A Virtual Iraq System for the Treatment of Combat-Related Posttraumatic Stress Disorder

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Abstract

Posttraumatic Stress Disorder (PTSD) is reported to be caused by traumatic events that are outside the range of usual human experience including (but not limited to) military combat, violent personal assault, being kidnapped or taken hostage and terrorist attacks. Initial data suggests that at least 1 out of 5 Iraq War veterans are exhibiting symptoms of depression, anxiety and PTSD. Virtual Reality (VR) delivered exposure therapy for PTSD has been previously used with reports of positive outcomes. The current paper is a follow-up to a paper presented at *IEEE VR2006* and will present the rationale and description of a VR PTSD therapy application (*Virtual Iraq*) and present the findings from its use with active duty service members since the *VR2006* presentation. *Virtual Iraq* consists of a series of customizable virtual scenarios designed to represent relevant Middle Eastern VR contexts for exposure therapy, including a city and desert road convoy environment. User-centered design feedback needed to iteratively evolve the system was gathered from returning Iraq War veterans in the USA and from a system deployed in Iraq and tested by an Army Combat Stress Control Team. Results from an open clinical trial using *Virtual Iraq* at the Naval Medical Center-San Diego with 20 treatment completers indicate that 16 no longer met PTSD diagnostic criteria at post-treatment, with only one not maintaining treatment gains at 3 month follow-up.

Keywords: Virtual Reality, Posttraumatic Stress Disorder, PTSD, Exposure Therapy, Full Spectrum Warrior

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.6.3 [Computing Methodologies]: Simulation and Modeling—Applications; J.3 [Computer Applications]: Life and Medical Sciences—Health; J.4 [Computer Applications]: Social and Behavioral Sciences—Psychology

1 Introduction

War is perhaps one of the most challenging situations that a human being can experience. The physical, emotional, cognitive and psychological demands of a combat environment place enormous stress on even the best-prepared military personnel. The high level of stress that is naturally experienced in combat can put a significant percentage of service members (SMs) at risk for developing Posttraumatic Stress Disorder (PTSD) upon the return home. According to the DSM-IV [1], PTSD is caused by traumatic events that are outside the range of usual human experiences including (but not limited to) military combat, violent personal assault and rape, being kidnapped or taken hostage, terrorist attacks, and automobile accidents. Such incidents would be distressing to almost anyone, and is usually experienced with intense fear, terror, and helplessness. Typically, the initiating event involves actual or threatened death or serious injury, or other threat to one's physical integrity; or the witnessing or awareness of an event that involves death, injury, or a threat to the physical integrity of another person. The essential feature of PTSD is the development of characteristic symptoms that may include: intrusive thoughts, nightmares and flashbacks, avoidance of reminders of the traumatic event, emotional numbing, and hyper-alertness. Symptoms of PTSD are often intensified when the person is exposed to stimulus cues that resemble or symbolize the original trauma in a *non-therapeutic* setting. Such *uncontrolled* cue exposure may lead the person to react with a survival mentality and mode of response that could put the patient and others at considerable risk.

In the early 21st century the conflicts in Iraq and Afghanistan again drew US military personnel into combat. The Iraq/Afghanistan combat theatres, with their ubiquitous battlefronts, ambiguous enemy identification, and repeated extended deployments has produced significant numbers of returning American SMs reporting symptoms that are congruent with the diagnosis of PTSD and other mental disorders. In the first systematic study of mental health problems due to these conflicts, "…The percentage of study subjects whose responses met the screening criteria for major depression, generalized anxiety, or PTSD was significantly higher after duty in Iraq (15.6 to 17.1 percent) than after duty in Afghanistan (11.2 percent) or before deployment to Iraq (9.3 percent)" [2]. These estimates were made before the violence escalated even further and other reports since the original Hoge et al. publication, have indicated equivalent or higher numbers of returning military SMs and veterans reporting positive for PTSD and symptoms of other forms of mental disorders [3-5].

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

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efficacy [6-10]. PE is a form of individual psychotherapy based on Foa and Kozak's [11] 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. This belief then manifests itself in cognitive and behavioral avoidance strategies that limit exposure to potentially corrective information that could be incorporated into and alter the fear structure. Successful treatment requires emotional processing of the fear structures in order to modify their pathological elements so that the stimuli no longer invoke fear. Emotional processing first requires accessing and activating the fear structure associated with the traumatic event and then incorporating information that is not compatible with it. 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 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 [12]. The comparative empirical support for exposure therapy was also recently documented in a review by the Institute of Medicine at the National Academies of Science of 53 studies of pharmaceuticals and 37 studies of psychotherapies used in PTSD treatment [13]. 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 [14]. 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 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.

The first effort to apply VRET began in 1997 when researchers at Georgia Tech and Emory University began testing the *Virtual Vietnam* VR scenario with Vietnam veterans diagnosed with PTSD. This occurred over 20 years after the end of the Vietnam War. During those intervening years, in spite of valiant efforts to develop and apply traditional psychotherapeutic and pharmacological treatment approaches to PTSD, the progression of the disorder in some veterans significantly impacted their psychological well-being, functional abilities and quality of life, as well as that of their families and friends. This initial effort yielded encouraging results in a case study of a 50-year-old, male Vietnam veteran meeting *DSM* criteria for PTSD [15]. Results indicated post-treatment improvement on all measures of PTSD and maintenance of these gains at a 6-month follow-up; with a 34% decrease in clinician-rated symptoms of PTSD and a 45% decrease on self-reported symptoms of PTSD. This case study was followed by an open clinical trial with Vietnam veterans [8]. In this study, 16 male veterans with PTSD were exposed to two head-mounted display-delivered virtual environments, a virtual clearing surrounded by jungle scenery and a virtual Huey helicopter, in which the therapist controlled various visual and auditory effects (e.g. rockets, explosions, day/night, shouting). After an average of 13 exposure therapy sessions over 5-7 weeks, there was a significant reduction in PTSD and related symptoms.

Similar positive results were reported by Difede et al. [16] for PTSD that resulted from the attack on the World Trade Center in a case study using VRET with a patient who had failed to improve with traditional exposure therapy. This group has since reported positive results from a wait-list controlled study using the same VR World Trade Center application [17]. The VR group demonstrated statistically and clinically significant decreases on the "gold standard" Clinician Administered PTSD Scale (CAPS) relative to both pre-treatment and to the wait-list control group with a between-groups post treatment effect size of 1.54. Seven of 10 people in the VR group no longer carried the diagnosis of PTSD, while all of the wait-list controls retained the diagnosis following the waiting period and treatment gains were maintained at 6-month follow-up. Also noteworthy was the finding that five of the 10 VR patients had previously participated in imaginal exposure treatment with no clinical benefit. Such initial results are encouraging and suggest that VR may be a useful component within a comprehensive treatment approach for persons with combat/terrorist attack-related PTSD.

2 Design and Development of the Virtual Iraq 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 VR exposure therapy environments known as *Virtual Iraq*. The initial prototype system was originally constructed by recycling virtual art assets that were 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 newly created art and technology assets available to ICT in a process highly informed by feedback from both clinicians and SMs with combat experience in Iraq and Afghanistan.

2.1 Virtual Iraq Content and Clinician Interface

Virtual Iraq consists of Middle Eastern themed city and desert road environments (see Figure 1, color plate) and was designed to resemble the general contexts that most SMs experience during deployment to Iraq. The 18 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, based on a determination as to which environments most closely match the patient's needs, relevant to their individual trauma-related experiences. The "Desert Road" scenario consists of a roadway through an expansive desert area with sand dunes, occasional areas of vegetation, intact and broken down structures, bridges, battle wreckage, a checkpoint, debris and virtual human figures (see Figure 2, color plate). The user is positioned inside of a HUMVEE that supports the perception of travel within a convoy or as a lone vehicle with selectable positions as a driver, 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., 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 Figure 3, color plate) 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 via a separate "Wizard of Oz" clinician's interface, while the clinician is in full audio contact with the patient (see Figure 4, color plate). 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. Via the interface, the patient can be placed by the clinician 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, 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 VR exposure therapy applications.

The specification, creation and addition of trigger stimulus options into the *Virtual Iraq* system has been an evolving process throughout the development of the application based on continually solicited patient and clinician feedback. We began this part of the design process by including options that have been reported to be relevant by returning soldiers and military subject matter experts. For example, the Hoge et al., [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. We 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 non-clinical 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.

2.2 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 while the second one drives the simulation via the user's head-mounted display (HMD) and navigation interface (gamepad or gun controller). The HMD that was chosen was the *eMagin z800*, with displays capable of 800x600 resolution within a 40-degree 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 $1500 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 (FSCA) with Emergent's *Gamebryo* used as a rendering engine. From an application designer perspective, the FSCA is a scriptable environment, where you define a new environment, add behaviors and redefine part of the UI without any need for additional programming. Pre-existing 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 (<$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 [18].

3 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 (WRAMC), the Weill Medical College of Cornell University and at 14 other VA, Military and University Laboratory sites for VRET research and a variety of other PTSD-related investigations. However, the user-centered design process for optimizing Virtual Iraq for clinical use is noteworthy and will be described before summarizing the VRET treatment protocol and results from the initial open clinical trial.

3.1 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 Figure 5, color plate). This formative feedback from non-diagnosed 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. More formal evaluation of the system took place at MAMC from late 2006 to early 2007 [19]. Ninety-three screened SMs (all non-PSTD) evaluated the *Virtual Iraq* scenarios shortly after returning from deployment in Iraq. SMs experienced the city and HUMVEE environments while exposed to scripted researcher-initiated VR trigger stimuli to simulate an actual treatment session. SMs then completed standardized questionnaires to evaluate the realism, sense of "presence" (the feeling of being in Iraq), sensory stimuli, and overall technical capabilities of *Virtual Iraq*. Items were rated on a scale from 0 (Poor) to 10 (Excellent). Qualitative feedback was also collected to determine additional required software improvements. The results suggested that the *Virtual Iraq* environment in its form at the time was realistic and provided a good sense of "being back in Iraq".

Average ratings across environments were between adequate and excellent for all evaluated aspects of the virtual environments. Auditory stimuli realism (M=7.9; SD=1.7) and quality (M=7.9; SD=1.8) were rated higher than visual realism (M=6.7; SD=2.1) and quality (M=7.0; SD=2.0). Soldiers had high ratings of the computer's ability to update visual graphics during movement (M=8.4; SD=1.7). The 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). This data, along with the collected qualitative feedback, was 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.

3.2 Service Member 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 towards the use of technology in behavioral healthcare [20]. One section of the survey asked these active duty SMs to rate on a 5-point scale how willing they would be to receive mental health treatment ("Not Willing at All" to "Very Willing") via traditional approaches (e.g. face-to-face counseling) and a variety of technology-oriented delivery methods (e.g. website, video teleconferencing, use of VR). Eighty-three percent of participants reported that they were neutral-to-very willing to use some form of technology as part of their behavioral healthcare, 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.

4 VRET OPEN CLINICAL TRIAL PROTOCOL AND RESULTS

4.1 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 twenty active duty SMs (19 male, 1 female, Mean Age=28, Age Range: 21-51) 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.

4.1 Clinical Protocol

The standard VRET exposure therapy protocol consisted of 2X weekly, 90-120 minute sessions over five weeks that also included physiological monitoring (HR, GSR and respiration) as part of the data collection. The VRET protocol followed the principles of graded prolonged behavioral exposure [12] 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 (PE), 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 minutes 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 four through ten is 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 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) [22], Beck Anxiety Inventory (BAI) [21] and Patient Health Questionnaire-Depression (PHQ-9) [23].

4.2 Results

Results from the first 20 *Virtual Iraq* treatment completers have indicated 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 (standard deviation) values went from 54.4 (9.7) to 35.6 (17.4). Paired pre/post t-test analysis showed these differences to be significant ($t=5.99$, $df=19$, $p < .001$). 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 PCL-M cutoff value of 50 (prescores= 49, 46, 42, 36, 38) and reported decreased values at post treatment (postscores= 23, 19, 22, 22, 24, respectively). Mean and individual participant PCL-M scores at baseline, post treatment and 3-month follow-up are graphed in Figures 6 and 7. For this same group, mean Beck Anxiety Inventory scores significantly decreased 33% from 18.6 (9.5) to 11.9 (13.6), ($t=3.37$, $df=19$, $p < .003$) 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 Figure 8). Also, two of the successful treatment completers had documented mild and moderate traumatic brain injuries, which suggest that this form of exposure can be usefully applied with this population.

5 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 based on these early results. However, 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 three-month post-treatment follow-up. Based on this initial open clinical trial, 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.

It should be noted that in spite of these initial positive results for treatment completers, challenges existed with treatment attrition in this active duty population. Seven participants who were assessed and approved for the study 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 four. While some of these active duty participants left due 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). While 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 healthcare 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 "post-deployment *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 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”.

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 Figure 9, color plate) that has more mountainous terrain and relevant building architecture. During the course of the ongoing R&D 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 based on physiological reactivity to a series of virtual combat engagements.
- stress inoculation training to psychologically prepare military personnel for what might occur in real combat.
- the effectiveness of using VR as an assessment tool immediately upon redeployment home to determine who may be “at risk” for developing full-blown 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 2nd or 3rd deployment.
- differences among 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., fMRI, DTI), traditional physiological measurement (e.g., EEG, EKG, GSR) and other responses (e.g., eyeblink, 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 and at the Weill Cornell Medical College after successful results were reported with VRET+D-cycloserine for treating fear of heights [24].
- 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. VR exposure therapy 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.

6 ACKNOWLEDGEMENTS

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7 BLACK AND WHITE DATA FIGURES (SEE LAST PAGE FOR COLOR FIGURES 1-5,9)

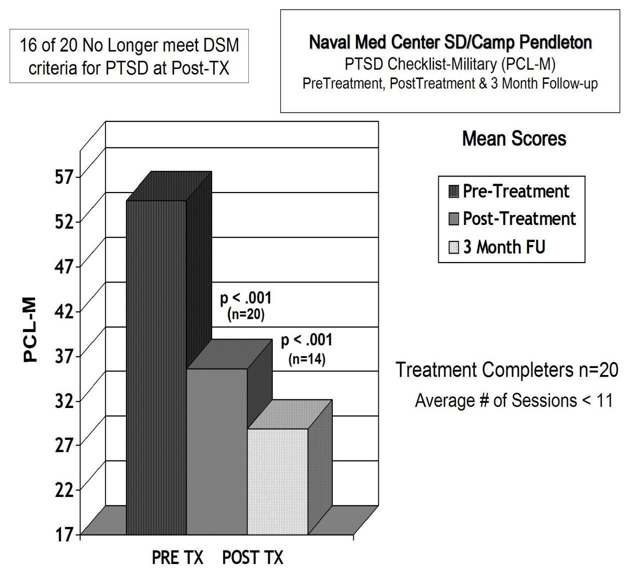

Figure 6. Mean PTSD Checklist scores across treatment

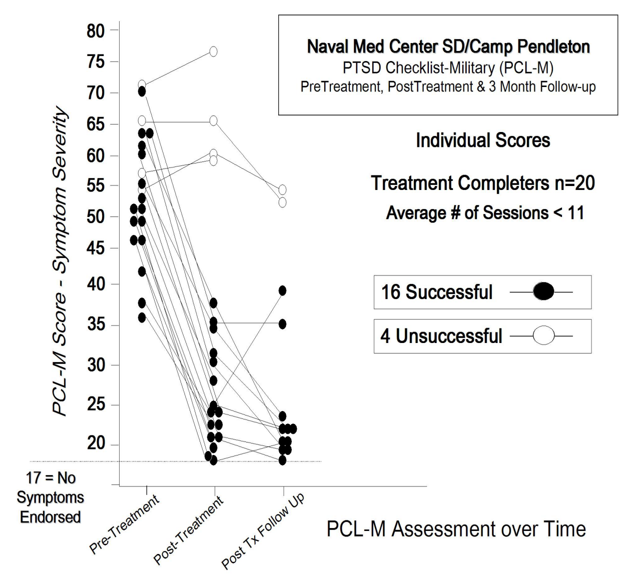

Figure 7. Individual PTSD Checklist scores across treatment

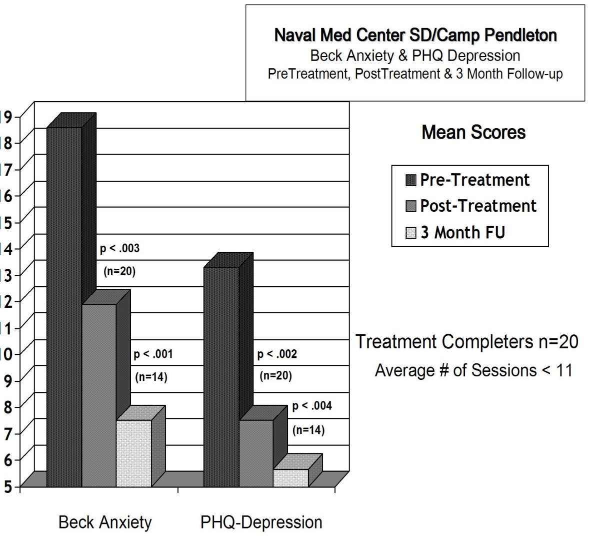

Figure 8. Beck Anxiety Scale and PHQ-Depression scores across treatment

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Figure 1. Scenes from *Virtual Iraq* City and Desert Road HUMVEE interior

Fig. 2. Desert Road Checkpoint

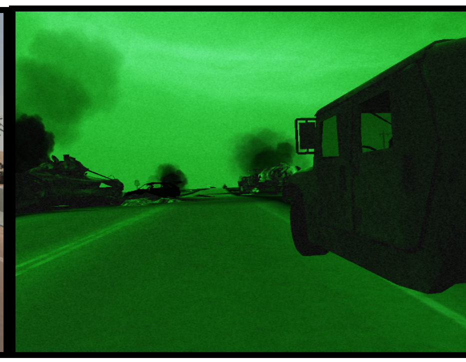

Fig. 3. Night Vision Setting

Fig. 4. Clinician's Interface (wireless version)

Figure 5. User Centered Feedback from Iraq Stress Control Team

Figure 9. Scenes from Virtual Afghanistan HUMVEE Turret Position