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Chapter 14

USING VIRTUAL REALITY FOR CLINICAL ASSESSMENT AND INTERVENTION

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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 three fundamental areas where Clinical VR has shown significant potential to enhance clinical practice and research (Exposure Therapy, Neuropsychological Assessment and Clinical Training with Virtual Patient agents). At the end of each of these sections, a detailed use-case will be presented. 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 possibilities, while casting a blind eye to the pragmatic challenges that exist for building useful and usable applications.

The goal of this chapter is to present a clear rationale for VR use across diverse areas of clinical practice and present examples of how this has been done successfully. While significant work has been done in other areas of Clinical VR (e.g. pain distraction, eating disorders, motor rehabilitation, etc.), a full treatment of such a broad literature is beyond the scope of this chapter. Thus, we have opted to provide more depth on specific clinical areas

where VR has been applied to address Anxiety Disorders with exposure therapy, neuropsychological assessment and new visionary work developing virtual humans to serve the role of virtual standardized patients for clinical training.

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 possible using previously available 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, 2008a; Parsons, Rizzo, Rogers, and York, 2009; Powers and Emmelkamp, 2008; Rizzo et al., 2004; Rizzo and Kim, 2005; Rizzo et al., 2011abc) Rose, Brooks and Rizzo, 2005; Riva, 2011). 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 (Rothbaum et al., 2001; Difede et al., 2002, 2007; Rizzo et al., 2010ab, 2011b), 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 (Stanton et al., 1998; Rizzo et al., 2004), functional skill training and motor rehabilitation with patients having central nervous system dysfunction (e.g., stroke, TBI, SCI, cerebral palsy, multiple sclerosis, 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 (Brooks et al., 1999; Brown et al., 1998; Matheis et al., 2005; Pugnetti et al., 1995; 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 research and development is also producing artificially intelligent virtual human patients that are being used to train clinical skills to

health professionals (Kenny et al., 2010; Parsons et al., 2008b; Rizzo et al., in press; Lok et al., 2007).

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 healthcare issues and clinical disorders. 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. 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.

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.

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 habituation, graduated exposure to feared or trauma-relevant stimuli can be delivered systematically in VR. As well, rather than try to predict real world functional performance from a decontextualized measure of attention when assessing children suspected of having ADHD, one can look at the effects of systematically increasing ecologically relevant attentional demands in a virtual environment, such as a classroom, social setting or home. These examples illustrate how VR technology can be used to provide exquisite timing and control over context-relevant imagery and stimulus load/complexity, all of which can be manipulated in a dynamic fashion contingent on the needs and responses of the client or research participant. Within such VEs, human performance can be digitally captured in real time in support of a precise and detailed analysis of relevant responses in relation to systematic stimulus presentations. In this regard, VR can be seen as capable of producing the "ultimate Skinner Box" for conducting human research, assessment and intervention.

Revolutionary advances in the underlying VR enabling technologies (i.e., computation speed and power, graphics and image rendering software, display systems, interface devices,

immersive audio, haptics tools, wireless tracking, voice recognition, intelligent agents, and authoring software) have supported the creation of low-cost and usable VR systems capable of running on a commodity level personal computer. Such advances in technological "prowess" and accessibility have provided the hardware platforms needed for the conduct of human research and clinical intervention within more usable and useful VR scenarios. This convergence of the exponential advances in underlying VR enabling technologies with a growing body of clinical research and experience has fueled the evolution of the discipline of *Clinical Virtual Reality*. This has now supported the emergence of accessible VR systems that can uniquely target a wide range of psychological, cognitive and physical clinical targets and research questions.

This is in sharp contrast to what was possible in the mid-1990s when discussion of the potential for VR applications in the clinical assessment and intervention domains first emerged (Pugnetti, Mendozzi, Motta, Cattaneo, Barbieri, and Brancotti, 1995; Rizzo, 1994; Rose, Attree and Johnson, 1996). At that point in time, the technology to deliver on the anticipated VR "vision" was not in place. Consequently, during these early years, VR suffered from a somewhat imbalanced "expectation-to-delivery" ratio, as most users who eagerly lined up to try such systems during that time will attest. The "real" thing never quite measured up to expectations generated by some of the initial media hype, as delivered for example in the films "*The Lawnmower Man*" and "*Disclosure*"! Yet the idea of producing simulated virtual environments that allowed for the systematic delivery of ecologically relevant challenges was compelling and made intuitive sense. As well, the long and rich history of encouraging findings from the predecessor literature in aviation simulation (Hays et al., 1992) lent support to the concept that testing, training and treatment in highly proceduralized VR simulation environments would be a useful direction for clinical disciplines to explore (Johnston, 1995; Rizzo, 1994). Within this context, a small group of innovative clinicians and researchers also began the initial work of exploring the use of VR technology for applications designed to treat simple phobias (Hodges et al., 1995; Lamson, 1994; Rothbaum et al., 1995), while others addressed cognitive/functional performance in populations with central nervous system dysfunction (Brown et al., 1998; Pugnetti et al., 1995; Rizzo, 1994; Rose et al., 1996). While a good deal of this early work employed the costly, cumbersome, low resolution VR head mounted displays (HMDs) that were available at the time or simply used flatscreen monitors or stereoscopic projection approaches, these systems began to produce encouraging results (Cromby et al., 1996; Rizzo et al., 1998; Rose et al., 2000; Stanton et al., 1998). From these nascent efforts, findings emerged that began to demonstrate the unique value of the technology, served to inform ideas for future applications and created a grassroots level of enthusiasm for using VR that has continued grow and be supported into the present day. However, now instead of having to rely on $200,000 graphic workstations (and other expensive peripheral technologies) that were required back in 1990's, clinicians and researchers in the 21st century can now create and deliver compelling virtual worlds using a standard laptop and a $1500 HMD or stereo television. The technology has now caught up with the vision and such exponential advances are expected to continue to advance the science and practice in the discipline of Clinical VR.

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" haptic/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).

The use of such ubiquitous display and interface devices has promoted widespread access to this form of non-immersive interactive media, primarily in the domain of entertainment. Moreover, researchers have investigated the value and usability of commercially available interaction devices and methods that can be used with flatscreen-delivered VEs that can allow users to interact with digital content using more naturalistic body actions beyond what is possible with traditional game interfaces (e.g. *Konami Dance Dance Revolution, Sony Eyetoy, Nintendo Wii, Novint Falcon, Microsoft Kinect*, etc.) (Lange et al., 2009, 2010). Regardless of the hardware and display format, the capacity of VR technology to create controllable, multisensory, interactive 3D stimulus environments, within which human performance can be motivated, captured and measured, offers clinical and research options that are not possible using traditional methods.

The following sections of this chapter will detail the history, rationales and key research for Clinical VR application in three areas: 1) Exposure therapy for Anxiety Disorders; 2) Neuropsychological Assessment for Central Nervous System (CNS) dysfunction; and 3) Virtual Patients for Clinical Training. The VR Exposure therapy and Neuropsychological areas were selected based on the consistent evolution of the research and the growing clinical adoption of applications in these areas. The Virtual Patients area, although in a nascent stage of development, was selected based on its estimated potential for future growth and clinical impact by the authors. At the end of each section, use-cases are presented of applications from our lab that illustrate the process for design, development and evaluation of a system in each of the outlined areas. While significant VR research and development activity is ongoing in the areas of substance abuse, eating disorders, pain distraction, social skills training, game-based cognitive and motor rehabilitation, etc., it was necessary to constrain the scope of what could presented with sufficient detail within the available page limitations for this chapter.

EXPOSURE THERAPY

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 posits 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, indicating 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.

VR has also been applied as a method for delivering for 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, 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. Such initial results are encouraging and suggest that VR may be a useful component within a comprehensive treatment approach for persons with combat/terrorist attack-related PTSD. *For more information, see the Virtual World Trade Center video at*: http://www.youtube.com/watch?v=XAR9QDwBILc

Use Case: 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 junk. Access to building interiors and rooftops is available and the backdrop surrounding the navigable exposure zone creates the illusion of being embedded within a section of a sprawling densely populated desert city.

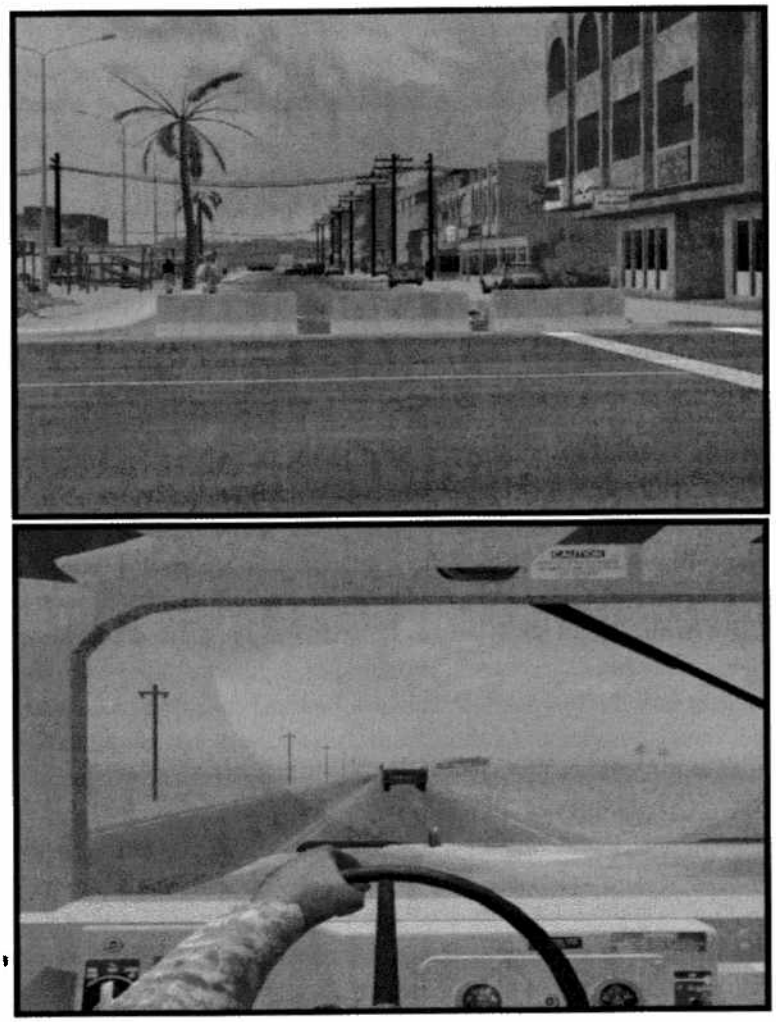


Figure 15.1. Scene from *Virtual Iraq/Afghanistan* City and Desert Road HUMVEE scenarios.

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, a checkpoint, debris 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).

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, motors, city noise, prayer call, etc.). Users can navigate in both scenarios via the use of a standard gamepad controller, although the option for use of a 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 the VR scenarios. It is our firm belief that the principles of exposure therapy are incompatible with the cathartic acting out of a revenge fantasy that a responsive weapon might encourage.

In addition to the visual stimuli presented in the VR Head-Mounted Display (HMD), directional 3D audio, vibrotactile and olfactory stimuli can be delivered into the *Virtual Iraq* scenarios in real-time by the clinician. The presentation of additive, combat-relevant stimuli into the VR scenarios can be controlled in real time via a separate "Wizard of Oz" clinician's interface, while the clinician is in full audio contact with the patient. The clinician's interface is a key feature that provides a clinician with the capacity to customize the therapy experience to the individual needs of the patient. This interface allows a clinician to place the patient in VR scenario locations that resemble the setting in which the trauma-relevant events occurred and ambient light and sound conditions can be modified to match the patients description of their experience. The clinician can then gradually introduce and control real time trigger stimuli (visual, auditory, olfactory and tactile), via the clinician's interface, as required to foster the anxiety modulation needed for therapeutic habituation and emotional processing in a customized fashion according to the patient's past experience and treatment progress. The clinician's interface options have been designed with the aid of feedback from clinicians with the goal to provide a usable and flexible control panel system for conducting thoughtfully administered exposure therapy that can be readily customized to address the individual needs of the patient. Such options for real time stimulus delivery flexibility and user experience customization are key elements for these types of VR exposure therapy applications.

The specification, creation and addition of trigger stimulus options into the *Virtual Iraq* system has been an evolving process throughout the development of the application based on continually solicited patient and clinician feedback. 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 began our initial effort to conceptualize what was both functionally relevant and technically possible to include as trigger stimuli.

Currently the 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. Clinicians can also similarly trigger dynamic audiovisual events such as helicopter flyovers, bridge attacks, exploding vehicles and IEDs. The creation of more complex events that can be intuitively delivered in *Virtual Iraq/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 the second one displays the actual simulation scenes that is presented to the user in their head-mounted display (HMD) as they navigate using an interface (gamepad or gun controller). The HMD that was chosen was the *eMagin z800*, with displays capable of 800x600 resolution within a 40-degree diagonal field of view (http://www.emagin.com/). The major selling point for using this HMD was the presence of a built-in head tracking system. At under $1500 per unit with built-in head tracking, this integrated display/tracking solution was viewed as the best option to minimize costs and maximize the access to this system. The simulation's real-time 3D scenes are presented using Emergent's *Gamebryo* rendering engine. Pre-existing art assets were integrated using *Alias' Maya 6* and *AutoDesk 3D Studio Max 7* with new art created primarily in *Maya*.

Olfactory and tactile stimuli can 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. As well, these same features have broadened the applicability of *Virtual Iraq* as a research tool for studies that require systematic control of stimulus presentation within combat relevant environments (Rizzo et al., 2012). A direct link to a *YouTube* channel with videos that illustrate features of this system and of former patients discussing their experience with the VRET approach can be found at: http://www.youtube.com/user/AlbertSkipRizzo

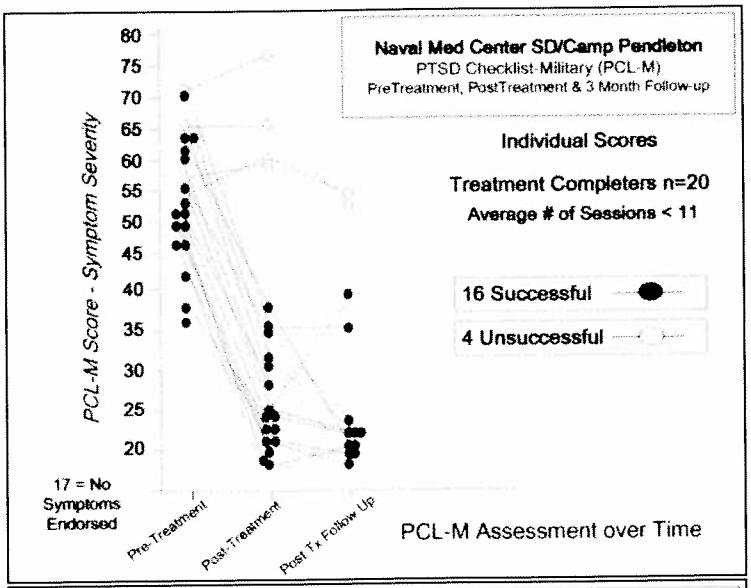
The *Virtual Iraq/Afghanistan* system was designed and built from a user-centered design process that involved feedback from active duty SMs and veterans that began with solicited responses to the initial prototype. User-centered design feedback needed to iteratively evolve the system was gathered from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

The Office of Naval Research, who 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 recently redeployed from Iraq/Afghanistan at the Naval Medical Center San Diego and at Camp Pendleton and had engaged in previous PTSD treatments (e.g., group counseling, EMDR, medication, 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 clinician to help inform their pacing of the VRET.

The first VRET session consisted of a clinical interview that identified the index trauma, provided psychoeducation on trauma and PTSD, and 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 with no provocative trigger stimuli introduced. Sessions 4-10 focused on the participant engaging in the VR while recounting the trauma narrative.

Generally, participants were instructed that they would be asked to recount their trauma in the first person, as if it were happening again with as much attention to sensory detail as they could provide. Using clinical judgment, the therapist might prompt the patient with

questions about their experience or provide encouraging remarks as deemed necessary to facilitate the recounting of the trauma narrative. The treatment included homework, such as requesting the participant to listen to the audiotape of their exposure narrative from the most recent session as a form of continual exposure for processing the index trauma to further enhance the probability for habituation to occur. Self-report measures were obtained at baseline and prior to sessions 3,5,7,9,10 and one week and three months post treatment to assess in-treatment and follow-up symptom status. The measures used were the PTSD Checklist-Military Version (PCL-M) (Blanchard et al., 1996), Beck Anxiety Inventory (BAI) (Beck et al., 1988) and Patient Health Questionnaire-Depression (PHQ-9) (Kroenke and Spitzer, 2002).



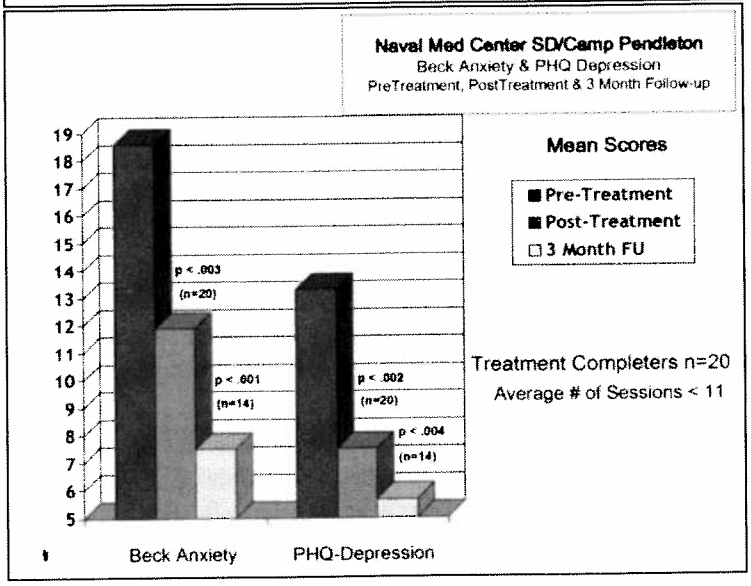


Figure 15.2. PCL-M scores across treatment Figure 15.3. BAI and PHQ-Depression scores.

Analyses of the first 20 active duty service members to complete treatment (19 male, 1 female, Mean Age=28, Age Range: 21-51) produced positive clinical outcomes. For this sample, mean pre/post PCL-M scores decreased in a statistical and clinically meaningful fashion; 54.4 (SD =9.7) to 35.6 (SD = 17.4). Paired pre/post t-test analysis showed these differences to be significant ($t=5.99$, $df=19$, $p < .001$). Correcting for the PCL-M no-symptom baseline of 17 indicated a greater than 50% decrease in symptoms and 16 of the 20 completers no longer met DSM criteria for PTSD at post treatment. Five participants in this group with PTSD diagnoses had pre-treatment baseline scores below the conservative cutoff value of 50 (pre-scores = 49, 46, 42, 36, 38) and reported decreased values at post treatment (post-scores = 23, 19, 22, 22, 24, respectively). Individual participant PCL-M scores at baseline, post treatment and 3-month follow-up are in Figure 2. 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 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.

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 and this will likely be an area of interest for some time to come.

Three randomized controlled trials (RCT) are ongoing with the *Virtual Iraq/Afghanistan* system with active duty and Veteran populations. Two RCTs are focusing on comparisons of treatment efficacy between VRET and imaginal PE, while the third RCT investigates the additive value of supplementing VRET and imaginal PE with a cognitive enhancer called D-

Cycloserine (DCS). DCS, a N-methyl-d-aspartate partial agonist, has been shown to facilitate extinction learning in laboratory animals when infused bilaterally within the 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 had significantly enhanced decreases in fear within the virtual environment 1 week and 3 months post-treatment, and reported significantly more improvement than the placebo group in their overall acrophobic symptoms at 3 month follow-up and on a psychophysiological measure of anxiety. The current multi-site PTSD RCT will test the effect of DCS vs. Placebo when added to VRET and PE with active duty and veteran samples (n=300).

This research has been supported by the relatively quick adoption of the VRET approach by approximately 55 Military, VA and University clinic sites over the last three years. Based on the outcomes from our initial open clinical trial and similar positive results from other research groups, we are encouraged by these early successes and continue to gather feedback from patients regarding the therapy and the *Virtual Iraq/Afghanistan* treatment environments. Patient feedback is particularly relevant now that the *Virtual Iraq/Afghanistan* project is undergoing a full rebuild using advanced software tools (*Unity 3D* Software) to provide more diversity of content and added functionality. In this regard, the new system has its design "roots" from feedback acquired from non-diagnosed SMs 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, and also for the use of the simulation for other purposes including PTSD and neurocognitive assessment, and for the creation of a stress resilience training system (Rizzo et al., 2011b; 2012).

Other research groups are also currently in the early stages of applying VR to treat PTSD in survivors of war and terrorist attacks (Gamito et al., 2007; Josman et al., 2006; Wood et al., 2008). One research group has reported "partial remission" of PTSD symptoms in four of six Iraq war SMs using VR combined with meditation and attentional refocusing (Wood et al., 2008). However, it is difficult to draw any conclusions from this work as the authors did not provide a clear specification or statistical analysis of the pre/post PTSD Checklist-Military version (PCL-M) scores other than to report a baseline PCL-M mean of 47.3, which is actually below the PTSD cutoff of fifty specified in Weathers et al. (1993). Another research group in Portugal, where there are an estimated 25,000 survivors with PTSD from their 1961-1974 colonial wars in Mozambique, Angola and Guiné, has constructed a VR exposure scenario by modifying a common PC-based combat game (Gamito et al., 2007). This group has reported an initial case study where the patient did not complete treatment due to experiencing a distressing flashback following the seventh session. While this is rarely reported in the exposure literature, this report highlights the need for well-trained clinicians with expertise in the delivery of exposure therapy at a rate that the patient can effectively handle and process and in the sensitive monitoring of patient status. Finally, in Israel, Josman et al. (2006) are implementing a VR terrorist "bus bombing" PTSD treatment scenario in which participants are positioned in an urban cafe across the street from a site where a civilian bus may explode.

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. Additionally, if one reviews the history of the impact of war on advances in clinical care it could be suggested that VR is an idea whose time has come. For example, during WW I, the Army Alpha/Beta test emerged from the need for better cognitive ability assessment and 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 "shellshock". Based on these examples, one of the outcomes of the OIF/OEF conflicts could be the military's support for research and development in the area of Clinical VR that could potentially drive increase recognition and use in the civilian sector. However, this will only occur if positive cost-effective outcomes are produced with military VRET applications. 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, they are not intended to be automated treatment protocols that are administered in a "self-help" format. The presentation of such emotionally evocative VR combat-related scenarios, while providing treatment options not possible until recently, will most likely produce therapeutic benefits when administered within the context of appropriate care via a thoughtful professional appreciation of the complexity and impact of these behavioral health challenges.

NEUROPSYCHOLOGICAL VR APPLICATIONS

In the broadest sense, neuropsychology is an applied science that evaluates how specific activities in the brain are expressed in observable behaviors (Lezak, 1995). Effective neuropsychological assessment (NA) is a prerequisite for both the scientific analysis and treatment of CNS-based cognitive/functional impairments as well as for research investigating normal functioning. The NA of persons with CNS disorders using psychometric evaluation tools serves a number of functions. These include the determination of a diagnosis, the provision of normative data on the status of impaired cognitive and functional abilities, the production of information for the design of rehabilitative strategies, and the measurement of treatment efficacy. NA also serves to create data for the scientific understanding of brain functioning through the examination of measurable sequelae that occur following brain damage or dysfunction.

Thus, treatment and rehabilitation of the cognitive, psychological and motoric sequelae of CNS dysfunction often relies on assessment devices to inform diagnosis and to track changes in clinical status. Typically, these assessments employ chapter and pencil psychometrics, hands-on analog tests, computer-delivered continuous performance tests, and observation/rating of behavior in real world functional environments (or within the context of physical mock-ups). On one end of the spectrum, traditional neuropsychological methods applied to impairment assessment and rehabilitation commonly use paper and pencil-based

psychometric tests. Although these approaches provide highly systematic control and delivery of constrained performance challenges, they have also been criticized as limited in the area of *ecological* validity, that is, the degree of relevance or similarity that a test or training system has relative to the "real" world, and in its value for predicting or improving "everyday" functioning (Neisser, 1978). Adherents of this view challenge the usefulness of constrained chapter and pencil tests and analog tasks for addressing the complex integrated functioning that is required for successful performance in the real world. On the other end of the spectrum, a common method applied in the occupational sciences discipline to assess and rehabilitate functional abilities employs behavioral observation and ratings of human performance in the "real-world" or via physical mock-ups of functional environments (Weiss and Jessel, 1998). Mock-ups of daily living environments (i.e., kitchens, bathrooms, etc.) and workspaces (i.e., offices, factory settings, etc.) are typically built, within which persons with cognitive impairments are observed while their performance is evaluated.

Aside from the real economic costs to physically build the environments and to provide human resources to conduct such evaluations, this approach is limited in the systematic control of real-world stimulus challenges and in its capacity to provide detailed performance data capture. As well, many functional environments in everyday life do not easily lend themselves to mock-ups, as is readily apparent in the domain of driving skill assessment and training. In this regard, "Behind-the-Wheel" driving assessments, considered to be the gold standard in this area, are often conducted in only the safest possible conditions (i.e., good weather, low traffic roadways, etc.), and actually provide a limited "window" into how driving performance would fare under more realistic (and often unpredictable) conditions.

Neuropsychology is where VR stands to have significant impact. While the last 15 years have seen the majority of VR research and clinical application occur in the area of exposure therapy, the considerable potential of VR for the study, assessment and rehabilitation of human cognitive and functional processes been also been recognized (Pugnetti, Mendozzi, Motta, et.al., 1995; Rizzo, 1994; Rizzo, Buckwalter and van der Zaag, 2002; Rizzo et al., 2004; Rose, 1996; Rose et al., 2005). Indeed, in a U.S. National Institute of Health report of the National Advisory Mental Health Council (1995), the impact of virtual reality environments on cognition was specifically cited with the recommendation that: "Research is needed to understand both the positive and negative effects of such participation on children's and adults' perceptual and cognitive skills..." (p.51). One area where the potential for both "positive and negative effects" exists, is in the application of VR for neuropsychological assessment, rehabilitation and research. In this regard, VR could serve to advance the study of brain/behavior relationships as well as produce innovative evaluation and intervention options that are unavailable with traditional methods.

What makes VR application development in this area so distinctively important is that it represents the potential for more than a simple linear extension of existing computer technology for human use. This was recognized early on in a visionary article ("The Experience Society") by VR pioneer, Myron Kruegar (1993), in his prophetic statement that, "...Virtual Reality arrives at a moment when computer technology in general is moving from automating the paradigms of the past, to creating new ones for the future". (p. 163). In this comment Krueger encapsulated what had also been so limited in neuropsychology's approach to using computer and information technology at that time and opened a conceptual door to VR's potential to advance neuropsychological research and practice. Indeed, neuropsychology's use of technology up to that time could be characterized as mainly translating existing

traditional chapter and pencil tools directly into computer delivered formats. In its defense, neuropsychology has been increasingly integrating advanced neural imaging technology tools (i.e., fMRI, DTI, SPECT, QUEEG, CT, etc.) in its quest for a better accounting of the structure and process underlying brain/behavior relationships. However, while these advances in *response* measurement have led to new findings and conceptualizations, the *stimulus* delivery end of the equation has lagged behind. By way of VRs capacity to place a person within an immersive, interactive computer generated simulation environment, new possibilities exist that go well beyond simply automating the delivery of existing chapter and pencil testing and training tools on a personal computer. VR offers the potential to fundamentally advance this area with innovative applications that leverage the immersive, involving and interactive assets available in VEs to deliver quantifiable analog-like stimulus protocols within the context of functionally relevant (and controllable) environments. Until now, these features have not been pragmatically available with existing methods in neuropsychology and thus VR may have plenty to offer in these vital and challenging areas.

A primary strength that VR offers assessment is in the creation of simulated "everyday" environments in which performance can be tested in systematic fashion. By designing VEs that not only *look like* the real world, but actually incorporate challenges that require integrated functional behaviors, the ecological validity of assessment methods could be enhanced. As well, within a VE, the experimental control required for rigorous scientific analysis and replication can still be maintained within simulated contexts that embody the complex challenges found in naturalistic settings. Thus, on a theoretical level, VR-derived results could have greater predictive validity and clinical relevance for the challenges that patients face in everyday life compared to chapter and pencil testing. On a more pragmatic level, rather than relying on costly physical mock-ups of functional assessment and rehabilitation environments, VR offers the option to produce and distribute identical "standard" simulation environments. Within such digital assessment (and rehabilitation) scenarios, normative data can be accumulated for performance comparisons in an automated fashion, needed for assessment/diagnosis and for treatment/rehabilitation purposes.

As well, a challenge to the conceptual growth of the field of psychometric testing methods was leveled in a 1997 *American Psychologist* article by intelligence theorist, Robert Sternberg (1997) in which he compared currently used intelligence and ability tests to black and white TV, rotary-dial phones, and the UNIVAC computer. His argument started by observing that the first edition of the most widely used intelligence test, the *Wechsler Adult Intelligence Scale* appeared in 1939, well before the UNIVAC. However, while computer and other information technology and telecommunication tools (i.e., TV, telephones, and sound recording) had undergone a revolution since then, with the exception of essentially cosmetic changes, tests of cognitive ability have remained essentially unchanged. Sternberg posited that "dynamic" interactive testing would be needed to provide a new option that could supplement traditional "static" tests. The "dynamic" assessment approach requires the provision of guided performance feedback as a component in tests that measure learning. This method appears well suited to the assets available with VR technology. In fact, VR might be the most efficient vehicle for conducting dynamic testing in an "ecologically valid" manner while still maintaining an acceptable level of experimental control.

Thus, it is possible that the use of VR technology could revolutionize our approach to NA. However, while encouraging on a theoretical level, the value of this technology for neuropsychology still needs to be substantiated via systematic empirical research with normal

and clinical populations that can be replicated by others. To accomplish this first requires specification as to the real assets that VR offers that add value over existing assessment methodologies, as well as further exploration of its current limitations. The current status of VR technology applied to clinical populations, while provocative, is still limited by the small (but growing) number of controlled studies in this area. This is to be expected, considering the technology's relatively recent development and the lack of familiarity with VR technology by established researchers employing the traditional tools and tactics of their fields. In spite of this, a nascent body of work has emerged which can provide knowledge for guiding future research efforts.

In the mid-90's, using graphic imagery that would be considered primitive by today's standards, Pugnetti et al. (1995,1998) developed a HMD-delivered VR scenario that embodied the cognitive challenges that characterize the Wisconsin Card Sorting Test (WCST). The scenario consisted of a virtual building within which users were required to use environmental clues to aid in the correct selection of appropriate doorways needed to pass from room to room through the structure. The doorway choices varied according to the categories of shape, color and number of portholes. Similar to the WCST, the correct choice criteria were changed after a fixed number of successful trials, and the user was then required to shift cognitive set, look for clues and devise a new choice strategy in order to successfully pass into the next room. In one study, Pugnetti et al. (1998) compared a mixed group of neurological patients (multiple sclerosis, stroke, and traumatic brain injury) with normals' performance on both the WCST and on this head mounted display executive function system. Results indicated that the VR results mirrored previous anecdotal observations by family members of everyday performance deficits in the patient populations. Though the psychometric properties of the VE task were comparable to the WCST in terms of gross differentiation of patients and controls, weak correlations between the two methods suggested that the methods measured different aspects of these functions. A detailed analysis of the VR task data indicated that specific preservative errors appeared earlier in the test sequence compared to the WCST. The authors suggested that "...this finding depends on the more complex (and complete) cognitive demands of the VE setting at the beginning of the test when perceptuomotor, visuospatial (orientation), memory, and conceptual aspects of the task need to be fully integrated into an efficient routine" (p.160). The detection of these early "integrative" difficulties for this complex cognitive function may be particularly relevant for the task of predicting real world capabilities from test results. This was further evidenced in a detailed single subject case study of a stroke patient using this system. In this report (Mendozzi, Motta, Barbieri, Alpini and Pugnetti, 1998), results indicated that the VR system was more accurate in identifying executive function deficits in a highly educated patient two years post-stroke, who had a normal WCST performance. The VR system, although using graphic imagery that would never be mistaken for the real world, was successful in detecting deficits that had been reported to be limiting the patient's everyday performance, yet were missed using existing NP tests. These results are in line with the observation that patients with executive disorders often perform relatively well on traditional NP tests of "frontal lobe function", yet show marked impairment in controlling and monitoring behavior in real-life situations (Shallice and Burgess, 1991).

Similar findings were reported by McGeorge et al. (2001) in a study comparing real world and virtual world "errand running" performance in five traumatic brain injury patients and five matched normal controls. The selection of the patient sample for this study was based on staff ratings that indicated poor planning skills. However, the patient and control

groups did not differ significantly from normative values on the Behavioural Assessment of the Dysexecutive Syndrome (BADS) battery (Wilson et al., 1996). Videotaped performance of subjects was coded and compared while performing a series of errands in the University of Aberdeen psychology department (real world) and within a flatscreen VR scenario modeled after this environment. Performance in both the real and virtual environment, as defined as the number of errands completed in a 20-minute period, was highly correlated ($r = .79$; $p<.01$). Interestingly, while the groups did not differ on age-corrected standardized scores on the BADS, significant differences *were* found between the groups in both the real world and virtual testing. This finding suggests several things. First, performance in the real and virtual world was functionally similar, second, patient and control groups could be discriminated equally using real and virtual tests while this discrimination was not picked up by standardized testing with the BADS, and third, that both measures of real and virtual world performance showed concordance with staff observations of planning skills. That these results support the view that VR testing may possess higher ecological value is in line with the observation by Shallice and Burgess (1991) that traditional neuropsychological tests do not demand the planning of behavior over more than a few minutes, or the prioritization of competing subtasks and may result in less effective prediction of real world performance.

Other research has also demonstrated VR's usefulness for neuropsychological assessment, particularly for visuospatial processes (Kaufmann et al., 2005; Koenig et al., 2009, 2010; McGee et al., 2000; Parsons, et al., 2005; Rizzo et al., 2001). For example, VR systems have been used to assess mental rotation, a cognitive function whereby a person needs to visualize the movement and organization of objects in a 3-dimensional space (Shepard and Metzler, 1971). Mental rotation is important for everyday tasks such as driving, organizing items in a limited space and any activity that relies on dynamic imagery for prediction of object movement. In the normal population, men outperform women on the mental rotation task. However, "hands-on" performance on a VR spatial rotation task that mimicked the task structure of the original mental rotation task, showed no gender difference and mental rotation was shown to be dramatically improved in both women and low performing men after a brief 10-15 minute period of interaction with the hands-on virtual reality interaction task (Rizzo et al., 2001). Along similar lines, the Morris Water Maze test of spatial navigation and place learning, commonly used with rodents, has also been simulated in a virtual environment as a test for humans (Astur et al., 2002, 2004). In this application, the person being tested must use visual cues in the surrounding environment to help guide navigation to a hidden platform. Used in conjunction with fMRI, the test can be applied to determine whether a person has decreased hippocampal activity that might be indicative of Alzheimer's disease (Shipman, and Astur, 2008) and with Schizophrenia (Folley et al., 2010). Such integration of VR as a complex stimulus delivery tool with advanced brain imaging and psychophysiological techniques may allow neuropsychology to reach its stated purpose, that of determining unequivocal brain-behavior relationships.

Along with this seminal work with adults, other researchers have followed the aircraft simulation metaphor with the creation of VR worlds designed to assess cognitive and functional performance in children with a range of CNS-related disease or injury conditions. For example, researchers have created virtual homes, classrooms, public spaces and traffic-filled streets to test and train children with autistic spectrum disorder (ASD) and other developmental disorders on activities relevant to fire safety (Rizzo, Strickland and Bouchard, 2004), social skills (Parsons et al., 2000), functional attention (Rizzo et al., 2006), street-

crossing (Strickland et al., 1996; Bart et al., 2008) and earthquake safety (Raloff, 2006). Even a virtual obstacle course was created for determining if a child is capable of using a motorized wheelchair safely and effectively, and to support training if they're not quite ready yet (Inman et al. 1997). For those interested in more detail on Clinical VR research in children, see Parsons et al., (2009) and Rizzo et al., (2011a).

Use Case: The Virtual Classroom Attention Assessment Project

The original Virtual Classroom project began in 1999 as part of a basic research application program at the University of Southern California aimed at developing VR technology applications to improve our capacity to understand, measure, and treat the cognitive/functional impairments commonly found in clinical populations with CNS dysfunction as well as advance the scientific study of normal processes and function. The Virtual Classroom was designed as a HMD VR system for the assessment of attention processes in children. Efforts to target this cognitive process were supported by the widespread occurrence and relative significance of attention impairments seen in a variety of clinical conditions that effect children. Notable examples of childhood clinical conditions where attention difficulties are seen include Attention Deficit Hyperactivity Disorders (ADHD), Traumatic Brain Injury and Fetal Alcohol Syndrome. With these clinical conditions, VR technology provides specific assets for assessing attention that are not available using existing methods. For example, HMDs that serve to occlude the distractions of the outside world are well suited for these types of cognitive assessment applications. Within a HMD, researchers and clinicians can provide a controlled stimulus environment where attention (and other cognitive) challenges can be presented along with the precise delivery and control of "distracting" auditory and visual stimuli within the virtual environment. This level of experimental control allows for the development of attention assessment/rehabilitation tasks that are more similar to what is found in the real world and when delivered in the context of a relevant functional virtual environment, could improve on the ecological validity of measurement and treatment in this area. The first project with the Virtual Classroom focused on attention assessment in children with ADHD. The heterogeneous features of ADHD, a behavioral disorder marked by inattention, impulsivity, and/or hyperactivity, have made consensus regarding its diagnosis difficult. Furthermore, traditional methods for assessing ADHD in children have been questioned regarding issues of reliability and validity. Popular behavioral checklists have been criticized as biased and not a consistent predictor of ADHD, and correlations between concordant measures of ADHD, such as parent and teacher ratings of hyperactivity, have been repeatedly shown to be modest at best and frequently low or absent (Barkley, 1990; Colegrove et al., 1997). Due to the complexity of the disorder and the limitations of traditional assessment techniques, diagnostic information is required from multiple types of ADHD measures and a variety of sources in order for the diagnosis to be given (American Psychiatric Association, 2000; Greenhill, 1998). Thus, in the area of ADHD assessment where traditional diagnostic techniques have been plagued by subjectivities and inconsistencies, it was believed that an objective and reliable VR strategy might add value over existing approaches and methods.

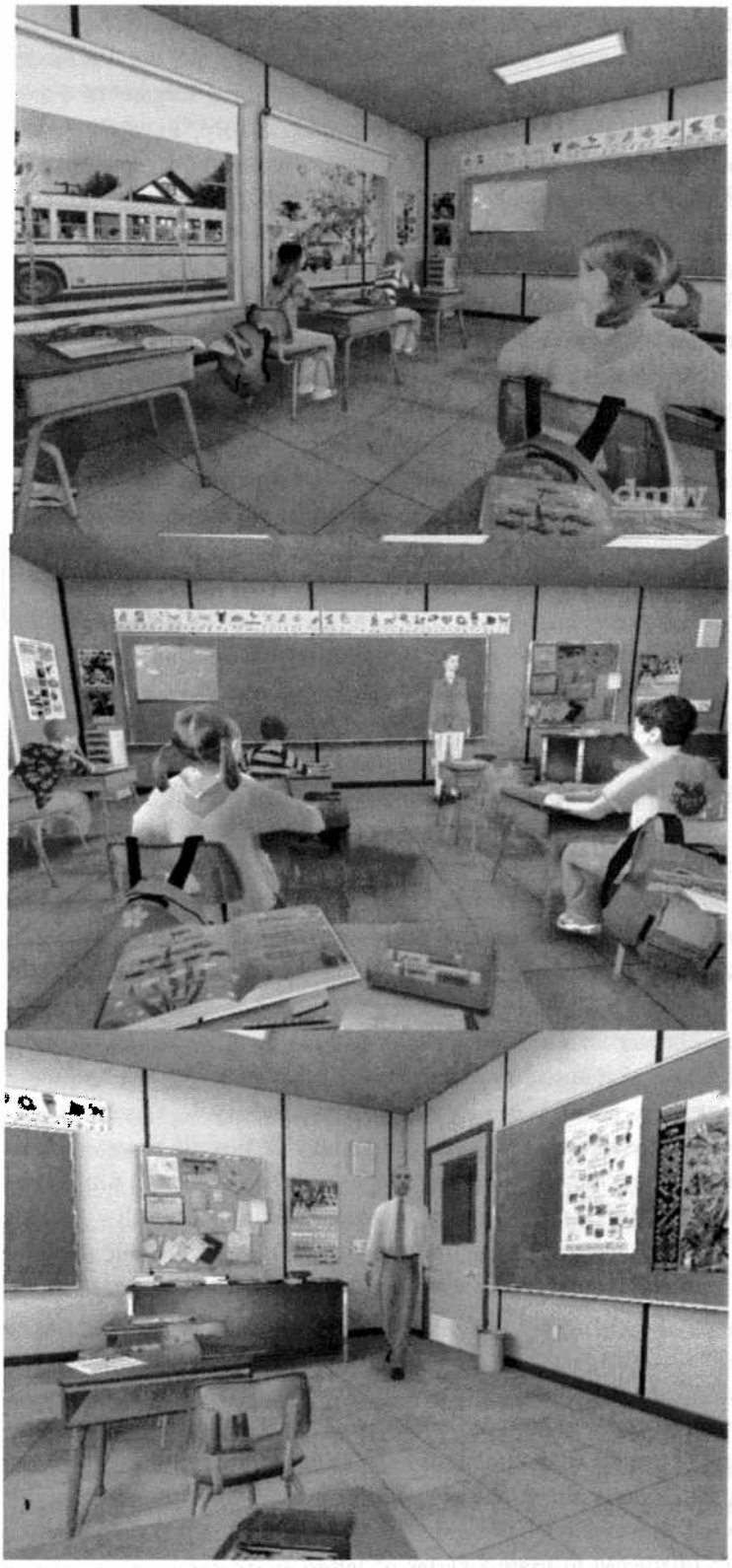


Figure 15.4. Scenes from the Virtual Classroom.

The initial research version of the system was run on a standard Pentium 3 processor with the nVIDIA G2 graphics card. The HMD used in this study was the V8 model from Virtual Research. Tracking of the head, arm and leg used three 6-Degree of Freedom magnetic "Flock of Birds" trackers from Ascension Technology Corp. In addition to tracking head movement in real time to update the graphics display in the HMD, the tracking system also served to capture body movement metrics from the tracked locations. This provided concurrent data on the hyperactivity component that is a commonly observed feature of ADHD. The research version of the Virtual Classroom scenario consisted of a standard rectangular classroom environment containing desks, a female teacher, a blackboard across the front wall, a side wall with a large window looking out onto a playground and street with moving vehicles, and on each end of the opposite wall, a pair of doorways through which activity occurred (see Figure 4). Within this scenario, children's attention performance was assessed while a series of common classroom distracters (i.e., ambient classroom noise, activity occurring outside the window, etc.) were systematically controlled and manipulated within the virtual environment. The child sat at a virtual desk within the virtual classroom and on-task attention was measured in terms of reaction time performance and error profiles on a variety of attention challenge tasks that were delivered visually using the blackboard or auditorily via a virtual teacher's voice.

Prior to any clinical tests with the Virtual Classroom, we applied a user-centered design methodology to insure that the application was usable and safe for children. User-centered approaches generally require the involvement of the targeted user group in the early design and development phase of scenario development. This involves a series of tight, short heuristic and formative evaluation cycles conducted on basic components of the system. Consideration of user characteristics in this fashion has increasingly become standard practice in VR development (Hix and Gabbard, 2002). In the Virtual Classroom's user-centered design evaluation phase, twenty non-diagnosed children (ages 6-12) tried various evolving forms of the system over the first year of development and their performance was observed while trying out a variety of basic selective and alternating attention tasks. One such task involved having users recite the letters that appeared on the blackboard, while naming the color of a virtual chapter airplane that passed across the classroom at random intervals. We also solicited feedback pertaining to aesthetics and usability of the VE and incorporated some of this feedback into the iterative design-evaluate-redesign cycle. Overall, these initial results indicated little difficulty in adapting to use of the HMD, no self-reported occurrence of side effects as determined by post-test interviews using the Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993) and excellent performance on the stimulus tracking challenges.

Following this user centered design phase, we conducted a clinical trial that compared eight physician-referred ADHD males (age 6-12) with ten non-diagnosed male children. The groups did not significantly differ in mean age, grade level, ethnicity, or handedness and all ADHD diagnosed children were currently taking stimulant medication as treatment for their condition. However, ADHD participants were off medication during the testing period with all testing occurring between 9am and 11am prior to normal medication ingestion. ADHD participants were excluded from the study if they presented with comorbid autism, mental retardation, Full Scale IQ score < 85, or head injury with loss of consciousness greater than 30 minutes. These same exclusion criteria were applied to the normal control group. Research participants were instructed to view a series of letters presented on the blackboard and to hit the response button only after he viewed the letter "X" preceded by an "A" (successive

discrimination task). This AX continuous performance task consisted of the letters A, B, C, D, E, F, G, H, J, L, and X. The letters were white on a gray background (the virtual blackboard) and presented in a fixed position directly in front of the participant. The stimuli remained on the screen for 150 msec, with a fixed interstimulus interval of 1350 msec. The target letter X (correct hit stimuli) and the letter X without the A (incorrect hit stimuli) each appeared with equal probability of 10%. The letters A and H both appeared with a frequency of 20%. The remaining eight letters occurred with 5% probability.

Participants were instructed to press the mouse button as quickly and accurately as possible (with their dominant hand) upon detection of an X after an A (correct hit stimuli) and withhold their response to any other sequence of letters. Four hundred stimuli were presented during each of two 10-minute conditions. The two 10-minute conditions consisted of: one without distraction and one with distractions (pure audio-classroom noises, pure visual-chapter airplane flying across the visual field and mixed audiovisual-a car "rumbling" by the window and a person walking into the classroom with hall sounds occurring when the door to the room was opened). Distracters were each displayed for 5 sec, and presented in randomly assigned equally appearing intervals of 10 sec, 15 sec, or 25 sec. and 36 distracters (9 of each) were included in the 10-minute condition. As well, six degree of freedom tracking from the head, arm and leg was used to produce movement metrics needed to analyze the motor hyperactivity component in conjunction with the cognitive performance. VR performance was also compared with results from standard neuropsychological testing. The following results summarize the outcomes of this study:

- No significant side effects were observed in either group based on pre- and post-VR Simulator Sickness Questionnaire testing.
- Children with ADHD had *slower* correct hit reaction time compared with normal controls on the distraction condition (760ms vs. 610ms; t (1,16) = -2.76, p <.03).
- Children with ADHD had higher reaction time *variability* on correct hits compared with normal controls on both the no-distraction (SD= 220ms vs. 160ms; t (1,16) = -2.22, p < .05) and distraction conditions (SD= 250ms vs. 170ms; t (1,16) = -2.52, p < .03).
- Children with ADHD made more Omission errors (missed targets) compared with normal controls on both the no-distraction (14 vs. 4.4; t (1,16) = -4.37, p < .01) and distraction conditions (21 vs. 7.2; t (1,16) = - 4.15, p < .01).
- Children with ADHD made more Commission errors (impulsive responding in the absence of a target) compared with normal controls on both the no-distraction (16 vs. 3.7; t (1,16) = -3.15, p < .01) and distraction conditions (12.1 vs. 4.2; t (1,16) = -3.22, p < .01)
- Children with ADHD made more Omission errors in the distraction condition compared to the non-distraction condition (21 vs. 14; t (1,16) = -3.50, p < .01). No such differences on Omission and Commission errors were found with the non-diagnosed children across no-distraction and distraction conditions.
- Exploratory analysis of motor movement in children with ADHD (tracked from head, arm and leg) indicated higher activity levels on all metrics compared to non-diagnosed children across both conditions.

- Exploratory analysis of motor movement in children with ADHD also indicated higher activity levels on all metrics in the distraction condition compared to the non-distraction condition. This difference was not found with the normal control children.
- Exploratory analysis using a neural net algorithm (support vector machine analysis) trained to recognize a stereotypic leg movement on the first five participants in each group was able to accurately discriminate the remaining subjects to groups at 100%.

These data suggested that the Virtual Classroom had good potential as an efficient, cost-effective and scalable tool for conducting attention performance measurement beyond what existed using traditional methodologies. The system allowed for controlled performance assessment within an ecologically valid environment and appeared to parse out significant effects due to the presence of distraction stimuli. Additionally, the capacity to integrate measures of movement via the tracking technology further added value to this form of assessment when compared to traditional analog tests and rating scales. In this regard, a HMD appeared to be the optimal display format. Although one of the common criticisms of HMD technology concerns field of view (FOV) limitations, in this application the limited FOV fostered head movement to supplant eye movement as the primary method for scanning the Virtual Classroom. This type of "poor-man's" tracking of behavioral attention within the controlled stimulus environment obtained in the HMD allowed for ongoing documentation as to where the user was "looking" during test stimulus content delivery.

For example, a child missing a target while directly looking at the blackboard is illustrating an attentional error that is fundamentally different from the occurrence of a missed target due to the child looking out the window at a distraction. The documentation provided by head tracking in a HMD can be used to produce metrics of percent time on task during stimulus "hit" trials as well as allowing for a re-creation of a naturalistic behavioral performance record for later review. In the current research, ADHD children were found to miss targets due to looking away from the blackboard during 25% of the "hit" trials as opposed to normal subjects who were documented to be looking away at less than 1% of the time. This form of integrated cognitive/behavioral performance record of attention performance during delivery of systematic distraction is simply not obtainable using other methods. More detailed information on the rationale, methodology, other studies and long-term vision for this project can be found in (Rizzo et al., 2006; Parsons et al., 2007; Pollack et al., 2010; Gilboa et al., 2011). *For more information, see a Virtual Classroom Video at*: http://www.youtube.com/watch?v=JBIhey7sjzg and http://www.youtube.com/watch?v= daUu3iXyWWY.

VIRTUAL PATIENTS FOR CLINICAL TRAINING

Clinical interest in artificially intelligent (AI) agents designed for interaction with humans can trace its roots to the work of MIT AI researcher, Joe Weizenbaum. In 1966, he wrote a language analysis program called ELIZA that was designed to imitate a Rogerian therapist. The system allowed a computer user to interact with a virtual therapist by typing simple sentence responses to the computerized therapist's questions. Weizenbaum reasoned that simulating a non-directional psychotherapist was one of the easiest ways of simulating human verbal interactions and it was a compelling simulation that worked well on teletype

computers (and is even instantiated on the internet today; http://www-ai.ijs.si/eliza-cgi-bin/eliza_script). In spite of the fact that the illusion of Eliza's intelligence soon disappears due to its inability to handle complexity or nuance, Weizenbaum was reportedly shocked upon learning how seriously people took the ELIZA program (Howell and Muller, 2000). And this led him to conclude that it would be immoral to substitute a computer for human functions that "...involves interpersonal respect, understanding, and love." (Weizenbaum, 1976).

More recently, seminal research and development has appeared in the creation of highly interactive, artificially intelligent and natural language capable virtual human (VH) agents. No longer at the level of a prop to add context or minimal faux interaction in a virtual world, these agents are designed to perceive and act in a 3D virtual world, engage in face-to-face spoken dialogues with real users (and other VHs) and in some cases, they are capable of exhibiting human-like emotional reactions. Previous classic work on VHs in the computer graphics community focused on perception and action in 3D worlds, but largely ignored dialogue and emotions. This has now changed. Artificially intelligent VH agents can now be created that control computer generated bodies and can interact with users through speech and gesture in virtual environments (Gratch et al., 2002). Advanced virtual humans can engage in rich conversations (Traum et al., 2008), recognize nonverbal cues (Morency et al., 2008), reason about social and emotional factors (Gratch and Marsella, 2004) and synthesize human communication and nonverbal expressions (Thiebaux et al., 2008). Such fully embodied conversational characters have been around since the early 90's (Bickmore and Cassell, 2005) and there has been much work on full systems that have been designed and used for training (Evans et al., 1989; Kenny et al., 2007; Prendinger and Ishizuka, 2004; Rickel et al., 2001), intelligent kiosks (McCauley and D'Mello, 2006), and virtual receptionists (Babu et al., 2006). Both in appearance and behavior, VHs have now passed through "infancy" and are ready for service in a variety of clinical and research applications.

An integral part of medical and psychological clinical education involves training in interviewing skills, symptom/ability assessment, diagnosis and interpersonal communication. In the medical field, students initially learn these skills through a mixture of classroom lectures, observation, and role-playing practice with *standardized patients*–persons recruited and trained to take on the characteristics of a real patient, thereby affording medical students a realistic opportunity to practice and be evaluated in a simulated clinical environment.

Although a valuable tool, there are several limitations with the use of standardized patients that can be mitigated through VR simulation technology. First, standardized patients are expensive. For example, although there are 130 medical schools in the U.S., few sites provide standardized patient assessments as part of the U.S. Medical Licensing Examination at a cost of several thousand dollars per student (ECFMG, 2011). Second, there is the issue of standardization. Despite the expense of standardized patient programs, the standardized patients themselves are typically low skilled actors making about $15/hr and administrators face constant turnover resulting in considerable challenges to the consistency of patient portrayals. This limits the value of this approach for producing reliable and valid interactions needed for the psychometric evaluation of clinicians in training. Finally, the diversity of the conditions that standardized patients can characterize is limited by availability of human actors and their skills. This is even a greater problem when the actor needs to be a child, adolescent, elder, or in the mimicking of nuanced or complex symptom presentations.

The situation is even more challenging in the training of clinical psychology and social work students. Rarely are live standardized patients used in such clinical training. Most direct patient interaction skills are acquired via role-playing with supervising clinicians and fellow graduate students, with closely supervised "on-the-job" training providing the brunt of experiential training. While one-way mirrors provide a window for the direct observation of trainees, audio and video recordings are a more common method of providing supervisors with information on the clinical skills of trainees. As well, the imposition of recording has been reported to have demonstrable effects on the therapeutic process that may confound the end goal of clinical training (Bogolub, 1986).

In this regard, Virtual Patients can fulfill the role of standardized patients by simulating diverse varieties of clinical presentations with a high degree of consistency, and sufficient realism (Stevens et al., 2005), as well as being always available for *anytime-anywhere* training. Similar to the compelling case made over the years for Clinical VR generally, VP applications can likewise enable the precise stimulus presentation and control (dynamic behavior, conversational dialog and interaction) needed for rigorous laboratory research, yet embedded within the context of an ecologically relevant simulated environment. Toward this end, there is a growing literature on the use of VPs in the testing and training of bioethics, basic patient communication, interactive conversations, history taking, clinical assessment, and clinical decision-making (Bickmore and Giorgino, 2006; Bickmore et al., 2007; Lok et al., 2007, 2011; Kenny et al., 2007, 2011; Parsons et al., 2008b; Rizzo et al., in press; Wendling et al, 2011). There has also been a significant amount of work creating physical manikins and virtual patients that represent physical problems (Kotranza et al, 2008), such as how to attend to a wound, or interviewing a patient with a stomach problem to assess the condition, and initial results suggest that VPs can provide valid and reliable representations of live patients (Triola et al., 2006).

However, research into the use of VPs in psychology and related psychosocial clinical training has been limited and can best be considered "fledgling". For example, Beutler and Harwood (2005) describe the development of a VR system for training in psychotherapy (characters primarily with psychological disorders or medical conditions in which a psychological condition may complicate a straightforward medical diagnosis) and summarize training-relevant research findings. Other than the above cited work, by Beutler et al., the Lok lab, and the Kenny, Parsons and Rizzo lab, we could find no other references on the use and evaluation of VPs in clinical psychology training to date, despite online searches through MEDLINE, Ovid, and the psychotherapy literature. From this, there appears to be a gap in research into the design and evaluation of intelligent VPs that have realistic interaction and communication capabilities for training clinical interviewing, diagnostic assessment and therapy skills in novice mental health clinicians.

USE CASE: VIRTUAL PATIENTS FOR CLINICAL TRAINING

The remainder of this chapter will detail some of our work developing and evaluating the use of artificially intelligent VHs designed to serve the role of virtual patients for training clinical interaction skills in novice clinicians. While we believe that the use of VHs to serve the role of virtual therapists is still fraught with both technical and ethical concerns, we have

had success in the initial creation of VHs that can mimic the content and interaction of a patient with a clinical disorder for training purposes. We will also briefly discuss our related emerging work developing an online VH presence (SimCoach) for providing assistance to military personnel and significant others in the access of relevant psychological health and TBI care information. This project aims to break down barriers to care (e.g. unawareness, stigma, complexity of the military psychological healthcare system, etc.) and assist users in the process of initiating a first contact with a live human healthcare provider.

The art and science of evaluating interviewing skills using VPs is still a young discipline with many challenges. One formative approach is to compare performances obtained during interviews with both live standardized patients and with VPs, and then to conduct correlational analyses of metrics of interest. This information can then be evaluated relative to an Objective Structured Clinical Examination (OSCE) (Walters et al, 2005). Such tests typically take from 20-30 minutes and require a faculty member to watch the student perform a clinical interview while being videotaped. The evaluation consists of a self-assessment rating along with faculty assessment and a review of the videotape. This practice is common, although is applied variably, based on the actors, available faculty members and space and time constraints at the training site. A general complication involved in teaching general interviewing skills is that there are multiple theoretical orientations and techniques to choose from and the challenge will be to determine what commonality exists across these methods for the creation of usable and believable VPs that are adaptable to all clinical orientations. To minimize this problem in our initial efforts, we have concentrated on assessing the skills required to diagnose very specific mental disorders (i.e., conduct disorder, PTSD, depression, etc.). We also use the setting of an initial intake interview to constrain the test setting for acquiring comprehensible data to drive future research. In our test protocols, clinicians are typically provided some knowledge as to why the virtual patient is there (i.e., a referral question), but need to ask the patient strategic questions to obtain a detailed history useful for specifying a clinical condition in support of coming to a differential diagnosis and for formulating a treatment plan. In this manner, the system is designed to allow novice clinicians the opportunity to practice asking interview questions that eventually lead to the narrowing down of the alternative diagnostic options, leading to the arrival of a working diagnosis based on the VP meeting the criteria for a specific DSM diagnosis.

Our initial project in this area involved the creation of a virtual patient, named "Justin". Justin portrays a 16-year old male with a conduct disorder who is being forced to participate in therapy by his family. The system was designed to allow novice clinicians to practice asking interview questions, to attempt to create a positive therapeutic alliance and to gather clinical information from this very challenging VP. Justin was designed as a first step in our research. At the time, the project was unfunded and thus required our lab to take the economically inspired route of recycling a virtual character from a military negotiation-training scenario to play the part of Justin. The research group agreed that this sort of patient was one that could be convincingly created within the limits of the technology (and funding) available to us at the time.

For example, such resistant patients typically respond slowly to therapist questions and often use a limited and highly stereotyped vocabulary. This allowed us to create a believable VP within limited resources for dialog development. As well, novice clinicians have been typically observed to have a difficult time learning the value of "waiting out" periods of silence and non-participation with these patients. We initially collected user interaction and

dialog data from a small sample of psychiatric residents and psychology graduate students as part of our iterative design process to evolve this application area. The project produced a successful proof of concept demonstrator, which then led to the acquisition of funding that currently supports our new projects in this area.

Following our successful Justin proof of concept, our 2nd VP project involved the creation of an adolescent female sexual assault victim, "Justina". The aim of this work was two fold: 1. Explore the potential for creating a system for use as a clinical interview trainer for promoting sensitive and effective clinical interviewing skills with a VP that had experienced significant personal trauma; and 2. Create a system whereby the dialog content could be manipulated to create multiple versions of Justina to provide a test of whether novice clinicians would ask the appropriate questions to assess whether Justina met the criteria for the DSM-4r diagnosis of PTSD based on symptoms reported during the clinical interview.

For the PTSD content domain, 459 questions were created that mapped roughly 4 to 1 to a set of 116 responses. The aim was to build an initial language domain corpus generated from subject matter experts and then capture novel questions from a pilot group of users (psychiatry residents) during interviews with Justina. The novel questions that were generated could then be fed into the system in order to iteratively build the language corpus. We also focused on how well subjects asked questions that covered the six major symptom clusters that can characterize PTSD following a traumatic event. While this approach did not give the Justina character a lot of depth, it did provide more breadth for PTSD-related responses, which for initial testing seemed prudent for generating a wide variety of questions for the next Justina iteration. (This 2nd iteration is currently in progress.)

In the initial test, a total of 15 Psychiatry residents (6 females, 9 males; mean age = 29.80, SD 3.67) participated in the study and were asked to perform a 15-minute interaction with the VP to take an initial history and determine a preliminary diagnosis based on this brief interaction with the character.

The participants were asked to talk normally, as they would to a standardized patient, but were informed that the system was a research prototype that uses an experimental speech recognition system that would sometimes not understand them. They were instructed that they were free to ask any kind of question and the system would try to respond appropriately, but if it didn't, they could ask the same question in a different way.

From post questionnaire ratings on a 7-point likert scale, the average subject rating for believability of the system was 4.5. Subjects reported their ability to understand the patient at an average of 5.1, but rated the system at 5.3 as frustrating to talk to, due to speech recognition problems, out of domain answers or inappropriate responses. However, most of the participants left favorable comments that they thought this technology would be useful in the future, and that they enjoyed the experience of trying different ways to talk to the character in order to elicit a relevant response to a complex question. When the patient responded back appropriately to a question, test subjects informally reported that the experience was very satisfying.

Analysis of concordance between user questions and VP response pairs indicated moderate effects sizes for Trauma inquiries ($r = 0.45$), Re-experiencing symptoms ($r = 0.55$), Avoidance ($r = 0.35$), and in the non-PTSD general communication category ($r = 0.56$), but only small effects were found for Arousal/Hypervigilance ($r = 0.13$) and Life impact ($r = 0.13$). These relationships between questions asked by a novice clinician and concordant replies from the VP suggest that a fluid interaction was sometimes present in terms of rapport,

discussion of the traumatic event, the experience of intrusive recollections and discussion related to the issue of avoidance.

Low concordance rates on the arousal and life impact criteria, indicated that a larger domain of possible questions and answers for these areas was not adequately modeled in this pilot effort and this is now being addressed in the 2nd iteration of Justina. We have also commenced two projects that present military VPs for the training of both MDs and Social Workers for better performance in their interactions with both Active Duty and Veteran patients (see Figure 5).

If this exploratory work continues to show promise, we intend to address a longer-term vision—that of creating a comprehensive DSM diagnostic trainer that has a diverse library of VPs modeled after each diagnostic category. The VPs would be created to represent a wide range of age, gender and ethnic backgrounds and could be interchangeably loaded with the language and emotional models defined by the criteria specified in any of the DSM disorders. We believe this vision will also afford many research opportunities for investigating the functional and ethical issues involved in the process of creating and interacting with virtual humans and patients. While ethical challenges may be more intuitively appreciated in cases where the target user is a patient with a clinical condition seeking a virtual clinician, the training of clinicians with VPs will also require a full appreciation of how this form of training impacts clinical performance with *real* patients. These are not trivial concerns and will require careful ethical and scientific consideration.

The systematic use of artificially intelligent virtual humans in clinical virtual reality applications is still clearly in its infancy. But the days of limited use of VH's as simple props or static elements to add realism or context to a clinical VR application are clearly in the past. In this section we have presented an example of the creation and use of VH characters to serve the role of digital "standardized patients" for training clinical skills, in both psychological and medical care domains. This initial effort and other VP project we have in progress (Rizzo et al., in press) have also lead to new opportunities for exploring the use of VHs to serve as online mental healthcare guides or coaches (Rizzo et al., 2011c).

This work is focused on breaking down barriers to care (stigma, unawareness, complexity, etc.) by providing military Service Members, Veterans, and their families with confidential help in exploring and accessing psychological healthcare content and for promoting the initiation of care with a live provider if needed. These projects are nascent efforts in this area, yet in spite of the current limits of the technology, it is our view that the clinical targets selected can still be usefully addressed.

The capacity to conduct clinical training within simulations that provide access to credible virtual human patients where novice clinicians can gain exposure to the presentation of a variety of clinical conditions will soon provide a safe and effective means for learning skills before actual training with real patients and for supplementing continuing education throughout the professional lifespan. And as the underlying enabling technologies continue to advance, significant opportunities will emerge that will reshape the clinical training landscape. The birth of this field has already happened, the next step is to insure that it has a healthy upbringing. *For more information, see a Virtual Patient and SimCoach Video at:* http://www.youtube.com/watch?v=PPbcl8Z-8Ec and http://www.youtube.com/watch?v=JiHlTioZktc

Figure 15.5. Military Male Virtual Patient Characters (Versions 1 and 2).

CONCLUSION

The use of computer-based VR simulation technology will play an increasing role in how clinical care (and training) and scientific research is conducted in the future. Advances in the underlying enabling technologies and continuing cost reductions in system hardware are expected to make it possible for VR to shortly become a mainstream tool in this area. With this view in mind, this chapter has aimed to provide a detailed specification of rationales, research and development across three major areas of Clinical VR. However, VR is not a panacea for all the challenges that occur in clinical care.

By presenting the history, rationale and brief reviews of key literature, along with use-cases for the application of VR in each section, it is hoped that clinicians and researchers may use this information to understand the basis for when VR is well matched to the needs of clinical care in certain areas and when it is technological overkill in others. As well, the task of building really good VR systems that are both usable and useful is a challenging endeavor that requires a interdisciplinary mix of domain-specific knowledge. This sort of collaboration can be supported by providing clinicians with an informed view of what is possible with the technology and why, with what makes the most sense from a clinical perspective. Armed with this information, clinical experts can begin to partner with scientists in other more technical disciplines for the thoughtful development of Clinical VR applications that meet the needs of clinical populations of interest.

Finally, one of the guiding principles in the Clinical VR area concerns how novel and innovative VR approaches can extend the skills of a well-trained clinician. VR approaches are not intended to be automated assessment or treatment protocols that are administered in a "self-help" format without the need for informed clinical expertise. As long as VR technology is viewed in the context of its value as a *tool* for extending clinical skill rather than a replacement for it, we believe that effective VR system development and application will bring the benefits of the information age to clinical populations in ways that go beyond the limits of the past.

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