Virtual Reality Exposure Therapy for Combat-Related Posttraumatic Stress Disorder

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Virtual reality (VR) technology is rapidly evolving to support prolonged exposure (PE) therapy, a proven treatment for combat-related posttraumatic stress disorder. Building on the successful 2007 Virtual Iraq/Afghanistan VRET system, a team of behavioral scientists, software engineers, and virtual artists has created Bravemind, a flexible VR system that offers significantly enhanced PE treatment possibilities.

In the early 1990s, behavioral healthcare professionals began to envision using virtual reality (VR) simulations for clinical intervention, particularly as a means to deliver exposure therapy in treating specific phobias, but were limited by the rudimentary systems then available. Over just two decades, dramatic advances in underlying VR technologies—computational speed, 3D graphics rendering, audiovisual and haptic displays, user interfaces and tracking devices, voice recognition capabilities, intelligent agents, and authoring software—have greatly expanded treatment opportunities. Driven in part by the digital gaming and entertainment industries, these advances have led to the emergence of sophisticated yet cost-effective VR systems that run on commodity-level personal computers and provide interactive, immersive experiences and scenarios that open many doors for psychological research and behavioral health applications in the 21st century.

More specifically, the spike over the last 10 years in the number of US service personnel returning from battlegrounds in Afghanistan and Iraq with traumatic injuries has driven an intense focus on marshaling computer technology to enhance, expand, and extend clinical care methodologies. The US Department of Defense (DoD) and Department of Veterans Affairs (VA) have responded to this urgency with substantial funding to foster innovations in behavioral healthcare technology for purposes of treatment as well as to reduce "barriers to care."[1] This support is evident most dramatically in the resources now devoted to research on traumatic brain injury, posttraumatic stress disorder (PTSD), and comorbid health conditions, with a special focus on clinical VR technology that can help assess, treat, and optimally prevent PTSD.

COMBAT-RELATED PTSD

The physical, emotional, cognitive, and psychological demands military personnel face in combat create enormous stress for even the best prepared. The particular challenges characterizing the ground wars in Iraq and Afghanistan have produced significant numbers of active service members and veterans at risk for developing PTSD and other psychosocial and behavioral health conditions.

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As of December 2012, the DoD's Defense Medical Surveillance System database reported 131,341 active-duty service members diagnosed with PTSD.[2] In a meta-analysis across studies since 2001, 13.2 percent of operational infantry units met overall criteria for PTSD, with PTSD incidence rising dramatically from 25 to 30 percent in those units experiencing the highest levels of direct combat.[3] During this same period, the prevalence of PTSD among discharged veterans receiving treatment at VA clinics has been reported at 29 percent.[2] These findings make a compelling case for a continued focus on developing and enhancing diverse evidence-based treatment options for combat-related PTSD.

Anticipating a need for behavioral therapies appropriate to serve Gulf War combatants, the USC Institute for Creative Technologies in 2004 developed a prototype Virtual Iraq VRET system for initial user feasibility testing.

PROLONGED EXPOSURE THERAPY

Among the many approaches used to treat people diagnosed with PTSD, prolonged exposure (PE) therapy[4] has significant scientific evidence supporting its therapeutic efficacy.[1] Such treatment typically involves a patient's graded and repeated imaginal reliving and narrative recounting of the traumatic event within a therapeutic setting.

Although PE therapy relies primarily on sensory memory and imagination, the exposure process is not passive. Patients are asked to recount their trauma verbally in the first person with their eyes closed, as if it were happening again, with as much attention to sensory detail as they can. Based on his or her clinical judgment, the therapist might prompt the patient with questions about the experience or provide encouraging remarks to facilitate recounting the trauma narrative. This approach provides a low-threat context in which a patient can confront and therapeutically process trauma-relevant memories and emotions as well as de-condition the cycle associated with the disorder via a process known as habituation/extinction.

VR AS A PE THERAPY TOOL

While PE therapy's efficacy has been established in multiple studies with diverse trauma populations, many patients are unwilling or unable to effectively visualize the traumatic event, an occurrence that may result in treatment failure. In fact, avoiding reminders of the trauma is a cardinal symptom of PTSD. To address this problem, researchers have explored VR as a tool for delivering exposure therapy (such as VRET). The rationale for this is clear and compelling. Used as part of an evidence-based PE protocol, VR can provide a way to immerse users in simulations of the traumatic experience. Moreover, the clinician can precisely control the scene's emotional intensity and customize the pace and relevance of the exposure for the individual patient.

VRET effectively circumvents the natural tendency to avoid traumatic memories by directly delivering multisensory and contextual cues that help the patient retrieve, confront, and process these experiences. VR also provides the therapist with an objective and consistent format for documenting the sensory stimuli to which a patient is exposed and the resulting reactions; this is not possible when the therapy operates exclusively within the unseen world of the patient's imagination.

Success using VRET for patients with non-PTSD anxiety disorders such as specific phobias has been documented in multiple independent literature meta-analyses, most recently by David Opris and his colleagues.[5] In addition, multiple studies report positive outcomes using VRET for patients diagnosed with PTSD unrelated to combat in Iraq and Afghanistan, who were unresponsive to a previous course of imaginal-only PE treatment.[6,7]

Using VR as a delivery system for PE therapy in cases of combat-related PTSD could also help break down barriers to care by improving treatment appeal, acceptability, and adherence among those most at need.[8] Although perhaps reluctant to seek out traditional talk therapies, the current generation of military service members and veterans, most of whom grew up with digital gaming technology, might perceive less stigma attached to VR therapy, and so be more attracted to and comfortable with this treatment option.

THE VIRTUAL IRAQ/AFGHANISTAN VRET SYSTEM

Anticipating a need for behavioral therapies appropriate to serve Gulf War combatants, the USC Institute for Creative Technologies in 2004 developed a prototype Virtual Iraq VRET system for initial user feasibility testing. Supported by a clear theoretical rationale and the current literature, this prototype was followed by a full Virtual Iraq/Afghanistan VRET system, developed between 2005 and 2007 with funding from the US Office of Naval Research.

To maximize its clinical relevance, the system combined theory-driven design with iterative user-centered feedback cycles involving military personnel who served in Iraq and Afghanistan. Pre-clinical testing was conducted at Fort Lewis, Washington, and with a US Army Combat and Operational Stress Control unit stationed in Iraq.[8] This feedback from service members not diagnosed with PTSD, and from later clinical users, has provided essential input for the system design's ongoing evolution in content and usability.

The 2007 system consists of four customizable scenarios representing relevant contexts for treating combat-related PTSD: three Humvee driving scenarios—set respectively in Iraq, Afghanistan, and the US—and a navigable dismounted patrol scenario set in a 24-block Middle Eastern city. General driving navigation uses a standard Logitech F310 game pad; for interactions in the dismounted foot patrol, an Ion GoPad thumb mouse affixed to a user-held mock M4 carbine rifle supports travel. The simulation's real-time 3D scenes use Emergent's Gamebryo as the rendering engine, and visual stimuli are presented within an orientation-tracked Emagin Z-800 head-mounted display (HMD). (We developed the system with an HMD component based on the idea that immersing users more fully in these controlled stimulus environment, enhances the emotional engagement required for therapeutic exposure; we should note, however, that no studies have compared the relative effectiveness for PTSD patients of delivering simulation content via a less immersive large-screen display.)

Directional 3D audio, vibrotactile, and olfactory stimuli relevant to the scene can also be delivered to users, controlled and modified in real time by the clinician via a separate *Wizard of Oz*–type interface. A key feature, this interface lets clinicians customize each therapy experience to the patient's individual needs, placing users in VR scenario locations that resemble the settings where traumatic events occurred. The clinician can modify ambient lighting and sound conditions to match the patient's description of the experience, and then gradually introduce and control real-time trigger stimuli—gunfire, explosions, insurgent attacks, and the like. This clinician control, customized to an individual's past experience and overall treatment progress, fosters the anxiety modulation necessary for the patient's therapeutic habituation to and emotional processing of the past traumatic experiences.

The 2007 Virtual Iraq/Afghanistan VRET system has so far been disseminated to over 60 early-adopter sites including VA medical centers and military, university, and private clinics for use as a PE therapy tool and to collect further data regarding outcome effectiveness.

VRET TREATMENT PROCEDURE

VRET treatment follows the standard evidence-based protocol for imaginal-only PE therapy[4] and consists of weekly 90- to 120-minute individualized, patient-driven sessions over 10 weeks.

During the first session, the clinician generally aims to develop a working therapeutic alliance with the patient as is standard for most clinical approaches. The clinician might attempt to identify and discuss some of the patient's traumatic experiences, provide psychoeducation on trauma and PTSD, and present instruction on a deep breathing technique for general stress management.

The second session follows up on topics from the first, as needed, and then focuses on providing the patient with a clear explanation and rationale for PE. In some cases, the patient is engaged in light practice with imaginal exposure that focuses on the less provocative elements of his or her traumatic experience.

The third session introduces the rationale for VRET. The patient is encouraged to explore a personally relevant scenario within the Virtual Iraq/Afghanistan environment for approximately 25 minutes, without recounting any trauma narrative and with no provocative trigger stimuli. This enables the participant to learn how to navigate the system, and functions as a bridge from imaginal exposure alone to imaginal exposure combined with VRET.

During the fourth through tenth sessions, full VRET therapy is conducted: the participant engages in a Virtual Iraq/Afghanistan environment while verbally recounting his or her trauma narrative. The goal during these active exposure sessions is for patients to experience moderate yet manageable anxiety levels while, with the therapist's encouragement, they activate, confront, and process difficult trauma memories and emotions they likely avoid elsewhere—and often have never discussed with anyone before. When this process is conducted in a safe, supportive clinical setting at a pace the patient can handle, the patient's anxiety typically habituates by way of a learning process known as "extinction." As this occurs, the patient is encouraged to confront additional, more provocative elements within the VR scenarios, which the therapist can introduce in real time via the clinician control panel.

Treatment throughout also includes homework; for example, during the week following a session the therapist might have the participant listen to an audiotape of his or her trauma narrative from that session, providing further exposure to help the patient continue processing the trauma outside the treatment setting. Assessing status over the course of treatment typically involves a combination of patient self-report symptom questionnaires and structured interviews with the therapist; active psychophysiological reactivity tests are sometimes used as well.

A more detailed description of this system, general PTSD assessment procedures, and the methodology for a standard VRET clinical protocol is provided elsewhere.[9]

RESEARCH OUTCOMES

Initial clinical tests of the Virtual Iraq/Afghanistan VRET system conducted with active-duty service members produced encouraging results. Three early case report studies documented the system's feasibility and safety, and showed positive clinical outcomes.[10–12] Two later open clinical trials with active-duty service members reported similar outcomes.[13,14]

In one trial involving an average of 11 sessions with 20 active-duty service members (19 male and 1 female, with

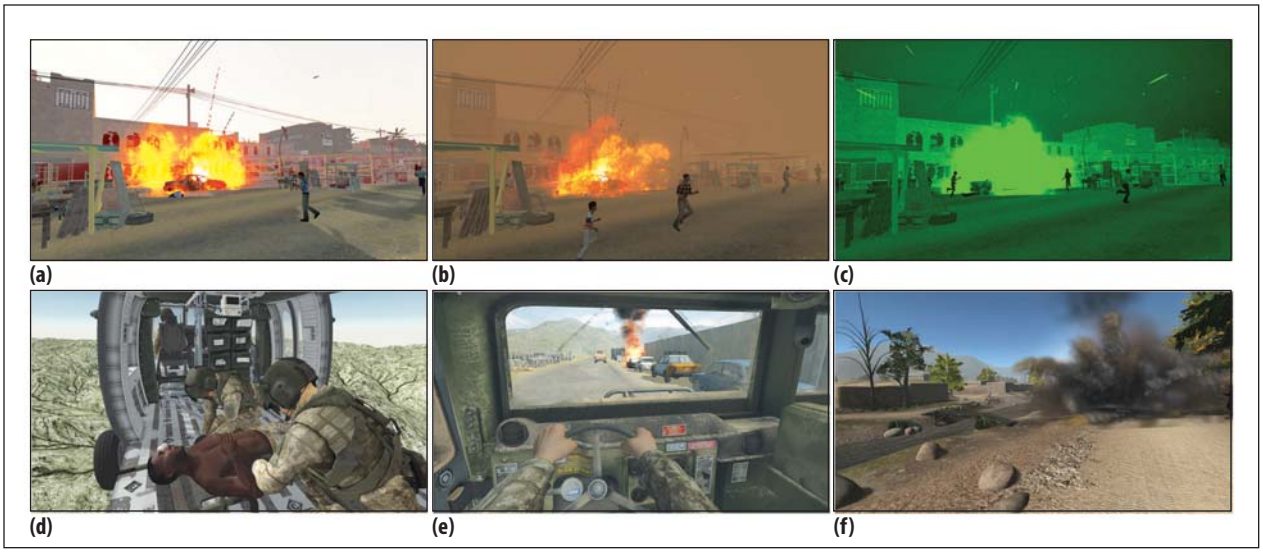

Figure 1. Images from 4 of the 14 scenario settings available in Bravemind, a virtual reality system for delivering prolonged exposure therapy (VRET) in cases of patients with combat-related posttraumatic stress disorder (PTSD). (a, b, c) A vehicle-borne improvised explosive device (IED) in an Iraq city showing three customizable views: a daytime setting, an evening setting with a sandstorm, and a perspective with night-vision goggles. (d) A helicopter extraction scenario. (e) A checkpoint explosion. (f) An IED in an Afghan village.

a mean age of 28) who completed treatment, results using the diagnostic PTSD checklist–military version (PCL-M) showed scores decreasing pre- and posttreatment in a statistically and clinically meaningful fashion from 54.4 (standard deviation: 9.7) to 35.6 (standard deviation: 17.4).[13] Paired pre– and post–*t*-test analysis showed these differences to be significant ($t = 5.99$, $df = 19$, $p < .001$), with 16 of the 20 completers no longer meeting the PCL-M criteria for PTSD after treatment and an average 50 percent decrease in symptoms among all completers. Beck Anxiety Inventory scores significantly decreased (33 percent), and mean Patient Health Questionnaire depression scores decreased even more (49 percent). Treatment gains were maintained at a posttreatment follow-up three months later, and anecdotal patient reports suggested that participants saw improvements in everyday life functioning.

Another open clinical trial conducted with 24 active-duty soldiers produced significant pre- and posttreatment reductions in PCL-M scores and a large treatment effect size (Cohen's $d = 1.17$).[14] After an average of seven sessions, 45 percent of those treated no longer screened positive for PTSD, and 62 percent had reliably improved. In a small preliminary quasi-randomized controlled trial,[15] 7 of 10 participants with PTSD showed a 30 percent or greater improvement with VR, while only 1 of 9 participants in a usual PE treatment group showed similar improvement.

Five randomized clinical trials (RCTs) are currently ongoing using the Virtual Iraq/Afghanistan VRET system with both current active-service member and veteran populations. Two of these focus on comparing treatment efficacy between VRET and imaginal PE. Another is comparing VRET to VRET along with a supplemental care approach. Two more RCTs are investigating the additive value of supplementing VRET and PE with a cognitive enhancer called D-Cycloserine (DCS). DCS, an N-methyl-d-aspartate partial agonist, has been shown to facilitate extinction learning in laboratory animals when infused bilaterally within the amygdala (the "fight or flight" conditioning center in the brain) prior to extinction training. Recent evidence of both VRET and DCS effectiveness has been reported by JoAnne Difede and her colleagues.[16] Significant funding for these RCTs underscores the interest the DoD and VA have in exploring innovative VRET approaches.

BRAVEMIND

Based on these encouraging clinical outcomes using VRET to treat combat-related PTSD and an urgent need to provide the best care for active-duty and veteran service members who increasingly report PTSD symptoms, in 2011 the US Army funded development of an updated and expanded Virtual Iraq/Afghanistan system called Bravemind. Among this effort's primary goals are to increase the original system's VR scenario content diversity and improve stimulus delivery customization to better address the needs of clinical users reporting a wide range of traumatic experiences. Bravemind draws on the large body of patient and clinician feedback from those who used the previous 2007 VRET system.

The system has been rebuilt from the ground up using the state-of-the-art Unity game engine. The four original

2007 environments have been completely redesigned, and 10 additional scenario settings have been added, including separate Iraq and Afghanistan cities with both slum and residential areas, a rural Afghan village, an industrial zone, a roadway checkpoint, a mountainous forward operations base, and a simulated Bagram Airfield, the largest US military base in Afghanistan. Figure 1 shows some images from these new scenario settings.

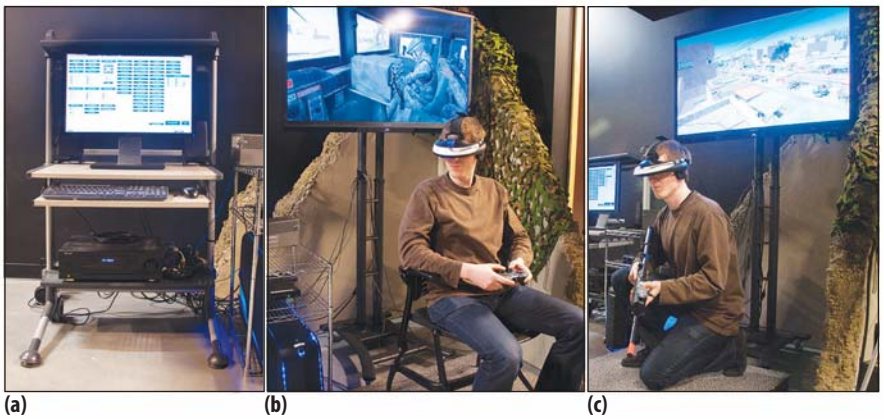

Figure 2. Sample Bravemind system components. (a) A clinician interface for modifying VR settings in real time to match user experiences. (b) VR head-mounted display and traditional gamepad used by a seated participant in a driving scenario. (c) Rifle-mounted mini-gamepad used in a walking scenario.

New system features include the choice of Humvees, MRAP (mine-resistant ambush-protected) vehicles, or helicopters; vehicle-to-foot patrol transitioning; expanded weather and time-of-day controls; customizable sound trigger profiles; and an updated clinician interface designed to improve usability based on professional feedback. The Unity engine's higher-fidelity graphic art and animation have enhanced the stimulus content's realism and credibility, and present an experience uniquely different from commercial videogames. The system has also been designed to use off-the-shelf components—standard laptop/PC, head-mounted display, and tracking/interface technology, for example—aimed at reducing costs to well under $5,000.

The Bravemind system, shown in Figure 2, is now being distributed to clinical sites and provides a flexible software architecture that can support efficiently adding new content to expand and diversify functionality as novel clinical needs are specified.

BRAVEMIND SYSTEM EVOLUTION

Bravemind was designed specifically to support customizable options for a range of relevant traumatic experiences with new functionalities. Currently, for example, the system is evolving to address the unique therapeutic needs of combat medics and hospital corpsmen as well as active-duty service members and veterans with PTSD who have also experienced military sexual trauma. In addition, the software has been reconfigured to provide a VR tool currently under testing for cognitive assessment purposes and to provide psychological resilience training prior to combat deployment.[17]

We consider these first two emerging applications here.

VRET for combat medics and corpsmen

Our prior clinical work and recent government reports indicate a growing need to address PTSD in Navy and Marine medics and Army and Air Force corpsmen, those service members whose primary role is providing medical treatment to the wounded.

Combat medics and corpsmen represent a unique population among deployed military ranks, serving double duty both professionally and psychologically. In addition to bearing full soldiering responsibilities, medics must also calmly and efficiently care for the devastating injuries of modern warfare, and are more exposed than other soldiers to seriously wounded and dying comrades. Unlike hospital doctors or nurses, who rarely know their patients personally, medics face the added pressure of camaraderie with the patients they are trying to keep alive. And when one patient dies, medics often experience self-doubt—an emotion they must hide, or risk losing their platoon's confidence.

Treating these men and women requires specialized VR content relevant to their experiences, providing emotionally challenging situations fundamentally different from what has proven effective with other service members. For this reason, Bravemind scenarios have been tailored with significant new graphic art, motion-capture animation, and airborne vehicle integration, as well as a library of virtual human content to emulate the range of wounds, burns, and other injuries and manifest realistic injury behaviors common to combat environments. In addition, we have developed helicopter insertion and extraction scenarios and a Bagram Air Force Base hospital setting for medic and corpsmen "first receivers."

This system is currently nearing completion and will be available for clinical use in mid-2014.

VRET for military sexual trauma

In addition to witnessing death and experiencing life-threatening injury, sexual violation can be a trigger for PTSD. Service members who suffer actual or threatened sexual violation or assault from within the ranks or in a military context may exhibit a psychological condition known as military sexual trauma (MST). MST places soldiers already undergoing the trauma inherent in combat at especially high risk for developing PTSD.

Ultimately, we believe clinical VRET has potential civilian applications well beyond treating military service personnel for PTSD. In fact, over the last century, war has provided an impetus for many advances in clinical care.

A 2012 report issued by the Joint Chiefs of Staff, together with the DoD's Sexual Assault Prevention and Response Program,[18] specifies the need for improvements in "advocacy coordination, medical services, legal support, and [behavioral health] counseling for the victim" of military sexual assault. This issue poses grave concern in the military as reports of sexual violation and assault have risen over the last decade and also garnered significant media and congressional attention. Overall, 6.1 percent of female and 1.2 percent of male active-duty service members indicated they experienced unwanted sexual contact in 2012. For women, this rate is statistically significantly higher than in 2010, when it was reported at 4.4 percent.[18]

A bleaker picture emerges when we consider reports from postdischarge veteran surveys. In a nationwide randomly selected sample of women seeking care through VA medical centers, approximately one in four reported experiencing sexual trauma while on active duty.[19] Prevalence rates of MST in women were 20 to 25 percent for sexual assault and 24 to 60 percent for sexual harassment. Thus, even though the DoD is mobilizing to reduce MST incidence with new education and prevention programs, a significant effort is also required to develop and disseminate effective treatments to address the needs of those already experiencing PTSD due to MST. While both men and women can experience MST, the growing number of women transitioning to a full combat role underscores this work's urgency.

Content currently in development for the Bravemind system will provide customizable options to conduct VRET with persons who have experienced MST. This novel component involves embedding within existing Bravemind scenarios new settings such as barracks, tents, latrines, work quarters, and other contexts that MST victims have reported as locations where sexual assault occurred. The system will not attempt to re-create actual sexual assaults; rather it will set up contexts surrounding such assaults that can support users in therapeutic confrontation and processing of MST memories in accordance with the protocol established to implement PE using the simulations.[9]

Following projected completion of the new content in summer 2014, we plan a pilot RCT with 34 male and female participants. Nothing like this has been attempted previously with immersive VRET, and the challenges for such unique and sensitive content are significant.

Ultimately, we believe clinical VRET has potential civilian applications well beyond treating military service personnel for PTSD. In fact, over the last century, war has provided an impetus for many advances in clinical care. During World War I, the Army Alpha and Army Beta tests emerged as systems to assess and classify cognitive ability; these served as prototypes for later widely used civilian psychometric tests. Clinical psychology as a treatment-oriented profession was born from the need to provide care to the many veterans returning from World War II with "shell shock" or "battle fatigue." The Vietnam War drove recognition of PTSD as a definable and treatable clinical disorder outside the context of war alone.

Similarly, the US military's current support for research and development advancing clinical systems to treat PTSD that leverage new interactive and immersive technologies such as VR could have a lasting influence on civilian healthcare long after the last Afghanistan war veteran has returned home.

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