VIRTUAL REALITY AS A TOOL FOR DELIVERING PTSD EXPOSURE THERAPY

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INTRODUCTION

Virtual Reality (VR) technology offers new opportunities for the development of innovative assessment and intervention tools. VR-based testing, training, and treatment approaches that would be difficult, if not impossible, to deliver using traditional methods are now being developed that take advantage of the assets available with VR technology. If empirical studies continue to demonstrate effectiveness, VR applications could provide new options for targeting the cognitive, psychological, motor and functional impairments that result from various psychological and physical disorders and conditions. VR allows for the precise presentation and control of stimuli within dynamic multi-sensory 3D computer generated environments, as well as providing advanced methods for capturing and quantifying behavioral responses. These characteristics serve as the basis for the rationale for VR applications in the clinical assessment, intervention and training domains. This chapter will begin with a brief review of the history and rationale for the use of VR with clinical populations followed by a description of the technology for creating and using VR clinically. The chapter will then focus on reviewing the rationale for VR Exposure Therapy (VRET) applied to Anxiety Disorders. The use of VRET for the treatment of PTSD will then be detailed followed by a description of the Virtual Iraq/Afghanistan VRET system and the results from its use with OEF/OIF Service Members and Veterans.

THE HISTORY AND RATIONALE FOR CLINICAL VIRTUAL REALITY

Virtual reality (VR) has undergone a transition in the past few years that has taken it out of the realm of expensive toy and into that of functional technology. Over the last 15 years, a virtual revolution has taken place in the use of VR simulation technology for clinical purposes. Although media hype may have oversold VR's potential during the early stages of the technology's development, a uniquely suited match exists between the assets available with VR technology and applications in the clinical sciences. 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 intervention options that were not previously possible using existing approaches. The unique match between Virtual Reality technology assets and the needs of various clinical application areas has been recognized by a determined and expanding cadre of researchers and clinicians who have not only recognized the potential impact of VR technology, but have now generated a significant research literature that documents the many clinical and research targets where VR can add value over traditional assessment and intervention methods (Glantz et al., 2003; Holden, 2005; Parsons and Rizzo,

2008; Parsons, Rizzo, Rogers, and York, 2009; Powers and Emmelkamp, 2008; Rizzo et al., 2004; Rizzo and Kim, 2005; Rizzo et al., 2011abc; Riva, 2011; Rose, Brooks and Rizzo, 2005). Based on this, VR has now emerged as a promising tool in many domains of clinical care and research.

Virtual environments (VEs) have been developed that are now demonstrating effectiveness in a number of areas in clinical psychology, neuropsychology and in both cognitive and motor rehabilitation. A short list of areas where Clinical VR has been usefully applied includes fear reduction in persons with simple phobias (Parsons and Rizzo, 2008a; Powers and Emmelkamp, 2008), treatment for PTSD (Difede et al., 2002, 2007; Rizzo et al., 2010ab, 2011b; Rothbaum et al., 2001), stress management in cancer patients (Schneider et al., 2010), acute pain reduction during wound care and physical therapy with burn patients (Hoffman et al., 2011) and in other painful procedures (Gold et al., 2006), body image disturbances in patients with eating disorders (Riva, 2011), navigation and spatial training in children and adults with motor impairments (Rizzo et al., 2004; Stanton et al., 1998), functional skill training and motor rehabilitation with patients having central nervous system dysfunction (e.g., stroke, TBI, SCI, cerebral palsy, multiple sclerosis, etc.) (Holden, 2005; Merians et al., 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, Rogers, and 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. Emerging R & D is also producing artificially intelligent virtual human patients that are being used to train clinical skills to health professionals (Lok et al., 2007; Rizzo et al., in press).

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 intervention purposes. Within these environments, researchers and clinicians can present ecologically relevant stimuli embedded in a meaningful and familiar context. From this, VR offers the potential to create systematic human testing, training and treatment environments that allow for the precise control of complex, immersive, dynamic 3D stimulus presentations, within which sophisticated interaction, behavioral tracking and performance recording is possible. 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 under a range of stimulus conditions that are not easily deliverable and controllable in the real world. In essence, clinicians can now create simulated environments that mimic the outside world and use them in clinical settings to immerse patients in simulations that support the aims and mechanics of a specific assessment or therapeutic approach. 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 children and adults with clinical health conditions. As well, the clinical and research targets chosen for these applications reflect an informed appreciation for the assets that are available with VR

technology (Rizzo et al., 2004) by clinicians/developers initially designing and using systems in this area. When combining these assets within the context of functionally relevant, ecologically enhanced VEs, a fundamental advancement could emerge in how human assessment and intervention can be addressed in many clinical and research disciplines. For example, instead of relying solely on unverifiable imagery processes in clients with anxiety disorders to produce the therapeutic effects of extinction and habituation, graduated exposure to feared or trauma-relevant stimuli can be delivered systematically in VR. These initiatives give hope that in the 21st century, new and useful tools will be developed that will advance clinical areas that have long been mired in the methods of the past.

VIRTUAL REALITY DEFINITIONS AND TECHNOLOGY

Virtual Reality has been very generally defined as "...a way for humans to visualize, manipulate, and interact with computers and extremely complex data." (Aukstakalnis and Blatner, 1992). From this baseline perspective, VR can be seen as an advanced form of human-computer interface (Rizzo, Buckwalter and Neumann, 1997) that allows the user to "interact" with computers and digital content in a more natural or sophisticated fashion relative to what is afforded by standard mouse and keyboard input devices. And in some cases, with the aid of specialized VR display devices, users can become "immersed" *within* a computer generated simulated environment that changes in a natural/intuitive way with user interaction. VR sensory stimuli can be delivered by using various forms of visual display technology that can present real-time computer graphics and/or photographic images/video along with a variety of other sensory display devices that can present audio, "force-feedback" touch sensations and even olfactory content to the user.

However, VR is not defined or limited by any one technological approach or hardware set up. The creation of an engaged virtual reality *user experience* can be accomplished using combinations of a wide variety of interaction devices, sensory display systems, and in the design of content presented in a computer-generated graphic world. For example, *Immersive VR* can be produced by combining computers, head mounted displays (HMDs), body tracking sensors, specialized interface devices and real-time graphics to immerse a participant in a computer-generated simulated world that changes in a natural way with head and body motion. Thus, an engaged immersive 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 sensory 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 HMD and head tracking system that allows delivery of real-time computer-generated images and sounds of a simulated virtual scene rendered in relation to user movements that corresponds to what the individual would see, hear and feel if the scene were real. Another method uses stereoscopic projection screens arrayed in various configurations, including six-walled rooms known as CAVES that allow users to interact in a less encumbered, wide field of view simulation environment. However, such CAVE systems are more costly and complex and are typically beyond the practical resources of a clinical service provider or basic researcher. In these immersive systems, one of the key aims is to perceptually replace the outside world with that of the simulated environment to create a specific user experience.

Immersive HMD VR has been most commonly employed in applications where a controlled stimulus environment is desirable for constraining a user's perceptual experience within a specific synthetic world. This format has been often used in Clinical VR applications for anxiety disorder exposure therapy, analgesic distraction for patients suffering from acutely painful medical procedures and in the cognitive assessment of users with CNS dysfunction to measure performance under a range of systematically delivered task challenges and distractions.

By contrast, *Non-Immersive VR* is commonly experienced using modern computer and console games systems (as well as in non-game research lab generated systems). This format presents a three-dimensional (3D) graphic environment on a flatscreen monitor, projection system or television (no real world occlusion) within which the user can navigate and interact. Albeit delivered on a less immersive display, such graphic worlds are still essentially a virtual reality *environment*. VEs presented on these widely available commodity display systems have the capacity to provide the user with significant options for interaction with dynamic digital content using traditional computer and game interface devices (e.g., keyboard, mouse, game pads, joysticks, etc.) in addition to more complex interaction devices that can track more natural user activity (e.g., data gloves, 3D mice, treadmills and some high-end "force feedback" exoskeleton devices). And recently, off-the-shelf systems, like the Microsoft Kinect are now being shown to provide a novel way for users to interact with VEs using natural body interaction via low cost 3D camera-based sensing of full body movement (Lange et al., in press).

EXPOSURE THERAPY AND THE EARLY USE OF VIRTUAL REALITY

The use of VR to address psychological disorders began in the mid-nineties with its use as a tool to deliver prolonged exposure (PE) therapy targeting anxiety disorders, primarily for specific phobias (e.g., heights, flying, spiders, enclosed spaces). PE is a form of individual psychotherapy based on the Foa and Kozak (1986) emotional processing theory, which posits that phobic disorders and PTSD involve pathological fear structures that are activated when information represented in the structures is encountered. Emotional processing theory purports that fear memories include information about stimuli, responses, and meaning (Foa and Kozak, 1986; Foa, Skeketee, and Rothbaum, 1989) and that 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. As escape and avoidance from feared situations are intrinsically (albeit, temporarily) rewarding, phobic disorders can perpetuate without treatment. Consequently, several theorists have proposed that conditioning processes are involved in the etiology and maintenance of anxiety disorders. These theorists invoke Mowrer's (1960) two-factor theory, which specifies that both Pavlovian and instrumental conditioning are involved in the acquisition of fear and avoidance behavior. Successful treatment requires emotional processing of the fear structures in order to modify their pathological elements so that the stimuli no longer invoke fear, and any method capable of activating the fear structure and modifying it would be predicted to improve symptoms of anxiety.

Imaginal PE entails engaging mentally with the fear structure through repeatedly revisiting the feared or traumatic event in a safe environment. The proposed mechanisms for symptom reduction involves activation and emotional processing, extinction/habituation of the anxiety, cognitive reprocessing of pathogenic meanings, the learning of new responses to previously feared stimuli, and ultimately an integration of corrective nonpathological information into the fear structure (Foa et al., 1996; Bryant et al., 2003). Thus, VR was seen early on to be a potential tool for the treatment of anxiety disorders; if an individual can become immersed in a feared virtual environment, activation and modification of the fear structure was possible. From this, the use of VR to deliver PE was the first psychological treatment area to gain traction clinically, perhaps in part due to the intuitive match between what the technology could deliver and the theoretical requirement of PE to systematically expose/engage users to progressively more challenging stimuli needed to activate the fear structure.

Moreover, even during the early days of VR, this was not so technically challenging to achieve. VEs could be created that required little complex user interaction beyond simple navigation within a simulation that presented users with scenarios that represented key elements of the targeted fear structure that could be made progressively more provocative (views from tall buildings, aircraft interiors, spiders in kitchens, etc.). And even with the limited graphic realism available at the time, phobic patients were observed to be "primed" to suspend disbelief and react emotionally to virtual content that represented what they feared. In general, the phenomenon that users of VR could become immersed in VE's provided a potentially powerful tool for activating relevant fears in the PE treatment of specific phobias in the service of therapeutic exposure.

From this starting point, a body of literature evolved that suggested that the use of virtual reality exposure therapy (VRET) was effective. Case studies in the 1990's initially documented the successful use of VR in the treatment of fear of flying (Rothbaum, Hodges, Watson, Kessler, and Opdyke, 1996; Smith, Rothbaum, and Hodges, 1999), claustrophobia (Botella et al., 1998), acrophobia (Rothbaum et al., 1995), and spider phobia (Carlin, Hoffman, and Weghorst, 1997). For example, in an early wait list controlled study, VRET was used to treat the fear of heights, exposing patients to virtual footbridges, virtual balconies, and a virtual elevator (Rothbaum et al., 1995). Patients were encouraged to spend as much time in each situation as needed for their anxiety to decrease and were allowed to progress at their own pace. The therapist saw on a computer monitor what the participant saw in the virtual environment and therefore was able to comment appropriately.

Results showed that anxiety, avoidance, and distress decreased significantly from pre- to post-treatment for the VRE group but not for the wait list control group. Examination of attitude ratings on a semantic differential scale revealed positive attitudes toward heights for the VRE group and negative attitudes toward heights for the wait list group. The average anxiety ratings decreased steadily across sessions, indicating habituation for those participants in treatment. Furthermore, 7 of the 10 VRE treatment completers exposed themselves to height situations in real life during treatment although they were not specifically instructed to do. These exposures

appeared to be meaningful, including riding 72 floors in a glass elevator and intentionally parking at the edge of the top floor of a parking deck.

This research group then compared VRET to both an in vivo PE therapy condition and to a wait list (WL) control in the treatment of the fear of flying (Rothbaum et. al., 2000). Treatment consisted of eight individual therapy sessions conducted over six weeks, with four sessions of anxiety management training followed either by exposure to a virtual airplane (VRET) or exposure to an *actual airplane* at the airport (PE). For participants in the VRE group, exposure in the virtual airplane included sitting in the virtual airplane, taxi, take off, landing, and flying in both calm and turbulent weather according to a treatment manual (Rothbaum et. al., 1999). For PE sessions, in vivo exposure was conducted at the airport during Sessions 5 - 8. Immediately following the treatment or wait list period, all patients were asked to participate in a behavioral avoidance test consisting of a commercial round-trip flight.

The results indicated that each active treatment was superior to WL and that there were no differences between VRET and in vivo PE. For WL participants, there were no differences between pre and post self-report measures of anxiety and avoidance, and only one of the 15 wait-list participants completed the graduation flight. In contrast, participants receiving VRET or in vivo PE showed substantial improvement, as measured by self-report questionnaires, willingness to participate in the graduation flight, self-report levels of anxiety on the flight, and self-ratings of improvement. There were no differences between the two treatments on any measures of improvement. Comparison of post-treatment to the 6-month follow-up data for the primary outcome measures for the two treatment groups indicated no significant differences, suggesting that treated participants maintained their treatment gains. By the 6-month follow-up, 93% of treated participants had flown since completing treatment. Since that time, an evolved body of literature of controlled studies has emerged and two recent meta-analyses of the available literature (Parsons and Rizzo, 2008a; Powers and Emmelkamp, 2008) concurred with the finding that VR is an efficacious approach for delivering PE, that it outperformed imaginal PE and was as effective as in vivo exposure.

VIRTUAL REALITY EXPOSURE THERAPY FOR PTSD

VR has also been applied as a method for delivering PE for posttraumatic stress disorder (PTSD). Among the many approaches that have been used to treat PTSD, exposure therapy appears to have the best-documented therapeutic efficacy (NAS, 2007). Such treatment typically involves the graded and repeated imaginal reliving of the traumatic event within the therapeutic setting. Similar to PE for specific phobias, 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. However, while the efficacy of imaginal exposure has been established in multiple studies with diverse trauma populations (Bryant, 2005; Rothbaum and Schwartz, 2002; Van Etten and Taylor, 1998), 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 and Morral, 1998). To address this problem, researchers have recently turned to the use of VR to deliver exposure therapy by immersing clients in simulations of trauma-relevant environments that allow for precise control of stimulus conditions.

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 (Rothbaum et al., 2001). 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 (Rothbaum et al., 1999).

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 (Rothbaum et al., 2001). In this study, 16 male veterans with PTSD were exposed to two HMD-delivered virtual environments, a virtual clearing surrounded by jungle scenery and a virtual Huey helicopter, in which the therapist controlled various visual and auditory effects (e.g. rockets, explosions, day/night, and shouting). After an average of 13 exposure therapy sessions over 5-7 weeks, there was a significant reduction in PTSD and related symptoms. *For more information, see the 9-minute Virtual Vietnam Documentary video at*: http://www.youtube.com/watch?v=C_2ZkvAMih8.

Similar positive results were reported by Difede et al. (2002) 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 imaginal exposure therapy. This group later reported positive results from a wait-list controlled study using the same World Trade Center VR application (Difede et al., 2007). 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, yet were successfully treated with VRET. Such initial results were encouraging and suggest that VR may be a useful component within a comprehensive treatment approach for persons with combat/terrorist attack-related PTSD. *For more information, see the Virtual World Trade Center video at*: http://www.youtube.com/watch?v=XAR9QDwBILc

THE VIRTUAL IRAQ/AFGHANISTAN PTSD EXPOSURE THERAPY PROJECT

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/Afghanistan* application 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.

The *Virtual Iraq/Afghanistan* PTSD Exposure Therapy System consists of Middle Eastern themed city and desert road environments (see Figure 1) and was designed to resemble the general contexts that most Service Members (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 trash and war wreckage. 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 components of the 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/debris, a checkpoint, and virtual human figures. The user is positioned inside of a HUMVEE that supports the perception of travel within a convoy or as a lone vehicle with selectable positions as a driver, 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).

Figure 1. Latest version of *Virtual Iraq/Afghanistan* City and Desert Road HUMVEE scenarios.

Both the city and desert road HUMVEE scenarios are adjustable for time of day or night, weather conditions, illumination, night vision and ambient sound (wind, engine noise, traffic sounds, distant gunfire, call to prayer, local voices, etc.). Users can navigate in both scenarios via the use of a standard gamepad controller, although the option for use of an accurately-weighted replica M4 weapon with a "thumb-mouse" controller that supports movement during the city foot patrol is also available. (This was based on repeated requests from 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 any of 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, vibration (using a "bass-shaking" platform that the user stands or sits on to get the haptic sensation of the Humvee motor running) 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 Figure 2), while the clinician is in full audio contact with the patient.

Figure 2. Clinician Interface for controlling stimulus delivery in *Virtual Iraq/Afghanistan*

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, 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 of providing 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 essential components for these types of VR exposure therapy applications.

The specification, creation and addition of trigger stimulus options into the *Virtual Iraq/Afghanistan* system has been an evolving process throughout the development of the application based on continually solicited patient and clinician feedback. This part of the design process began by including options that have been reported to be relevant by returning soldiers and military subject matter experts. For example, Hoge et al., (2004) presented a listing of emotionally challenging combat-related events that were commonly reported by their Iraq/Afghanistan SM 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 considered what was both functionally relevant and technically possible to include as trigger stimuli.

The current system offers 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. While many of these stimuli have been taken from commercial sound effects collections, the latest version of the system features a large number of ambient sounds that were recorded specifically for *Virtual Iraq/Afghanistan* at various locations in Baghdad. Given that sound is the stimulus that can be most accurately reproduced in a VR setting, we have gone to great lengths to incorporate authentic, uncompressed recordings of M-4 fire, military banter, Humvees rattling along on bumpy roads, boots on gravel, and even such locally-inflected auditory stimuli as Iraqi voices, Baghdad traffic, and indigenous birdsong into the latest generation of *Virtual Iraq* scenarios. Our technicians are planning trips to military installations in the US and in Afghanistan to capture additional relevant sounds for the application.

In addition to purely sonic events, clinicians can also trigger dynamic intersensorial events such as helicopter flyovers, bridge attacks, exploding vehicles and IED detonations. The creation of more complex events that can be intuitively delivered in *Virtual Iraq/Afghanistan* 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 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.

Whenever possible, *Virtual Iraq/Afghanistan* was designed to use off the shelf equipment in order to minimize costs and maximize the access and availability of the finished system. The minimum computing requirements for the current application is a Pentium 4 computer with 1

GB RAM, and a 128 MB DirectX 9-compatible 3D graphics card. Two computer monitors are required, one to display the clinician's interface and a second to display the actual simulation scenes that the user is experiencing in their head-mounted display (HMD) as they navigate using an interface device (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 Emergent's *Gamebryo* rendering engine. Pre-existing art was integrated using *Alias' Maya 6* and *AutoDesk 3D Studio Max 7* with new art created primarily in *Maya*.

Olfactory and tactile stimuli can also 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/Afghanistan* to allow a clinician the flexibility to engage users across a wide range of unique and highly customizable levels of exposure intensity. At the same time, these same features have broadened the applicability of *Virtual Iraq/Afghanistan* as a research tool for studies that require systematic control of stimulus presentation within combat relevant environments (Rizzo et al., 2011b). A direct link to a *YouTube* channel with videos that illustrate features of this system and depict former patients discussing their experience with the VRET approach can be found at: http://www.youtube.com/user/AlbertSkipRizzo

The *Virtual Iraq/Afghanistan* system was designed and built from a user-centered design process that involved feedback from active duty SMs and veterans dating back to solicited responses to the initial prototype. User-centered design feedback needed to iteratively evolve *Virtual Iraq/Afghanistan* was gathered from an Army Combat Stress Control Team that deployed to Iraq with the system, as well as 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 vis-à-vis SMs'

acceptance of and interest in the treatment, and initial clinical successes (Gerardi et al., 2008; Reger et al., 2008, 2009, 2011; Wilson et al., 2008).

The Office of Naval Research, the agency that had funded the initial system development of *Virtual Iraq/Afghanistan*, also supported an initial open clinical trial to evaluate the feasibility of using VRET with active duty participants. The study participants were SMs recently redeployed from Iraq/Afghanistan at the Naval Medical Center San Diego and at Camp Pendleton, who had engaged in previous PTSD treatments (e.g., group counseling, EMDR, medication, etc.) without benefit. The standard treatment protocol consisted of 2X weekly, 90-120 minute sessions over five weeks. The VRET exposure exercises followed the principles of prolonged exposure therapy (Foa et al., 1999) and the pace was individualized and patient-driven. Physiological monitoring (heart rate, galvanic skin response and respiration) was used to provide additional user state information to the clinicians 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 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 minutes without the introduction of any provocative trigger stimuli. 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 et al., 1996), Beck Anxiety Inventory (BAI) (Beck et al., 1988) and Patient Health Questionnaire-Depression (PHQ-9) (Koneke and 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; 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 Figure 3.) Mean Beck Anxiety Inventory 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 Figure 3). The average number of sessions for this sample was just under 11. Also, two of the successful treatment completers had documented mild and moderate traumatic brain injuries (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 an accepted military-relevant diagnostic screening measure (PCL-M), 80% of the treatment completers in the initial VRET sample showed both statistically and clinically meaningful reductions in PTSD, anxiety and depression symptoms, and anecdotal evidence from patient reports suggested that they saw improvements in their everyday life. These improvements were also maintained at three-month post-treatment follow-up.

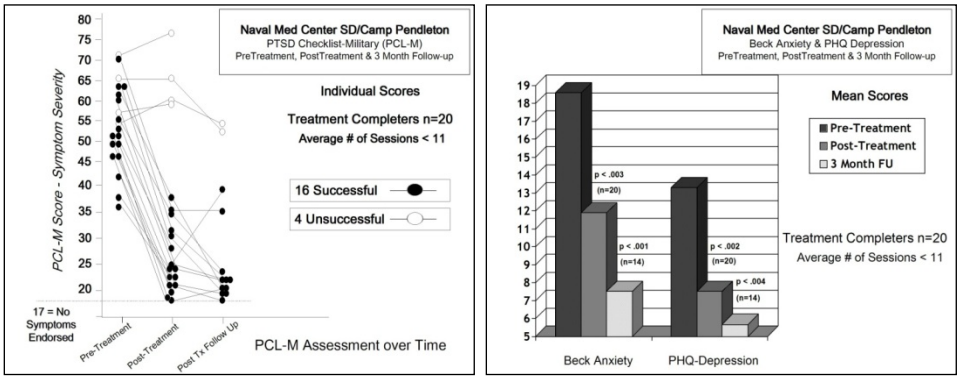

Figure 3. PCL-M scores across treatment and BAI and PHQ-Depression scores.

The following brief case descriptions illustrate the VRET intervention using the standard protocol and within a modified delivery approach.

Case 1

The patient was a 22-year-old female Army private who met DSM-IV criteria for PTSD and Major Depressive Disorder, Recurrent (MDD). Her service in Iraq typically involved direct evaluation of locations immediately following suicide and/or IED bombings and she was exposed to significant human carnage during the course of her 1 year deployment. Upon returning stateside, following an evaluation, she was diagnosed with PTSD and agreed to participate in our standardized 10 session clinical research protocol (detailed in this chapter). Subjective Units of Distress (SUDs; 0-100 scale) were gathered every five minutes during the virtual reality exposure, and the homework included listening to the audiotapes of the patient's self-generated verbal narrative of her trauma relevant experiences while participating in the virtual reality exposure. The *Virtual Iraq* city scenario was primarily used to expose the patient

to street scenes that included Iraqi civilians, explosions and a vehicle-borne improvised explosive device (VBIED) that, when ignited, could cause visible bodily injury to civilian characters in the vicinity. Multiple settings for civilian trauma levels—from mild injury to very severe—were used by the clinician to pace the exposure in later sessions. The patient showed a gradual and progressive improvement over the course of the VRET sessions. Scores on the PCL-M, PHQ-9, and BAI, prior to treatment were 42, 20, and 12, respectively. Post-treatment scores on these measures decreased to 22, 3, and 0. At follow-up, the subject did not meet DSM-IV diagnostic criteria for PTSD, and met remission status for MDD. The patient presented self-report and psychophysiological signs of habituation across VRET sessions and self-reported a concomitant decline across homework sessions while listening to the audiotape of her trauma narrative recorded during treatment sessions. For example, SUDs ratings while listening to the audiotape at home initially fell in the 30-35 range; these ratings declined to the 10-15 range at the end of treatment. Following completion of treatment, the patient was able to return to her unit. At her three month follow-up, she continued to maintain the therapeutic gains observed at the end of treatment, with scores on the PCL-M, PHQ-9 and BAI, at 18, 1, and 1, respectively.

Case 2

The patient was a 29-year- old male U.S. Marine who was deployed to Iraq for seven months. After returning to the USA, he appears to have suffered from PTSD for approximately six months before being diagnosed. After a suicide attempt, the patient was psychiatrically hospitalized and diagnosed with Chronic PTSD. At that time, he was given a prescription for Sertraline and assigned a limited duty status that prevented him from returning to his unit of combat engineers. The patient was contacted and he participated in the initial assessment session, where he was administered the PCL-M, PHQ-9 and the BAI assessments. Results from these tests confirmed the diagnosis of PTSD, and indicated that the patient had ongoing significant symptoms of PTSD, depression, and anxiety. The patient initially dropped out before treatment began, stating that he was unwilling to participate in the formal, structured study. However, he reported that he still wanted to participate in VRET, as dictated by clinical judgment rather than within the standard study protocol that required a commitment to 10 VRET sessions. After some negotiation, the patient participated in one session of general, supportive therapy by phone lasting approximately one hour. Following this he agreed to participate further and was then seen for six bi-weekly, 90-120 min sessions that incorporated supportive therapy, traditional imaginal exposure therapy, and VRET. A diverse variety of exposure settings were used with this patient in both the Humvee desert and Iraqi city environments. This included IED and RPG attacks while in the passenger seat of the vehicle as well as exposure to the full range of content within the Iraqi City scenario.

Despite the appearance of significant, new interpersonal stressors during treatment, the patient showed a rapid and dramatic improvement and no longer reported himself to be suicidal. Self-report and physiological (heart rate, GSR, respiration) responses in the *Virtual Iraq* simulation of combat indicated a progressive habituation effect across sessions. By the end of treatment, the patient showed little distress or abnormal physiological reactivity despite maximal stimulation in the VR environment. Scores on the PCL-M, PHQ-9, and BAI prior to treatment were 62, 16, and 28, respectively. Post-treatment scores on these measures

decreased to 37, 5, and 22. Based on these indicators, he was tentatively judged to have been adequately treated and was returned to his unit's psychiatrist for a fitness for duty evaluation. Independent evaluation determined that the patient was fit for full duty and he was returned for duty with his previous unit. One month after the completion of treatment, a repeat evaluation was performed which showed ongoing remission of PTSD symptoms and confirmed that the patient was functioning well in his previous military duties. At one month follow-up post treatment, the patient's scores were 21, 4, and 15, all in the sub-clinical range. A check-in by phone three months post treatment indicated that the patient was functioning well. These results were also further corroborated by family members.

To view videos of SMs and Veterans discussing their experiences with PTSD and the VRET system, please see:
CNN: Marine Corp Vet Battles PTSD with Virtual Reality:
http://www.youtube.com/watch?v=hjyRu1e-Jmo&feature=channel_video_title
PBS: Active Duty Marine (Camp Pendleton) Interview:
http://www.youtube.com/watch?v=FUl6E76XPs4
CBC: "The National" Virtual Iraq with Patient discussing treatment:
http://www.youtube.com/watch?v=Ltl9zbDRZWY
ABC Nightline: Reservist profiled on his PTSD Treatment using Virtual Iraq:
http://www.youtube.com/watch?v=CqB28tyrBNY
PBS Frontline: PTSD Therapy Session at VA using Virtual Iraq.mpg:
http://www.youtube.com/watch?v=4F4i6vEZ-H4
PBS Frontline: Army Reservist Vet Discusses PTSD Treatment with Virtual Iraq Part 1:
http://www.youtube.com/watch?v=smrespIIJmI
PBS Frontline: Army Reservist Vet Discusses PTSD Treatment with Virtual Iraq Part 2:
http://www.youtube.com/watch?v=4Da5Pn42ovA

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 and Gahm, 2008). Following those, an open clinical trial with 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) (Reger et al., 2011). 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). 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 PE 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 with eight treatment completers 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; this will likely be an area of interest for some time to come.

Three randomized controlled trials (RCTs) 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, an N-methyl-d-aspartate partial agonist, has been shown to facilitate extinction learning in laboratory animals when infused bilaterally within the amygdala prior to extinction training (Walker, Ressler, Lu, and 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 experienced significant 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. This group also achieved lower scores on a psychophysiological measure of anxiety than the placebo group. 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 55 Military, VA and University clinic sites over the last four 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 (*Unity 3D* Software) and the addition of authentic site-specific audio recordings to provide more diversity of content, added functionality, and increased verisimilitude. In this regard, the new system has its design "roots" from feedback acquired from non-diagnosed SMs as well as 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, as well as for other purposes including PTSD and neurocognitive assessment and the creation of a stress resilience training system (Rizzo et al., 2011b).

CONCLUSIONS

Interest in VR technology to create tools for enhancing exposure therapy practice and research has grown in recent years as initial positive outcomes have been reported with its implementation. The enthusiasm that is common among proponents of the use of VR for exposure-based treatment partly derives from the view that VR technology provides the capacity for clinicians to deliver specific, consistent and controllable trauma-relevant stimulus environments that do not rely exclusively on the hidden world and variable nature of a patient's imagination. Moreover, the technology required to produce and use VR systems has advanced concomitantly as system costs have decreased.

An important issue to consider with the use of VRET is in the area of breaking down barriers to care. This needs 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., (2004) report, was the observation that among OEF/OIF veterans "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 methodologies have 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 re-conceptualized 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 SM 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".

Finally, if one reviews the history of the impact of war on advances in clinical care it could be suggested that Clinical VR may be 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; that development later set the stage for the civilian intelligence testing movement during the mid-20th Century. As well, 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 "shell shock." In similar fashion, one of the clinical "game changing" outcomes of the OIF/OEF conflicts could derive from the military's support for research and development in the area of Clinical VR that could potentially drive increased recognition and adoption within the civilian sector. However, this will only occur if positive cost-effective outcomes are produced with military VRET applications. As in all areas of new technology design and development, it is easy for one to get caught up in excitement that surrounds the potential clinical opportunities, while casting a blind eye to the pragmatic challenges that exist for building and disseminating useful and usable applications. Thus far, this has not been the case with VRET funders, developers and clinicians, most of whom have approached this area with an honest measure of healthy skepticism. It should be noted though, that there has been a growing interest in VRET within the clinical community as clinical tests are incrementally demonstrating that it can be implemented safely, at a reasonable cost, and that it has now begun to yield clinical outcomes that are at the least equivalent to the more traditional imagination-based method for administering exposure therapy. Yet, it should also be noted that any rush to adopt VRET should not disregard principles of evidence-based and ethical clinical practice. While novel VR systems can extend the skills of a well-trained clinician, the *Virtual Iraq/Afghanistan* system was not designed to be used as an automated treatment protocol 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 within the context of appropriate care via a thoughtful professional appreciation of the complexity and impact of this behavioral health challenge.

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