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Development and early evaluation of the *Virtual Iraq/Afghanistan* exposure therapy system for combat-related PTSD

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Numerous reports indicate that the growing incidence of posttraumatic stress disorder (PTSD) in returning Operation Enduring Freedom (OEF)/Operation Iraqi Freedom (OIF) military personnel is creating a significant health care and economic 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. The current paper will detail the development and early results from use of the *Virtual Iraq/Afghanistan* exposure therapy system. The system consists of a series of customizable virtual scenarios designed to represent relevant Middle Eastern contexts for exposure therapy, including a city and desert road convoy environment. The process for gathering user-centered design feedback from returning OEF/OIF military personnel and from a system deployed in Iraq (as was needed to iteratively evolve the system) will be discussed, along with a brief summary of results from an open clinical trial using *Virtual Iraq* with 20 treatment completers, which indicated that 16 no longer met PTSD checklist-military criteria for PTSD after treatment.

Keywords: virtual reality; exposure therapy; PTSD; behavior therapy; veterans; service members; military; invisible wounds of war

Introduction

War is one of the most challenging environments that a human can experience. The cognitive, emotional, and physical demands of a combat environment place enormous stress on even the best-prepared military personnel: the human costs are high. Since the start of the Operation Enduring Freedom (OEF)/ Operation Iraqi Freedom (OIF) conflicts in Afghanistan and Iraq, 1.6 million troops have been deployed. As of March 2009, there have been 4,923 deaths and 33,856 service members (SMs) wounded in action (WIA).[1] Of the WIA, the total includes 935 major limb amputations and 351 minor amputations and as of 2008, traumatic brain injury (TBI) has been diagnosed in 43,779 patients (many of which are not included in the WIA statistics as mild TBI is often reported retrospectively, upon redeployment home). Moreover, the stressful experiences that are characteristic of the OIF/OEF warfighting environments have been seen to produce 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 (15.6–17.1%) than after duty in Afghanistan (11.2%) or before deployment to Iraq (9.3%)" (p. 13).[2] Reports since that time on OIF/OEF PTSD and psychosocial disorder rates suggest even higher

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incidence statistics.[1,3,4] For example, as of 2008, the Military Health System has recorded 39,365 active duty patients who have been diagnosed with PTSD[1] and the Rand Analysis on PTSD[4] estimated that more than 300,000 active duty and discharged veterans will suffer from the symptoms of PTSD and major depression. These figures are troubling and make a strong case for continued efforts at developing and enhancing the availability of evidence-based treatments to address a mental health care challenge that will have significant impact for many years to come.

At the same time, a revolution has occurred in the development of virtual reality (VR) systems for enhancing therapeutic practice. Technological advances in the areas of computation speed and power, graphics and image rendering, display systems, tracking, interface technology, authoring software, and artificial intelligence have supported the creation of low-cost and usable PC-based VR systems. As well, a determined and expanding cadre of researchers and clinicians have not only recognized the potential impact of VR technology but have also now generated a significant research literature that documents the many clinical targets where VR can add value over traditional assessment and intervention approaches.[5–9] 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 those with clinical disorders.

This paper will detail the development process and briefly summarize an early open clinical test of a VR exposure therapy (VRET) application designed for the treatment of PTSD related to OIF/OEF combat exposure in active duty and veteran populations. Although randomized controlled trials are currently under way to compare VRET with traditional imaginal exposure approaches to determine its relative efficacy, encouraging results thus far suggest that VRET may be a viable treatment alternative. Moreover, the use of VR for clinical care may have some appeal to a generation of SMs and veterans who have grown up "digital" and are comfortable with treatment delivered within this computer and information technology format.

Clinical VR applications for psychological health

The unique match between VR technology assets and the needs of various clinical treatment approaches has been recognized by a number of authors and an encouraging body of research has emerged, particularly in the area of exposure therapy for anxiety disorders.[6,7,10–17] Whereas in the mid-1990s, VR was generally seen as "a hammer looking for a nail," it soon became apparent to some scientists in both the engineering and clinical communities that VR could bring something to clinical care that was not possible before its advent. The capacity of VR technology to create controllable, multisensory, interactive three-dimensional (3D) stimulus environments, within which human behavior could be motivated and measured, offered 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 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 could be used to create relevant simulated environments where assessment and treatment of cognitive, emotional, and motor problems could take place.

A short list of areas where "Clinical VR" has been usefully applied includes fear reduction in persons with simple phobias,[6,7] treatment for PTSD,[14,17–19] stress management in cancer patients,[20] acute pain reduction during wound care and physical therapy with burn patients,[21] body image disturbances in patients with eating disorders,[9] navigation and spatial training in children and adults with motor impairments,[11,22] functional skill training and motor rehabilitation with patients having central nervous system dysfunction (e.g., stroke, TBI, spinal cord injury cerebral palsy, multiple sclerosis, etc.),[5,23] and in the assessment and rehabilitation of attention, memory, spatial skills, and executive cognitive functions in both clinical and unimpaired populations.[8,24] 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 use VR as an "ultimate skinner box" that allows them to bring simulated elements from the outside world into the treatment setting and immerse patients in simulations that support the aims and mechanics of a specific therapeutic approach.

Concurrent with the emerging acknowledgment of the unique value of Clinical VR by scientists and clinicians, has come a growing awareness of its potential relevance and impact by the general public. Although much of this recognition may be due to the high visibility of digital 3D games, the Nintendo Wii, and massive shared internet-based virtual worlds (World of Warcraft, Halo, and 2nd Life), the public consciousness is also routinely exposed to popular media reports on clinical and research VR applications. Whether this should be viewed as "hype" or "help" to a field that has had a storied history of alternating periods of public enchantment and disregard still remains to be seen. Regardless, growing public awareness coupled with the solid scientific results has brought the field of Clinical VR past the point where skeptics can be taken seriously when they characterize VR as a "fad technology." A description of the technology required for VRET and a review of the literature on its use with anxiety disorders is presented elsewhere in this issue.[25]

Development of the *Virtual Iraq/Afghanistan* exposure therapy system

In 2004, the University of Southern California's Institute for Creative Technologies (ICT), in collaboration with the authors of this paper, partnered on a project funded by the Office of Naval Research (ONR) to develop a series of VRET environments known as *Virtual Iraq*. The initial prototype system was constructed by recycling virtual art assets that were originally designed for the commercially successful X-Box game and U.S. Army-funded combat tactical simulation trainer, *Full Spectrum Warrior*. The first prototype was then continually evolved with specifically created art and technology assets available to ICT in a process that was highly informed by feedback from both clinicians and SMs with combat experience in Iraq and Afghanistan.

Figure 1. **Scenes from *Virtual Iraq* City and Desert Road high-mobility multipurpose wheeled vehicle (HUMVEE) interior. (In color in *Annals* online.)**

Virtual Iraq *content and clinician interface*

Virtual Iraq consists of Middle Eastern themed city and desert road environments (see Fig. 1) and was designed to resemble the general contexts that most SMs experience during deployment to Iraq. The 24 square block "City" setting has a variety of elements including a marketplace, desolate streets, checkpoints, ramshackle buildings, warehouses, mosques, shops, and dirt lots strewn with junk. Access to building interiors and rooftops is available and the backdrop surrounding the navigable exposure zone creates the illusion of being embedded within a section of a sprawling densely populated desert city. Vehicles are active in streets and animated virtual pedestrians (civilian and military) can be added or eliminated from the scenes. The software has been designed such that users can be "teleported" to specific locations within the city, on the basis of a determination as to which components of the

Figure 2. Desert road checkpoint. (In color in *Annals* online.)

environment most closely match the patient's needs, relevant to their individual trauma-related experiences.

The "Desert Road" scenario consists of a roadway through an expansive desert area with sand dunes, occasional areas of vegetation, intact and broken down structures, bridges, battle wreckage, a checkpoint, debris, and virtual human figures (see Fig. 2). The user is positioned inside of a high-mobility multipurpose wheeled vehicle (HUMVEE) that supports the perception of travel within a convoy or as a lone vehicle with selectable positions as a driver, passenger, or from the more exposed turret position above the roof of the vehicle. The number of soldiers in the cab of the HUMVEE can also be varied as well as their capacity to become wounded during certain attack scenarios (e.g., improvised explosive devices (IEDs), rooftop/bridge attacks).

Both the city and desert road HUMVEE scenarios are adjustable for time of day or night, weather conditions, illumination, night vision (see Fig. 3), and ambient sound (wind, motors, city noise, prayer call, etc.). Users can navigate in both scenarios via the use of a standard gamepad controller, although we have recently added the option for a replica M4 weapon with a "thumb-mouse" controller that supports movement during the city foot patrol. This was based on repeated requests from Iraq-experienced SMs who provided frank feedback indicating that to walk within such a setting without a weapon in hand was completely unnatural and distracting! However, there is no option for firing a weapon within the VR scenarios. It is our firm belief that the principles of exposure therapy are incompatible with the cathartic acting out of a revenge fantasy that a responsive weapon might encourage.

In addition to the visual stimuli presented in the VR head-mounted display (HMD), directional 3D audio, vibrotactile, and olfactory stimuli can be delivered into the *Virtual Iraq* scenarios in real time by the clinician. The presentation of additive, combat-relevant stimuli into the VR scenarios can be controlled in real time via a separate "Wizard of Oz" clinician's interface (see Fig. 4), while the clinician is in full audio contact with the patient. The clinician's interface is a key feature that provides a clinician with the capacity to customize the therapy experience to the individual needs of the patient. This interface allows a clinician to place the patient in VR scenario locations that resemble the setting in which the trauma-relevant events occurred and ambient light and sound conditions can be modified to match the patients description of their experience. The clinician can then gradually introduce and control real-time trigger stimuli (visual, auditory,

Figure 3. Night vision setting. (In color in *Annals* online.)

Figure 4. Clinician's interface (wireless version). (In color in *Annals* online.)

olfactory, and tactile), *via* the clinician's interface, as required to foster the anxiety modulation needed for therapeutic habituation and emotional processing in a customized fashion according to the patient's past experience and treatment progress. The clinician's interface options have been designed with the aid of feedback from clinicians with the goal to provide a usable and flexible control panel system for conducting thoughtfully administered exposure therapy that can be readily customized to address the individual needs of the patient. Such options for real-time stimulus delivery flexibility and user experience customization are key elements for these types of VRET applications.

The specification, creation, and addition of trigger stimulus options into the *Virtual Iraq* system has been an evolving process throughout the development of the application on the basis of continually solicited patient and clinician feedback. We began this part of the design process by including options that have been reported to be relevant by returning soldiers and military subject matter experts. For example, the Hoge *et al.* [2] study of Iraq/Afghanistan SMs presented a listing of combat-related events that were commonly experienced in their sample. These events provided a useful starting point for conceptualizing how relevant trigger stimuli could be presented in a VR environment. Such commonly reported events included: "*Being attacked or ambushed. . .receiving incoming artillery, rocket, or mortar fire. . . being shot at or receiving small-arms fire. . .seeing dead bodies or human remains. . .*" (p. 18). From this and other sources, we began our initial effort to conceptualize what was both functionally relevant and technically possible to include as trigger stimuli.

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

Virtual Iraq *hardware and software*

Whenever possible, *Virtual Iraq* was designed to use off-the-shelf equipment in order to minimizes costs and maximize the access and availability of the finished system. The minimum computing requirements for the current application are two Pentium 4 computers each with 1 GB RAM, and a 128 MB DirectX 9-compatible *NVIDIA* 3D graphics card. The two computers are linked using a null Ethernet cable (or wireless network option) with one running the clinician's interface, whereas the second one drives the simulation via the user's HMD and navigation interface (gamepad or gun controller). The HMD that was chosen was the *eMagin z800*, with displays capable of 800 × 600 resolution within a 40° diagonal field of view (http://www.emagin.com/). The major selling point for using this HMD was the presence of a built-in head tracking system. At under U.S. $1,500 per unit with built-in head tracking, this integrated display/tracking solution was viewed as the best option to minimize costs and maximize the access to this system. The simulation's real-time 3D scenes are presented using the FlatWorld Simulation Control Architecture with Emergent's *Gamebryo* used as a rendering engine. Preexisting art assets were integrated using *Alias' Maya 6* and *AutoDesk 3D Studio Max 7* with new art created primarily in *Maya*.

Olfactory and tactile stimuli can be delivered into the simulation to further augment the experience of the environment. Olfactory stimuli are produced by the *EnviroScent, Inc. Scent Palette*. This is a USB-driven device that contains eight pressurized chambers, within which individual smell cartridges can be inserted, a series of fans and a small air compressor to propel the customized scents to participants. The scent delivery is controlled by mouse clicks on the clinician's interface. Scents may be employed as direct stimuli (e.g., scent of smoke as a user walks by a burning vehicle) or as cues to help immerse users in the world (e.g., ethnic food cooking). The

scents selected for this application include burning rubber, cordite, garbage, body odor, smoke, diesel fuel, Iraqi food spices, and gunpowder. Vibration is also used as an additional user sensory input. Vibration is generated through the use of a *Logitech* force-feedback game control pad and through low-cost (<U.S. $120) audio-tactile sound transducers from *Aura Sound Inc*. located beneath the patient's floor platform and seat. Audio files are customized to provide vibration consistent with relevant visual and audio stimuli in the scenario. For example, in the HUMVEE desert road scenario, the user experiences engine vibrations as the vehicle moves across the virtual terrain and a shaking floor can accompany explosions. This package of controllable multisensory stimulus options was included in the design of *Virtual Iraq* to allow a clinician the flexibility to engage users across a wide range of unique and highly customizable levels of exposure intensity. As well, these same features have broadened the applicability of *Virtual Iraq* as a research tool for studies that require systematic control of stimulus presentation within combat relevant environments.[26]

Preliminary user-centered design phase

The *Virtual Iraq* scenario is currently being implemented as an exposure therapy tool with active duty SMs and veterans at Madigan Army Medical Center (MAMC) at Ft. Lewis, WA, the Naval Medical Center-San Diego (NMCSD), Camp Pendleton, Emory University, Walter Reed Army Medical Center, the Weill Medical College of Cornell University, and at approximately 35 other VA, Military, and University Laboratory sites for VRET research and a variety of other PTSD-related investigations. However, the user-centered design process for optimizing *Virtual Iraq* for clinical use is noteworthy and will be described before briefly summarizing the VRET treatment protocol and results from the initial open clinical trial.

User-centered feedback from non-PTSD SMs

User-centered tests with early prototypes of the *Virtual Iraq* application were conducted at the NMCSD and within an Army Combat Stress Control Team in Iraq (see Fig. 5). This formative feedback from nondiagnosed Iraq-experienced military personnel provided essential information that fed an iterative design process on the content, realism, and usability of the initial "intuitively designed" system.

Figure 5. **User-centered feedback from Iraq stress control team. (In color in *Annals* online.)**

More formal evaluation of the system took place at MAMC from late 2006 to early 2007.[27] Ninety-three screened SMs (all non-PTSD) evaluated the *Virtual Iraq* scenarios shortly after returning from deployment in Iraq. SMs experienced the city and HUMVEE environments while exposed to scripted researcher-initiated VR trigger stimuli to simulate an actual treatment session. SMs then completed standardized questionnaires to evaluate the realism, sense of "presence" (the feeling of being in Iraq), sensory stimuli, and overall technical capabilities of *Virtual Iraq*. Items were rated on a scale from 0 (poor) to 10 (excellent). Qualitative feedback was also collected to determine additional required software improvements. The results suggested that the *Virtual Iraq* environment in its form at the time was realistic and provided a good sense of "being back in Iraq."

Average ratings across environments were between adequate and excellent for all evaluated

aspects of the virtual environments. Auditory stimuli realism (M = 7.9, SD = 1.7) and quality (M = 7.9, SD = 1.8) were rated higher than visual realism (M = 6.7, SD = 2.1) and quality (M = 7.0, SD = 2.0). Soldiers had high ratings of the computer's ability to update visual graphics during movement (M = 8.4, SD = 1.7). The *eMagin* HMD was reportedly very comfortable (M = 8.2, SD = 1.7), and the average ratings for the ability to move within the virtual environment was generally adequate or above (M = 6.1, SD = 2.5). These data, along with the collected qualitative feedback, were used to inform upgrades to the current version of *Virtual Iraq* that is now in clinical use and this "design-collect feedback-redesign" cycle will continue throughout the lifecycle of this project.

SM acceptance of VR in treatment

The user-centered results indicated that *Virtual Iraq* was capable of producing the level of engagement in Iraq-experienced SMs that was believed to be required for exposure therapy. However, successful clinical implementation also requires patients to accept the approach as a useful and credible behavioral health treatment. To address this issue, a survey study with 325 Army SMs from the MAMC/Fort Lewis deployment screening clinic was conducted to assess knowledge of current technologies and attitudes toward the use of technology in behavioral health care.[28] One section of the survey asked these active duty SMs to rate on a five-point scale how willing they would be to receive mental health treatment ("Not Willing at All" to "Very Willing") via traditional approaches (e.g., face-to-face counseling) and a variety of technology-oriented delivery methods (e.g., website, video teleconferencing, and use of VR). Eighty-three percent of participants reported that they were neutral-to-very willing to use some form of technology as part of their behavioral health care, with 58% reporting some willingness to use a VR treatment program. Seventy-one percent of SMs were equally or more willing to use some form of technological treatment than solely talking to a therapist in a traditional setting. Most interesting is that 20% of SMs who stated they were not willing to seek traditional psychotherapy rated their willingness to use a VR-based treatment as neutral to very willing. One possible interpretation of this finding is that a subgroup of this sample of SMs with a significant disinterest in traditional mental health treatment would be willing to pursue treatment with a VR-based approach. It is also possible that these findings generalize to SMs who have disengaged from or terminated traditional treatment.

VRET open clinical trial protocol and results

Participants

The ONR funding for the *Virtual Iraq* system development also supported an initial open clinical trial to evaluate the efficacy of VRET for use with active duty participants at NMCSD and Camp Pendleton. The participants were 20 active duty SMs (19 male, one female, mean age = 28 years, age range 21–51 years) who recently redeployed from Iraq and who had engaged in previous PTSD treatments (e.g., group counseling, medications, etc.) without benefit. However, in this initial open clinical trial, elements of the protocol were occasionally modified (i.e., adjusting the number and timing of sessions) to meet patients' needs and thus these data represent outcomes from an uncontrolled feasibility trial.

Clinical protocol

The standard VRET exposure therapy protocol consisted of 2× weekly, 90–120 min sessions over 5 weeks that also included physiological monitoring (heart rate (HR), galvanic skin response (GSR), and respiration) as part of the data collection. The VRET protocol followed the principles of graded prolonged behavioral exposure[29] and the pace was individualized and patient driven. The first VRET session consisted of a clinical interview that identified the index (or most significant) trauma experience, provided psychoeducation on trauma and PTSD, and 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; a 1–100 self-rating of current distress), the rationale for prolonged exposure, including imaginal exposure and *in vivo* (i.e., real-world) exposure. The participants also engaged in their first experience of imaginal exposure of a significant trauma event and an *in vivo* hierarchical exposure list was constructed, with the first item assigned as homework. Session three introduced the rationale for VRET and the participant experienced the *Virtual Iraq* environment without recounting any trauma narrative for approximately 25 min with no provocative trigger stimuli introduced.

The purpose of not recounting any trauma events was to allow the participant to learn how to navigate in *Virtual Iraq* in an exploratory manner and to function as a "bridge session" from imaginal alone to imaginal exposure combined with virtual reality (VRET). Sessions 4–10 are when the VRET proper was conducted with the participant engaging in the VR while recounting the trauma narrative.

During the VRET sessions, participants were asked to recount their trauma experiences in the first person, as if it were happening again with as much attention to sensory detail as they could provide. Using clinical judgment, the therapist might prompt the patient with questions about their experience or provide encouraging remarks as deemed necessary to facilitate the recounting of the trauma narrative. The treatment included homework, such as requesting the participant to listen to the audiotape of their exposure narrative from the most recent session. Listening to the audiotape several times over a week functioned as a source of continual exposure to promote processing of the trauma events with the aim to further enhance the process of therapeutic habituation outside of the therapy office. *In vivo* hierarchy exposure items were assigned in a sequential fashion, starting with the lowest rated item. A new item was assigned once the participant demonstrated approximately a 50% reduction of SUDs ratings on the previous item. Self-report measures were obtained at baseline, prior to sessions 3, 5, 7, 9, 10, and at 1 week and 3 months after treatment to assess in-treatment and follow-up symptom status. The measures used were the PTSD Checklist-Military Version (PCL-M),[30] Beck Anxiety Inventory (BAI),[31] and Patient Health Questionnaire (PHQ-9) (Depression).[32]

Results

A paper that fully details the results from this project is currently under review.[33] Analyses from the first 20 *Virtual Iraq* treatment completers have suggested positive clinical outcomes. The average number of VRET sessions for this sample was just under 11. For this sample, mean pre-/post-PCL-M scores decreased in a statistical and clinically meaningful fashion; mean (SD) values went from 54.4 (9.7) to 35.6 (17.4). Paired pre-/post-t-test analysis showed these differences to be significant ($t = 5.99$, df $= 19$, $P < 0.001$). Correcting for the PCL-M no-symptom baseline of 17 indicated a greater than 50% decrease

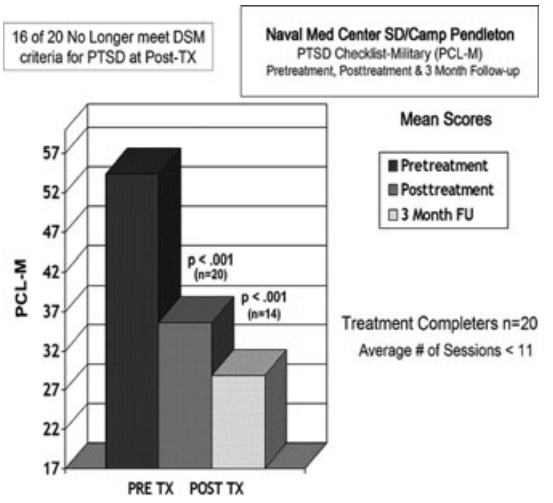

Figure 6. Mean posttraumatic stress disorder (PTSD) checklist scores across treatment.

in symptoms and 16 of the 20 completers no longer met Diagnostic and Statistical Manual of Mental Disorders criteria for PTSD at posttreatment. Five participants in this group with PTSD diagnoses had pretreatment baseline scores below the conservative PCL-M cutoff value of 50 (prescores = 49, 46, 42, 36, and 38) and reported decreased values at posttreatment (postscores = 23, 19, 22, 22, and 24, respectively). Mean and individual participant PCL-M scores at baseline, after treatment, and 3-month follow-up are graphed in Figures 6 and 7. For this same group, mean BAI scores significantly decreased

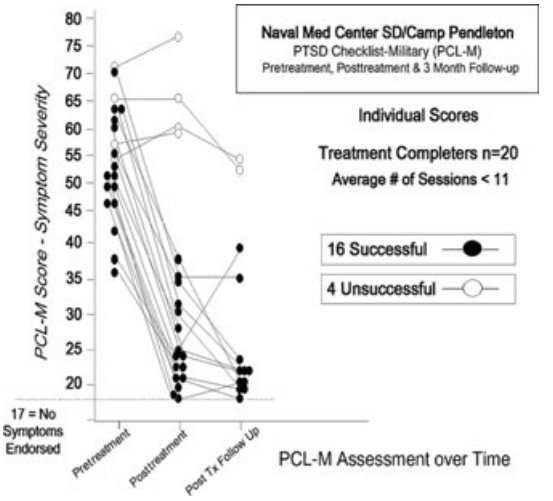

Figure 7. Individual posttraumatic stress disorder (PTSD) Checklist scores across treatment.

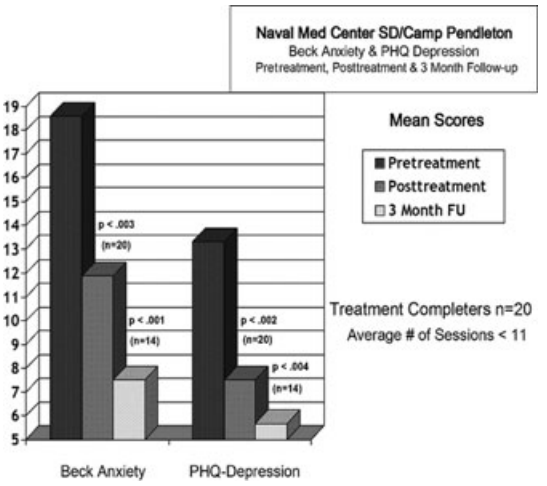

Figure 8. **Beck Anxiety Scale and Patient Health Questionnaire-Depression scores across treatment.**

33% from 18.6 (10.7) to 11.9 (13.3), ($t = 3.67$, df = 19, $P < 0.003$) and mean PHQ-9 (Depression) scores decreased 49% from 13.3 (5.4) to 7.1 (6.7) ($t = 3.68$, df = 19, $P < 0.002$) (see Fig. 8). Also, two of the successful treatment completers had documented mild and moderate TBIs, which suggest that this form of exposure can be usefully applied with this population.

Conclusions and future research

Results from uncontrolled trials and case reports are difficult to generalize from, and we are cautious not to make excessive claims on the basis of these early results. However, in the summary of results from an open clinical trial using accepted diagnostic measures, 80% of the treatment completers in this 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 situations. These improvements were also maintained at 3-month posttreatment follow-up. Similar findings are about to be reported by Reger *et al.*[34] with another active duty sample of U.S. Army participant. On the basis of these initial open clinical trial results and single case reports by Reger & Gahm[35] and Gerardi *et al.*,[36] we are encouraged by these early successes and continue to gather feedback from patients regarding the therapy and the *Virtual Iraq* environment. The system is currently being updated with added functionality that has its design "roots" from feedback acquired from these initial patients and the clinicians who have used the system thus far. These findings will be used to develop, explore, and test hypotheses as to how we can improve treatment and also determine what patient characteristics may predict who will complete and benefit from VRET and who may be best served by other approaches. As well, three randomized controlled trials are currently in progress that will compare the efficacy of VR exposure with the traditional imaginal approach, and in one study, provide a test of the additive value of conducting both forms of exposure therapy with the adjunctive use of a cognitive enhancer medication (D-cycloserine).

It should be noted that in spite of these initial positive results for treatment completers, challenges exist with treatment attrition in active duty populations. Seven participants who were assessed and approved for the result described above failed to appear at the first session, six attended the first session and dropped out prior to formal commencement of VRET, and seven dropped out at various points following the start of VRET proper in session 4. Although some of these active duty participants left owing to transfers and other reasons beyond their control, these dropout numbers are concerning and we are in the process of examining all data gathered from this subset of the total sample to search for discriminating factors.

Such treatment attrition rates need to be viewed in the context of research that suggests there is an urgent need to reduce the stigma of seeking mental health treatment in military populations. For example, one of the more foreboding findings in the Hoge *et al.*[2] report was the observation that among Iraq/Afghanistan War veterans, "*. . . those whose responses were positive for a mental disorder, only 23 to 40 percent sought mental health care. Those whose responses were positive for a mental disorder were twice as likely as those whose responses were negative to report concern about possible stigmatization and other barriers to seeking mental health care*" (p. 13). Although military training methodology has better-prepared soldiers for combat 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 mental health care that is in need of attention. To address this concern, a VR system for

PTSD treatment could serve as a component within a reconceptualized approach to how treatment is accessed by SMs and veterans returning from combat. Perhaps VR exposure could be embedded within the context of "postdeployment *reset* training" whereby the perceived stigma of seeking treatment could be lessened as the soldier would simply be involved in this "training" in similar fashion to other designated duties upon redeployment stateside. VRET therapy may also offer an additional attraction and promote treatment seeking by certain demographic groups in need of care. The current generation of young military personnel, having grown up with digital game technology, may actually be more attracted to and comfortable with participation in VRET as an alternative to what is perceived as traditional "talk therapy."

The current clinical research and development program with the *Virtual Iraq* application is also providing important knowledge for determining the feasibility of expanding the range of applications that can be created from this system to address other scientific questions. For example, following a similar design process, we have now created a *Virtual Afghanistan* themed scenario (see Fig. 6) that has more mountainous terrain and relevant building architecture. During the course of the ongoing research and development evolution of this application, our design approach has always focused on the creation of a flexible VR system/tool that could address *both* clinical and scientific PTSD research questions in a more comprehensive fashion. In this regard, we aim to repurpose the *Virtual Iraq* and *Virtual Afghanistan* applications as tools to investigate a variety of clinical and scientific questions including:

- The feasibility of assessing soldiers prior to deployment to predict potential risk for developing PTSD or other mental health difficulties on the basis of physiological reactivity to a series of virtual combat engagements.
- The creation of a stress resilience training tool where users are put in standardized simulations of emotionally challenging situations that may provide a more meaningful context in which to learn and practice cognitive coping strategies and psychologically prepare for what might occur in real combat situations.
- The effectiveness of using VR as an assessment tool immediately upon redeployment home to determine who may be "at risk" for developing PTSD after an incubation period. Physiological reactivity could figure well as a marker variable for this project and a prospective longitudinal study is needed in this area. This is particularly important for maximizing the probability that a soldier at risk would be directed into a "reset" program before being sent on a second or third deployment.
- The comparison of National Guard, reservist personnel, Army/Navy/Marine/Air Force standing military SMs and veterans in terms of their susceptibility for developing PTSD and if variations in the course of treatment would be required. This is also relevant for the study of PTSD treatment response differences due to multiple deployments, age, gender, education, family support, and previous civilian exposure to trauma.
- The neuroscience of PTSD via the use of brain imaging (e.g., functional magnetic resonance imaging and diffusion tensor imaging), traditional physiological measurement (e.g., electroencephalography, electrocardiography, and GSR), and other responses (e.g., eyeblink and startle response) by leveraging the high controllability of stimulus presentation that is available within the *Virtual Iraq/Afghanistan* applications.
- The interaction effects of the use of VR exposure in combination with pharmacological treatments. Randomized controlled trials comparing VRET alone and VRET + D-cycloserine are in progress at Emory University, the Weill Cornell Medical College, and University of Southern California, instigated by successful results, were reported with VRET + D-cycloserine for treating fear of heights.[37]
- The expansion of the functionality of the existing *Virtual Iraq* system based on the results of ongoing and future research. This will involve refining the system in terms of the breadth of scenarios/trigger events, the stimulus content, and the level of artificial intelligence of virtual humans that "inhabit" the system.

Finally, a guiding principle in the development of *Virtual Iraq* concerns how novel VR systems can extend the skills of a well-trained clinician. VRET is not intended to be an automated treatment or

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 with a professional appreciation of the complexity and impact of this disorder.

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Conflicts of interest

The authors declare no conflicts of interest.

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