S.E. = 1.56, $t = -3.24$, $p = 0.001$, $R^2 = 0.017$). Thus, the social interaction component of TMT was more effective than EXP Only treatment in increasing social interaction. There were no significant changes from post-treatment to follow-up, indicating that treatment gains were maintained.

4.1.2.4. Sleep. There were no significant main effects for time or significant time x group interactions at any assessment point (see Tables 3 and 4). There was a significant main effect for group, where the EXP group reported longer sleep duration at posttreatment than at six-month follow-up, whereas that was not the case for the TMT group ($\beta = 0.99$, S.E. = 0.36, $t = 2.73$, $p = 0.009$, $R^2 = 0.040$). It should be noted that the difference is only a decrease of 18 minutes. For nightmares, there was a significant main effect for time (pre vs mid-treatment; $\beta = -0.06$, S.E. = 0.02, $t = -2.97$, $p = 0.003$, $R^2 = 0.007$), indicating a significant decrease in nightmares after VR exposure therapy. There were no other effects for time, group and no time x group interactions. All treatment gains were maintained at

Table 5
Pre and Post Outcome on PTSD Measures for Treatment Completers (n = 31 for TMT and 18 for EXP).

Measures	TMT M and (sd)	EXP M and (sd)
CAPS		
Pre	84.0 (19.6)	83.5 (17.8)
Post	44.1 (22.2)	33.2 (17.0)
3-month follow-up	40.2 (22.6)	32.5 (21.7)
6-month follow-up	41.8 (24.5)	30.4 (18.8)
PCL-M		
Pre	63.8 (11.6)	59.6 (12.2)
Mid	40.3 (14.7)	36.1 (10.4)
Post	41.2 (15.1)	32.1 (9.6)
3-month follow-up	41.3 (15.2)	34.2 (10.6)
6-month follow-up	38.5 (13.9)	30.2 (8.7)
CGI- Severity		
Pre	5.0 (1.1)	5.1 (1.0)
Mid	3.1 (1.1)	2.9 (1.0)
Post	3.0 (1.3)	2.7 (1.0)
3-month follow-up	2.6 (1.3)	2.4 (1.5)
6-month follow-up	2.6 (1.3)	2.2 (1.1)
CGI-Improvement		
Mid	2.0 (0.8)	1.8 (0.8)
Post	2.0 (0.8)	1.6 (0.7)
3-month follow-up	1.8 (1.0)	1.8 (1.2)
6-month follow-up	2.1 (1.2)	1.4 (0.5)

follow-up.

4.2. Completer analysis

4.2.1. Outcome variables

Restricting analysis to completers only, all results were analyzed using linear mixed effect regression (LMER) using a random slope-intercept model and adjusted for age. LMER results for completers were identical to the outcome for the intent to treat sample.[1] In Tables 5 and 6 (below), scores on outcome measures for the completers sample are presented.

4.2.2. Responder criteria

A priori, we defined responder criteria as individuals who showed improvement at the end of the active intervention phase (immediate post-treatment) of at least 1 rating category on both the CGI improvement and severity ratings. Based on these criteria, 87.1% of the participants in TMT and 88.9% of the participants in EXP Only responded to the treatment.

4.2.3. Relapse

Relapses were defined a priori as the exacerbation or return of symptoms such that all CGI, HAMA, HAMD, and CAPS ratings returned to or were above (worse than) baseline levels *or* that functioning deteriorated to the point where acute psychiatric hospitalization was necessary to ensure patient safety. No participant required hospitalization. No participants in the EXP group met the relapse criteria and only one participant in the TMT group met these criteria for a relapse rate of 4.5%.

4.2.4. Iatrogenic effects

The clinician at the start of each session as well as at each follow-up visit queried suicidal ideation, suicidal attempts, and substance abuse. There were no instances of increased suicidal ideation and no suicidal attempts. Similarly, there were no instances of increased substance abuse as a result of the intensive nature of the treatment program.

[1] LMER completer analysis available from the first author upon request.

Table 6
Pre, Post, And Follow-up Behavioral and Emotional Symptoms (n = 31 for TMT and 18 for EXP).

Measure	TMT M and (sd)	EXP M and (sd)
Daily Rating of Global Anger		
Pre	4.4 (2.3)	3.9 (2.3)
Mid	3.1 (2.2)	2.7 (1.5)
Post	2.9 (2.3)	2.5 (1.7)
3-month follow-up	2.9 (2.3)	2.1 (2.0)
6-month follow-up	2.1 (2.0)	2.6 (1.4)
Hamilton Depression Scale		
Pre	25.5 (10.1)	21.1 (6.6)
Mid	15.5 (8.6)	13.5 (6.9)
Post	13.5 (9.1)	10.1 (5.8)
3-month follow-up	14.0 (7.3)	8.5 (4.9)
6-month follow-up	13.2 (7.8)	11.5 (7.8)
Duration of Daily Social Interaction[a] (minutes per day)		
Pre	51.6 (59.7)	43.0 (36.0)
Mid	62.1 (75.5)	58.5 (79.7)
Post	98.7 (130.5)	48.2 (48.6)
3-month follow-up	103.6 (189.8)	51.2 (48.5)
6-month follow-up	93.0 (114.5)	79.2 (54.0)
Sleep Duration (hours)		
Pre	5.3 (1.3)	5.4 (1.9)
Mid	5.5 (1.5)	5.7 (1.8)
Post	5.4 (1.3)	6.1 (1.3)
3-month follow-up	5.4 (1.2)	6.0 (1.9)
6-month follow-up	5.3 (1.7)	5.7 (2.6)
Nightmares (per night)		
Pre	0.8 (1.0)	0.7 (1.0)
Mid	0.6 (0.9)	0.5 (0.9)
Post	0.6 (0.6)	0.5 (1.1)
3-month follow-up	0.4 (0.6)	0.6 (1.4)
6 months follow up	0.3 (0.5)	0.4 (0.5)

[a] Higher score on this variable represents better social functioning.

Table 7
Reliable and Clinically Significant Change Scores on the CAPS for Treatment Completers.

CAPS	TMT n = 31		EXP n = 18	
	N	%	*N*	%
Deteriorated	0	0%	0	0%
No reliable change	1	3%	0	0%
Reliable change, but not clinically significant	17	55%	9	50%
Reliable and clinically significant change	13	42%	9	50%

Clinical significant threshold on CAPS = 48.96.

4.2.5. Reliable and clinically significant change

Using the formulas proposed by Hageman and Arrindell (1999), we calculated the percentage of completers who deteriorated, did not change, had a reliable change, and had a reliable and clinically significant change on the primary outcome measure, the CAPS. Results based on group are presented below. Except for one person, all participants demonstrated reliable change or reliable and clinically significant change at post-treatment. There were no differences between treatment groups (See Table 7).

5. Discussion

The results of this investigation indicate that VRET is an efficacious intervention for combat-related PTSD. The intervention resulted in statistically significant improvement across a range of symptoms, all treatment gains were maintained at three- and six-month follow-up and the outcome was identical, whether treatment completers or the intent to treat sample was used. These results are consistent with, but clinically superior to, a prior RCT using an identical design (TMT vs. EXP

plus a psychoeducation; Beidel et al., 2011). Specifically, although both RCTs reported significant decreases in CAPS and PCL scores, only in the current investigation were those scores clinically meaningful. There were several differences in the studies in terms of sample characteristics (OIF/OEF vs. Vietnam veterans), chronicity (< 15 years vs. 40 years) and manner of conducting EXP (both used a flooding paradigm, but the Vietnam study used imaginal exposure vs VRET that was used in the current investigation). Thus, although it is difficult to determine why the clinical outcome was enhanced for the current trial, the use of VRET is certainly one possibility that merits further investigation.

Returning to the results of this investigation, VRET significantly decreased PTSD symptoms as assessed by the CAPS and the PCL-M. The average decrease in CAPS score was 41.7 points (Intent to Treat sample), which is larger than the results of two other investigations (Reger et al., 2016; Rothbaum et al., 2014), but is consistent with the results of our intensive outpatient pilot program (Beidel et al., 2017). Since all four studies used the same VR system, one logical explanation for the differences is the manner in which exposure therapy was implemented.

The individual exposure therapy component of TMT is mechanistically different from PE and represents a theoretically different conceptualization of how exposure therapy should be delivered. PE attempts to reduce the physiological and emotional reactivity associated with a traumatic event through imaginal exposure and supplements this arousal reduction with emotional processing in the same 90-min session. Initially, PE uses a graduated imaginal and in vivo exposure (hierarchy). Focusing specifically on the "hot spots" encountered during PE imaginal sessions (typically session 5 or 6) is only introduced after habituation to the relatively less-distressing parts of the memory has begun to occur (Foa, Hembree, & Rothbaum, 2007). In contrast, the TMT individual exposure therapy component uses an intensive (flooding) approach, fully immersing the participant into the entire traumatic event from the first treatment session. Although the specific mechanisms of TMT are currently being investigated (Trachik et al., in preparation), it is possible that a true immersive flooding technique better facilitates the mechanisms of expectancy violation or habituation and allows for more rapid new learning to occur.

Another important distinction is the time spent imagining the exposure scene. The emotional processing component of PE uses Socratic questioning and cognitive restructuring at the end of each session (Foa et al., 2007). The actual exposure is often reported as consisting of 30–45 min of the 90-min treatment session. In contrast, TMT exposure therapy sessions are not based on time, but continue until the participant reports decreased distress (i.e., within session habituation). The theory is that exposure weakens the fear response, thus allowing new learning (i.e., extinction learning) to occur (e.g., Davis, Ressler, Rothbaum, & Richardson, 2006). As the patient engages with traumatic cues without the feared negative consequences, new learning is acquired and new neuronal connections are formed. Thus, fear habituation is essential to this learning process. Initially, individual exposure may last 90–120 min for within session habituation to occur.

Although several investigators have noted that within session habituation is not necessary for efficacious treatment outcome (e.g., Baker et al., 2010; Nacasch et al., 2015), participants in those investigations typically consisted of specific phobias or traumatic events such as car accidents. It is unclear that the results obtained from those conditions are applicable to combat-related PTSD. Although a direct comparison of the two approaches to VRET is necessary to draw more definitive conclusions, the results of this investigation, as well as a prior investigation (Beidel et al., 2017) indicate that VRET (when conducted so as to achieve both within session and between session habituation) can be efficacious for the treatment of combat-related PTSD. Furthermore, as the mechanisms of TMT have yet to be elucidated, the additional time to achieve within session habituation may have allowed for expectancy violation to occur (Craske et al., 2008) in a greater number of patients and to a greater degree than in shorter exposure interventions.

In addition to significantly decreasing the core symptoms of combat-related PTSD, in this investigation, VRET also significantly decreased symptoms of depression and anger. TMT was developed based on earlier work with Vietnam veterans and earlier conceptualizations of the factor structure of PTSD (Frueh et al., 1996). Based on those models and our clinical observation, we had not observed typical exposure therapy to significantly impact these emotions. Thus, even in this investigation, we hypothesized that it would be the group treatment component of TMT that would decrease anger and depression. Significant decreases in these emotions occurred before the initiation of the group treatment, suggesting the potent efficacy of intensive exposure therapy, even in the absence of formal emotional processing. A recent investigation of PE also documents its efficacy on depression (Reger et al., 2016) but to our knowledge this is the first study to report direct effects on anger reduction.

In contrast to the results for anger and depression, only individuals who participated in the group component of TMT reported increased time spent in social activities, consistent with our hypothesis. This increase likely resulted from the social reintegration component of TMT, but also may have been influenced by the inclusion of behavioral activation for depression, which challenges individuals to engage in activities consistent with their goals and values. Conversely, we made no prediction about the effects of any exposure or group intervention on sleep duration and none was found, consistent with other investigations (Pruiksma et al., 2016). One possible conclusion is that changing behaviors such as social engagement and sleep, as opposed to changing emotions, may require interventions directly targeted at the problematic symptom.

Also consistent with other investigations of treatment for combat-related PTSD, there was a substantial dropout rate in this study. Additionally, one finding that remains unexplained is the differential dropout rate between the two groups during VRET. Both groups were treated by the same therapists and received identical treatment. Neither patient nor therapist knew the group assignment until the participant completed VRET. Yet the dropout rate for the EXP plus psychoeducation group was almost twice the dropout rate for participants who later participated in the group component of TMT. Although we examined numerous demographic and clinical variables, we were not able to determine any specific reason for the differential dropout. Overall, we did find that, at mid-treatment, dropouts had significantly lower overall clinician-rated distress ($\underline{M}$ = 1.5, s.d. = 2.7) than patients who continued onto group treatment ($\underline{M}$ = 2.8, s.d. = 1.52, $p < 0.05$), suggesting that individuals who dropped out were experiencing less overall distress than those who continued to the group phase of treatment (based on a 9-point Likert scale assessing overall level of distress). Furthermore, although not statistically significant (Wilcoxon $p = 0.10$), among those participants who were service-connected for PTSD, the average service-connected disability percentage for completers was 44.3%, whereas it was higher (61.00%) for dropouts. Determining the reasons for dropout continues to be a challenge because efficacious treatments are not effective if patients do not receive the treatment.

With this study, we have now replicated the results of TMT with a second population consisting of OIF/OEF veterans and active-duty military personnel with combat-related PTSD. What is different between the two investigations is the length of the treatment program. Whereas in this investigation we used a 17-week treatment format, in our previous investigation (Beidel et al., 2017), the 29-sessions were implemented in an intensive outpatient program (IOP) over a three-week period. Dropout rates were different for the two treatment formats. In this investigation TMT resulted in a dropout rate of 28%, lower (although not significantly lower) than EXP (50%) or the dropout rates of 40% reported by other recent large-scale trials (Imel, Laska, Jakupcak, & Simpson, 2013; Steenkamp et al., 2015). In contrast, delivering the program over a three-week period resulted in a dropout rate of 2% (Beidel et al., 2017). Our intervention (17 weeks) was probably the longest of any recently published trial, and it appears that shorter

interventions such as our IOP produce the same outcome in less time. A drop-out rate of 2% as found in our intensive outpatient program is a critical consideration when deciding how to design and implement a treatment program, as it suggests that more people will get efficacious treatment.

As with any study, this one has its limitations. In addition to the dropout rate, a second limitation is that despite randomization, the group receiving TMT was slightly and consistently more impaired across virtually every baseline variable. Although none of the differences were significant, how the combination of these variables might have affected treatment is unclear. A third limitation is that our investigation did not compare our form of exposure therapy (intensive exposure) with or without VR to a different exposure model, something that we plan to do in future investigations.

In summary, the results of this investigation indicate that VRET resulted in substantial and significant decreases in PTSD symptoms, as indicated by an average decrease of 41.7 points on the CAPS, with 42%-50% of each group demonstrating reliable and clinically significant changes on this measure (and all but one participant demonstrating at least reliable change). The outcome of this investigation is more positive than other recently published trials that have used the same VR system to treat combat-related PTSD, suggesting that the results may have to do with the way exposure therapy was implemented. Additionally, the results of this investigation demonstrated that intensive exposure therapy can be delivered safely, with no iatrogenic or negative outcomes. Furthermore, all positive results were maintained at six-month follow-up, with a very low relapse rate (4.5%). Future research should continue to investigate augmentations to the delivery of existing interventions for PTSD and additional treatment components (e.g., sleep hygiene) that may lead to more comprehensive treatment gains. Ongoing investigations in our clinic are examining even longer-term follow-up as well as treatment modifications to further address the needs of veterans and military personnel with combat-related PTSD.

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