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ORIGINAL PAPER

Virtual Reality Exposure for PTSD Due to Military Combat and Terrorist Attacks

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Abstract Humans exposed to war and terrorist attacks are at risk for the development of posttraumatic stress disorder (PTSD). Numerous reports indicate that the incidence of PTSD in both returning Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) military personnel and survivors of the 9/11 World Trade Center (WTC) attacks is significant. These situations have served to motivate research on how to better develop and disseminate evidence-based treatments for PTSD and other related psychosocial conditions. Virtual reality (VR) delivered exposure therapy for PTSD is currently being used to treat combat and terrorist attack related PTSD with initial reports of positive outcomes. This paper presents an overview and rationale for the use of VR exposure therapy with anxiety disorders and PTSD and describes the status of two systems (Virtual Iraq/Afghanistan and Virtual World Trade Center) developed for this purpose.

Keywords Posttraumatic stress disorder · Anxiety disorders · Virtual reality · Prolonged exposure

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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. Thus, it is no surprise that the stressful experiences that have been characteristic of the Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) combat theatres have produced significant numbers of SMs and Veterans at risk for developing PTSD and other psychosocial/behavioral health conditions. In a meta-analysis across studies since 2001, 13.2 % of OEF/OIF operational infantry units met criteria for PTSD with the PTSD incidence rising dramatically (ranging from 25 to 30 %) in infantry units with the highest levels of direct combat (Kok et al. 2012). During this same time period, the prevalence of PTSD among discharged veterans receiving treatment at VA clinics has been reported to be 29 % (Fischer 2013). These findings make a compelling case for a continued focus on developing and enhancing the availability of diverse evidence-based treatment options to address this military behavioral healthcare challenge.

Similarly, trauma experienced from acts of terror can have a significant effect on the psychological well-being of the civilian population. The World Trade Center (WTC) attacks of September 11, 2001 were unprecedented in their unique impact, with the loss of almost 3000 lives, more than 10,000 eyewitnesses in New York, and thousands of disaster workers who were exposed on that day (and in the aftermath at Ground Zero) to the massive devastation and loss of life. Unsurprisingly, the psychological effects were substantial. Screenings 1–2 months following 9/11 found rates of probable PTSD ranging from 7.5 % in Manhattan residents (Galea et al. 2002) to nearly 40 % in individuals in the area of

the attacks (Rosenczweig et al. 2002). The WTC Health Registry found estimated PTSD prevalence at 12.4 % among almost 29,000 rescue and recovery workers two to three years after 9/11 (Perrin et al. 2007) and a rate of 23 % estimated PTSD among over 43,000 participants screened in three waves over 10 years (Ghuman et al. 2014). The World Trade Center Worker and Volunteer Medical Screening Program reported probable PTSD in 11 % of over 10,000 workers in the 5 years following the attacks. In our own studies of almost 3,000 non-rescue workers deployed to Ground Zero, we found rates of 8 % with full PTSD and an additional 9 % with sub threshold PTSD 10–34 months following the attacks (Cukor et al. 2011).

These dramatic geopolitical events (OEF/OIF/WTC) put a high profile on the impact of trauma on its human victims. This provided an impetus for innovative efforts to develop and evaluate the use of Virtual Reality simulations of the Afghanistan/Iraq combat zones and the WTC attack as tools for delivering trauma-focused exposure therapy to treat PTSD. It is within this historical context that this paper will discuss two efforts to apply VR technology for the treatment of PTSD. This includes a short review of the previous literature, descriptions of the system components and the treatment protocol, discussion of the initial research and results, and the presentation of two cases that have been treated with each of these systems.

The Rationale for Virtual Reality Exposure

Prolonged Exposure (PE)

Prolonged exposure (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 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 often invoking Mowrer's (1960) two-factor theory 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 non-pathological information into the fear structure (Bryant et al. 2003; Foa et al. 1996).

When PE is used for PTSD the approach typically involves the graded and repeated imaginal reliving and narrative recounting of the traumatic event by the client within the therapeutic setting. Clients are asked to verbally recount their trauma experience in the first person with their eyes closed, as if it were happening again with as much attention to sensory detail as they can. Using clinical judgment, the therapist might prompt the client with questions about their experience or provide encouraging remarks as deemed necessary to facilitate the recounting of the trauma narrative. This approach is believed to provide a low-threat context where the client can begin to confront and therapeutically process trauma-relevant memories and emotions as well as de-condition the learning cycle of the disorder via an extinction learning process.

Virtual Reality Exposure (VRE)

VR can be seen as an advanced form of human–computer interaction (Rizzo et al. 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. 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/intuitive way with head and body motion. One common configuration employs a combination of a HMD and head tracking system that allows delivery of real-time images and sounds of a simulated virtual scene rendered in relation to user movements that corresponds to what the individual would see and hear if the scene were real. Thus, an engaged virtual experience creates the illusion of being immersed "in" a virtual space within which the user can interact.

The use of VR to address psychological disorders began in the mid-90s with its use as a tool to deliver exposure therapy targeting anxiety disorders. Primarily targeting specific phobias (e.g., heights, flying, spiders, enclosed spaces), virtual environments could be created that provided views from tall

buildings, aircraft interiors, spiders in kitchens, elevators, etc. In general, the phenomenon that users of VR could become immersed in digital 3D graphic rendering of a feared environment provided a potentially powerful tool for activating and modifying relevant fears in the PE treatment of specific phobias. From this starting point, a body of literature evolved that suggested that the use of virtual reality exposure (VRE) therapy was effective. Case studies in the 1990s initially documented the successful use of VR in the treatment of acrophobia (Rothbaum et al. 1995), fear of flying (Rothbaum et al. 1996), spider phobia (Carlin et al. 1997), and claustrophobia (Botella et al. 1998). For example, in an early wait list controlled study, VRE was used to treat the fear of heights, exposing clients to virtual footbridges, virtual balconies, and a virtual elevator (Rothbaum et al. 1995). Clients 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.

Since that time, an evolved body of controlled studies targeting specific phobias has emerged and two meta-analyses of the available literature (Parsons and Rizzo 2008; Powers and Emmelkamp 2008) concurred with the finding that VR is an efficacious approach for delivering PE, that it sometimes outperformed imaginal PE and was as effective as in vivo exposure. A newer meta-analysis and a systematic review of this literature expand on the findings (Opris et al. 2012; Scozzari and Gamberini 2011) and further support the notion that VR is an effective method for delivering exposure within an evidence-based CBT protocol to treat these types of anxiety disorders.

Virtual Reality Exposure for Posttraumatic Stress Disorder

In the late 1990s researchers began to test the use of VRE for the treatment of posttraumatic stress disorder (PTSD) by systematically immersing users in simulations of trauma-relevant environments. While the efficacy of imaginal PE for PTSD has been established in multiple studies with diverse trauma populations (Bryant 2005; Rothbaum and Schwartz 2002), it is reported that some clients are unwilling or unable to effectively visualize the traumatic event (Difede and Hoffman 2002). This is a crucial concern since avoidance of cues and reminders of the trauma is one of the cardinal symptoms of the DSM 5 (American Psychiatric Association 2012) 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 et al. 1998). Similar to its use in treating specific phobias, the rationale for using VR as a tool to deliver PE for PTSD is straightforward. Clients can be immersed in simulations of trauma-relevant environments in which the emotional intensity of the scenes can be precisely controlled by the clinician to customize the pace and relevance of the exposure for the individual client. In this fashion, VRE offers a way to circumvent the natural avoidance tendency by directly delivering multi-sensory and context-relevant scenes and cues that aid in the retrieval, confrontation, and processing of traumatic experiences.

The first effort to apply VRE for PTSD 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 4-r criteria for PTSD (Rothbaum and Hodges 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.

The Implementation of VRE Therapy for PTSD: Technical Development

Development of the Virtual Iraq/Afghanistan VRE System

In anticipation of the impending military behavioral health needs, the USC Institute for Creative Technologies developed an initial prototype Virtual Iraq VRE system in 2004 for running initial user tests to determine feasibility. This

was followed by the creation of a full Virtual Iraq/Afghanistan VRE system developed during 2005–2007, funded by the U.S. Office of Naval Research. This early version system was the product of both theory-driven design and iterative user-centered feedback cycles with OEF/OIF service members to maximize its ultimate relevance for clinical users. Pre-clinical user-testing was conducted at Ft. Lewis, Washington and within an Army Combat Stress Control Team in Iraq (Reger et al. 2009). This feedback from non-diagnosed SMs (and later by clinical users) has provided essential input for an iterative design process that has served to continuously evolve the content and usability of the clinical VRE system to the current day.

The 2007 system consisted of four customizable scenarios designed to represent relevant contexts for VRE: three Humvee driving scenarios within Iraq, Afghanistan and USA-themed settings and a 24-block middle-eastern city that was navigable in a dismounted patrol format. General navigation for driving used a standard game pad and when interacting in the dismounted foot patrol, a thumb mouse affixed to a user-held mock M4 gun supported travel. The visual stimuli presented within an orientation-tracked *Emagin Z-800* head mounted display (HMD). Directional 3D audio, vibrotactile and olfactory stimuli of relevance could also be delivered to users. Such stimuli could be controlled and modified in real time by the clinician via a separate "Wizard of Oz"-type clinician interface. This interface is a key feature that allows clinicians to customize the therapy experience to the individual needs of the client. Using the interface, clinicians can place users in various VR scenario locations that resemble the settings in which the client's trauma-relevant events had occurred. Ambient lighting and sound conditions can be modified to match the client's description of their experience and the clinician can then gradually introduce and control real time trigger stimuli (e.g., gunfire, explosions, insurgent attacks, etc.). This level of clinician control is required to foster the anxiety modulation needed for therapeutic exposure and emotional processing in a fashion customized to the client's past experience and treatment progress. The use of a VR HMD to immerse the user within these controlled stimulus environments is believed to help support user engagement with typically avoided trauma-relevant experiences as required to activate the emotions needed for therapeutic exposure to occur. This system was been disseminated to over 60 early-adopter clinical sites (e.g., VA Medical Centers, military, university and private clinics) for use as a tool to deliver PE and to collect outcome data as to its effectiveness.

In 2011, the U.S. Army funded the development of an updated and expanded version of Virtual Iraq/Afghanistan system. Now referred to as *BRAVEMIND*, one of the primary goals for this effort was to increase the diversity of the VR scenario content and improve the customizability of stimulus delivery to better address the needs of clinical users who have had a diverse range of trauma experiences. This effort was supported by drawing on the vast amount of user feedback generated from both clients' and clinicians' feedback from use of the previous 2007 VRE system. The system was rebuilt from the ground up using the state-of-the-art current software. The four original 2007 environments have been completely rebuilt and ten additional scenarios have been added for a total of 14, including: separate Iraq and Afghanistan cities, a rural Afghan village, an industrial zone, a roadway checkpoint, slum and high-end residential areas, a mountainous forward operating base, and a Bagram Air Force Base setting. New features include selectable Humvee/MRAP/Helicopter vehicles, vehicle-to-foot patrol transitioning, expanded weather and time of day controls, customizable sound trigger profiles, and an updated clinical interface designed with clinician feedback to enhance usability. The system was also designed to use off the shelf components with the aim to reduce equipment costs to under $5000 and a detailed equipment/software manual is available from the first author.

Development of the World Trade Center VRE System

In the months immediately following the World Trade Center attacks, a collaboration between Dr. JoAnn Difede at Weill Cornell Medical College and Dr. Hunter Hoffman of the Human Interface Technology Laboratory at University of Washington set out to develop a virtual reality environment and protocol that would address the needs of the anticipated thousands of disaster workers and civilians who would develop PTSD related to 9/11. This early virtual setup utilized MultiGen-Paradigm Inc. Vega VR software coupled with a 1024 $\times$ 768 resolution Kaiser XL-50 VR helmet, with 40° horizontal field of view. Users viewed the virtual environment through two goggle-sized miniature LCD computer screens embedded in the helmet. Immersion in the environment was enhanced by the use of the Polhemus^{TM} Fastrak position tracking system, which tracked the movement and position of the user's head. Thus as the users turned their heads in the environment, their visual field would change, displaying different city blocks and buildings.

The World Trade Center virtual environment was designed to enable the therapist to introduce progressively more intense and detailed stimuli with the push of a button. Visual stimuli mirrored the actual landscape of lower Manhattan and simulated the events of that day. Auditory stimuli were based upon audio recordings made by national

news networks. Throughout, the therapist observed the same stimuli as the participant on a computer monitor. The user began in downtown New York City on a sunny day with a clear view of the towers. At the therapist's touch of pre-programmed computer keys, an airplane could fly by or into the towers. Progressively more detailed scenes would approximate the events of September 11th, including planes hitting the North and South towers with sounds of explosions, the towers burning accompanied by falling debris and screams, distant avatars in the towers and falling from them, and finally the collapse of each of the towers followed by blinding dust clouds. Clients would describe their experiences on the day of 9/11, as visual and audio stimuli would be introduced to match their experiences. Guidelines in the treatment protocol detailed a graded hierarchical exposure such that clients would progress in the intensity of stimuli only once they showed a significant reduction in distress to the existing sensory experience. This was carefully constructed to prevent overwhelming the client and to follow the principals of graded exposure therapy utilized in other exposure treatments.

Research Outcomes

Initial positive results were reported in a case study by Difede and Hoffman (2002) for PTSD related to the terrorist attack on the World Trade Center (WTC) using VRE with a client who had failed to improve with traditional imaginal exposure therapy. The authors reported a 90 % reduction in PTSD symptoms as measured by the "gold standard" Clinician Administered PTSD Scale (CAPS), and an 83 % reduction in depressive symptomatology as measured by the Beck Depression Inventory (Beck et al. 1988). This research group later reported positive results from a wait-list controlled study using the same WTC VR application (Difede et al. 2007). The VR group demonstrated statistically and clinically significant decreases on the 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 ten 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 clients who had previously participated in imaginal PE with no clinical benefit, showed a 25–50 % improvement following VRE.

Initial clinical tests of the Virtual Iraq/Afghanistan system also produced promising results. Three early case studies reported positive results using this system (Gerardi et al. 2008; Reger and Gahm 2008; Rizzo et al. 2007). In the first open clinical trial, analyses of 20 active duty treatment completers produced positive clinical outcomes (Rizzo et al. 2010). For this sample, mean pre/post PCL-M (Blanchard et al. 1996) 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 ($t = 5.99$, $df = 19$, $p < .001$) and 16 of the 20 completers no longer met PCL-M criteria for PTSD at post treatment. Mean Beck Anxiety Inventory (Beck et al. 1988) scores significantly decreased 33 % from 18.6 (SD = 9.5) to 11.9 (SD = 13.6), ($t = 3.37$, $df = 19$, $p < .003$) and mean PHQ-9 (Kroenke and Spitzer 2002) depression scores decreased 49 % from 13.3 (SD = 5.4) to 7.1 (SD = 6.7), ($t = 3.68$, $df = 19$, $p < .002$). These improvements were also maintained at three-month post-treatment follow-up.

Other reports have also indicated positive outcomes including an open clinical trial with active duty soldiers ($n = 24$) which 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 seven sessions, 45 % of those treated no longer screened positive for PTSD and 62 % had reliably improved. In a small preliminary quasi-randomized controlled trial (Mclay et al. 2011) 7 of 10 participants with PTSD showed a 30 % or greater improvement with VR, while only 1 of 9 participants in a "treatment as usual" group showed similar improvement. The results are limited by small size, lack of blinding, a single therapist, and comparison to a set relatively uncontrolled usual care conditions, but it did add to the incremental evidence suggesting VR to be a safe and effective treatment for combat-related PTSD.

The overall trend of these positive findings (in the absence of any reports of negative findings) is encouraging for the view that VRE is safe and may be an effective approach for delivering an evidence-based treatment (PE) for PTSD. Three randomized controlled trials (RCTs) are currently ongoing using the Virtual Iraq/Afghanistan system with SMs and Veteran populations. One RCT is focusing on comparisons of treatment efficacy between VRE and imaginal PE (Reger and Gahm 2010) and another is testing VRE compared with VRE + a supplemental care approach (Beidel et al. 2010). Another RCT is investigating the additive value of supplementing VRE and PE with a cognitive enhancer called D-cycloserine (DCS) (Difede et al. 2010). DCS, an *N*-methyl-D-aspartate partial agonist, has been shown to facilitate extinction learning in laboratory animals when infused bilaterally within the amygdala ("fight or flight" conditioning center in the brain) prior to extinction training. Recent evidence of both VRE and DCS effectiveness has been reported by Difede et al. (2013) in a clinical trial with WTC PTSD clients. In a double-blinded controlled comparison between VRE + DCS and VRE + Placebo, both groups had clinically meaningful

and statistically significant positive outcomes with the DCS group achieving equivalent gains with fewer sessions. Significant funding support for these RCTs underscore the interest that the DOD/VA has in exploring this innovative approach for delivering PE using VR.

The Implementation of VRE for PTSD: Clinical Delivery

General VRE Treatment Procedures

The VRE treatment procedure follows the standard evidence-based protocol for "imagination-only" PE therapy (Foa et al. 2007) and consists of weekly, 90–120 min individualized and client-driven sessions over 10 weeks. During the first session, the clinician generally aims to develop a working therapeutic alliance with the client as is standard for most clinical approaches. The clinician may attempt to identify and discuss some of the client's trauma experiences, provide psychoeducation on trauma and PTSD, and present instruction on a deep breathing technique for general stress management purposes. The second session follows up on topics from session 1 as needed and then focuses on providing the client with a clear explanation and rationale for PE. In some cases, the client is engaged in light practice with imaginal exposure that focuses on less provocative elements of their trauma experience. In session 3 the rationale for VRE is introduced and the client is encouraged to explore a personally relevant area of the simulation environment without recounting any trauma narrative for approximately 25 min, with no provocative trigger stimuli introduced. The purpose of this is to allow the participant to learn how to navigate the system, and to function as a "bridge session" from imaginal alone to imaginal exposure combined with VRE. Sessions four through ten is when the VRE proper is conducted with the participant engaging in the VR while verbally recounting the trauma narrative. The treatment also includes homework, such as requesting the participant to listen to an audiotape of their exposure narrative from the most recent session and in vivo exposure activities for processing the trauma outside of the treatment setting. Assessment of PTSD status is typically done with a combination of self-report symptom questionnaires, structured interview methods, and sometimes active psychophysiological reactivity tests. A more detailed description of this system, PTSD assessment procedures, and the methodology for a standard VRE clinical protocol can be found elsewhere (Rothbaum et al. 2008).

Virtual Iraq/Afghanistan Case Study

John was a 30 year old Army veteran of the war in Iraq. He deployed twice during his military service, and had been home for 3 years at the time of treatment. John was married with a young child, and attending school to learn a trade. He reported experiencing intrusive thoughts, especially at night when trying to fall asleep, nightmares, very strong startle reaction to any loud or unpredictable noise, irritable mood, impatience with a "short fuse", and tension and distance in his marriage. He also had some difficulty with concentration in school, and described being easily angered by the comments of fellow students who he saw as "clueless", sometimes resulting in him having to leave class. John was very avoidant of any situation he perceived as dangerous, such as being in crowds, and only attended mandatory events such as classes. He also kept a weapon at home, and was extremely vigilant when night fell. He acknowledged drinking too much, as he reported that it was the only thing that helped him stop thinking about events in Iraq and allowed him to eventually fall asleep. He reported being tired of hearing family and friends tell him that they are worried about him and that he is not the guy he was before he deployed. He came to treatment with the understanding that he needed to do something to keep his marriage intact, although he was ambivalent about the relationship, stating, "I just don't seem to care". He reported that he doesn't engage much with his daughter, and that he did feel bad about that.

During the first session, John's symptoms of PTSD and their impact on his life were discussed, and the rationale for exposure therapy was explained, along with a description of the immersive nature of VRE therapy. John was also taught a breathing/relaxation technique to use between sessions. He was asked to identify and describe his index (most distressing) trauma in detail, in order to prepare for the VR therapy to follow. John had not spoken about the event previously, and was wary of doing so, but managed to follow through. The identified event occurred while John was driving the lead Humvee vehicle in a convoy going through a city area of Iraq, late in the afternoon on a sunny day. John described noticing the people on the street starting to thin out as he drove, and then an insurgent holding an AK-47 suddenly coming around a corner up ahead, holding a young woman in front of him as a shield. John kept driving, yelled out to alert others in the vehicle, hesitated briefly, and then shot the insurgent, also killing the woman. He recalled looking in his side view mirror as he drove, and seeing her lying on the street, receding in his view. The therapist later matched the most appropriate VR scenario and available cues to John's reported traumatic event.

John began the VRE seated in the Humvee driver position, feeling the vibration under his feet and using the controller to drive ahead down a Baghdad-like city street. Humvee radio sounds were introduced, and John described his thoughts and feelings in the first person as he moved down the street (for example, beginning to suspect

something was wrong as the crowd thinned out, feeling a sense of apprehension and feeling his heart start to pound). He then described the sudden appearance of the insurgent, and this image was introduced. John continued to describe his experience of disbelief and then his training "kicking in" as he took action, simultaneously making a split-second decision around saving the hostage and taking the chance that the insurgent (and possible accomplices) would then take out the following trucks in the convoy, vs. eliminating the threat. The sound of John's weapon was also introduced into the VR scenario. John's subjective units of distress (SUDS) ratings were monitored via a self-reported 1–100 level scale throughout his repeated recounting of the event. After going through the event multiple times, John then processed the experience, expressing exhaustion, surprise at all of the details he remembered as he went through the repetitions, and commenting on the realistic nature of the virtual environment leading him to feel as if he was "there, but safe here".

Subsequent sessions focusing in on the "hot spots" of the memory allowed John to put the event in context, identify emotional reactions which were put aside out of necessity at the time, and realizing the complexity of the "no-win" situation he was placed in. He was able to both express and feel sorrow over the loss of an innocent life, and to acknowledge all of the factors which came together at that moment which were not in his control, especially the decision of the insurgent to place the woman's life in such grave danger. As he progressed in treatment, John was able to acknowledge the fact that his decision likely resulted in the saving of lives, and that he had done the best that he could in that moment. He began to talk with his wife about what was happening in treatment, and reported that she was feeling more included and more able to understand some of what he had been through. John also noticed a softening of feelings toward his daughter, which pleased him. Additionally John reported improvement in his ability to sleep without nightmares waking him, and began challenging some of his fears around going to restaurants, movies, etc. At follow-up, John's symptoms continued to decrease in frequency and intensity, and he reported improved ability to be comfortable in public situations.

Virtual World Trade Center Case Report

David was a 45 year-old firefighter who first sought treatment for PTSD 5 years after the World Trade Center attacks. David had just gone through a divorce and had shared custody of his son who was experiencing significant issues in school himself. David was still working with the fire department but was in trouble with superiors for his verbal explosiveness and for breaking protocols and putting himself in danger more than once. The threat of potential dismissal spurred him to pursue treatment which he had avoided until that point because, as he stated, "I help other people, I don't ask for help." Though he had experienced numerous traumas throughout the course of his career, David identified the index trauma of 9/11 as "the one that just broke me". He met criteria for PTSD related to the attacks of 9/11 as well as a comorbid Major Depressive Disorder. An assessment of daily activity revealed that David took numerous work shifts, spending as many hours at the job as his superiors would allow, but was otherwise socially isolated and avoided family and friends. He reported nightmares daily and avoided sleep as much as possible since his dreams were so unpleasant. Content of the nightmares alternated between individuals who died on 9/11 blaming him for not helping them, and watching his own loved ones in danger. Other prominent symptoms included frequent intrusive thoughts, avoidance of thoughts, feelings, and reminders of the trauma, emotional numbing, anhedonia, feelings of detachment, and increased startle and hypervigilance.

David had never revealed the details of his trauma experience to others, and he successfully removed himself emotionally from the retelling when describing the event during the assessment. On September 11, he had responded to the attacks immediately, arriving at the buildings soon after the second plane had collided with the South Tower. He stood frozen at the devastation and the sight of individuals hanging from windows and jumping from the buildings. The North Tower collapsed as he was preparing to enter and he ran for his life, choking on the debris and dust and finally jumping beneath a vehicle. David described the moments when he realized the devastating loss of life that was occurring and how many of his firefighter brethren had died. He did not return home for days after 9/11 and only after being forced by his superiors to do so. Still, he returned to the site soon after and spent weeks digging there. David's composure broke as he described some of the sights he saw when working on "the pile." The bodies or body parts and the personal items that gave glimpses into the lives of those who had died left indelible marks in his memory. He left Ground Zero for short periods of time, often to go to funerals or wakes, of which he attended dozens. David blamed himself for not doing enough to save people on that day and for not running into the towers like so many others. The fact that he was alive served as a constant reminder to him of his failure to help. At the same time he faulted himself for the destruction of his family, for ignoring them during this difficult time, for bringing the ugliness home when he did return, and for in essence, causing them to lose a husband and father on that day as well.

A treatment plan was set with an emphasis on the use of exposure therapy with the virtual WTC environment. David was notably moved during his first immersion in the environment. He commented on the blueness of the sky, "It really was that blue" and began narrating his experience on that day.

Over the course of ten sessions, David told his experience repeatedly. By the third exposure session, he began to work on "hot spots"—identifying the most intense parts of his experience and focusing on them individually and repeatedly. David was very engaged in the exposure exercise, weeping openly as he spoke about the loss of life and the fear of losing his own. He slowly progressed through the virtual reality sequences. In initial sessions he narrated his event while simply looking at the towers from a distance without auditory stimuli. As he habituated to stimuli, the therapist began to match the elements of his experience more closely. He was placed in the virtual environment at closer proximity to the towers as he had been on that day, and auditory and visual elements were added to reflect his experience. The towers were shown with gaping holes in flames, accompanied by sounds of screams and fear. As he described seeing the South Tower collapse, the virtual environment displayed the South Tower crumbling, accompanied by the rumbling sound, as he was virtually overrun by the dust cloud. Slowly he habituated to each of the sensory elements as well. Processing of the event was conducted after each exposure exercise and focused on his grief and guilt. Over time David began to display habituation to the retellings of the events. He was able to describe his experience with significantly less overwhelming emotion. He began to express a realization that there was simply no right way to deal with this horrible situation. He began to replace his thoughts of "I should have saved people" to "I wish I could have saved people but the situation did not allow for it". He was able to forgive missteps with his family and recognize he was a fallible person in a difficult situation.

As treatment end approached, David reported that he felt as if a load had been lifted off his shoulders. By telling his experience and habituating to the details, the event became a tragedy that saddened him, rather than an event that defined his life and made him feel overwhelmed by emotion. He began to engage more with those around him, both physically and emotionally, especially his son. He increased his level of activity outside of work and reported slowly gaining enjoyment from these efforts. His nightmares decreased significantly, and he no longer avoided reminders of the trauma. David began to look forward to a future instead of focusing on the past. Though he knew he would always be changed by his experience on 9/11, David reported that through treatment he had learned not to live in the shadow of the trauma, defined by his symptoms from it, but to embrace life and look to the future.

Conclusions

Interest in using VR technology to deliver exposure therapy for PTSD has grown in recent years as positive outcomes have been reported with its initial implementation. When clinicians were surveyed as to interventions predicted to increase in the next decade, VR ranked 4th out of 45 options with other computer-supported methods occupying four out of the top five positions (Norcross et al. 2013). VR for exposure-based treatment may have particular appeal to clinicians in that it uses the latest advances in human–computer interaction to deliver consistent, controllable, and immersive trauma-relevant stimulus environments that do not rely exclusively on the variable nature and ultimately hidden world of a client's imagination. VR also provides an objective and consistent format for documenting the sensory stimuli that the client is exposed to that can be precisely linked to physiological and self-reported reactions for treatment documentation and research. In addition to these functional stimulus/response quantification assets, the use of VR as a PE delivery system may also be found to break down barriers to care by improving treatment appeal, acceptability and adherence by those in need of care. The current generation of young military SMs and veterans, many having grown up with digital gaming technology, may be more attracted to and comfortable with participation in a VR therapy approach (Wilson et al. 2008) and this could lead to increased accessing of care by those in need. Thus, more research is needed to determine if VRE is perceived with less stigma by "digital generation" SMs and Veterans relative to what they perceive as traditional talk therapies.

While it can be said that VR simply provides a novel and engaging mechanism for delivering an already endorsed, evidence-based approach (CBT with exposure), more research is needed to provide scientific support for that claim. Although the current state of the literature is promising (especially with the solid evidence for VRE effectiveness in the treatment of specific phobias), the existing research for VRE therapy with PTSD provides only preliminary evidence for its efficacy. Positive results from three published case reports, two open trials, two waitlist controlled studies and one small RCT have formed the initial basis for support thus far, but RCTs with larger sample-sizes are still needed to provide confirmatory evidence for the efficacy of VRE with PTSD. As well, it will be important to conduct dismantling studies to better specify what elements of VRE are crucial for differentiating VRE from standard CBT exposure approaches, for improving the treatment, and for providing a better understanding of the mechanisms that may predict who this treatment may appeal to and who will benefit from it. Subject variables including gender, age, video game experience, number of deployments, and past trauma history may provide useful covariates to support better prediction as to who might benefit from what form of exposure. As well, research on variations from the standard protocol delivery of VRE in terms of the frequency and duration of

sessions, the additive value of multisensory stimuli—i.e., olfaction, and the addition of pharmacological agents (D-cycloserine) or CNS focused procedures (vagal nerve stimulation), could also be usefully studied for their impact on treatment outcomes within the controlled stimulus environment that a VR simulation provides. Such clinical research efforts are now more feasible, with the rapid advances in the technology that have driven the recent availability of off-the-shelf VR equipment that is cheaper, less complex and of higher quality than what was available just two years ago. Thus, it is likely that VRE interventions for PTSD will continue to drive novel research and address the significant clinical and social welfare challenges that exist with those who suffer from the experience of trauma. For an extensive collection of videos on this project (simulation videos, patient interviews, media reports) the reader is directed to: http://www.youtube.com/watch?v=2wmM2aCZ3JA&list=PLMuMO5eoYy_BDmAfZrFSLBLlniAtvAdad.

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