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Virtual Reality as a Tool for Delivering PTSD Exposure Therapy and Stress Resilience Training

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The incidence of post-traumatic stress disorder (PTSD) in returning Operation Enduring Freedom and Operation Iraqi Freedom military personnel has created a significant behavioral health care challenge. One emerging form of treatment for combat-related PTSD that has shown promise involves the delivery of exposure therapy using immersive virtual reality (VR). Initial outcomes from open clinical trials have been positive, and fully randomized controlled trials are currently in progress. Inspired by the initial success of our research using VR to emotionally engage and successfully treat persons undergoing exposure therapy for PTSD, we have developed a similar VR-based approach to deliver resilience training prior to an initial deployment. The STress Resilience In Virtual Environments (STRIVE) project aims to create a set of combat simulations (derived from our existing virtual Iraq/Afghanistan PTSD exposure therapy system) that are part of a multiepisode interactive narrative experience. Users can be immersed within challenging virtual combat contexts and interact with virtual characters as part of an experiential approach for learning psychoeducational material, stress management techniques, emotional coping strategies believed to enhance stress resilience. This article describes the development and evaluation of the virtual Iraq/Afghanistan exposure therapy system and then details its current transition into the STRIVE tool for predeployment stress resilience training.

Keywords: PTSD, stress resilience, allostatic load, cognitive coping, virtual reality

INTRODUCTION

The physical, emotional, cognitive, and psychological demands of a combat environment place enormous stress on even the best-prepared military personnel. The stressful experiences that are characteristic of the Operation Enduring Freedom (OEF)/Operation Iraqi Freedom (OIF) war-fighting environments have produced significant numbers of returning service members (SMs) at risk for developing post-traumatic stress disorder (PTSD) and other psychosocial health conditions. In the first systematic study of OEF/OIF mental health problems, the results indicated that "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)" (Hoge et al., 2004, p. 13). Reports since that time on OEF/OIF PTSD and psychosocial disorder rates suggest even higher incidence rates (Fischer, 2010; Seal, Bertenthal, Miner, Sen, & Marmar, 2007; Tanielian et al., 2008). For example, as of 2010, the Military Health System recorded 66,934 active duty patients who have been diagnosed with PTSD (Fischer, 2010), and the Rand Analysis (Tanielian et al., 2008) estimated that at a 1.5 million deployment level, more than 300,000 active duty and discharged veterans will suffer from the symptoms of PTSD and major depression. With total deployment numbers now having increased to more than 2 million, the Rand Analysis likely underestimates the current number of SMs who may require (and could benefit from) clinical attention upon the return home. These findings make a compelling case for a continued focus on developing and enhancing the availability of

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evidence-based treatments to address a mental health care challenge that has had a significant impact on the lives of our SMs, veterans, and their significant others, all of whom deserve our best efforts to provide optimal care.

VIRTUAL REALITY EXPOSURE THERAPY

Concurrent with the start and progression of OEF/OIF, a virtual revolution has taken place in the use of virtual reality (VR) simulation technology for clinical and training purposes. Technological advances in the areas of computation speed and power, graphics and image rendering, display systems, body tracking, interface technology, haptic devices, authoring software, and artificial intelligence have supported the creation of low-cost and usable VR systems capable of running on a commodity-level personal computer. VR allows for the precise presentation and control of stimuli within dynamic, multisensory, 3D, computer-generated environments, as well as providing advanced methods for capturing and quantifying behavioral responses. These characteristics serve as the basis of rationale for VR applications in the clinical assessment, intervention, and training domains. The unique match between VR technology assets and the needs of various clinical treatment and training approaches has been recognized by a number of scientists and clinicians, and an encouraging body of research has emerged that documents the many clinical targets where VR can add value to clinical assessment and intervention (Holden, 2005; Parsons & Rizzo, 2008; Rizzo, Parsons, et al., 2011; Riva, 2011; Rose, Brooks, & Rizzo, 2005). To do this, VR scientists have constructed virtual airplanes, skyscrapers, spiders, battlefields, social settings, beaches, fantasy worlds, and the mundane (but highly relevant) functional environments of the schoolroom, office, home, street, and supermarket. Emerging R&D is also producing artificially intelligent virtual human agents that are being used in the role of virtual patients for teaching clinical skills to novice clinical professionals (Lok et al., 2007; Rizzo et al., in press) and as anonymous online health care support agents (Rizzo, Lange, et al., 2011). This convergence of exponential advances in underlying VR-enabling technologies with a growing body of clinical research and experience has fueled the evolution of the discipline of clinical virtual reality. And this state of affairs now stands to transform the vision of future clinical practice and research to address the needs of both civilian and military populations with clinical health conditions.

THE VIRTUAL IRAQ/AFGHANISTAN EXPOSURE THERAPY SYSTEM

Among the many approaches that have been used to treat persons with PTSD, graduated exposure therapy appears to have the best-documented therapeutic efficacy (Bryant, 2005; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001). Such treatment typically involves the graded and repeated imaginal reliving and narrative recounting of the traumatic event within the therapeutic setting. This approach is believed to provide a low-threat context where the client can begin to confront and therapeutically process the emotions that are relevant to a 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 (Rothbaum, Hodges, Smith, Lee, & Price, 2000; Rothbaum et al., 2001; Rothbaum & Schwartz, 2002), 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 VR to deliver exposure therapy (VRET) by immersing users in simulations of trauma-relevant environments in which the emotional intensity of the scenes can be precisely controlled by the clinician in collaboration with the patients' wishes. In this fashion, VRET offers a way to circumvent the natural avoidance tendency by directly delivering multisensory and context-relevant cues that aid in the confrontation and processing of traumatic memories without demanding that the patient actively try to access his or her experience through effortful memory retrieval. Within a VR environment, the hidden world of the patient's imagination is not exclusively relied upon, and VRET may also offer an appealing treatment option that is perceived with less stigma by "digital generation" SMs and veterans who may be more reluctant to seek out what they perceive as traditional talk therapies.

These ideas have been supported by three reports in which patients with PTSD were unresponsive to previous imaginal exposure treatments but went on to respond successfully to VRET (Difede & Hoffman, 2002; Difede et al., 2007; Rothbaum et al., 2001). In addition, VR provides an objective and consistent format for documenting the sensory stimuli to which the patient is exposed that is not possible when operating within the unseen world of the patient's imagination. Based on this, the University of Southern California Institute for Creative Technologies developed a "Virtual Iraq/Afghanistan" simulation that is being used in a variety of clinical trials to investigate the potential for this form of treatment (see Figure 1).

The treatment environment consists of a series of virtual scenarios designed to represent relevant contexts for VRET, including city and desert road environments. In addition to the visual stimuli presented in the VR head-mounted display, directional 3D audio and vibrotactile and olfactory stimuli of relevance can be delivered. Stimulus presentation is controlled by the clinician via a separate "Wizard of Oz" interface, with the clinician in full audio contact with the patient. User-centered tests of the application were conducted at the Naval Medical Center San Diego and within an Army

FIGURE 1 Virtual Iraq/Afghanistan: "Middle Eastern City" and "Desert Road" Humvee scenarios.

Combat Stress Control Team in Iraq. This feedback from non-diagnosed personnel provided information on the content and usability of our application, which fed an iterative design process leading to the creation of the current clinical scenarios. A detailed description of the virtual Iraq/Afghanistan system and the methodology for a standard VRET clinical protocol can be found in other recent studies (e.g., Rothbaum, Difede, & Rizzo, 2008).

Initial clinical tests of the system have produced promising results. In the first open clinical trial, analyses of 20 active duty treatment completers (19 male, 1 female, $M_{\text{age}} = 28$, age range: 21–51) produced positive clinical outcomes (Rizzo, Parsons, et al., 2011; Mclay et al., 2012). For this sample, mean pre- and post-PTSD Checklist—Military Version (PCL-M; Blanchard, Jones-Alexander, Buckley, & Forneris, 1996) scores decreased in a statistical and clinically meaningful fashion: from 54.4 ($SD = 9.7$) to 35.6 ($SD = 17.4$). Paired pre- and post-t-test analysis showed these differences to be significant ($t = 5.99$, $df = 19$, $p < .001$). Correcting for the PCL-M no-symptom baseline of 17 indicated a greater than 50% decrease in symptoms; 16 of the 20 completers no longer met PCL-M criteria for PTSD at posttreatment. Five participants in this group with PTSD diagnoses had pretreatment baseline scores below the conservative cutoff value of 50 (pretreatment scores = 49, 46, 42, 36, 38) and reported decreased values at post treatment (posttreatment scores = 23, 19, 22, 22, 24, respectively). Mean Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988) scores significantly decreased 33%, from 18.6 ($SD = 9.5$) to 11.9 ($SD = 13.6$), ($t = 3.37$, $df = 19$, $p < .003$) and mean Patient Health Questionnaire (PHQ-9; Kroenke and Spitzer, 2002) (depression) scores decreased 49% from 13.3 ($SD = 5.4$) to 7.1 ($SD = 6.7$), ($t = 3.68$, $df = 19$, $p < .002$). The average number of sessions for this sample was just under 11. Results from uncontrolled open trials are difficult to generalize from, and we are cautious not to make excessive claims based on these early results. However, using an accepted military-relevant diagnostic screening measure (PCL-M), 80% of the treatment completers in the initial VRET sample showed both statistically and clinically meaningful reductions in PTSD, anxiety, and depression symptoms, and anecdotal evidence from patient reports suggested that they saw improvements in their everyday life. These improvements were also maintained at three-month posttreatment follow-up.

Other studies have also reported positive outcomes. Two early case studies reported positive results using this system (Gerardi, Rothbaum, Ressler, Heekin, & Rizzo, 2008; Reger & Gahm, 2008). Following those, an open clinical trial with active duty soldiers ($n = 24$) produced significant pretreatment and posttreatment reductions in PCL-M scores and a large treatment effect size (Cohen's $d = 1.17$) (Reger & Gahm, 2011). After an average of seven sessions, 45% of those treated no longer screened positive for PTSD, and 62% had reliably improved. Three randomized controlled trials (RCTs) are ongoing using the virtual Iraq/Afghanistan system with active duty and veteran populations. Two RCTs are focusing on comparisons of treatment efficacy between VRET and prolonged imaginal exposure (PE) (Reger & Gahm, 2010; Reger et al., 2011) and VRET compared with VRET plus a supplemental care approach (Beidel, Frueh, & Uhde, 2010).

A third RCT (Difede, Rothbaum, & Rizzo, 2010–2013) is investigating the additive value of supplementing VRET and imaginal 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 prior to extinction training (Walker, Ressler, Lu, & Davis, 2002). The first clinical test in humans that combined DCS with VRET was performed by Ressler and colleagues (2004) and included participants diagnosed with acrophobia ($n = 28$). Participants who received DCS with VRET experienced significant decreases in fear within the virtual environment one week and three months posttreatment, and they reported significantly more improvement than the placebo group in their overall acrophobic symptoms at three-month follow-up. This group also achieved lower scores on a psychophysiological measure of anxiety than the placebo group. The current multisite PTSD RCT will test the effect of DCS versus placebo when added to VRET and PE with active duty and veteran samples ($n = 300$).

THE STRESS RESILIENCE IN VIRTUAL ENVIRONMENTS (STRIVE) APPROACH

The current urgency in efforts to address the psychological wounds of war in SMs and veterans has also driven an emerging focus within the military on emphasizing a proactive approach for better preparing SMs for the emotional challenges they may face during a combat deployment to reduce the potential for later adverse psychological reactions such as PTSD and depression. This focus on stress resilience training prior to deployment represents no less than a quantum shift in military culture and can now be seen emanating from the highest levels of command in the military. For example, in an *American Psychologist* article, General George Casey (2011) of the U.S. Army makes the case that "soldiers can 'be' better before deploying to combat so they will not have to 'get' better after they return" (p. 1), and he then calls for a shift in the military "to a culture in which psychological fitness is recognized as every bit as important as physical fitness" (p. 2). This level of endorsement can be seen in practice by way of the significant funding and resources applied to stress resilience training within the Comprehensive Soldier Fitness program (Cornum, Matthews, & Seligman, 2011). The core aim of such approaches is to promote psychological fitness and better prepare service members for the psychological stressors that they may experience during a combat deployment.

Resilience is the dynamic process by which individuals exhibit positive adaptation when they encounter significant adversity, trauma, tragedy, threats, or other sources of stress (McEwen & Stellar, 1993). The Department of Defense (DOD) has focused significant attention on this area with a variety of programs being developed for this purpose across the branches of the military (Hovar, 2010; Luthar, Cicchetti, & Becker, 2000). Perhaps the program that is attempting to influence the largest number of SMs is the aforementioned Comprehensive Soldier Fitness (CSF) program (Cornum et al., 2011). This project has created and disseminated training that aims to improve emotional coping skills and ultimate resilience across all Army SMs. One element of this program draws input from principles of cognitive-behavioral science, which generally advances the view that it is not the event that causes the emotion but rather how a person appraises the event (based on how he or she thinks about the event) that leads to the emotion (Ortony, Clore, & Collins, 1988). From this theoretical base, it then follows that internal thinking or appraisals about combat events can be "taught" in a way that leads to more healthy and resilient reactions to stress. This approach does not imply that people with effective coping skills do not feel some level of rational emotional pain when confronted with a challenging event that would normally be stressful to any individual. Instead, the aim is to teach skills that may assist soldiers in an effort to cope with traumatic stressors more successfully.

The STRIVE (STress Resilience In Virtual Environments) project has evolved from the virtual Iraq/Afghanistan VRET system and aims to foster stress resilience by creating a set of combat simulations that can be used as contexts for the experiential learning of cognitive-behavioral emotional coping strategies in SMs prior to deployment. This will involve immersing and engaging SMs within a variety of virtual missions where they are confronted with emotionally challenging situations that are inherent in the OEF/OIF combat environment. Interaction by SMs within such emotionally challenging scenarios will aim to provide a more meaningful context in which to learn and practice psychoeducational and cognitive coping strategies that are believed to psychologically prepare them for combat deployment. To accomplish this, STRIVE is being designed as a 30-episode interactive narrative in VR, akin to being immersed within a *Band of Brothers*-type story line that spans a typical deployment cycle. At the end of each of the graded 10-minute episodes, an emotionally challenging event occurs, designed in part from feedback provided by SMs undergoing PTSD treatment (e.g., seeing/handling human remains, death/injury of a squad member, the death/injury of a civilian child). At that point in the episode, the virtual world "freezes in place" and an intelligent virtual human "mentor" (selected by the user) emerges from the midst of the chaotic VR scenario to guide the user through stress-related psychoeducational and self-management tactics, as well as provide rational restructuring exercises for appraising and processing the virtual experience. The stress resilience training component draws on evidence-based content that has been endorsed as part of standard classroom-delivered DOD stress resilience training programs, as well as content that has been successfully applied in nonmilitary contexts (e.g., humanitarian aid worker training, sports psychology, and other areas).

In this fashion, STRIVE provides a digital "emotional obstacle course" that can be used as a tool for providing context-relevant learning of emotional coping strategies under very tightly controlled and scripted simulated conditions. Training in this format is hypothesized to improve generalization to real-world situations via a state-dependent learning component (Godden & Baddeley, 1980) and further support resilience by leveraging the learning theory process of latent inhibition. Latent inhibition refers to the delayed learning that occurs as a result of preexposure to a stimulus without a consequence (Feldner, Monson, & Friedman, 2007; Lubow & Moore, 1959). Thus, exposure to a simulated combat context is believed to decrease the likelihood of fear conditioning during the real event (Sones, Thorp, & Raskind, 2011).

STRESS BIOMARKERS AND ALLOSTATIC LOAD

The STRIVE project also incorporates a novel basic science protocol. While other stress resilience projects incorporate one or two biomarkers of stress and or resilience, the STRIVE projects will measure what we refer to as the physiological fingerprint of stress, commonly called allostatic load (AL).

The theoretical construct of AL, initially developed by one of the STRIVE collaborators, Bruce McEwen, is a measure of cumulative wear and tear on physiological symptoms due to chronic stress (McEwen & Stellar, 1993). As a theoretical construct, it is a preliminary attempt to formulate the relationship between environmental stressors and disease, by hypothesizing mechanisms whereby multiple kinds of stressors confer risk simultaneously in multiple physiological systems. The construct of AL is based on the widely accepted response called allostasis. Sterling and Eyer (1988) defined allostasis as the body's set points for various physiological mechanisms, such as blood pressure or heart rate, which vary to meet specific external demands, for example, emotional stress. McEwen and Stellar (1993) furthered our understanding of allostasis by broadening its scope. Rather than discuss allostasis in terms of a single set point that changes in response to a stressor, they describe allostasis as the combination of all physiological coping mechanisms that are required to maintain equilibrium of the entire system. Thus, allostasis is the reaction and adaptation to stressors by multiple physiological systems that brings the system back to equilibrium. The related concept of homeostasis refers specifically to system parameters essential for survival (McEwen, 2002). To place AL into the context of allostasis, allostasis does not always proceed in a normal manner. Any of the major physiological systems—inflammatory, metabolic, immune, neuroendocrine, cardiovascular, and respiratory—can in the process of responding to stress exact a cost, or an allostatic load, that may result in some form of physiological or psychological disturbance. McEwen (2000) identified four types of AL: (1) frequent activation of allostatic systems; (2) prolonged failure to shut off allostatic activity after stress; (3) lack of adaptation to stress, and (4) inadequate response of allostatic systems leading to elevated activity of other, normally counterregulated allostatic systems after stress, for example, inadequate secretion of glucocorticoid, resulting in increased cytokines normally countered by glucocorticoids. Any of these types of AL interfere with the normal stress response of allostasis, thus increasing AL. This will increase one's risk for disease in the long term and may preclude the short-term development of physical hardiness and psychological resilience.

From a conceptual standpoint, the construct of AL is still undergoing development. More recent AL models posit the interaction of biomarkers on multiple levels. Juster, McEwen, and Lupien (2009) theorize that by measuring multisystemic interactions among primary mediators (e.g., levels of cortisol, adrenalin, noradrenalin) and relevant subclinical biomarkers representing secondary outcomes (e.g., serum high-density lipoprotein [HDL] and total cholesterol), one can identify individuals at high risk of tertiary outcomes (e.g., disease and mental illness). Yet we argue this approach does not fully encapsulate the dynamic, nonlinear, evolving, and adaptive nature of the interactions between these biomarkers. Moreover, these markers are not purely physiological. Psychological processes, including appraisal of and reactions to various stressors—for example, resilience—may constitute a separate but interdependent subsystem in the allostatic model. We support a case-based approach to analysis, which acknowledges that each allostatic system is unique in its configuration based on differences in (1) environmental context, including the user's socioeconomic status and the availability of psychosocial resources; (2) regulation and plasticity of bioallostatic systems; (3) regulation and plasticity of what we term psychoallostatic systems; (4) psychology, including personality and appraisal of stressors; (5) environmental stressors, which range from biological to sociological; and (6) health outcomes. AL will be measured via the development and integration of complex biomarkers known to indicate physiological dysfunction, and normal function, for numerous physiological systems (including immune, cardiovascular, metabolic).

In a first study of its kind, we will determine whether AL can predict acute response to stress (using EEG, GSR, ECG, pupil dilation, etc.), when participants are exposed to the stressful VR missions. Further analyses will determine whether AL can predict participants' responses to virtual mentor instructions on how the participants can cope with stress through stress resilience training. If we find that AL is capable of predicting either short-term response to stress or the ability to learn stress resilience, there would be numerous implications for the future use of AL, including identification of leadership profiles and informing the development of appropriate training systems for all SMs. Pilot research on this project is ongoing at the Immersive Infantry Training Center at Camp Pendleton, California.

CONCLUSIONS

The STRIVE program is designed both to create a VR application for enhancing SM stress resilience and to provide a highly controllable laboratory test bed for investigating the stress response. Success in this area could have significant impact on military training and for the prevention of combat stress–related disorders. Another option for use of the STRIVE system could involve its application as a VR tool for emotional assessment at the time of recruitment to the military. The large question with such an application involves whether it would be possible (and ethical) to assess prospective SMs in a series of challenging combat-relevant emotional environments delivered in the STRIVE system to predict their potential risk for developing PTSD or other mental health difficulties based on their verbal, behavioral, and physiological/hormonal reactions recorded during these virtual engagements. To use such information for recruitment decisions would require a change from the apparent doctrine that anyone can be made into infantry personnel. However, practical implementation of such an approach could advise that those who display reactions predicting they will be most at risk of having a negative stress reaction postcombat could either be assigned noncombat duties, not accepted into the services, or more preferably presented with the opportunity to participate in a stress resilience training program that could minimize their identified risk to posttrauma dysfunction. This is not a new concept. Since the early days of the Army Alpha/Beta, assessments have been routinely conducted that are designed to predict what role is best suited to the unique characteristics and talent of a given recruit. Moreover, potential recruits are not accepted into the military for many reasons that are more easily measurable (e.g., having a criminal record, poor physical fitness, significant health conditions).

For this effort, the pragmatic challenge would be in the conduct of prospective longitudinal validation research. This would require the initial testing of a large number of SMs within standardized virtual simulations (i.e., STRIVE) to record and measure reactions for establishing a baseline and for also determining if advanced data-mining procedures could detect whether consistent patterns of responding do in fact exist. SMs in this large sample could then be closely monitored for their mental health status during and after their deployment. Once a large enough sample of SMs was identified as having stress-related problems, it would be possible to go back to their physiological and behavioral data from the earlier simulation experience and analyze for a consistent reactivity pattern that could differentiate this group and then serve as a marker for predicting problems in future recruits.

The challenges for conducting this type of research are also significant beyond the pragmatics of conducting costly longitudinal research. These would include the pressure that an all-volunteer service puts on the military to attract and maintain sufficient numbers, the traditional view that all recruits can be trained to success, and the potential that some future SMs could be misidentified as high risk (false positives) and be denied access to joining the military. This further suggests that in addition to simply identifying the emotional and physiological profile associated with long-term stress-related dysfunction, a further step would be to tailor stress resilience training for specific emotional and physiological profiles. More extensive and in-depth stress resilience training programs could then be clearly proposed for those identified as at risk for PTSD and other psychosocial health conditions. And the implications for research into individual susceptibility to stress-related disorders could have ramifications beyond the military community. As we have seen throughout history, innovations that emerge in military health care, driven by the urgency of war, typically have a lasting influence on civilian health care long after the last shot is fired.

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