18 Virtual Reality Exposure Therapy for Combat-Related PTSD

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Contents

Abstract

War is one of the most challenging environments that a human can experience. The cognitive, emotional, and physical demands of a combat environment place enormous stress on even the best-prepared military personnel. The OEF-OIF (Operation Enduring Freedom-Operation Iraqi Freedom) combat theatre, with its ubiquitous battlefronts, ambiguous enemy identification, and repeated extended deployments, was anticipated to produce significant numbers of military personnel with post-traumatic stress disorder (PTSD) and other mental disorders. Recent studies are now confirming this expectation. Among the many approaches that have been used to treat PTSD, exposure therapy appears to have

From: *Post-Traumatic Stress Disorder*: *Basic Science and Clinical Practice*
Edited by: P. J. Shiromani et al., DOI: 10.1007/978-1-60327-329-9_18

the best-documented therapeutic efficacy. Such treatment typically involves the graded and repeated imaginal reliving of the traumatic event within the therapeutic setting and is believed to provide a low-threat context in which the patient can begin to therapeutically process trauma-relevant emotions as well as decondition the learning cycle of the disorder via a habituation/extinction process. While the efficacy of imaginal exposure has been established in multiple studies with diverse trauma populations, many patients are unwilling or unable to effectively visualize the traumatic event. To address this problem, researchers have recently turned to the use of virtual reality (VR) to deliver exposure therapy by immersing patients in simulations of trauma-relevant environments that allow for precise control of stimulus conditions. This chapter presents an overview of PTSD exposure therapy, a description of VR, and the rationale for how this technology has been applied as a tool to deliver exposure therapy along with a brief review of current research. We then provide a description of the current Virtual Iraq exposure therapy system and treatment protocol and present initial results from an open clinical trial with active duty military personnel and a brief case study. The chapter concludes with a summary of future directions in which VR technology can be further applied to more comprehensively address a range of PTSD-relevant issues.

Key Words: Clinical interface, exposure therapy, extinction, habituation, PTSD, virtual reality.

INTRODUCTION

War is perhaps one of the most challenging situations that a human being can experience. The physical, emotional, cognitive, and psychological demands of a combat environment place enormous stress on even the best-prepared military personnel. The high level of stress that is naturally experienced in combat typically results in a significant percentage of soldiers at risk for developing PTSD on the return home. Indeed, the Iraq/Afghanistan combat theatres, with their ubiquitous battlefronts, ambiguous enemy identification, and repeated extended deployments, have produced large numbers of returning American service members (SMs) reporting symptoms that are congruent with the diagnosis of post-traumatic stress disorder (PTSD) and other mental disorders. In the first systematic study of mental health problems due to these conflicts, "The percentage of study subjects whose responses met the screening criteria for major depression, generalized anxiety, or PTSD was significantly higher after duty in Iraq (15.6 to 17.1 percent) than after duty in Afghanistan (11.2 percent) or before deployment to Iraq (9.3 percent)" *(1)*. These estimates were made before the violence escalated even further, and other reports since the original Hoge et al. *(1)* publication have indicated equivalent or higher numbers of returning military SMs and veterans reporting positive for PTSD and symptoms of other forms of mental disorders *(2,3)*.

Among the many approaches that have been used to treat PTSD, exposure therapy appears to have the best-documented therapeutic efficacy *(4–9)*. Such treatment typically involves the graded and repeated imaginal reliving of the trau-

matic event within the therapeutic setting. This approach is believed to provide a low-threat context in which the patient can begin to therapeutically process the emotions that are relevant to the traumatic event as well as decondition the learning cycle of the disorder via a habituation/extinction process. While the efficacy of imaginal exposure has been established in multiple studies with diverse trauma populations *(6–9)*, many patients are unwilling or unable to effectively visualize the traumatic event. In fact, avoidance of reminders of the trauma is inherent in PTSD and is one of the cardinal symptoms of the disorder. To address this problem, researchers have recently turned to the use of virtual reality (VR) to deliver exposure therapy by immersing clients in simulations of trauma-relevant environments that allow for precise control of stimulus conditions. The enthusiasm that is common among proponents of the use of VR for exposure-based treatment derives from the view that VR technology provides the capacity for clinicians to deliver specific, consistent, and controllable trauma-relevant stimulus environments that do not rely exclusively on the hidden world of the patient's imagination.

This chapter presents an overview of virtual reality exposure therapy (VRET) starting with a description of VR technology, a brief overview of its application in the assessment and treatment of clinical disorders, and following a discussion of traditional imaginal exposure therapy, providing a rationale for the use of VR as a tool to deliver exposure therapy for combat-related PTSD. Previous research in this area is then reviewed, followed by a description of the current Virtual Iraq exposure therapy system and treatment protocol, presentation of initial results from an open clinical trial with active duty military personnel, and a brief case study. The chapter concludes with a summary of future directions in which we feel VR technology can be further applied to more comprehensively address a range of PTSD-relevant issues.

VIRTUAL REALITY AND CLINICAL APPLICATIONS

Virtual reality (VR) has undergone a transition over the last 10 years that has taken it out of the realm of expensive toy and into that of functional technology. The unique match between VR technology assets and the needs of various clinical aims has been recognized by a number of authors and an encouraging body of research has emerged *(10–14)*. VR can be generally defined as "a way for humans to visualize, manipulate, and interact with computers and extremely complex data" *(15)*. This advanced form of human-computer interaction is achieved via the integration of computers, real-time graphics, visual displays, body-tracking sensors, and specialized interface devices that serve to immerse a participant in a computer-generated simulated world that changes in a natural way with head and body motion. The capacity of VR technology to create controllable, multisensory, interactive three-dimensional (3D) stimulus environments within which a person can become immersed and interact offers clinical assessment and intervention options that are not possible using traditional methods *(10,12)*. Much like an aircraft simulator serves to test and train piloting ability under a variety of controlled conditions, VR can be used to create context-relevant

simulated environments where assessment and treatment of cognitive, emotional, and motor processes can take place. When used in this fashion, clinical VR can extend the skill of the clinician by allowing the clinician to precisely and systematically deliver complex, dynamic, and ecologically relevant stimulus presentations—within which sophisticated interaction, behavioral tracking, performance recording, and physiological monitoring can occur.

Virtual environments have been developed that are now demonstrating effectiveness in a number of areas in clinical psychology, neuropsychology, and rehabilitation. VR has been used with adults in many domains of psychological assessment and intervention, including exposure therapy for anxiety disorders such as fear of flying *(16–20)*, fear of heights *(21,22)*, and various other phobias *(23–28)*. As well, VR has been usefully implemented with PTSD (*29–32*), addictive behaviors *(33)*, and acute pain reduction *(34)* and for the assessment and rehabilitation of cognitive and motor impairments following stroke, brain injury, and other forms of neurological disorders *(12,13,35,36)*. To do this, scientists have constructed VR airplanes, skyscrapers, spiders, battlefields, social events populated with virtual humans, fantasy worlds, and the mundane (but highly relevant) functional environments of the schoolroom, office, home, street, and supermarket. These initiatives give hope that in the 21st century, new and useful simulation tools will be developed that can advance clinical approaches that have long been mired in the methods of the past.

The VR environments discussed in this chapter primarily display computer graphics in a motion-tracked head-mounted display (HMD) and are augmented with vibration platforms, localizable 3D sounds within the VR space, physical props, and in some scenarios, scent delivery technology to facilitate an immersive experience for participants. In this format, the multisensory immersive nature of VR typically leads to a strong sense of *presence* or "being there" reported by those immersed in the virtual environment.

EXPOSURE THERAPY FOR PTSD

PTSD is a severe and often chronic, disabling anxiety disorder that develops in some persons following exposure to a traumatic event that involves actual or threatened injury to themselves or to others. Prospective studies indicate that most traumatized individuals experience symptoms of PTSD in the immediate aftermath of the trauma. In a prospective study of rape victims, 94% met symptom criteria for PTSD in the first week following the assault *(37)*. Therefore, the symptoms of PTSD are part of the *normal reaction* to trauma. The majority of trauma victims naturally recover, as indicated by a gradual decrease in PTSD symptom severity over time. However, subsets of persons continue to exhibit severe PTSD symptoms long after a traumatic experience. Therefore, PTSD can be viewed as a failure of natural recovery that reflects in part a failure of fear extinction following trauma.

Consequently, several theorists have proposed that conditioning processes are involved in the etiology and maintenance of PTSD. These theorists invoke Mowrer's two-factor theory *(38)*, which posits that both Pavlovian and instrumental conditioning are involved in the acquisition of fear and avoidance behavior. Through

a generalization process, many stimuli may elicit fear and avoidance. Consistent with this hypothesis, emotional and physiological reactivity to stimuli resembling the original traumatic event, even years after the event's occurrence, is a prominent characteristic of PTSD and has been reliably replicated in the laboratory *(39,40)*. Further, cognitive and behavioral avoidance strategies are hypothesized to develop in an attempt to avoid or escape these distressing conditioned emotional reactions. The presence of extensive avoidance responses can also interfere with extinction by limiting the amount of exposure to the conditioned stimulus (CS) in the absence of the unconditioned stimulus (US).

Expert treatment guidelines for PTSD published for the first time in 1999 recommended that cognitive-behavioral treatment (CBT) with prolonged exposure (PE) should be the first-line therapy for PTSD *(41)*. PE is a form of individual psychotherapy based on Foa and Kozak's *(42)* emotional processing theory, which posits that PTSD involves pathological fear structures that are activated when information represented in the structures is encountered. These fear structures are composed of harmless stimuli that have been associated with danger *(43)* and are reflected in the belief that the world is a dangerous place. This belief then manifests itself in cognitive and behavioral avoidance strategies that limit exposure to potentially corrective information that could be incorporated into and alter the fear structure. Successful treatment requires emotional processing of the fear structures to modify their pathological elements so that the stimuli no longer invoke fear.

Emotional processing first requires accessing and activating the fear structure associated with the traumatic event and then incorporating information that is not compatible with it. PE accomplishes activation through imaginal and in vivo exposure exercises. Imaginal exposure entails engaging mentally with the fear structure through repeatedly revisiting the traumatic event in a safe environment. In practice, a person with PTSD typically is guided and encouraged by the clinician gradually to *imagine, narrate, and emotionally process* the traumatic event within the safe and supportive environment of the clinician's office. In vivo exposure requires approaching real situations such as driving a car or going to crowded public destinations that the patient has avoided since the traumatic event. The proposed mechanisms for symptom reduction involve activation and emotional processing of the traumatic memories, extinction/habituation of the anxiety, cognitive reprocessing of pathogenic meanings, the learning of new responses to previously feared stimuli, and ultimately an integration of corrective nonpathological information into the fear structure *(44,45)*. Such changes allow the survivor to tolerate memories of events without emotional flooding or rigid avoidance and to restore more realistic views of the self, others, and world *(42,43)*. PTSD patients can then begin to process emotional trauma memories adaptively as needed for successful coping and healing.

Strong evidence suggests that CBT is an efficacious treatment for PTSD *(44,46)*. Over 30 randomized controlled trials of psychotherapy for PTSD have been conducted, and many have specifically examined treatment approaches for combat veterans *(47)*. Two meta-analyses have synthesized this literature by examining PTSD outcomes following CBT. Both reported moderate-to-large effect

sizes, indicating significant symptom improvements following CBT treatment *(8,48)*. Within the CBT literature, exposure therapy has received significant empirical support *(4,49,50)*. The comparative empirical support for exposure therapy was also recently documented in a review by the Institute of Medicine at the National Academies of Science (sponsored by the U.S. Department of Veterans Affairs [VA]) of 53 studies of pharmaceuticals and 37 studies of psychotherapies used in PTSD treatment *(6)*. The report concluded that although there is not enough reliable evidence to draw conclusions about the effectiveness of most PTSD treatments, there is sufficient evidence to conclude that exposure therapies are effective in treating people with PTSD.

CHALLENGES FOR TREATING ACTIVE DUTY SERVICE MEMBERS/VETERANS WITH PTSD

Although traditional exposure therapy is considered to be the only approach for which the evidence is sufficient to support its efficacy in the treatment of PTSD, there are several reasons why it may not be the most viable option for many active duty SMs and veterans. For example, avoidance and numbing of painful memories and emotions associated with the traumatic event are characteristic of PTSD and can limit a SM's ability to engage in treatment known to relieve symptoms. Imagery-based exposure therapy requires a level of emotional engagement in the imaginal reliving of the trauma that many patients are unable to obtain or tolerate *(5)*. Studies addressing treatment failures have shown that a failure to engage emotionally is the best predictor of a poor treatment outcome *(51–54)*. Foa, Riggs, Massie, and Yarczower *(53)* showed that female rape victim's fear expression (a sign of emotional engagement) during the first reliving of rape memories was strongly related to improvement at posttreatment. Jaycox, Foa, and Morral *(54)* found that while all participants in a study investigating the use of PE with female assault victims made treatment gains, those with therapeutic levels of engagement made significantly greater improvement.

Equally challenging is the fact that stigma and concerns about peer and leadership perceptions of treatment may have a significant impact on whether a SM or veteran will seek care. Hoge et al. *(1)* reported significant fear of treatment stigma among deployed SMs that was greatest among those most in need of help. Those who screened positive for a mental disorder were twice as likely to report concerns about treatment stigma. In another study, Britt *(55)* examined the perceived stigma of psychological versus medical problems in SMs returning from a peacekeeping mission to Bosnia and found that SMs felt more stigmatized when admitting a psychological than a medical problem. This was magnified for SMs returning with their units rather than alone, suggesting that subjective norms influence stigma perceptions. The challenges associated with emotionally engaging with the fear structures as required in PE and the stigma associated with traditional "talk therapies" are significant barriers to optimizing access to care that could be addressed via a VR approach.

VIRTUAL REALITY EXPOSURE THERAPY

Researchers have explored the use of VR to deliver exposure therapy by immersing participants in customized simulations of trauma-relevant environments in which the emotional intensity of the scenes can be precisely controlled by the clinician. In this fashion, VRET offers a way to circumvent the natural avoidance tendency by directly delivering multisensory and context-relevant cues that evoke the trauma without demanding that the patient actively try to access personal experience through effortful memory retrieval. Within a VR environment, the hidden world of the patient's imagination is not exclusively relied on, and this is particularly relevant with PTSD, for which avoidance of cues and reminders of the trauma are cardinal symptoms of the disorder. In addition, VRET may offer an appealing, nontraditional treatment approach that is perceived with less stigma by "digital generation" SMs and veterans who may be reluctant to seek out what they perceive as traditional talk therapies.

The first effort to apply VRET began in 1997 when researchers at Georgia Tech and Emory University began testing the Virtual Vietnam VR scenario with Vietnam veterans diagnosed with PTSD *(5)*. This occurred over 20 years after the end of the Vietnam War. During those intervening years, in spite of valiant efforts to develop and apply traditional psychotherapeutic and pharmacological treatment approaches to PTSD, the progression of the disorder in some veterans had a significant impact on their psychological well-being, functional abilities, and quality of life as well as that of their families and friends. This initial effort yielded encouraging results in a case study of a 50-year-old, male Vietnam veteran meeting *Diagnostic and Statistical Manual of Mental Disorders* (DSM) criteria for PTSD *(56)*. Results indicated post-treatment improvement on all measures of PTSD and maintenance of these gains at a 6-month follow-up, with a 34% decrease in clinician-rated symptoms of PTSD and a 45% decrease on self-reported symptoms of PTSD. This case study was followed by an open clinical trial with Vietnam veterans *(5)*. In this study, 16 male veterans with PTSD were exposed to two HMD-delivered virtual environments: a virtual clearing surrounded by jungle scenery and a virtual Huey helicopter, in which the therapist controlled various visual and auditory effects (e.g., rockets, explosions, day/night, shouting). After an average of 13 exposure therapy sessions over 5–7 weeks, there was a significant reduction in PTSD and related symptoms.

Similar positive results were reported by Difede and Hoffman *(30)* for PTSD that resulted from the attack on the World Trade Center; they used a case study using VRET with a patient who had failed to improve with traditional exposure therapy. This group has recently reported positive results from a wait-list controlled study using the same World Trade Center VR application *(57)*. The VR group demonstrated statistically and clinically significant decreases on the "gold standard" Clinician-Administered PTSD Scale (CAPS) relative to both pretreatment and to the wait-list control group with a between-group posttreatment effect size of 1.54. Seven of ten people in the VR group no longer carried the diagnosis of PTSD, while all of the wait-list controls retained the diagnosis following the waiting period, and treatment gains

were maintained at 6-month follow-up. Also noteworthy was the finding that five of the ten VR patients had previously participated in imaginal exposure treatment with no clinical benefit. Such initial results are encouraging and suggest that VR may be a useful component within a comprehensive treatment approach for persons with combat/terrorist attack-related PTSD.

There are also other research groups currently in the early stages of applying VR to treat PTSD in survivors of war and terrorist attacks *(58–61)*. One research group has reported "partial remission" of PTSD symptoms in four of six Iraq war SMs using VR combined with meditation and attentional refocusing *(58)*. However, it is difficult to draw any conclusions from this work as the authors did not provide a clear specification or statistical analysis of the pre-/post-PTSD Checklist-Military version (PCL-M) scores other than to report a baseline PCL-M mean of 47.3, which is actually below the PTSD cutoff of 50 *(59)*. Another research group in Portugal, where there are an estimated 25,000 survivors with PTSD from their 1961–1974 colonial wars in Mozambique, Angola, and Guiné, has constructed a VR exposure scenario by modifying a common PC-based combat game *(60)*. This group has reported an initial case study in which the patient did not complete treatment due to experiencing a distressing flashback following the seventh session. While this is rarely reported in the exposure literature, this report highlights the need for well-trained clinicians with expertise in the delivery of exposure therapy at a rate that the patient can effectively handle and process and in the sensitive monitoring of patient status. Finally, in Israel, Josman et al. *(61)* are implementing a VR terrorist "bus bombing" PTSD treatment scenario in which participants are positioned in an urban cafe across the street from a site where a civilian bus may explode. This research program has only recently commenced, and no clinical data are currently available. However, analog pilot research by this group with non-PTSD participants is under way to examine emotional reactivity across VR exposure levels to characterize the evocative nature of the stimulus environment to inform future clinical use (Naomi Josman, personal communication, December 4, 2007).

DESIGN AND DEVELOPMENT OF THE VIRTUAL IRAQ EXPOSURE THERAPY SYSTEM

The University of Southern California's Institute for Creative Technologies (ICT), in collaboration with us, have partnered on a project funded by the Office of Naval Research (ONR); the U.S. Army Research, Development, and Engineering Command (RDECOM); and the Telemedicine and Advanced Technology Research Center (TATRC) to develop a series of VR exposure environments known as Virtual Iraq. This VR treatment system was originally constructed by recycling virtual art assets that were initially designed for the commercially successful X-Box game and U.S. Army-funded combat tactical simulation trainer Full Spectrum Warrior. Other existing and newly created art and technology assets available to ICT have been integrated into this continually evolving application.

Virtual Iraq consists of Middle Eastern themed city and desert road environments (see Figs. 1–4) and was designed to resemble the general contexts that most

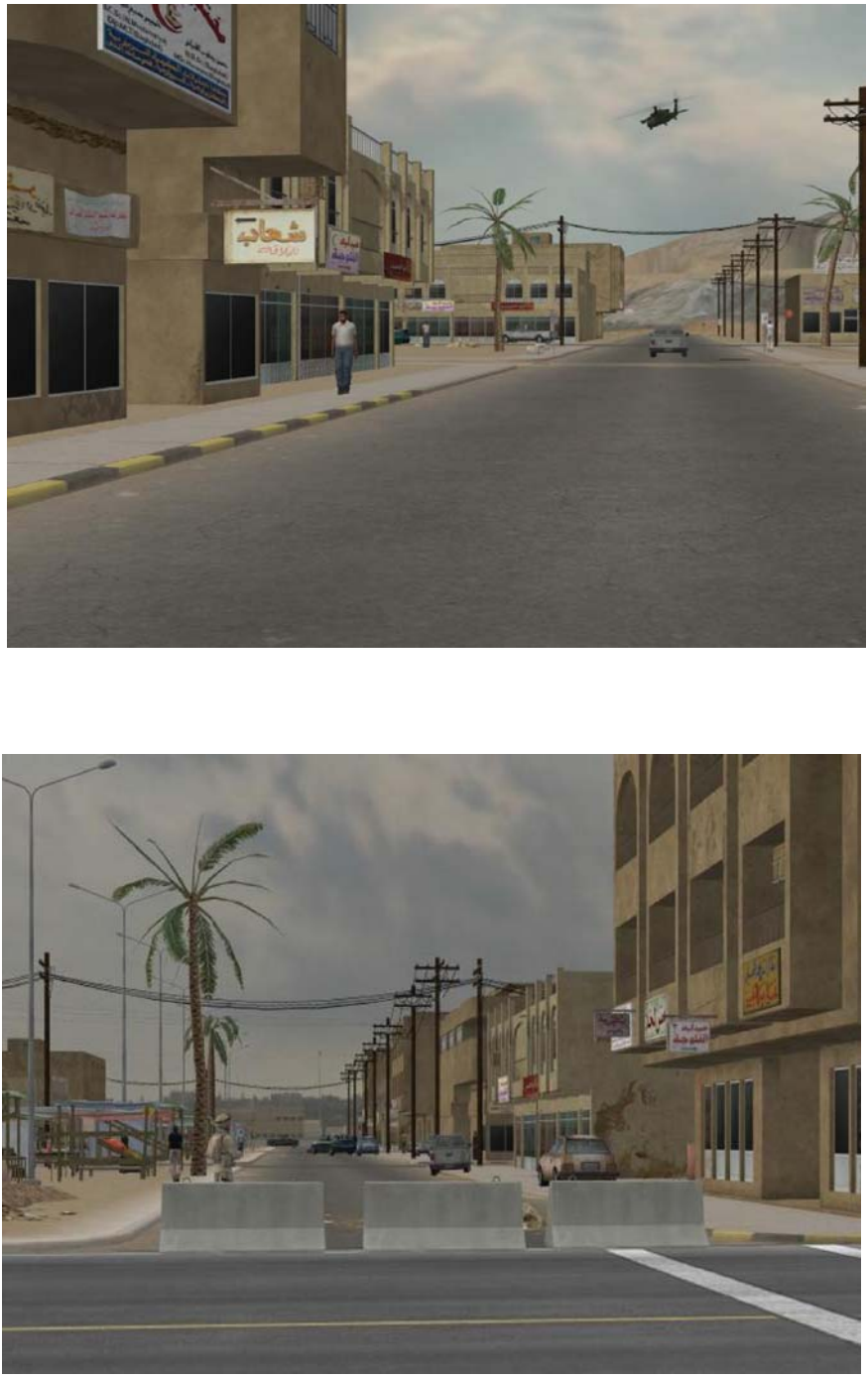

Fig. 1-4. Virtual Iraq city and desert HUMVEE scenario scenes (*See Color Plates*)

Fig. 1-4. (continued)

SMs experience during deployment to Iraq. The 18-square-block "city" setting has a variety of elements, including a marketplace, desolate streets, old buildings, ramshackle apartments, warehouses, mosques, shops, and dirt lots strewn with junk. Access to building interiors and rooftops is available, and the backdrop surrounding the navigable exposure zone creates the illusion of being embedded within a section of a sprawling densely populated desert city. Vehicles are active in streets, and animated virtual pedestrians (civilian and military) can be added or eliminated from the scenes. The software has been designed such that users can be teleported to specific locations within the city based on a determination regarding which environments most closely match the patient's needs relevant to their individual trauma-related experiences.

The "desert road" scenario consists of a roadway through an expansive desert area with sand dunes, occasional areas of vegetation, intact and broken-down structures, bridges, battle wreckage, a checkpoint, debris, and virtual human figures. The user is positioned inside of a Humvee that supports the perception of travel within a convoy or as a lone vehicle with selectable positions as a driver, a passenger, or an individual in the more exposed turret position above the roof of the vehicle. The number of soldiers in the cab of the Humvee can also be varied as well as their capacity to become wounded during certain attack scenarios (e.g., improvised explosive devices [IEDs], rooftop and bridge attacks). Both the city and Humvee scenarios are adjustable for time of day or night, weather conditions, night vision, illumination, and ambient sound (wind, motors, city noise, prayer call, etc.).

Users can navigate in both scenarios via the use of a standard game pad controller, although we have recently added the option for a replica M4 weapon with a "thumb-mouse" controller that supports movement during the city foot patrol. This was based on repeated requests from Iraq-experienced SMs, who provided frank feedback indicating that to walk within such a setting without a weapon in hand was completely unnatural and distracting. However, there is no option for firing a weapon within the VR scenarios. It is our firm belief that the principles of exposure therapy are incompatible with the cathartic acting out of a revenge fantasy that a responsive weapon might encourage.

In addition to the visual stimuli presented in the VR HMD, directional 3D audio, vibrotactile, and olfactory stimuli can be delivered into the VR scenarios in real time by the clinician. The presentation of additive, combat-relevant stimuli in the VR scenarios can be controlled via a separate "Wizard of Oz" control panel, while the clinician is in full audio contact with the patient. This clinical "interface" is a key feature that provides a clinician with the capacity to customize the therapy experience to the individual needs of the patient. The patient can be placed by the clinician in VR scenario locations that resemble the setting in which the trauma-relevant events occurred and modify ambient light and sound conditions to match the patient's description of his or her experience. The clinician can then gradually introduce and control real-time trigger stimuli (visual, auditory, olfactory, and tactile), via the clinician's interface, as required to foster the anxiety modulation needed for therapeutic habituation and emotional processing in

a customized fashion according to the patient's past experience and treatment progress. The clinician interface options have been designed with the aid of feedback from clinicians with the goal to provide a usable and flexible control panel system for conducting thoughtfully administered exposure therapy that can be readily customized to suit the needs of the patient. Such options for real-time stimulus delivery flexibility and user experience customization are key elements for these types of VR exposure applications.

The specification, creation, and addition of trigger stimulus options into the Virtual Iraq system has been an evolving process throughout the development of the application based on continually solicited patient and clinician feedback. We began this part of the design process by including options that have been reported to be relevant by returning soldiers and military subject matter experts. For example, the Hoge et al. *(1)* study of Iraq/Afghanistan SMs presented a listing of combat-related events that were commonly experienced in their sample. These events provided a useful starting point for conceptualizing how relevant trigger stimuli could be presented in a VR environment. Such commonly reported events included: "Being attacked or ambushed …, receiving incoming artillery, rocket, or mortar fire, … being shot at or receiving small-arms fire, … seeing dead bodies or human remains" (p. 18).

From this and other sources, we began our initial effort to conceptualize what was both functionally relevant and technically possible to include as trigger stimuli. Thus far, we have created a variety of auditory trigger stimuli (e.g., incoming mortars, weapons fire, voices, wind, etc.) that are actuated by the clinician via mouse clicks on the clinical interface. We can also similarly trigger dynamic audiovisual events such as helicopter flyovers, bridge attacks, exploding vehicles and IEDs, and so on. The creation of more complex events that can be intuitively delivered in Virtual Iraq from the clinicians' interface while providing a patient with options to interact or respond in a meaningful manner is one of the ongoing focuses in this project. However, such trigger options require not only interface design expertise, but also clinical wisdom regarding how much and what type of exposure is needed to produce a positive clinical effect. These issues have been keenly attended to in our initial nonclinical user-centered tests with Iraq-experienced SMs and in the current clinical trials with patients. This feedback is essential for informed VR scenario design beyond what is possible to imagine from the "ivory tower" of the academic world.

Whenever possible, Virtual Iraq was designed to use off-the-shelf equipment to minimize costs and maximize the access and availability of the finished system. The minimum computing requirements for the current application are two Pentium 4 computers each with 1 GB RAM, and a 128-MB DirectX 9-compatible NVIDIA 3D graphics card. The two computers are linked using a null Ethernet cable, with one running the therapist's clinical interface, while the second one drives the simulation via the user's HMD and navigation interface (game pad or gun controller). The HMD that was chosen was the eMagin z800, with displays capable of 800 × 600 resolution within a 40° diagonal field of view (http://www.emagin.com/). The major selling point for using this HMD was the presence of a

built-in head-tracking system. At under $1,500 per unit with built-in head tracking, this integrated display/tracking solution was viewed as the best option to minimize costs and maximize the access to this system. The simulation's real-time 3D scenes are presented using Numerical Design Limited's (NDL) Gamebryo rendering library. Preexisting art assets were integrated using Alias's Maya 6 and Autodesk 3D Studio Max 7, with new art created primarily in Maya.

We have also added olfactory and tactile stimuli to the experience of the environment. The Envirodine Incorporated Scent Palette is a USB (universal serial bus) device that uses up to eight smell cartridges, a series of fans, and a small air compressor to deliver scents to participants. The scents can also be controlled by mouse clicks on the clinical interface. Scents may be employed as direct stimuli (e.g., scent of smoke as a user walks by a burning vehicle) or as cues to help immerse users in the world (e.g., ethnic food cooking). The scents selected for this application include burning rubber, cordite, garbage, body odor, smoke, diesel fuel, Iraqi food spices, and gunpowder. Vibration is also used as an additional user sensory input. Vibration is generated through the use of a Logitech force-feedback game control pad and through low-cost (<$120) audio-tactile sound transducers (Aura Sound Inc.) located beneath the patient's floor platform and seat. Audio files are customized to provide vibration consistent with relevant visual and audio stimuli in the scenario. For example, explosions can be accompanied by a shaking floor, and in the Humvee scenario, the user experiences engine vibrations as the vehicle moves across the virtual terrain. This package of controllable multisensory stimulus options was included in the design of Virtual Iraq to allow a clinician the flexibility to engage users across a wide range of unique and highly customizable levels of exposure intensity. As well, these same features have broadened the applicability of Virtual Iraq as a research tool for studies that require systematic control of stimulus presentation within combat-relevant environments *(62)*.

STATUS OF CURRENT VIRTUAL IRAQ RESEARCH

The Virtual Iraq scenario is currently being implemented as an exposure therapy tool with active duty SMs and veterans at Madigan Army Medical Center (MAMC) at Fort Lewis, Washington; the Naval Medical Center–San Diego (NMCSD); Camp Pendleton; Emory University; Walter Reed Army Medical Center (WRAMC); the Weill Medical College of Cornell University; and at 14 other VA, military, and university laboratory sites for VRET research and a variety of other PTSD-related investigations. However, the user-centered design process for optimizing Virtual Iraq for clinical use is noteworthy and is briefly described before summarizing the status of the initial open clinical trial results.

User-Centered Feedback from Non-PTSD Service Members

User-centered tests with early prototypes of the Virtual Iraq application were conducted at the NMCSD and within an army combat stress control team in Iraq (see Fig. 5). This informal feedback provided by nondiagnosed Iraq-

Fig. 5. User Centered feedback on the Virtual Iraq application being collected by a U.S. Army Combat Stress Control team member (Reger), while in "real" Iraq (*See Color Plates*)

experienced military personnel provided essential information on the content, realism, and usability of the initial "intuitively designed" system that fed an iterative design process. More formal evaluation of the system took place at MAMC from late 2006 to early 2007 *(63,64)*. Ninety-three screened SMs (all non-PSTD) evaluated the Virtual Iraq scenarios shortly after returning from deployment in Iraq. SMs experienced the city and Humvee environments while exposed to scripted researcher-initiated VR trigger stimuli to simulate an actual treatment session. SMs then completed standardized questionnaires to evaluate the realism, sense of "presence" (the feeling of being in Iraq), sensory stimuli, and overall technical capabilities of Virtual Iraq. Items were rated on a scale from 0 (poor) to 10 (excellent). Qualitative feedback was also collected to determine additional required software improvements. The results suggested that the Virtual Iraq environment in its form at the time was realistic and provided a good sense of "being back in Iraq." Average ratings across environments were between adequate and excellent for all evaluated aspects of the virtual environments. Auditory stimuli realism (M = 7.9, SD = 1.7) and quality (M = 7.9, SD = 1.8) were rated higher than visual realism (M = 6.7, SD = 2.1) and quality (M = 7.0, SD = 2.0). Soldiers had high ratings of the computer's ability to update visual graphics during movement (M = 8.4, SD = 1.7). The HMD was reportedly very comfortable (M = 8.2, SD = 1.7), and the average ratings for the ability to move within the virtual environment was generally adequate or above (M = 6.1, SD = 2.5). These data, along with the collected qualitative feedback, were used to inform upgrades to the current version of Virtual Iraq that is now in clinical use, and this "design-collect feedback-redesign" cycle will continue throughout the life of the project.

Service Member Acceptance of VR in Treatment

The prior results indicated that the Virtual Iraq software was capable of producing the level of presence in Iraq-experienced SMs that was believed to be required for exposure therapy. However, successful clinical implementation also requires

patients to accept the approach as a useful and credible behavioral health treatment. To address this issue, a survey study with 325 army SMs from the Fort Lewis deployment screening clinic was conducted to assess knowledge of current technologies and attitudes toward the use of technology in behavioral health care *(65)*. One section of the survey asked these active duty SMs to rate on a 5-point scale how willing they would be to receive mental health treatment ("not willing at all" to "very willing") via traditional approaches (e.g., face-to-face counseling) and a variety of technology-oriented delivery methods (e.g., Web site, video teleconferencing, use of VR). Eighty-three percent of participants reported that they were neutral to very willing to use some form of technology as part of their behavioral health care, with 58% reporting some willingness to use a VR treatment program. Seventy-one percent of SMs were equally or more willing to use some form of technological treatment than solely talking to a therapist in a traditional setting. Most interesting is that 20% of SMs who stated they were not willing to seek traditional psychotherapy rated their willingness to use a VR-based treatment as neutral to very willing. One possible interpretation of this finding is that a subgroup of this sample of SMs with a significant disinterest in traditional mental health treatment would be willing to pursue treatment with a VR-based approach. It is also possible that these findings generalize to SMs who have disengaged from or terminated traditional treatment.

Preliminary Results from an Open Clinical Trial Using Virtual Iraq at the NMCSD

The Virtual Iraq system built from this user-centered design process is currently being tested in an open clinical trial with PTSD-diagnosed active duty SMs at NMCSD and Camp Pendleton. The ONR funded the initial system development of Virtual Iraq along with this initial trial to evaluate the feasibility of using VRET with active duty participants. The participants were SMs who recently redeployed from Iraq and who had engaged in previous PTSD treatments (e.g., group counseling, selective serotonin reuptake inhibitors [SSRIs], etc.) without benefit. The standard treatment protocol consisted of twice-weekly 90- to 120-min sessions over 5 weeks that also included physiological monitoring (heart rate [HR], Galvanic Skin Response [GSR], and respiration) as part of the data collection. However, in this open clinical trial, elements of the protocol were occasionally modified (i.e., adjusting the number and timing of sessions) to meet patient's needs; thus, these data represent an uncontrolled feasibility trial. The VRET exposure exercises followed the principles of graded behavioral exposure, and the pace was individualized and patient driven.

The first VRET session consisted of a clinical interview that identified the index trauma, provided psychoeducation on trauma and PTSD, and provided instruction on a deep-breathing technique for general stress management purposes. The second session provided instruction on the use of subjective units of distress (SUDs), the rationale for PE, including imaginal exposure and in vivo exposure. The participants also engaged in their first experience of imaginal exposure of the index trauma, and the in vivo hierarchy exposure list was constructed

with the first item assigned as homework. Session 3 introduced the rationale for VRET, and the participant experienced the VR environment without recounting the index trauma narrative for approximately 25 min with no provocative trigger stimuli introduced. The purpose of not recounting the index trauma was to allow the participant to navigate Virtual Iraq in an exploratory manner and to function as a "bridge session" from imaginal alone to imaginal exposure combined with VR. Sessions 4 through 10 focused on the participant engaging in the VR while recounting the trauma narrative. Generally, when participants were putting on the HMD, they were instructed that they would be asked to recount their trauma in the first person, as if it were happening again, with as much attention to sensory detail as they could provide. Using clinical judgment, the therapist might prompt the patient with questions about their experience or provide encouraging remarks as deemed necessary to facilitate the recounting of the trauma narrative.

The treatment included homework, such as requesting the participant to listen to the audiotape of their exposure narrative from the most recent session. Listening to the audiotape several times over a week functioned as continual exposure for processing the index trauma to further enhance the probability for habituation to occur. In vivo hierarchy exposure items were assigned in a sequential fashion, starting with the lowest-rated SUD item. A new item was assigned once the participant demonstrated approximately a 50% reduction of SUDs ratings on the previous item. Self-report measures were obtained at baseline and prior to sessions 3, 5, 7, 9, and 10 and 1 week and 3 months posttreatment to assess in-treatment and follow-up symptom status. The measures used were the PCL-M, Beck Anxiety Inventory (BAI), and Patient Health Questionnaire-Depression (PHQ-9) *(59,66–68)*.

As of the submission date for this chapter, initial analyses of our first 15 treatment completers (14 male, 1 female, mean age = 28, age range 21–51) have indicated positive clinical outcomes. For this sample, mean pre-/post-PCL-M scores decreased; mean (standard deviation) values went from 54.6 (10.4) to 35.8 (18.6). Paired pre/post *t*-test analysis showed these differences to be significant ($t = 5.28$, $df = 14$, $p < .0001$). Correcting for the PCL-M no-symptom baseline of 17 indicated a 50% decrease in symptoms, and 12 of the 15 completers no longer met DSM criteria for PTSD at posttreatment. Three participants in this group with PTSD diagnoses had pretreatment baseline scores below the cutoff value of 50 (prescores = 42, 36, 38) and reported decreased values at posttreatment (postscores = 22, 22, 24, respectively). Individual participant scores at baseline, posttreatment, and 3-month follow-up (for those available at this date) are in Fig. 6. For this same group, mean BAI scores significantly decreased 33% from 17.9 (9.5) to 11.6 (13.6), ($t = 2.4$, $df = 14$, $p < .03$) and mean PHQ-9 (depression) scores decreased 50% from 13.7 (4.5) to 6.9 (6.2) ($t = 3.2$, $df = 14$, $p < .006$). The average number of sessions for this sample was just under 12. Also, two of the successful treatment completers had documented mild and moderate traumatic brain injuries, which suggests that this form of exposure can be useful (and beneficial) for this population.

In spite of these initial positive results for treatment completers, challenges existed with dropouts from this active duty sample. Seven participants who were assessed and approved for the study failed to appear at the first session, six

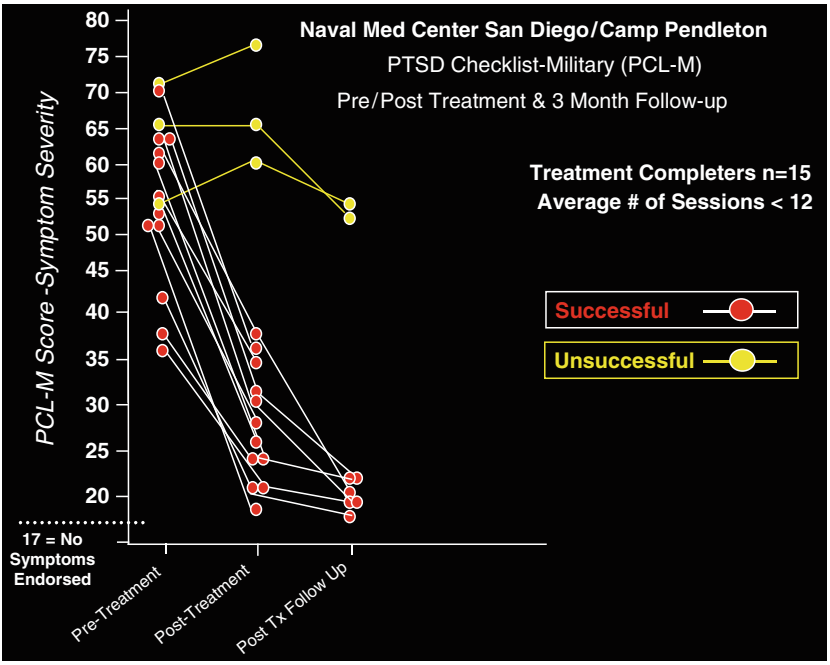

Fig. 6. Individual PTSD Checklist-military (PCL-M) from first 15 virtual reality exposure therapy (VRET) treatment completers. The average score pre- and posttreatment indicates a decline in scores. The scores remained low at 3-month follow-up. Three were unsuccessful (*See Color Plates*)

attended the first session and dropped out prior to formal commencement of VRET at session 4, and seven dropped out at various points following session 4. While some of these active duty participants left due to transfers and other reasons beyond their control, these dropout numbers are concerning, and we intend to examine all data gathered from this subset of the total sample to search for discriminating factors. This open trial will continue until we have 20 treatment completers, and at that point we intend to examine the dropout issue and to analyze the physiological data that we have logged throughout the course of this trial.

MAMC Case Study

The following case is included to illustrate the conduct and results from a course of treatment that did not follow the twice-a-week protocol used at NMCSD. With the demands placed on active duty SMs regarding training and transfers, it may not be realistic to expect that exposure sessions can be delivered within a consistently short time frame for all participants. The following case report was reviewed by the MAMC Department of Clinical Investigation, and explicit written consent from the patient for this case report was obtained on reviewing the text.

The patient was an active duty army SM in his 30s who presented with a mix of trauma-related anxiety symptoms associated with an index trauma experienced

during a convoy in Iraq. At the time of referral, he reported intense emotional and physiological reactivity when he encountered reminders of his experience. He had multiple nightmares a week and reported increased irritability, exaggerated startle, and avoidance of crowds, congested traffic, and public places. He had experienced limited benefit from approximately one-and-a-half years of psychotherapy that did not involve exposure. Treatment options were reviewed with the patient, including Eye Movement Desensitization and Reprocessing [EMDR], imaginal PE, and VR exposure. After considering the potential risks and benefits, he selected VRET.

Prior to starting treatment, his PTSD symptoms were assessed with the PCL-M. His baseline score on the PCL-M before beginning VRET was 71, well above the recommended cut point for screening positive for PTSD. He completed 11 sessions of VR exposure across 7 months, interrupted intermittently by the SM's vacations and several crises necessitating clinical attention. During VR exposure, SUDs ratings were obtained every 5 min. Consistent with the theoretical assumption that the multisensory nature of VR facilitates increased activation of the trauma memory, emotional engagement during the initial VR exposure session was high, with an initial SUDs of 80 and a peak SUDs of 90. The SM reported that tearfulness during post-VR exposure discussion was the first time he cried about losses during the deployment. Over the course of VRET, the SM demonstrated high levels of emotional engagement, and at termination, the SM reported significant improvement in symptoms and functioning. He was actively socializing with groups in a variety of crowded public places, and nightmares were rare. Irritability had decreased, and he reported decreased anxiety on encountering cues and reminders of his experience. Consistent with his description of improvement, his posttreatment PCL-M was 38, demonstrating a substantial drop from his baseline of 71.

Case reports have numerous limitations, and the efficacy of VRET cannot be established without controlled clinical trials. Numerous factors may figure into outcomes that can only be determined from a larger sample in a controlled randomized trial that includes both "intent-to-treat" and "treatment completer" analyses. Nonetheless, this case illustrates the successful use of VRET with an active duty SM, albeit outside the typically recommended time course. Although exposure sessions are often conducted once or twice a week for 2 to 3 months, this patient benefited from sessions of much lower frequency. As an aside, it is also interesting to note that the SM discussed his therapy with some of his peers, one of whom inquired about the appropriateness of this form of treatment for his symptoms. For more information on this project, two case summaries from the NMCSD trial and a more detailed case report of a National Guardsman successfully treated at Emory University are now in print *(69,70)*.

CONCLUSIONS

Results from such uncontrolled trials and case reports are difficult to generalize from, and we are cautious not to make excessive claims based on these early results. At the current time, we are encouraged by these early successes, and

we continue to gather feedback from the patients regarding the therapy and the Virtual Iraq environment in order to continue our iterative system development process. We continue to update the Virtual Iraq system with added functionality that has its design "roots" from feedback acquired from these initial patients and the clinicians who have used the system thus far. We are using these initial results to develop, explore, and test hypotheses regarding how we can improve treatment and determine which patient characteristics may predict who will benefit from VRET and who may be best served by other approaches.

The current clinical treatment research program with the Virtual Iraq application is also providing important data needed to determine the feasibility of expanding the range of applications that can be created from this initial research-and-development program. In the course of the ongoing evolution of this system, our approach has always focused on the creation of a VR system/tool that could address *both* clinical and scientific PTSD research questions in a more comprehensive fashion. In this regard, we are expanding our research program using the Virtual Iraq system to

study the feasibility of assessing soldiers in advance of deployment to predict those who might have a higher likelihood of developing PTSD or other mental health difficulties based on physiological reactivity (and other measures) to a series of virtual combat engagements.

deliver "stress inoculation" training to better prepare military personnel for what might occur in real combat environments.

study the effectiveness of using VR as an assessment tool that is administered immediately on redeployment to determine who may be "at risk" for developing full-blown PTSD after an incubation period. Psychophysiological reactivity could figure well as a marker variable for this project, and a prospective longitudinal study is needed in this area. This is particularly important for maximizing the probability that a soldier at risk would be directed into appropriate treatment or programming before being sent on a second or third deployment.

study the impact of multiple traumatic events on the course of PTSD as may be relevant for the reintegration of military personnel into civilian settings following multiple deployments.

study the differences between national guard, reservist personnel, army/marine/air force standing military SMs and veterans in terms of their susceptibility for developing PTSD and if variations in the course of treatment would be required. This is also relevant for the study of PTSD treatment response differences due to age, gender, education, family support, and previous exposure to trauma (as in the case of a reservist who served in emergency services as a civilian in the police or fire department, where exposure to traumatic events commonly occurs).

evolve understanding of the neuroscience of PTSD via the use of brain-imaging protocols (e.g., functional magnetic resonance imaging [fMRI], diffusion tensor imaging); traditional physiological measurement (e.g., electroencephalography [EEG], electrocardiography [EKG], GSR, etc.); and other forms of body-based responses (e.g., eyeblink, startle response, and other motor

behaviors) by leveraging the high controllability of stimulus events that is available with the Virtual Iraq application.

study the treatment efficacy of Virtual Iraq across a range of standard therapeutic issues (i.e., what rate of exposure is needed to optimally treat PTSD).

study the interaction between the use of VR exposure in combination with a host of pharmacological treatment strategies (e.g., D-cycloserine). Randomized controlled trials comparing VRET alone and VRET plus D-cycloserine are currently in progress at Emory University and at Weill Cornell Medical College after successful results were reported with VRET plus D-cycloserine for treating fear of heights *(71)*.

expand the functionality of our existing system based on the results of the ongoing and future research. This will involve refining the system in terms of the breadth of scenarios/trigger events, the audiovisual stimulus content, and the level of artificial intelligence of virtual human characters that "inhabit" the system.

One of the more foreboding findings in the Hoge et al. *(1)* report was the observation that, among Iraq/Afghanistan War veterans, "those whose responses were positive for a mental disorder, only 23 to 40 percent sought mental health care. Those whose responses were positive for a mental disorder were twice as likely as those whose responses were negative to report concern about possible stigmatization and other barriers to seeking mental health care" (p. 13). While military training methodology has better prepared soldiers for combat in recent years, such hesitancy to seek treatment for difficulties that emerge on return from combat, especially by those who may need it most, suggests an area of military mental health care that is in need of attention.

To address this concern, a VR system for PTSD treatment could serve as a component within a reconceptualized approach to how treatment is accessed by SMs and veterans returning from combat. Perhaps VR exposure could be embedded within the context of "postcombat reintegration training" by which the perceived stigma of seeking treatment could be lessened as the soldier would be simply involved in this "training" in similar fashion to other designated duties on redeployment stateside.

VRET therapy may also offer an additional attraction and promote treatment seeking by certain demographic groups in need of care. The current generation of young military personnel, having grown up with digital gaming technology, may actually be more attracted to and comfortable with participation in VRET as an alternative to what is viewed as traditional talk therapy (even though such talk therapy would obviously occur in the course of a multicomponent CBT approach for this disorder).

Finally, one of the guiding principles in our development work concerns how novel VR systems can extend the skills of a well-trained clinician. VR exposure therapy approaches are not intended to be automated treatment protocols that are administered in a "self-help" format. The presentation of such emotionally evocative VR combat-related scenarios, while providing treatment options not possible until recently, will most likely produce therapeutic benefits when administered within the context of appropriate care via a thoughtful professional appreciation of the complexity and impact of this disorder.

ACKNOWLEDGMENT

This research was funded by the Office of Naval Research, award N0014-05-1-0384 and the U.S. Army Research, Development, and Engineering Command/Telemedicine and Advanced Technology Research Center, award 53-0821-2404. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the ONR, RDECOM, or TATRC.

Disclosure: Dr. Rothbaum is a consultant to and owns equity in Virtually Better Incorporated, which is developing products related to the VR research described in this presentation. The terms of this arrangement have been reviewed and approved by Emory University in accordance with its conflict-of-interest policies.

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