J Clin Psychol Med Settings (2011) 18:176–187
DOI 10.1007/s10880-011-9247-2

Virtual Reality Goes to War: A Brief Review of the Future of Military Behavioral Healthcare

Albert Rizzo · Thomas D. Parsons · Belinda Lange · Patrick Kenny · John G. Buckwalter · Barbara Rothbaum · JoAnn Difede · John Frazier · Brad Newman · Josh Williams · Greg Reger

Published online: 7 May 2011

Abstract Numerous reports indicate that the incidence of posttraumatic stress disorder (PTSD) in returning OEF/OIF military personnel is creating a significant healthcare challenge. These findings have served to motivate research on how to better develop and disseminate evidence-based treatments for PTSD. Virtual Reality delivered exposure therapy for PTSD has been previously used with reports of positive outcomes. This article details how virtual reality applications are being designed and implemented across various points in the military deployment cycle to prevent, identify and treat combat-related PTSD in OIF/OEF Service Members and Veterans. The summarized projects in these areas have been developed at the University of Southern California Institute for Creative Technologies, a U.S. Army University Affiliated Research Center, and this paper will detail efforts to use virtual reality to deliver exposure therapy, assess PTSD and cognitive function and provide stress resilience training prior to deployment.

A. Rizzo (✉) · T. D. Parsons · B. Lange · P. Kenny · J. G. Buckwalter · J. Frazier · B. Newman · J. Williams
Institute for Creative Technologies, University of Southern California, 12015 Waterfront Dr., Playa Vista, CA 90094, USA
e-mail: arizzo@usc.edu

B. Rothbaum
Department of Psychiatry, Emory University, Atlanta, GA, USA

J. Difede
Department of Psychiatry, Weill Cornell Medical College, New York, NY, USA

G. Reger
National Center for Telehealth and Technology, Joint Base Lewis-McChord, Tacoma, WA, USA

Keywords Virtual reality · Exposure therapy · PTSD · Behavior therapy · Veterans, service members · Military · Invisible wounds of war · Stress resilience

The Military Healthcare Challenge

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. Since the start of the Operation Iraqi Freedom/Operation Enduring Freedom (OEF/OIF) conflicts in Afghanistan and Iraq, approximately 1.9 million troops have been deployed (Department of Defense [DoD], 2010a). As of December 2010, there have been 5,836 deaths and 41,583 Service Members (SMs) wounded in action (DOD, 2010b; Fischer, 2010). Of the wounded in action (WIA), the total includes 1,222 major limb amputations and 399 minor amputations and as of 2010, traumatic brain injury (TBI) has been diagnosed in 178,876 patients (many of which are not included in the WIA statistics since mild TBI is often reported retrospectively, upon redeployment home). Moreover, the stressful experiences that are characteristic of the OIF/OEF warfighting environments have produced significant numbers of returning SMs at risk for developing posttraumatic stress disorder (PTSD). In the first systematic study of OIF/OEF 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%) than after duty in Afghanistan (11.2 percent) or before deployment to Iraq (9.3 percent)" (Hoge et al., 2004). Reports since that time on OIF/OEF PTSD

and psychosocial disorder rates suggest even higher incidence statistics (Fischer, 2010; Seal, Bertenthal, Nuber, Sen, & Marmar, 2007; Tanielian et al., 2008). For example, as of 2010, the Military Health System has 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. These findings make a compelling case for continued focus on developing and enhancing the availability of 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 families, who deserve our best efforts to provide optimal care.

At the same time a virtual revolution has taken place in the use of Virtual Reality (VR) simulation technology for clinical 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. The unique match between VR technology assets and the needs of various clinical treatment 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 (Difede & Hoffman, 2002, Difede et al., 2007; Hoffman et al., 2011; Holden, 2005; Parsons & Rizzo, 2008a; Powers & Emmelkamp, 2008; Rizzo, Schultheis, Kerns, & Mateer, 2004; Rizzo et al., 2006; Rizzo, Difede, Rothbaum, & Reger, 2010; Riva, 2005; Rose, Brooks, & Rizzo, 2005; Rothbaum & Hodges, 1999; Rothbaum, Meadows, Resick, & Foy, 2000; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001; Rothbaum & Schwartz, 2002, Rothbaum, Rizzo, & Difede, 2010; Roy et al., 2010; Zimand et al., 2003). This convergence of the 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 in the disciplines of psychology, medicine, neuroscience, physical and occupational therapy, and in the many allied health fields that address the therapeutic needs of both civilian and military populations with clinical disorders.

This paper will discuss how VR applications are being designed and implemented across various points in the military deployment cycle to prevent, identify and treat combat-related PTSD in OIF/OEF service members. The paper will summarize projects in these areas that have been developed at the University of Southern California Institute for Creative Technologies, a U.S. Army University Affiliated Research Center, and will span the areas of VR Exposure Therapy, PTSD assessment, and Stress Resilience training prior to deployment. These are all areas of relevance to a generation of psychologists who will work within academic healthcare settings who will likely be called upon to address the needs of OIF/OEF wounded warriors for many years to come. As well, innovations that emerge in military healthcare, driven by the urgency of war, typically have a lasting influence on civilian clinical practice long after the last shot is fired.

Introduction to Clinical Virtual Reality

In its basic form, VR can be viewed as an advanced form of human–computer interface that allows the user to "interact" with and become "immersed" within a computer generated simulated environment (Rizzo, Buckwalter & Neumann, 1997). VR sensory stimuli can be delivered by using various forms of visual display technology that integrate real-time computer graphics and/or photographic images/video with a variety of other sensory output devices that can present audio, "force-feedback" haptic/touch sensations and even olfactory content to the user. An engaged interaction with a virtual experience can be supported by employing specialized tracking technology that senses the user's position and movement and uses that information to update the visual, audio and haptic/touch stimuli presented to the user to create the illusion of being immersed "in" a virtual space in which they can interact. One common configuration employs a combination of a head-mounted display (HMD) and head tracking system that allows delivery of computer-generated images and sounds of a simulated virtual scene that corresponds to what the individual would see and hear if the scene were real. Other methods employ 3D displays that project on a single wall or on a multiple wall space (multi-wall projection rooms are known as CAVES). As well, basic flat-screen display monitors have been used to deliver interactive VR scenarios that, while not immersive, are sometimes sufficient, cost-effective options for delivering testing, training, treatment and rehabilitative applications using VR.

By its nature, VR simulation technology is well suited to simulate the challenges that people face in naturalistic environments, and consequently can provide objective simulations that can be useful for clinical assessment and treatment purposes. The capacity of VR technology to create controllable, multisensory, interactive 3D stimulus environments, within which human behavior can be motivated and measured, offers clinical assessment and

treatment options that were not possible using traditional methods. As well, a long and rich history of encouraging findings from the aviation simulation literature (Hays, Jacobs, Prince, & Salas, 1992) has lent support to the concept that testing, training and treatment in highly proceduralized VR simulation environments would be a useful direction for psychology and rehabilitation to explore. Much like an aircraft simulator serves to test and train piloting ability under a variety of controlled conditions, VR can be used to create relevant simulated environments where assessment and treatment of cognitive, emotional and motor problems can take place.

A short list of areas where Clinical VR has been usefully applied includes fear reduction in persons with simple phobias (Parsons & Rizzo, 2008a; Powers & Emmelkamp, 2008), treatment for PTSD (Rothbaum et al., 2001; Difede & Hoffman, 2002, Difede et al., 2007; Rizzo, 2010; Rizzo, Difede, et al., 2010), stress management in cancer patients (Schneider, Kisby, & Flint, 2010), acute pain reduction during wound care and physical therapy with burn patients (Hoffman et al., 2011), body image disturbances in patients with eating disorders (Riva, 2005), navigation and spatial training in children and adults with motor impairments (Stanton, Foreman, & Wilson, 1998; Rizzo et al., 2004), functional skill training and motor rehabilitation with patients having central nervous system dysfunction (e.g., stroke, TBI, SCI, cerebral palsy, multiple sclerosis) (Holden, 2005; Merians, Fluet, Qiu, Saleh, Lafond, & Adamovich, 2010), and for the assessment and rehabilitation of attention, memory, spatial skills and other cognitive functions in both clinical and unimpaired populations (Rose et al., 2005; Rizzo et al., 2006; Parsons & Rizzo, 2008b; Parsons, Rizzo, Rogers, & York, 2009). 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. In essence, clinicians can now create simulated environments that mimic the outside world and use them in the clinical setting to immerse patients in simulations that support the aims and mechanics of a specific therapeutic approach.

Virtual Reality Exposure Therapy

Among the many approaches that have been used to treat PTSD, cognitive-behavioral treatment (CBT) with Prolonged Exposure (PE) appears to have the best-documented therapeutic efficacy (Foa, Davidson, & Frances, 1999; Institute of Medicine [IOM], 2007). PE is a form of individual psychotherapy based on the Foa and Kozak (1986) 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 and are reflected in the belief that the world is a dangerous place. Successful treatment requires emotional processing of the fear structures in order to modify their pathological elements so that the stimuli no longer invoke fear. 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. This approach is believed to provide a low-threat context where the patient can begin to therapeutically process the emotions that are relevant to the traumatic event as well as de-condition the avoidance learning cycle of the disorder via a habituation/extinction process. Expert treatment guidelines for PTSD published for the first time in 1999 recommended that CBT with PE should be the first-line therapy for PTSD (Foa et al., 1999). The comparative empirical support for exposure therapy was also recently documented in a review by the IOM at the National Academies of Science of 53 studies of pharmaceuticals and 37 studies of psychotherapies used in PTSD treatment (IOM, 2007). The report concluded that while 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.

While the efficacy of imaginal PE has been established in multiple studies with diverse trauma populations, many patients are unwilling or unable to effectively visualize the traumatic event. This is a crucial concern since avoidance of cues and reminders of the trauma is one of the cardinal symptoms of the DSM diagnosis of PTSD. In fact, research on this aspect of PTSD treatment suggests that the inability to emotionally engage (*in imagination*) is a predictor for negative treatment outcomes (Jaycox, Foa, & Morral, 1998, 1998). To address this problem, researchers have recently turned to the use of Virtual Reality (VR) to deliver exposure therapy (VRET) by immersing clients 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 multi-sensory and context-relevant cues that evoke the trauma without demanding that the patient actively try to access his/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, non-traditional 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. Previous successful research applying VRET for the treatment of PTSD has been detailed elsewhere (Difede et al., 2007; Rizzo, Reger, Gahm, Difede, & Rothbaum, 2009; Rothbaum et al., 2000).

Summary of the *Virtual Iraq/Afghanistan* Virtual Reality Exposure Therapy System

With this history in mind, the University of Southern California (USC) Institute for Creative Technologies (ICT) created an immersive VRET system for combat-related PTSD. The treatment environment was initially based on recycling virtual assets that were built for the commercially successful X-Box game and tactical training simulation scenario, *Full Spectrum Warrior*. Over the years other existing and newly created assets developed at the ICT have been integrated into this continually evolving application. The *Virtual Iraq* application (and the new *Virtual Afghanistan* scenario) consists of a series of virtual scenarios designed to represent relevant contexts for VR exposure therapy, including middle-eastern themed city and desert road environments. In addition to the visual stimuli presented in the VR HMD, directional 3D audio, vibrotactile and olfactory stimuli of relevance can be delivered. The presentation of additive, combat-relevant stimuli in the VR scenarios can be controlled by a therapist via a separate "Wizard of Oz" Clinical Interface, while in full audio contact with the patient. The clinical interface is a key feature in that it provides a clinician with the capacity to customize the therapy experience to the individual needs of the patient. The clinician can place the patient in VR scenario locations that resemble the setting in which the traumatic events initially occurred and can gradually introduce and control real time "trigger" stimuli (visual, auditory, olfactory and tactile) as is required to foster the anxiety modulation needed for therapeutic processing and habituation. More system details with links to video examples can be found in an online article posted to the Veterans Today website (Rizzo, 2010). A direct link to a *YouTube* channel that has videos that illustrate all the applications discussed in this article and provides videos of former patients discussing their experience with the VRET approach can be found at http://www.youtube.com/user/AlbertSkipRizzo.

Clinical Tests Using Virtual Iraq/Afghanistan

The *Virtual Iraq/Afghanistan* system was designed and built from a user-centered design process that involved feedback from active duty SMs and veterans in response to the first prototype. User-centered design feedback needed to iteratively evolve the system was gathered from a system deployed in Iraq with an Army Combat Stress Control Team and from returning OIF/OEF Veterans and patients in the US. Thus, leading up to the first clinical group test of treatment effectiveness, initial usability studies and case reports were published with positive findings in terms of SMs acceptance, interest in the treatment, and clinical successes (Gerardi, Rothbaum, Ressler, Heekin, & Rizzo, 2008; Reger & Gahm, 2008; Reger, Gahm, Rizzo, Swanson, & Duma, 2009; Reger et al., 2011; Wilson, Onorati, Mishkind, Reger, & Gahm, 2008).

The Office of Naval Research, who had funded the initial system development of Virtual Iraq, also supported an initial open clinical trial to evaluate the feasibility of using VRET with active duty participants. The study participants were recently redeployed from Iraq/Afghanistan at the Naval Medical Center San Diego and at Camp Pendleton and had engaged in previous PTSD treatments (e.g., group counseling, EMDR, medication) without benefit. The standard treatment protocol consisted of 2× weekly, 90–120 min sessions over 5 weeks. The VRET exposure exercises followed the principles of PE (Foa et al., 1999) and the pace was individualized and patient-driven. Physiological monitoring (heartrate, galvanic skin response and respiration) was used to provide additional user state information to the clinician to help inform their pacing of the VRET. The first VRET session consisted of a clinical interview that identified the index trauma, provided psychoeducation on trauma and PTSD, and gave 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 an in vivo hierarchical 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. Sessions 4–10 focused on the participant engaging in the VR while recounting the trauma narrative. Generally, participants 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 as a form of continual exposure for processing the index trauma to further enhance the probability for habituation to occur. Self-report measures were obtained at baseline and prior to sessions 3, 5, 7, 9, 10 and one week and three months post treatment to assess in-treatment and follow-up symptom status. The measures used were the PTSD Checklist-Military Version (PCL-M) (Blanchard, Jones-Alexander, Buckley, & Forneris, 1996), Beck Anxiety Inventory (BAI) (Beck, Epstein, Brown, & Steer, 1988) and Patient Health Questionnaire-Depression (PHQ-9) (Kroenke & Spitzer, 2002).

Analyses of the first 20 active duty service members to complete treatment (19 male, 1 female, Mean Age = 28, Age Range: 21–51) produced positive clinical outcomes. For this sample, mean pre/post PCL-M scores decreased in a statistical and clinically meaningful fashion; 54.4 (SD = 9.7) to 35.6 (SD = 17.4). Paired pre/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 and 16 of the 20 completers no longer met DSM criteria for PTSD at post treatment. Five participants in this group with PTSD diagnoses had pre-treatment baseline scores below the conservative cutoff value of 50 (pre-scores = 49, 46, 42, 36, 38) and reported decreased values at post treatment (post-scores = 23, 19, 22, 22, 24, respectively). Individual participant PCL-M scores at baseline, post treatment and 3-month follow-up are in Fig. 1. Mean BAI 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 PHQ-9 (depression) scores decreased 49% from 13.3 (SD = 5.4) to 7.1 (SD = 6.7), ($t = 3.68$, $df = 19$, $p < .002$) (see Fig. 2). The average number of sessions for this sample was just under 11. Also, two of the successful treatment completers had documented mild and moderate TBIs, which provide an early indication that this form of exposure therapy can be useful (and beneficial) for this population. 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 accepted diagnostic measures, 80% of the treatment completers in our 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 post-treatment follow-up.

Other studies have also reported positive outcomes. Two early case studies have been published that reported positive results using this system (Gerardi et al., 2008; Reger & Gahm, 2008). Following those, an open clinical trial with

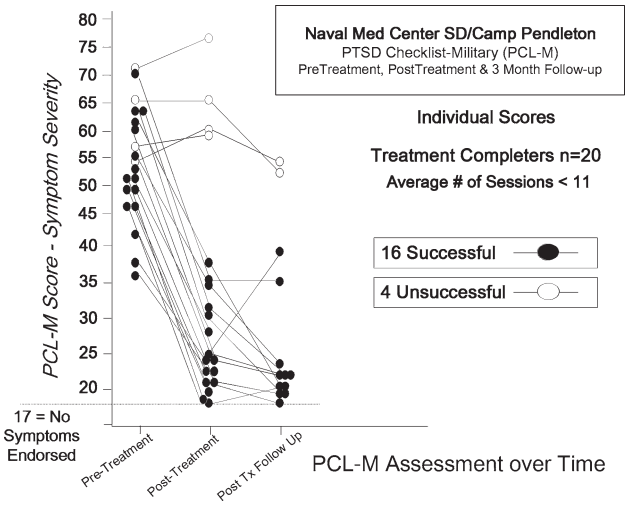

Fig. 1 PTSD Checklist-Military Version scores across treatment

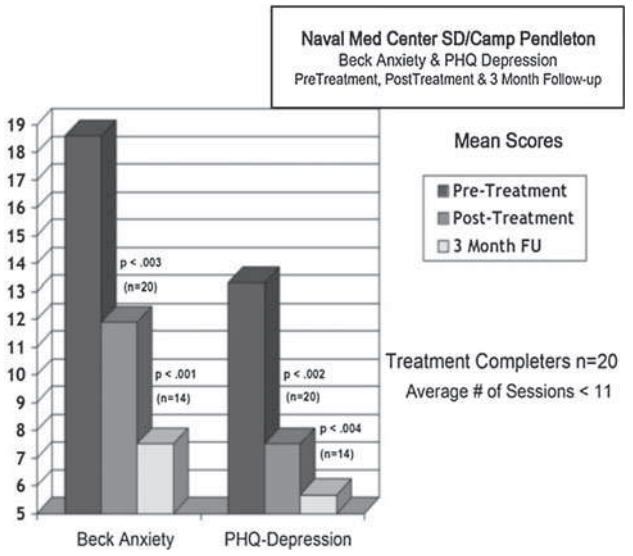

Fig. 2 Beck Anxiety Inventory and Patient Health Questionnaire-Depression scores

active duty soldiers ($n = 24$) produced significant pre/post reductions in PCL-M scores and a large treatment effect size (Cohen's $d = 1.17$). After an average of 7 sessions, 45% of those treated no longer screened positive for PTSD and 62% had reliably improved. These VRET results also outperformed a treatment-as-usual (TAU) Cognitive Behavioral Group approach (G. Reger, personal communication, January 5, 2009). Recently, some interesting mixed results have been reported from an ongoing study that used a combined sample of active duty soldiers ($n = 15$) who had undergone either VR or imaginal exposure therapy (Roy et al., 2010). While this combined sample revealed only modest pre/post treatment gains on the self-report Clinician Administered PTSD Scale (CAPS)

(Blake et al., 1990), fMRI scans conducted at pre/post treatment produced an interesting desynchrony of response systems; activation changes in the amygdala and key frontal regions of interest for PTSD indicated a significantly normalized brain response following treatment. Such conflicting results bring up the thorny issue of the reliability of self-report PTSD measures when there may be incentives to not report improvement in symptoms and this will likely be an area of interest for some time to come.

Currently three randomized controlled trials (RCT) are ongoing with the *Virtual Iraq/Afghanistan* system with active duty and Veteran populations. Two RCTs are focusing on comparisons of treatment efficacy between VRET and imaginal PE, while the third RCT investigates the additive value of supplementing VRET and imaginal PE with a cognitive enhancer called D-Cycloserine (DCS). DCS, a N-methyl-d-aspartate partial agonist, has been shown to facilitate extinction learning in laboratory animals when infused bilaterally within the bilateral 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 et al. (2004) with participants diagnosed with acrophobia ($n = 28$). Participants who received DCS + VRET had significantly enhanced decreases in fear within the virtual environment 1 week and 3 months post-treatment, and reported significantly more improvement than the placebo group in their overall acrophobic symptoms at 3 month follow-up and on a psychophysiological measure of anxiety. The current multi-site PTSD RCT will test the effect of DCS vs. Placebo when added to VRET and PE with active duty and veteran samples ($n = 300$).

This research has been supported by the relatively quick adoption of the VRET approach by approximately 48 Military, VA and University clinic sites over the last three years. Based on the outcomes from our initial open clinical trial and similar positive results from other research groups, we are encouraged by these early successes and continue to gather feedback from patients regarding the therapy and the *Virtual Iraq/Afghanistan* treatment environments. Patient feedback is particularly relevant now that the *Virtual Iraq/Afghanistan* project is undergoing a full rebuild using advanced software tools to provide more diversity of content and added functionality. In this regard, the new system has its design "roots" from feedback acquired from non-diagnosed SMs and from the clinicians and PTSD patients who have used the VRET system thus far. The new system is also being designed to facilitate the development, exploration and testing of hypotheses relevant to improving PTSD treatment, and also for the use of the simulation for other purposes including PTSD and neurocognitive assessment, and for the creation of a stress resilience training system.

Reuse for the *Virtual Iraq/Afghanistan* Simulation System

During the course of the ongoing evolution of the *Virtual Iraq/Afghanistan* VRET application, the design approach has always focused on the creation of a flexible Virtual Reality simulation tool that could address *both* clinical and scientific PTSD research questions in a more comprehensive fashion. The vision for this work was *not* to simply create a "one-off" tool for treatment, but instead to build the system in a fashion where the simulation could be re-used for other relevant purposes. In this regard, work is underway to repurpose the *Virtual Iraq/Afghanistan* content as the building blocks for an expanded set of systems that will produce new applications and investigate a variety of clinical and scientific questions relevant to assessment, intervention and stress resilience training. These applications will now be described briefly.

The Virtual Reality Cognitive Performance Assessment Test (VRCPAT)

The first project to reuse graphic and system assets from the *Virtual Iraq/Afghanistan* VRET simulation was the Virtual Reality Cognitive Performance Assessment Test (VRCPAT), an adaptive virtual environment for assessment and rehabilitation of neurocognitive functioning (Parsons & Rizzo, 2008b; Parsons & Courtney, 2010). The initial aim of this project was to create a battery of neurocognitive tests that could be administered within the context of a military relevant VR simulation (VRCPAT 1.0) and incorporate concurrent psychophysiological assessment. The project has also evolved a system that uses VR for cognitive performance and adaptive treatment (VRCPAT 2.0) in which data gleaned from the assessment module (VRCPAT 1.0) is used for refined analysis, management, and rehabilitation of SMs who have suffered blast injuries (Parsons, Iyer, Cosand, Courtney, & Rizzo, 2009; Parsons, Courtney et al., 2009; Reger, Parsons, Gahm, & Rizzo, 2010; Wu et al., 2010).

Cognitive performance testing is not a new area for the U.S. military. The Army Alpha/Beta intelligence tests from WWI provide a historical illustration of the quest for standardized performance assessment to better guide selection, placement and training decisions (ASVAB, 2010). Since that time, psychologists have routinely employed a wide range of performance assessment methods based on pencil and paper tests, behavioral rating scales, and most recently computerized cognitive screening instruments. As well, simulation technology has often been used to assess task specific performance primarily for ground vehicle and aircraft equipment operation. These efforts represent both of the extreme ends of the assessment

spectrum—basic paper and pencil tests/rating scales and high level simulation technology—for the measurement of vastly different criterion performance (declarative knowledge/processing ability vs. specific highly proceduralized skills). VRCPAT 1.0 was designed to fill the middle ground between these two poles by creating a battery of VR-delivered performance tests that will serve to generate a normative database for performance evaluation and comparison. This has also become increasingly relevant with the growing recognition of the high incidence of blast injury and its impact on brain/behavior function.

The VRCPAT 1.0 includes a range of neuropsychological measures to assess the relationship between brain structure/function and psychological processes and overt behaviors. Emerging research is now producing incremental evidence for the construct validity of VRCPAT tests of attention-vigilance (Parsons & Rizzo, 2008c), memory and learning (Parsons & Rizzo, 2008b), spatial cognition (Parsons, Pair, Brennan, Silva, & Rizzo, 2008) and executive functioning (Parsons, Cosand, Courtney, Iyer, & Rizzo, 2009). This approach leverages the assets that are available via the use of VR (Rizzo et al., 2004) to assess the cognitive performance of SMs within an ecologically relevant military context and is hypothesized to produce results that would better predict cognitive performance in a combat environment. Within such functionally relevant VR test simulations, task stimuli and parameters (e.g., type, number, order, and speed) can be consistently manipulated and user responses/behaviors can be closely monitored and automatically recorded. Thus, VRCPAT 1.0 allows the clinician to measure the complex integration of cognitive functions and behaviors in a fashion that may better assess real-world, functional abilities that are required for operation within the challenging and often times chaotic and stressful conditions that exist in the combat theatre. Again, this approach is different from that taken with traditional neuropsychological instruments, in which components of cognitive function are often measured in isolation, requiring clinicians to perform complex data integrations for prediction of real-world performance.

VRCPAT 2.0 (Virtual Reality for Cognitive Performance and Adaptive Treatment) is the next step in this process and takes the neurocognitive and psychophysiological profile information from the VRCPAT 1.0 and uses that data to drive the events or stimulus characteristics that are presented to a user in an adaptive virtual environment (Wu et al., 2010; Parsons, Courtney et al., 2009). The goal is to have an adaptive virtual environment that develops neurocognitive and affective profiles from estimations of SMs cognitive abilities following a blast injury (e.g., from cognitive tasks embedded in a VR-based simulation) and affective state (e.g., from physiological metrics), that may provide information that could be used to enhance rehabilitation procedures by informing the pacing of stimulus presentation based on the state of the user. Such an adaptive virtual environment can adjust the presentation of both the difficulty (e.g., simple versus complex) and intensity (safe versus threatening) of stimuli delivered to the user via real time sensing of their immediate neurocognitive and physiological status.

The Stress Resilience in Virtual Environments (STRIVE) Project

Resilience is the dynamic process by which individuals exhibit positive adaptation when they encounter significant adversity, trauma, tragedy, threats, or significant sources of stress (Luther, Cicchetti, & Becker, 2000). Stress resilience training prior to deployment represents a new direction for the reuse of the core *Virtual Iraq/Afghanistan* simulation assets. The STRIVE project aims to create a set of combat simulations (derived from the *Virtual Iraq/Afghanistan* project) that can be used as contexts for the experiential learning of cognitive-behavioral emotional coping strategies in SMs prior to deployment to better prepare them for the types of emotional challenges that are inherent in the combat environment.

Recently, the DoD has focused significant attention on the concept of "Stress Resilience Training" with a variety of programs being developed for this purpose across the branches of the military (Bartone, 2006; Hovar, 2010; ONR, 2010). Perhaps the program that is attempting to influence the largest number of service-members is the *Comprehensive Soldier Fitness (CSF)* program under the direction of Army Brigadier General Rhonda Cornum (CSF, 2010). 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 CBT/science, which generally advances the view that it is *not* the *event* that causes the *emotion*, and recognizes that how a person *appraises* an event (based on how they *think* about the event) is intertwined with 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 and achieve *Post Adversity Growth* from their experiences in combat (Cornum, 2010).

The use of STRIVE prior to deployment will involve immersing and engaging SMs within a variety of virtual

"missions" where emotionally challenging situations are presented that provide a more meaningful context in which to learn and practice cognitive coping strategies that better psychologically prepare them for the "savage clash of wills" (pp. 15) that is the job of combat (U.S. Army Training Doctrine Command (TRADOC), 2008). 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 storyline that spans a typical deployment cycle. At the end of each of the graded 5–10-min episodes, an emotionally challenging event occurs (e.g., seeing grotesque human remains, death or injury of a fellow squad member, accidentally being responsible for the death or injury of a civilian child). At that point in the virtual experience, the virtual world "freezes in place" and an intelligent virtual human "mentor" (previously selected by the user) emerges from the midst of the chaotic VR scenario to guide the user through rational restructuring exercises for appraising the virtual experience drawing on content already employed in the standard classroom-delivered DoD stress resilience training programs. It should be noted that the exact components that comprise resilience have not been settled upon and frequently different studies use at least some different components to structure their resilience training. We are conducting a complete factor analysis of dimensions of resilience, initially measuring 17 dimensions, to assure a comprehensive understanding of resilience. In this fashion, this digital "emotional obstacle course" can be used as a tool for providing more realistic and context-relevant learning of emotional coping strategies under very tightly controlled and scripted simulated conditions.

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 measures what we refer to as the "physiological fingerprint of stress," commonly called allostatic load (AL). The theoretical construct of allostatic load, 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 (Singer & Ryff, 2001). AL will be measured via the development and integration of complex biomarkers known to indicate physiological dysfunction, and normal function, for numerous physiological systems (i.e., immune, cardiovascular, metabolic). In a first study of its kind, we will analyze if AL can predict acute response to stress (e.g., skin conductance, pupil dilation), when participants are exposed to the stressful VR missions. Further analyses will determine if AL can predict participants' responses to the virtual mentors' 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 are numerous implications for the future use of AL, including identification of leadership profiles and for informing the development of appropriate training systems for all SMs.

Another option for use of the STRIVE system could involve its application as a VR tool for emotional assessment at the time of recruitment prior to admittance to the military. The large question with such an application involves whether it would be possible (and ethical) to assess SMs in a series of challenging combat-relevant emotional environments delivered in the STRIVE system, to predict 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 current military thinking, where doctrine dictates that anyone can be made into an infantryman. However, practical implementation of such an approach would advise that those who display reactions that predict them to be most at risk to have a challenging stress reaction post-combat, could either be assigned non-combat duties, not accepted into the services, or more preferably, be exposed to a type of stress resilience training that will minimize their identified risk to post-trauma dysfunction. This is not a new concept. Since the early days of the Army Alpha/Beta (ASVAB, 2010), assessments have been routinely conducted throughout basic training 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, such as having a criminal record, poor physical fitness, or suffering from a significant chronic health condition. For this effort, the pragmatic challenge would be in the conduct of prospective longitudinal validation studies that would investigate the concept that, by accurately measuring emotional reactivity and coping ability, one could identify patterns of behavioral and physiological reactions that would predict susceptibility to manifesting of stress related disorder following a combat deployment. 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 also determine 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

over their term of duty. Once a large enough sample of SMs were then identified as having significant problems following their combat deployments, it would be possible to go back and analyze their physiological and behavioral data from the earlier simulation experience and look 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 service members 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 start to tailor-make the stress resilience training programs for specific emotional and physiological profiles. The very success of STRIVE would in itself argue that individuals' responses to stress can be altered. More extensive and in-depth stress resilience training programs could then be clearly proposed for those identified as at risk for post-traumatic disorders.

PTSD Assessment Upon Redeployment

It is generally becoming more recognized that the current practice of sending SMs on repeated deployments with little respite in between is an unhealthy situation (some have been on 5–6 since 2002), especially in view of the fact that we are engaged in the longest war in American history. And, short of the unlikely reemergence of a national draft or the sudden end of the Global War on Terrorism, this practice will likely continue. It therefore becomes essential to develop better methods for knowing when a SMs has reached their limit, beyond which point they are at risk for degraded performance in theatre or for developing a chronic psychological disorder. Unfortunately, the methods currently in place to do this may not be effective and thus, a moral imperative exists to invest in finding new ways to solve this problem. It is our position that VR simulation systems can now be marshaled as stimulus tools for addressing the post deployment assessment question as to who is ready to get back into the fight and who needs another alternative (i.e. treatment, more time between deployments, or an honorable discharge).

Scenarios from the *Virtual Iraq/Afghanistan* VRET/STRIVE applications can be retooled as stimulus content that is presented to SMs while physiological/hormonal monitoring occurs. For this assessment purpose, the STRIVE project is creating a library of simulations of events that have been reported by combat Veterans as emotionally challenging, with the goal being the measurement of users reactions that might predict a pre-PTSD emotional response following a deployment. As with the pre-deployment assessment described above, it would be possible to determine if patterns of behavior and physiological responding could be identified that may predict whether a person is at risk for later development of a psychological disorder. The Brief Patient Health Questionnaire (a self report assessment) is typically used for this purpose with returning SMs to help determine who may be at risk. However, there is a general sense among professionals in this area that the total reliance on self-report questionnaires does not often predict who will run into trouble 3 months to 10 years down the road. For this purpose, at least three research groups (Mass General Hospital, the Providence VA and Walter Reed Army Medical Center) are investigating the effectiveness of using the *Virtual Iraq/Afghanistan* digital content in this manner immediately upon redeployment home. Another group is using similar content to assess "startle" reactions as a dependent measure of treatment effectiveness in a current VRET RCT (B. Rothbaum personal communication, July 10, 2007). The challenge for conducting research in this area is the need for longitudinal research that tracks a SM or Veteran's status over many years, but conducted in a way that is not intrusive, maintains confidentiality and is not stigmatizing. If such research could generate better ways to determine who is at risk for stress-related problems at a later point in time, evidence-based clinical care could be made available that might reduce human suffering and that alone would justify the costs for this type of long term longitudinal research.

Conclusions

Interest in Virtual Reality technology to create tools for enhancing clinical practice and research has grown in recent years due to both the advances in the technology required to produce and use VR systems and in the early positive outcomes that have been reported with its implementation. As well, a review of the history of the impact of war on advances in clinical care might suggest that VR is an idea whose time has come. For example, during WW I, the Army Alpha/Beta test emerged from the need for better cognitive ability assessment and set the stage for the civilian intelligence testing movement during the mid-20th Century. Moreover, the birth of clinical psychology as a treatment-oriented profession was borne out of the need to provide care to the many Veterans returning from WW II with "shellshock". It is our position that one of the

outcomes of the OIF/OEF conflicts will be the military's support for research and development in the area of Clinical VR that could potentially drive dual use in the civilian sector if cost-effective outcomes are produced with military applications. This article has presented some of the ways that we have approached Clinical VR system development and implementation that has aimed to maximize value by "repurposing" relevant core VR simulations of Iraq and Afghanistan to build novel applications that are designed to address combat stress assessment, resilience training and PTSD Treatment. Other VR applications that are relevant to military behavioral healthcare exist, but journal space limitations preclude a full detailing of those efforts in this article. For the interested reader, other work that uses artificially intelligent virtual humans in the (1) role of virtual SM patients for training clinicians and (2) as anonymous online healthcare guides designed to break down barriers for seeking care in those who are hesitant to initially access the professional services of a live provider can be found elsewhere (Rizzo, Lange, et al. 2010; Rizzo, Parsons, Buckwalter, & Kenny, 2011).

While the necessity for creating evidence-based treatments is typically a primary focus in clinical care, a significant bottleneck to ultimate behavioral health impact pertains to promoting access and dissemination. Nowhere is this more relevant than in the complex dynamics that exist in behavioral health care with military populations. One can create the best evidence-based treatment program, but if those who most need this help, cast a blind eye to it, then the ultimate value of the approach is diminished. In spite of a Herculean effort on the part of the DoD to produce and disseminate behavioral health programs for military personnel and their families, the complexity of the issues involved continue to challenge the best efforts of military care providers and administrators. One of the more foreboding findings in the Hoge et al. (2004) report, was the observation that among OIF/OEF SMs, "…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). Although military training methodology has better prepared SMs for war in recent years, such hesitancy to seek treatment for difficulties that emerge upon return from combat, especially by those who may need it most, suggests an area of military behavioral healthcare that is in need of attention.

To address this challenge, VR systems are being developed that meet the diverse requirements for measuring, preventing and treating PTSD and other post-combat related psychosocial disorders. For treatment purposes, VR could serve as a component within a reconceptualized approach to how care is accessed by SMs and Veterans. Perhaps a VRET variant could be embedded within the context of "post-combat reset training" whereby the perceived stigma of seeking treatment could be lessened as the SM would be simply involved in this "training" in similar fashion to other designated duties upon redeployment stateside. VRET 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 perceived as traditional "talk therapy". However, such efforts need to be based on empirical investigations that examine SM attitudes and behaviors relevant to accessing care. While the early results are encouraging for the use of VR for clinical care, more research is needed to better specify the added value for using a technology-based approach. As well, novel VR applications that address the challenging issues of assessing the cognitive impact of blast injury, the presence of PTSD (or risk level for developing PTSD) and for providing stress resilience training are all in the early stages of development. However, the moral and economic stakes are high for advancing the level of care available to our SMs and Veterans and this supports the case for further investigation of a VR approach to these healthcare challenges. For example, in addition to the ethical issues that naturally support the need to provide the best care for our military personnel, the long-term economic costs of *NOT* focusing on this problem will be significant. This was underscored in a recent Harvard JFK School of Government analysis of the budgetary costs of providing disability compensation benefits and medical care to the OIF/OEF veterans over the course of their lives (Bilmes, 2007). This analysis projected costs ranging from $350−$700 billion dollars and provides an economic justification for investing in research to advance methodologies for promoting military behavioral health, in addition to the core aim of reducing human suffering in those wounded warriors who have sacrificed so much in their service to our nation.

Finally, one of the guiding principles in our development work concerns how novel Virtual Reality systems can extend the skills of a well-trained clinician. VRET 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 these behavioral health challenges.

Acknowledgements The projects described here have been sponsored by the Office of Naval Research, TATRC, MRMC, DCoE, and U.S. Army Research, Development, and Engineering Command (RDECOM). Statements and opinions expressed do not necessarily reflect the position or the policy of the United States Government, and no official endorsement should be inferred.

References

ASVAB. (2010, December 14, 2010). *History of military testing*. Retrieved from http://officialasvab.com/history_coun.htm.

Bartone, P. T. (2006). Resilience under military operational stress: Can leaders influence hardiness? *Military Psychology, 18*, S131–S148.

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56*, 893–897.

Bilmes, L. (January 20, 2007). *Soldiers returning from Iraq and Afghanistan: The long-term costs of providing veterans medical care and disability benefits*. *Faculty Research Working Paper Series*. John F. Kennedy School of Government, Harvard University. Retrieved from http://ksgnotes1.harvard.edu/Research/wpaper.nsf/rwp/RWP07-001.

Blake, D. D., Weathers, F., Nagy, L. M., Kaloupek, D., Klauminizer, G., Charney, D., et al. (1990). A clinician rating scale for assessing current and lifetime PTSD: The CAPS-1. *Behavior Therapist, 13*, 187–188.

Blanchard, E. B., Jones-Alexander, J., Buckley, T. C., & Forneris, C. A. (1996). Psychometric properties of the PTSD checklist (PCL). *Behaviour Research and Therapy, 34*, 669–673.

Comprehensive Soldier Fitness Program. (December 1, 2010). Main page. Retrieved from http://www.army.mil/csf/index.html.

Cornum, R. (July 10, 2010). *Comprehensive soldier fitness*. Retrieved from http://www.army.mil/csf/resources.html.

Department of Defense. (December 4, 2010a). Retrieved from http://www.defense.gov/news/.

Department of Defense. (December 4, 2010b). Retrieved from http://www.defenselink.mil/news/casualty.pdf.

Difede, J., Cukor, J., Jayasinghe, N., Patt, I., Jedel, S., Spielman, L., et al. (2007). Virtual reality exposure therapy for the treatment of posttraumatic stress disorder following September 11, 2001. *Journal of Clinical Psychiatry, 68*, 1639–1647.

Difede, J., & Hoffman, H. G. (2002). Virtual reality exposure therapy for world trade center post-traumatic stress disorder: A case report. *Cyberpsychology and Behavior, 5*, 529–535.

Fischer, H. (December 4, 2010). *United States military casualty statistics: Operation new dawn, operation Iraqi freedom, and operation enduring freedom*. Congressional Research Service 7-5700:RS22452. Retrieved from http://opencrs.com/document/RS22452/.

Foa, E. B., Davidson, R. T., & Frances, A. (1999). Expert consensus guideline series: Treatment of posttraumatic stress disorder. *American Journal of Clinical Psychiatry, 60*, 5–76.

Foa, E. B., & Kozak, M. J. (1986). Emotional processing of fear: Exposure to corrective information. *Psychological Bulletin, 99*, 20–35.

Gerardi, M., Rothbaum, B. O., Ressler, K., Heekin, M., & Rizzo, A. A. (2008). Virtual reality exposure therapy using a virtual Iraq: Case report. *Journal of Traumatic Stress, 21*, 209–213.

Hays, R. T., Jacobs, J. W., Prince, C., & Salas, E. (1992). Requirements for future research in flight simulation training: Guidance based on a meta-analytic review. *International Journal of Aviation Psychology, 2*, 143–158.

Hoffman, H. G., Chambers, G. T., Meyer, W. J., Araceneaux, L. L., Russell, W. J., Seibel, E. J., et al. (2011). Virtual reality as an adjunctive non-pharmacologic analgesic for acute burn pain during medical procedures. *Annals of Behavioral Medicine, 41*(2), 183–191.

Hoge, C. W., Castro, C. A., Messer, S. C., McGurk, D., Cotting, D. I., & Koffman, R. L. (2004). Combat duty in Iraq and Afghanistan, mental health problems, and barriers to care. *New England Journal of Medicine, 351*, 13–22.

Holden, M. K. (2005). Virtual environments for motor rehabilitation: Review. *CyberPsychology and Behavior, 8*, 187–211.

Hovar, C. (December 10, 2010). *The military operational medicine research program for the US Army*. Retrieved from http://www.donhcs.com/hsr/21_march/doc/presentations/Carl%20Hover%20MRMC%20MOMRP%208%20slides.pdf.

Institute of Medicine Committee on Treatment of Posttraumatic Stress Disorder. (2007). *Treatment of posttraumatic stress disorder: An assessment of the evidence*. ISBN: 0-309-10925-6. Accessed on Aug 24, 2007, from http://www.nap.edu/catalog/11955.html.

Jaycox, L. H., Foa, E. B., & Morral, A. R. (1998). Influence of emotional engagement and habituation on exposure therapy for PTSD. *Journal of Consulting and Clinical Psychology, 66*, 186–192.

Kroenke, K., & Spitzer, R. L. (2002). The PHQ-9: A new depression and diagnostic severity measure. *Psychiatric Annals, 32*, 509–521.

Luthar, S. S., Cicchetti, D., & Becker, B. (2000). The construct of resilience: A critical evaluation and guidelines for future work. *Child Development, 71*, 543–562.

McEwen, B. S., & Stellar, E. (1993). Stress and the individual: Mechanism leading to disease. *Archives of Internal Medicine, 153*, 2093–2101.

Merians, A. S., Fluet, G. G., Qiu, Q., Saleh, S., Lafond, I., & Adamovich, S. V. (2010). Integrated arm and hand training using adaptive robotics and virtual reality simulations. In *Proceedings of the 2010 International Conference on Disability, Virtual Reality and Associated Technology* (pp. 213–222) Maia, Portugal.

ONR. (December 14, 2010). *The Office of Naval Research human performance training and education thrust*. Retrieved from http://www.onr.navy.mil/Science-Technology/Departments/Code-30/All-Programs/Human-Performance-Training.aspx.

Ortony, A., Clore, G. L., & Collins, A. (1988). *The cognitive structure of emotions*. Cambridge: Cambridge University Press.

Parsons, T. D., Cosand, L., Courtney, C., Iyer, A., & Rizzo, A. A. (2009). Neurocognitive workload assessment using the virtual reality cognitive performance assessment test. *Lecture Notes in Artificial Intelligence, 5639*, 243–252.

Parsons, T. D., & Courtney, C. (2010). Neurocognitive and psychophysiological interfaces for adaptive virtual environments. In C. T. Röcker & M. Ziefle (Eds.), *Human centered design of e-health technologies*. Hershey: IGI Global.

Parsons, T. D., Courtney, C., Cosand, L., Iyer, A., Rizzo, A. A., & Oie, K. (2009). Assessment of psychophysiological differences of west point cadets and civilian controls immersed within a virtual environment. *Lecture Notes in Artificial Intelligence, 5638*, 514–523.

Parsons, T. D., Iyer, A., Cosand, L., Courtney, C., & Rizzo, A. A. (2009). Neurocognitive and psychophysiological analysis of human performance within virtual reality environments. *Studies in Health Technology and Informatics, 142*, 247–252.

Parsons, T. D., Pair, J., Brennan, J., Silva, T., & Rizzo, A. A. (2008). Sex differences in spatial cognition within a virtual environment: Virtual reality cognitive performance assessment test (VRCPAT). *Journal of the International Neuropsychological Society, 14*, 2.

Parsons, T. D., & Rizzo, A. A. (2008a). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry, 39*, 250–261.

Parsons, T. D., & Rizzo, A. A. (2008b). Initial validation of a virtual environment for assessment of memory functioning: Virtual reality cognitive performance assessment test. *Cyberpsychology and Behavior, 11*, 17–25.

Parsons, T. D., & Rizzo, A. A. (2008c). Neuropsychological assessment of attentional processing using virtual reality. *Annual Review of CyberTherapy and Telemedicine, 6*, 23–28.

Parsons, T. D., Rizzo, A. A., Rogers, S. A., & York, P. (2009). Virtual reality in pediatric rehabilitation: A review. *Developmental Neurorehabilitation, 12*, 224–238.

Powers, M., & Emmelkamp, P. M. G. (2008). Virtual reality exposure therapy for anxiety disorders: A meta-analysis. *Journal of Anxiety Disorders, 22*, 561–569.

Reger, G., & Gahm, G. (2008). Virtual reality exposure therapy for active duty soldiers. *Journal of Clinical Psychology, 64*, 940–946.

Reger, G. M., Gahm, G. A., Rizzo, A. A., Swanson, R. A., & Duma, S. (2009). Soldier evaluation of the virtual reality Iraq. *Telemedicine and e-Health Journal, 15*, 100–103.

Reger, G. M., Holloway, K. M., Candy, C., Rothbaum, B. O., Difede, J., Rizzo, A. A. & Gahm, G. A. (2011). Effectiveness of virtual reality exposure therapy for active duty soldiers in a military mental health clinic. *Journal of Traumatic Stress, 24*(1), 93–96.

Reger, G. M., Parsons, T. D., Gahm, G. A., & Rizzo, A. A. (2010). Virtual reality assessment of cognitive functions: A promising tool to improve ecological validity. *Brain Injury, 7*, 24–26.

Ressler, K. J., Rothbaum, B. O., Tannenbaum, L., Anderson, P., Zimand, E., Hodges, L., et al. (2004). Facilitation of psychotherapy with D-cycloserine, a putative cognitive enhancer. *Archives of General Psychiatry, 61*, 1136–1144.

Riva, G. (2005). Virtual reality in psychotherapy: Review. *CyberPsychology and Behavior, 8*, 220–230.

Rizzo, A. (2010). Virtual Iraq/Afghanistan and how it is helping some troops and vets with PTSD. *Veterans Today*. http://www.veteranstoday.com/2010/07/29/virtual-iraqafghanistan-and-how-it-is-helping-some-troops-and-vets-with-ptsd/.

Rizzo, A. A., Buckwalter, J. G., & Neumann, U. (1997). Virtual reality and cognitive rehabilitation: A brief review of the future. *Journal of Head Trauma Rehabilitation, 12*, 1–15.

Rizzo, A., Difede, J., Rothbaum, B. O., & Reger, G. (2010). Virtual Iraq/Afghanistan: Development and early evaluation of a virtual reality exposure therapy system for combat-related PTSD. *Annals of the New York Academy of Sciences (NYAS), 1208*, 114–125.

Rizzo, A. A., Klimchuk, D., Mitura, R., Bowerly, T., Buckwalter, J. G., & Parsons, T. (2006). A virtual reality scenario for all seasons: The virtual classroom. *CNS Spectrums, 11*, 35–44.

Rizzo, A., Lange, B., Buckwalter, J. G., Forbell, E., Kim, J., Williams, J., et al. (2010). SimCoach: An intelligent virtual human system for providing healthcare information and support. In *Proceedings of the 2010 International Conference on Disability, Virtual Reality and Associated Technology* (pp. 213–222).

Rizzo, A. A., Parsons, T., Buckwalter, J. G., & Kenny, P. (2011). The birth of intelligent virtual patients in clinical training. *American Behavioral Scientist*.

Rizzo, A. A., Reger, G., Gahm G., Difede, J., & Rothbaum, B. O. (2009). Virtual reality exposure therapy for combat related PTSD. In P. Shiromani, T. Keane, & J. LeDoux (Eds.), *Posttraumatic stress disorder: Basic science and clinical practice* (pp. 375–399). New York: Humana Press.

Rizzo, A. A., Schultheis, M. T., Kerns, K., & Mateer, C. (2004). Analysis of assets for virtual reality applications in Neuropsychology. *Neuropsychological Rehabilitation, 14*, 207–239.

Rose, F. D., Brooks, B. M., & Rizzo, A. A. (2005). Virtual reality in brain damage rehabilitation: Review. *CyberPsych and Behavior, 8*, 241–262.

Rothbaum, B. O., & Hodges, L. F. (1999). The use of virtual reality exposure in the treatment of anxiety disorders. *Behavior Modification, 23*, 507–525.

Rothbaum, B. O., Hodges, L., Ready, D., Graap, K., & Alarcon, R. (2001). Virtual reality exposure therapy for Vietnam veterans with posttraumatic stress disorder. *Journal of Clinical Psychiatry, 62*, 617–622.

Rothbaum, B. O., Meadows, E. A., Resick, P., & Foy, D. W. (2000). Cognitive-behavioral therapy. In E. B. Foa, M. Keane, & M. J. Friedman (Eds.), *Effective treatments for PTSD* (pp. 60–83). New York: Guilford.

Rothbaum, B. O., Rizzo, A., & Difede, J. (2010). Virtual reality exposure therapy for combat-related posttraumatic stress disorder. *Annals of the New York Academy of Sciences (NYAS), 1208*, 126–132.

Rothbaum, B. O., & Schwartz, A. (2002). Exposure therapy for posttraumatic stress disorder. *American Journal of Psychotherapy, 56*, 59–75.

Roy, M. J., Francis, J., Friedlander, J., Banks-Williams, L., Lande, R. G., Taylor, P., et al. (2010). Improvement in cerebral function with treatment of posttraumatic stress disorder. *Annals of the New York Academy of Sciences (NYAS), 1208*, 142–149.

Schneider, S. M., Kisby, C. K. & Flint, E. P. (December 10, 2010). Effect of virtual reality on time perception in patients receiving chemotherapy. *Supportive Care in Cancer*, Retrieved from http://www.springerlink.com/content/?k=(au%3a(Susan+Schneider)+OR+ed%3a(Susan+Schneider))+pub%3a(Supportive+Cancer+Care).

Seal, K. H., Bertenthal, D., Nuber, C. R., Sen, S., & Marmar, C. (2007). Bringing the war back home: Mental health disorders among 103, 788 US veterans returning from Iraq and Afghanistan seen at Department of Veterans Affairs facilities. *Archives of Internal Medicine, 167*, 476–482.

Singer, B., & Ryff, C. D. (2001). Understanding aging via person-centered methods and the integration of numbers and narratives. In R. H. Binstock & L. K. George (Eds.), *Handbook of aging, the social sciences* (5th ed.). San Diego: Academic Press.

Stanton, D., Foreman, N., & Wilson, P. (1998). Uses of virtual reality in clinical training: Developing the spatial skills of children with mobility impairments. In G. Riva, B. Wiederhold, & E. Molinari (Eds.), *Virtual reality in clinical psychology and neuroscience* (pp. 219–232). Amsterdam: IOS Press.

Tanielian, T., Jaycox, L. H., Schell, T. L., Marshall, G. N., Burnam, M. A., Eibner, C., et al. (2008). Invisible wounds of war: Summary and recommendations for addressing psychological and cognitive iInjuries. *Rand Report*. Retrieved from http://veterans.rand.org/.

U.S. Army Training and Doctrine Command. (December 2, 2010). *The U.S army study of the human dimension in the future 2015–2024 (Pam 525-3-7-01)*. Retrieved from www.tradoc.army.mil/tpubs/pams/p525-66.pdf.

Walker, D. L., Ressler, K. J., Lu, K. T., & Davis, M. (2002). Facilitation of conditioned fear extinction by systemic administration or intra-amygdala infusions of D-cycloserine as assessed with fear-potentiated startle in rats. *Journal of Neuroscience, 22*, 2343–2351.

Wilson, J., Onorati, K., Mishkind, M., Reger, M., & Gahm, G. A. (2008). Soldier attitudes about technology-based approaches to mental healthcare. *Cyberpsychology and Behavior, 11*, 767–769.

Wu, D., Courtney, C., Lance, B., Narayanan, S. S., Dawson, M., Oie, K., et al. (2010). Optimal arousal identification and classification for affective computing: Virtual Reality Stroop Task. *IEEE Transactions on Affective Computing, 99*, 1–10.

Zimand, E., Anderson, P., Gershon, G., Graap, K., Hodges, L., & Rothbaum, B. (2003). Virtual reality therapy: Innovative treatment for anxiety disorders. *Primary Psychiatry, 9*, 51–54.