

Virtual Reality Applications to Address the Wounds of War

Albert “Skip” Rizzo, PhD; J. Galen Buckwalter, PhD; Eric Forbell, MS; Chris Reist, MD, MBA; JoAnn Difede, PhD; Barbara O. Rothbaum, PhD; Belinda Lange, PhD; Sebastian Koenig, PhD; and Thomas Talbot, MD

Albert “Skip” Rizzo, PhD, is Associate Director, Institute for Creative Technologies; and Research Professor, Department of Psychiatry and School of Gerontology, University of Southern California. J. Galen Buckwalter, PhD, is Research Scientist, University of Southern California Institute for Creative Technologies. Eric Forbell, MS, is Principal Software Engineer, University of Southern California Institute for Creative Technologies. Chris Reist, MD, MBA, is Associate Chief of Staff, Research and Development, Long Beach VA Healthcare System. JoAnn Difede, PhD, is Professor of Psychology in Psychiatry, Weill Medical College of Cornell University. Barbara O. Rothbaum, PhD, is Professor of Psychiatry, Emory University School of Medicine. Belinda Lange, PhD, is Research Scientist, University of Southern California Institute for Creative Technologies. Sebastian Koenig, PhD, is Research Scientist, University of Southern California Institute for Creative Technologies. Thomas Talbot, MD, is Senior Medical Advisor, University of Southern California Institute for Creative Technologies.

Address correspondence to: Albert “Skip” Rizzo, PhD, University of Southern California Institute for Creative Technologies, 12015 Waterfront Drive, Playa Vista, CA 90065; email: rizzo@ict.usc.edu.

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Numerous reports indicate that the incidence of posttraumatic stress disorder (PTSD) in returning Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) military personnel is creating a significant behavioral health care challenge. These findings have served to motivate research on how to better develop and disseminate evidence-based treatments for PTSD. This article details how virtual reality applications are being designed and implemented across

various points in the military deployment cycle to prevent, identify, and treat combat-related PTSD in OEF/OIF service members and veterans.

The summarized projects in these areas have been developed at the University of Southern California Institute for Creative Technologies (USC ICT), a US Army University Affiliated Research Center, and will detail efforts to use virtual reality to deliver exposure therapy and provide stress resilience training prior to deploy-

ment. A brief discussion will follow that details work developing and evaluating virtual human agents in the role of virtual patients that represent military personnel for training the next generation of clinical providers. As well, research and development creating virtual humans serving in the role of online health care guides that can be used to support anonymous access to military-relevant behavioral health care information will be discussed.

INTRODUCTION TO CLINICAL VIRTUAL REALITY

The US Department of Defense (DoD) continues to make a significant investment in research and development of virtual reality (VR) technology for a wide range of training applications.¹ This investment, along with rapid advances in the underlying engineering enabling technology, also has supported the development of innovative VR clinical assessment and intervention tools in both the military and civilian sectors. By its nature, VR applications can be designed to simulate naturalistic environments. Within these virtual environments, researchers and clinicians can present ecologically relevant stimuli embedded in a meaningful and familiar simulated context.

VR simulation technology also offers the potential to create systematic human testing, training and treatment environments that allow for the precise control of complex, immersive, dynamic 3-D stimulus presentations, within which sophisticated interaction, behavioral tracking, user response, and performance recording is possible. When combining these assets within the context of functionally relevant, ecologically enhanced VR scenarios, a fundamental advancement emerges in how human assessment and intervention can be addressed in many clinical and research disciplines. VR-

based testing, training, and treatment approaches that would be difficult, if not impossible, to deliver using traditional methods are now being developed, taking advantage of the assets available with VR technology.²

This unique match between VR technology assets and the needs of various clinical application areas has been recognized by a determined and expanding group of researchers and clinicians who not only understand the potential impact of VR technol-

Virtual reality has now emerged as a promising tool in many domains of clinical care and research.

ogy, but have also now generated a significant literature that documents the many clinical and research targets where VR can add value over traditional assessment and intervention methods.²⁻¹³

More specifically, a short list of areas where clinical VR has been usefully applied includes fear reduction in persons with specific phobias;^{6,7,14} treatment for PTSD^{9-11,15-17} stress management in patients with cancer;¹⁸ acute pain reduction during wound care; physical therapy with burn patients¹⁹ and others undergoing painful procedures;²⁰ body image disturbances in patients with eating disorders;¹² navigation and spatial training in children and adults with motor impairments;^{2,21} functional skill training and motor rehabilitation with patients having central nervous system dysfunction (eg, stroke, traumatic brain injury, spinal cord injury, cerebral palsy, multiple sclerosis, etc);^{4,22} and for the assessment and rehabilitation of attention, memory, spatial skills, and other

cognitive functions in both clinical and unimpaired populations.^{6,13,23}

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 also is producing artificially intelligent virtual human patients that are being used to train clinical skills to health professionals^{24,25} and to serve as anonymously accessible, online health care guides.¹¹ Based on these parallel advances in research and technology, VR has now emerged as a promising tool in many domains of clinical care and research.

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."²⁶ From this baseline perspective, VR can be seen as an advanced form of human-computer interface²⁷ 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.

In some cases, with the aid of specialized VR display devices, users can become "immersed" within a computer-generated simulated environment that changes in a natural/intuitive way with user interaction. VR sensory stimuli can be delivered by using various forms of visual display technology that can present real-time computer graphics and/or photographic images/video along with a variety of other sensory display devices that can present audio, "force-feedback" touch sensations, and even olfactory content to the user.

However, VR is not defined or limited by any one technological approach or hardware set-up. The creation of an engaged VR 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 where they can interact.

One common configuration employs a combination of an HMD and head tracking system that allows delivery of real-time computer-generated images and sounds of a simulated virtual scene rendered in relationship to user movements that correspond to what the individual would see, hear, and feel if the scene were real. 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 central nervous system 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 3-D graphic environment on a flat screen monitor, projection

Virtual reality exposure therapy offers a way to circumvent the patient’s natural avoidance tendency.

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 VR environment, 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 (eg, keyboard, mouse, game pads, joysticks, etc). This is in addition to more complex interaction devices that can track more natural user activity (eg, data gloves, 3-D mice, treadmills and some high-end “force feedback” exoskeleton devices).

Recently, off-the-shelf systems, such as the Microsoft Kinect, are now being shown to provide a novel way for users to interact with virtual environments (VEs) using natural body interaction via low-cost 3-D camera-based sensing of full body movement.²⁸

This article will illustrate how VR has been used to enhance the delivery

of prolonged exposure therapy, provide stress resilience training, and to enhance clinical interactions with virtual human representations.

VIRTUAL REALITY PROLONGED EXPOSURE FOR PTSD

Among the many approaches that have been used to treat persons with PTSD, prolonged exposure (PE) therapy appears to have the best-documented therapeutic efficacy.^{17,29-31} Such treatment typically involves the graded and repeated imaginal reliving and narrative recounting of the traumatic event within the therapeutic setting. This approach is believed to provide a low-threat context where the client can begin to confront and therapeutically process the emotions that are relevant to a traumatic event as well as decondition the learning cycle of the disorder via a habituation/extinction process.

While the efficacy of imaginal exposure has been established in multiple studies with diverse trauma populations,^{17,32,33} many patients are unwilling or unable to effectively visualize the traumatic event. In fact, avoidance of reminders of the trauma is inherent in PTSD and is one of the cardinal symptoms of the disorder.

Virtual Reality Exposure Therapy

To address this problem, researchers have recently turned to the use of VR to deliver exposure therapy (VRET) by immersing users in simulations of trauma-relevant environments in which the emotional intensity of the scenes can be precisely controlled by the clinician, in collaboration with the patients’ wishes. In this fashion, VRET offers a way to circumvent the patient’s natural avoidance tendency by directly delivering multi-sensory and context-relevant cues that aid in the confrontation and processing of traumatic memories, without demand-

ing that the patient actively try to access his/her experience through effortful memory retrieval.

Within a VR environment, the hidden world of the patient's imagination is not exclusively relied upon and VRET may also offer an appealing treatment option that is perceived with less stigma by "digital generation" service members (SMs) and veterans who may be more reluctant to seek out what they perceive as traditional talk therapies. These ideas have been supported by three reports in which patients with PTSD were unresponsive to previous imaginal exposure treatments, but went on to respond successfully to VRET.¹⁵⁻¹⁷ As well, VR provides an objective and consistent format for documenting the sensory stimuli that the patient is exposed to that is not possible when operating within the unseen world of the patient's imagination.

Virtual Iraq/Afghanistan

Based on this rationale and previous research, the USC ICT developed a "Virtual Iraq/Afghanistan" simulation that is being used in a variety of clinical trials to investigate the potential for this form of treatment. The treatment environment consists of a series of virtual scenarios designed to represent relevant contexts for VRET, including city and desert road environments. In addition to the visual stimuli presented in the VR HMD, directional 3-D audio, vibro-tactile, and olfactory stimuli of relevance can be delivered. Stimulus presentation is controlled by the clinician via a separate "Wizard of Oz" (where the subject interacts with what he or she believes to be an autonomous program, but one that is instead operated by an unseen person) interface, with the clinician in full audio contact with the patient. The design of the system was enhanced by feedback derived from user-centered

tests with the application that were conducted at Fort Lewis, Washington, and within an Army Combat Stress Control Team in Iraq.³⁴

This feedback from nondiagnosed personnel provided information on the content and usability of our application that fed an iterative design process leading to the creation of the current clinical scenarios. A detailed description of the Virtual Iraq/Afghanistan system and the methodology for a standard VRET clinical protocol can be found elsewhere.³⁵

Initial clinical tests of the system have produced promising results. In the first open clinical trial, analyses of 20 active duty treatment completers (19 male, 1 female, mean age = 28 years; age range: 21 to 51 years) produced positive clinical outcomes.⁹ For this sample, mean pre/post PTSD military checklist (PCL-M)³⁶ scores decreased in a statistical and clinically meaningful fashion: 54.4 (SD = 9.7) to 35.6 (SD = 17.4). Paired pre/post *t*-test analysis showed these differences to be significant ($t = 5.99$, $df = 19$, $P < .001$).

Correcting for the PCL-M, no-symptom baseline of 17 indicated a greater than 50% decrease in symptoms; 16 of the 20 completers no longer met PCL-M criteria for PTSD at post-treatment follow-up. 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). Mean Beck Anxiety Inventory³⁷ 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-9³⁸ (depression) scores decreased 49% from 13.3 (SD = 5.4) to 7.1 (SD = 6.7), ($t = 3.68$, $df = 19$, $P < .002$).

The average number of sessions for this sample was just less than 11. Pos-

itive results from uncontrolled open trials are difficult to generalize from and we have been 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 3-month post-treatment follow-up.

Additional VRET Studies

Other studies also have reported positive outcomes. Two early case studies reported positive results using this system.^{39,40} Following those, another 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 $d = 1.17$).⁴¹ After an average of seven sessions, 45% of those treated no longer screened positive for PTSD and 62% had reliably improved.

In a small preliminary quasi-randomized controlled trial,⁴² seven of 10 participants with PTSD showed a 30% or greater improvement with VR, whereas only one of nine participants in a "treatment as usual" group showed similar improvement. The results are limited by small size, lack of blinding, a single therapist, and comparison to a set relatively uncontrolled usual care conditions, but it did add to the incremental evidence suggesting VR to be a safe and effective treatment for combat-related PTSD.

At the 2012 American Psychiatric Association annual meeting, McLay⁴³ presented data from a comparison of VRET with the traditional, evidence-based prolonged exposure approach in

active duty SMs. The results showed significantly better maintenance of positive treatment outcomes at 3-month follow-up for Virtual Iraq/Afghanistan system compared with traditional PE.⁴³ The overall trend of these positive findings (in the absence of any reports of negative findings) is encouraging for the view that VRET is safe and may be an effective approach for delivering an evidence-based treatment (prolonged exposure) for PTSD.

Four randomized controlled trials (RCTs) are ongoing with the Virtual Iraq/Afghanistan system with active duty and veteran populations. Two RCTs are focusing on comparisons of treatment efficacy between VRET and PE,^{41,44} and another is testing VRET compared with VRET and a supplemental care approach.⁴⁵

A fourth RCT⁴⁶ is investigating the additive value of supplementing VRET and imaginal PE with a cognitive enhancer called D-Cycloserine (DCS). DCS, an N-methyl-d-aspartate partial agonist, has been shown to facilitate extinction learning in laboratory animals when infused bilaterally within the amygdala prior to extinction training.⁴⁷ The first clinical test in humans that combined orally administered DCS with VRET was performed by Ressler et al⁴⁸ with participants diagnosed with acrophobia ($n = 28$). Participants who received DCS plus VRET experienced significant decreases in fear within the virtual environment at 1 week and at 3 months post-treatment, and reported significantly more improvement than the placebo group in their overall acrophobic symptoms at 3-month follow-up.

The DCS group also achieved lower scores on a psychophysiological measure of anxiety than the placebo group. The current multi-site PTSD RCT (National Intrepid Center of Excellence, Cornell-Weill, and the Long Beach Veterans Affairs Medical Center) is

testing the effect of DCS vs. placebo when added to VRET and PE with active duty and veteran samples ($n = 300$). DoD funding support for these RCTs underscore the interest that the DOD/Veterans Affairs (VA) has in exploring this innovative approach for delivering exposure therapy using VR.

Evidence-Based Nature of VRET

While RCTs are the gold standard for emerging treatment approaches to gain wide acceptance by the scientific community, it should be noted that at its core, the therapeutic model/principle that underlies VRET (cognitive-behavior therapy [CBT] with exposure) is in fact evidence-based. VRET is simply the delivery of this evidence-based treatment in a format that may serve to engage a wider range of patients in the necessary confrontation and processing of traumatic memories or “fear-structures”⁴⁹ needed for positive clinical outcomes. Thus, even equivalent positive results with PE in these RCTs would validate its use as another safe and evidence-based therapeutic option.

The VRET approach also could serve to draw SMs and veterans into treatment, many of whom have grown up “digital” and may be more likely to seek care in this format compared with what they perceive as traditional talk therapy. This is important since numerous reports from both military and civilian blue ribbon panels underscore the importance of breaking down “barriers to care” for improving the awareness, availability, accessibility, and acceptance of behavioral health care in the military,⁵⁰ Institute of Medicine,^{30,31} Dole-Shalala Commission Report,⁵¹ the Rand Report,⁵² and American Psychological Association.⁵³

VIRTUAL REALITY RESILIENCE TRAINING

Resilience is the dynamic process by which individuals exhibit positive adaptation when they encounter sig-

nificant adversity, trauma, tragedy, threats, or other sources of stress.⁵⁴ The core aim of resilience training is to promote psychological fitness and better prepare service members for the psychological stressors that they may experience during a combat deployment. There is a powerful rationale for developing methods that promote SM resilience and psychological fitness prior to a combat deployment.

Shift in Military Policy

The current urgency to address the psychological wounds of war in SMs and veterans also has driven an emerging focus within the military on emphasizing a proactive approach for better preparing service members for the emotional challenges they may face during a combat deployment to reduce the potential for later adverse psychological reactions such as PTSD and depression. This focus on resilience training prior to deployment represents no less than a quantum shift in military culture and can now be seen emanating from the highest levels of command in the military. For example, in an *American Psychologist* article, Army General George Casey⁵⁵ states that “... soldiers can ‘be’ better before deploying to combat so they will not have to ‘get’ better after they return.” He then calls for a shift in the military “... to a culture in which psychological fitness is recognized as every bit as important as physical fitness.”

Connection between Thinking and Feeling

This level of endorsement can be seen in practice by way of the significant funding and resources applied to a variety of resilience training programs across all branches of the US military.⁵⁶⁻⁵⁸ Perhaps the program that is attempting to influence the largest number of service members is the Comprehensive Soldier Fitness (CSF)

program.⁵⁸ This project has created and disseminated training that aims to improve emotional coping skills and ultimate resilience across all Army SMs. One element of this program draws input from principles of cognitive-behavioral science, which generally advances the view that it is not the event that causes an emotion, but rather how a person appraises the event (based on how they think about the event) that leads to the emotion.⁵⁹

From this theoretical base, it then follows that internal thinking or appraisals about combat events can be “taught” in a way that leads to more healthy and resilient reactions to stress. This approach does not imply that people with effective coping skills do not feel some level of “rational” emotional pain when confronted with an event that would be challenging emotionally and mentally to any individual. Instead, the aim is to teach skills that may assist soldiers to cope with traumatic stressors more successfully.

The core motive with such efforts is to provide resilience training that would promote psychological fitness and reduce the later incidence of PTSD and other psychological health conditions upon redeployment home (eg, depression, suicide, substance use). A recent study on the CFS program reported results from a longitudinal study over 18 months with 22,000 soldiers indicating positive outcomes,⁶⁰ but this report has been criticized for its exclusive reliance on self-report data and on other methodological grounds.⁶¹ Regardless of those academic “battles,” the post-deployment psychological health statistics are alarming and provide a compelling justification for continued efforts to better prepare SMs for the onslaught of emotional challenges that they may face during a combat deployment.

‘Stress Resilience in Virtual Environments’

Recently, the USC ICT has begun development of the STress Resilience In Virtual Environments (STRIVE) project, which expands on the Virtual Iraq/Afghanistan simulations devel-



oped for VRET. The STRIVE project aims to foster stress resilience by creating a set of combat simulations that can be used as contexts for SMs to experientially learn stress reduction tactics and cognitive-behavioral emotional coping strategies prior to deployment.

This approach involves immersing and engaging SMs within a variety of virtual “mission” episodes where they are confronted with emotionally challenging situations that are inherent to the OEF/OIF combat environment. Interaction by SMs within such emotionally challenging scenarios aims to provide a more meaningful context in which to engage with psychoeducational information and to learn and practice stress-reduction tactics and cognitive coping strategies that are believed to better prepare a SM for the psychological challenges that may occur during a combat deployment.

To accomplish this, STRIVE is being designed as a 30-episode interactive narrative in VR, akin to being immersed within a “Band of Brothers” type storyline that spans a typi-

cal deployment cycle. Within these episodes, SMs will get to know the distinct personalities of the virtual human characters in their squad and interact within an immersive digital narrative that employs cinematic strategies for enhancing engagement with the evolving storyline (eg, strategic use of narration, montage shots, dynamic camera direction).

At the end of each of the graded 10-minute episodes, an emotionally challenging event occurs, designed in part from feedback provided by SMs undergoing PTSD treatment (eg, seeing/handling human remains, death/injury of a squad member, killing someone, the death/injury of a civilian child). At that point in the episode, the virtual world “freezes in place” and a virtual human “mentor” character emerges from the midst of the chaotic VR scenario to guide the user through stress-reduction psychoeducational and self-management tactics, as well as providing rational restructuring exercises for appraising and processing the virtual experience. The resilience training component is drawing on evidence-based content that has been endorsed as part of standard classroom-delivered DoD stress resilience training programs, as well as content that has been successfully applied in nonmilitary contexts (eg, humanitarian aid worker training, sports psychology).

‘Context-Relevant Learning’

In this fashion, STRIVE provides a digital “emotional obstacle course” that can be used as a tool for providing context-relevant learning of emotional coping strategies under very tightly controlled and scripted simulated conditions. Training in this format is hypothesized to improve generalization to real world situations via a state-dependent learning component,⁶² and further support resilience by lever-

aging the learning theory process of “latent inhibition,” which is defined as delayed learning that occurs as a result of pre-exposure to a stimulus without a consequence.^{63,64} Thus, the exposure to a simulated combat context is believed to decrease the likelihood of fear conditioning during the real event.⁶⁵

The STRIVE project also incorporates a novel basic science protocol. While other stress resilience research efforts typically incorporate one or two biomarkers of stress and or resilience, the STRIVE projects will measure what we refer to as the “physiological fingerprint of stress,” commonly called allostatic load (AL). The theoretical construct of AL, initially developed by one of the STRIVE collaborators, Bruce McEwen, is a measure of cumulative wear and tear on physiological symptoms due to chronic stress.⁵⁴ As a theoretical construct, it is a preliminary attempt to formulate the relationship between environmental stressors and disease, by hypothesizing mechanisms whereby multiple kinds of stressors confer risk simultaneously in multiple physiological systems.

Allostasis, Equilibrium, and Homeostasis

The construct of AL is based on the widely accepted response called allostasis. Sterling and Eyer⁶⁶ defined allostasis as the body’s set points for various physiological mechanisms, such as blood pressure or heart rate, which vary to meet specific external demands, eg, emotional stress. McEwen and Stellar⁵⁴ furthered our understanding of allostasis by broadening its scope. Rather than discuss allostasis in terms of a single set point that changed in response to a stressor, they described allostasis as the combination of all physiological coping mechanisms that are required to maintain equilibrium of the entire

system. Thus, allostasis is the reaction and adaptation to stressors by multiple physiological systems that brings the system back to equilibrium.

The related concept of homeostasis refers specifically to system parameters essential for survival.⁶⁷ To place AL into the context of allostasis requires the view that allostasis does not

This project represents a direct application development effort while also serving as an “ultimate Skinner Box” for the study of stress reactions.

always proceed in a normal manner. Any of the major physiological systems (eg, inflammatory, metabolic, immune, neuroendocrine, cardiovascular, respiratory) in the process of responding to stress can exact a cost, or an AL, that can result in some form of physiological or psychological disturbance.

McEwen⁶⁸ identified four types of AL: frequent activation of allostatic systems; a prolonged failure to shut off allostatic activity after stress; a lack of adaptation to stress; and an inadequate response of allostatic systems leading to elevated activity of other, normally counter-regulated allostatic systems after stress (eg, inadequate secretion of glucocorticoid resulting in increased cytokines normally countered by glucocorticoids). Any of these types of AL intervene with the normal stress response of allostasis, thus increasing the negative health impact from stress. This will increase one’s risk for disease in the long-term and may preclude the short-term development of physical hardiness and psychological resilience.

In a first study of its kind, the STRIVE project will determine if AL

can predict acute response to stress (eg, electroencephalogram, galvanic skin response, electrocardiogram, pupil dilation, etc) when participants are exposed to the stressful simulated VR missions. Further analyses will determine if AL can predict participants’ responses to virtual mentor instructions on how the participants can cope with stress through resilience training. If we find that AL is capable of predicting either short-term response to stress or the ability to learn stress resilience, there would be numerous implications for the future use of AL, including identification of leadership profiles and for informing the development of appropriate training systems for all SMs.

Pilot research on this project is ongoing at the Immersive Infantry Training center at Marine Corps Base Camp Pendleton. This project is noteworthy in that it represents a direct application development effort (resilience training) while also serving as an “ultimate Skinner Box” for the scientific study of stress reactions using objective physiological assessment measures.

USE OF ‘VIRTUAL HUMANS’

Recent shifts in the social and scientific landscape have now set the stage for the next major movement in clinical VR with the “birth” of intelligent virtual humans. With advances in the enabling technologies allowing the design of ever more believable context-relevant “structural” VR environments (eg, combat scenes, homes, classrooms, offices, markets), the next important challenge will involve populating these environments with virtual human (VH) representations that are capable of fostering believable interaction with real VR users.

This is not to say that representations of human forms have not usefully appeared in previous clinical VR scenarios. In fact, since the mid-1990s, VR applications have routinely employed

VHs to serve as stimulus elements to enhance the realism of a virtual world simply by their static presence. However, seminal research and development has appeared in the creation of highly interactive, artificially intelligent and natural language-capable VH agents that can engage real human users in a credible fashion. No longer at the level of a prop to add context or minimal faux interaction in a virtual world, VH representations can be designed to perceive and act in a 3-D VR world, engage in face-to-face spoken dialogues with real users (and other virtual humans), and in some cases they are capable of exhibiting human-like emotional reactions. Both in appearance and behavior, VHs have now evolved to the point where they can become usable components for a variety of clinical and research applications.

These advances in VH technology have now supported developments for military behavioral health in two key domains: the creation of virtual patients that can be used for training novice clinician care providers in areas that are relevant for working with military populations; and virtual human support agents to serve as online guides for promoting anonymous access to psychological health care information, and for assisting military personnel and family members in breaking down barriers to initiating care.

VIRTUAL PATIENTS VS. HUMAN STANDARDIZED PATIENTS

Since 1963, when Howard Barrows, MD, at the University of Southern California, trained the first human standardized patient,⁶⁹ this approach using live actors has long been considered to be the gold standard medical education experience for both learning and evaluation purposes.⁷⁰⁻⁷² Human standardized patients (HSPs) are paid actors who pretend to be patients for educational interviews and provide the

most realistic and challenging experience for those learning the practice of medicine because they most closely approximate a genuine patient encounter. HSPs are also a key component in medical licensing examinations. For example, HSPs are used on the United States Medical Licensing Examination (USMLE) Step 2 Clinical Skills exam,

The diversity of clinical conditions that human standardized patients can characterize is limited by human actors and their skills.

which is mandatory for obtaining medical licensure in the US.

HSP encounters engage a number of clinical skill domains, including social, communication, judgment, and diagnostic acumen in a real time setting. All other kinds of practice encounters fall short of this because they either do not force the learner to combine clinical skill domains or they “spoon feed” data to the student with the practice case that turns the learning more into a pattern recognition exercise, rather than a realistic clinical problem-solving experience. The HSP is the only type of encounter where it is up to the learner to naturalistically pose questions to obtain data and information about the case that then needs to be integrated for the formulation of a diagnostic hypothesis and/or treatment plan.

Limitations of Human Standardized Patients

Despite the well-known superiority of HSPs to other instructional methods,^{73,74} they are employed sparingly. The reason for this limited use is primarily due to the very high costs

to hire, train, and maintain a diverse group of patient actors. Moreover, despite the expense of HSP programs, the standardized patients themselves are typically low-skilled actors and administrators face constant turnover resulting in considerable challenges for maintaining the consistency of diverse patient portrayals for training students. This limits the value of this approach for producing realistic and valid interactions needed for the reliable evaluation and training of novice clinicians. Thus, the diversity of clinical conditions that HSP can characterize is limited by availability of human actors and their skills. HSPs that are hired may provide suboptimal variation control and are limited to healthy appearing adult encounters. This is even a greater problem when the actor needs to be a child, adolescent, elder, person with a disability or in the portrayal of nuanced or complex symptom presentations.

The situation is even more challenging in the training of psychology/social work and other allied health professional 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.

However, the imposition of recording has been reported to have demonstrable effects on the therapeutic process that may confound the end goal of clinical training⁷⁵ and the supervisor review of raw recordings is a time-consuming process that imposes a significant drain on resources.

Virtual Patients

The development and implementation of computer-generated virtual patients (VPs) could address these limitations by providing diverse varieties of digital clinical presentations with a high degree of consistency and sufficient realism.

In this regard, VPs can fulfill the role of human standardized patients by simulating diverse varieties of clinical presentations with a high degree of consistency, and sufficient realism, 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 dialogue, and interaction) needed for rigorous laboratory research, yet embedded within the context of an ecologically relevant simulated environment.

Virtual Patient with Conduct Disorder

The USC ICT began work in this area in 2007 with an initial project that involved the creation of a VP, named “Justin.” Justin portrayed a 16-year-old male with a conduct disorder forced by his family to participate in therapy. 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 and resistant 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 dialogue development. As well, novice clinicians have been typically observed to have a difficult time learning the value of “waiting out” periods of silence and nonparticipation with these patients.

We initially collected user interaction and dialogue 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 research in this area.

Sexual Assault Virtual Patient

Following our successful Justin proof of concept, our second VP project involved the creation of a female sexual assault victim, “Justina.” The aim of this work was twofold: 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 create a system whereby the dialogue content could be manipulated to create multiple versions of Justina. This was to provide a test of whether novice clinicians would ask the appropriate questions to assess whether Justina met the criteria for the *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (*DSM-IV*) 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 lan-

guage 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 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.

In the initial test, a total of 15 psychiatry residents (six females, nine males; mean age = 29.80 years, 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 speak 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 did not, 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 will be useful in the future, and that they enjoyed the experience of trying different ways to talk to the character to elicit an relevant response to a complex question.

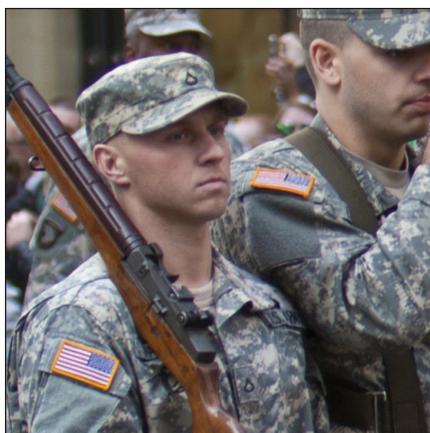
When the patient responded back appropriately to a question, test subjects informally reported that the experience was very satisfying. Analysis of concordance between user questions and VP response pairs indicated moderate effects sizes for trauma inquiries ($r = 0.45$), re-experiencing symptoms ($r = 0.55$), 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 our next generation VH research and development.

We are currently collaborating with the USC School of Social Work, Center for Innovation in Research (CIR), which essentially is a master of social work degree program with an emphasis on military social work. The current project with CIR focuses on the creation of military VPs that will allow social work trainees to gain practical training experiences with VHs that portray behavior more relevant to military culture and common clinical conditions. A sample video of the military VPs being interviewed by a social

work trainee (conducting a suicide assessment) can be found at: www.youtube.com/watch?v=CQTEcJJ_RhY.

Follow-on work to these VP projects has been funded to develop a toolkit that allows clinical educators to author VPs for clinical training. One



The military culture needs to be modified so that mental health services are more accepted and less stigmatized.

of the aims of the system is to build an interface that allows clinical educators to create a VP with the same ease as creating a Powerpoint presentation. Such VPs, authored by clinical professionals, would then become available to an open source community to broaden the opportunities for diverse clinical training experiences.

ONLINE VIRTUAL HUMAN HEALTH CARE GUIDE

Research suggests that there is an urgent need to reduce the stigma of seeking mental health treatment in SM and veteran populations. One of the more foreboding findings in an early report by Hoge et al⁷⁶ was the observation that among Iraq/Afghanistan War veterans, "...those whose responses were positive for a mental disorder,

only 23% to 40% sought mental health care. Those whose responses were positive for a mental disorder were twice as likely as those whose responses were negative to report concern about possible stigmatization and other barriers to seeking mental health care."

While US military training methodology has better prepared soldiers for combat in recent years, such hesitancy to seek treatment for difficulties that emerge upon return from combat, especially by those who may need it most, suggests an area of military mental health care that is in need of attention. Moreover, the dissemination of health care information to military SMs, veterans and their significant others is a persistent and growing challenge. Although medical information is increasingly available over the Internet, users can find the process of accessing it to be overwhelming, contradictory and impersonal.

Challenges to Providing Military Mental Health Services

Despite a Herculean effort on the part of the DoD to produce and disseminate behavioral health programs for military personnel and their families, the complexity of the issues involved continue to challenge the best efforts of military mental health care experts, administrators, and providers. Since 2004, numerous blue ribbon panels of experts have attempted to assess the current DoD and VA health care delivery system and provide recommendations for improvement,⁵⁰ including the National Academies of Science Institute of Medicine,³⁰ Dole-Shalala Commission Report,⁵¹ the Rand Report,⁵² and the American Psychological Association.⁵³ Most of these reports cite two major areas in need of improvement:

1) Support for RCTs that test the efficacy of treatment methodologies, leading to wider dissemination of evidenced based approaches.



Figure 1. SimCoach archetypes: retired Sergeant Major, female civilian, female aviator, battle buddy.

2) Identification and implementation of ways to enhance the health care dissemination/delivery system for military personnel and their families in a fashion that provides better awareness and access to care, while reducing the stigma of help-seeking.

For example, the American Psychological Association Presidential Task Force on Military Deployment Services for Youth, Families and Service Members⁵³ stated in 2007 that they were, "... not able to find any evidence of a well-coordinated or well-disseminated approach to providing behavioral health care to service members and their families." The APA report also went on to describe three primary barriers to military mental health treatment: availability, acceptability, and accessibility. More specifically:

1) Well-trained mental health specialists are not in adequate supply (availability).

2) The military culture needs to be modified so that mental health services are more accepted and less stigmatized.

3) Even if providers were available and seeking treatment was deemed acceptable, appropriate mental health services are often not readily accessible due to a variety of factors (eg, long waiting lists, limited clinic hours, a poor referral process and geographical location).

The overarching goal reported from this and other reports is to provide better awareness and access to existing care while concurrently reducing the complexity and stigma in seeking psy-

chological help. In essence, new methods are needed to reduce such barriers to care.

SimCoach Created to Improve Military Mental Health Service Usage

The SimCoach project aims to address this challenge by supporting users in their efforts to anonymously seek health care information and advice by way of online interaction with an intelligent, interactive, embodied virtual human health care guide. The primary goal of the SimCoach project is to break down barriers to care (eg, stigma, unawareness, complexity) by providing military SM, veterans, and their significant others with confidential help in exploring and accessing health care content and, if needed, for encouraging and supporting the initiation of care with a live provider.

Rather than being a traditional Web portal, SimCoach allow users to initiate and engage in a dialogue about their health care concerns with an interactive VH. Generally, these intelligent graphical characters are designed to use speech, gesture, and emotion to introduce the capabilities of the system, solicit basic anonymous background information about the user's history and clinical/psychosocial concerns, provide advice and support, present the user with relevant online content, and potentially facilitate the process of seeking appropriate care with a live clinical provider.

An implicit motive of the Sim-

Coach project is that of supporting users who are determined to be in need, to make the decision to take the first step toward initiating psychological or medical care with a live provider.

It is not the goal of SimCoach to breakdown all of the barriers to care or to provide diagnostic or therapeutic services that are best delivered by a live clinical provider. Rather, SimCoach was designed to foster comfort and confidence by promoting users' private and anonymous efforts to understand their situations better, to explore available options, and initiate treatment when appropriate. Coordinating this experience is a VH SimCoach, selected by the user from a variety of archetypal character options (see Figure 1), who can answer direct questions and/or guide the user through a sequence of user-specific questions, exercises, and assessments.

This interaction between the VH and the user provides the system with the information needed to guide users to the appropriate next step of engagement with the system or with encouragement to initiate contact with a live provider.

Again, the SimCoach project is not conceived as a replacement for human clinical providers and experts. Instead, SimCoach aims to start the process of engaging the user by providing support and encouragement, increasing awareness of their situation and treatment options, and in assisting individuals who may otherwise be initially uncomfortable talking to a live care provider.

Users can flexibly interact with a SimCoach character by typing text and clicking on character-generated menu options. Since SimCoach was designed to be an easily accessible Web-based application that requires no downloadable software, it was believed that voice recognition was not at a state where it could be reliably used at the start of the project in 2010. The feasibility of providing the option for spoken, natural language dialogue interaction is currently being explored to determine if off-the-shelf voice recognition programs are sufficiently accurate to maintain an engaged interaction between a SimCoach and a user.

The options for a SimCoach's appearance, behavior and dialogue has been designed to maximize user comfort and satisfaction, but also to facilitate fluid and truthful disclosure of clinically relevant information. Focus groups, "Wizard of OZ" studies, and iterative formative tests of the system were employed with a diverse cross section of our targeted user group to create options for SimCoach interaction that would be both engaging and useful for this population's needs. Results from these user tests indicated some key areas that were determined to be important, including user-choice of character archetypes across gender and age ranges, informal dialogue interaction, and interestingly, a preference for characters that were not in uniform.

Also, interspersed within the program are options that allow the user to respond to simple screening instruments, such as the PCL-M that are delivered in a conversational format with results fed back to the user in a supportive fashion. These screening results serve to inform the SimCoach's creation of a model of the user to enhance the reliability and accuracy of the SimCoach output to the user, to support user self-awareness

SIDEBAR.

Links to Online Videos Demonstrating Use of Virtual Reality for PTSD

- Approximately 60 videos from the USC Institute for Creative Technologies MedVR Research Group: www.youtube.com/playlist?list=UUQrbzaW3x9wWoZPI4-I4GSA&feature=plcp
- Video of a virtual patient with voice recognition: www.youtube.com/watch?v=CQTEcJJ_RhY

via feedback and to better guide the delivery of relevant information based on this self-report data. Moreover, an enhancement in user engagement with a SimCoach may be produced if a more accurate assessment of the user's needs is derived from this process to inform the relevancy of the interaction.

Focus on Privacy Protection

Engagement also is supported by ensuring that the specific health care content that a SimCoach can deliver to users is relevant to persons with a military background (and of course, to their significant others). This was addressed by leveraging content assets that were originally created for established DoD and VA websites specifically designed to address the needs of this user group (eg, after deployment, Military OneSource, National Center for PTSD). Our early research with this user group indicated a hesitancy to directly access these sites when users sought behavioral health information with a common complaint being that there was a fear that their use of those sites may be monitored and might jeopardize advancement in their military careers or later applications for disability benefits.

Despite significant efforts by the DoD and VA to dispel the idea that user tracking was employed on these sites, the prevailing suspicion led many of the users in our samples to conduct such health care queries using Google, Yahoo and Medscape. To ad-

dress this user concern, supplemental content presented by the SimCoach (eg, video, self-assessment questionnaires, resource links) are typically "pulled" into the site, rather than directing users away "to" those sites.

'Go-to Relationship'

As the system evolves, it is our view that engagement would be enhanced if the user was able to interact with the SimCoach repeatedly over time. Ideally, users could progress at their own pace over days or even weeks as they perhaps develop a "relationship" with a SimCoach character as a "go-to" source of health care information and feedback. However, this option for evolving the SimCoach comfort zone with users over time would require significant database resources to render the SimCoach capable of "remembering" the information acquired from previous visits and to build on that information in similar fashion to that of a growing human relationship.

Moreover, the persistence of a SimCoach memory for previous sessions would also require the user to sign into the system with a user name and password. This would necessitate the SimCoach system to "reside" on a high security server, such that content from previous visits could be stored and accessed with subsequent visits.

Such functionality might be a double-edged sword, as anonymity is a hallmark feature to draw in users who may be hesitant to know that their interactions are being stored, even if it

resulted in a more relevant, less redundant, and perhaps more meaningful interaction with a SimCoach over time. Likely, this would necessarily have to be a clearly stated “opt-in” function, as the technology may support this in the future.

Users also have the option to print out a PDF summary of the SimCoach session. This is important for later personal review and for the access to links that the SimCoach provided in the session to relevant Web content or to bring with them when seeking clinical care to enhance their comfort level, armed with knowledge, when dealing with human clinical care providers and experts. We have also created software authoring tools that allows other clinical professionals to create SimCoach content to enhance the likelihood that the program will evolve based on other care perspectives and emerging needs in the future.

The current version of SimCoach is undergoing beta-testing with a limited group of test-site users. Results from this user-centered testing will serve to advance the development of a SimCoach system that is expected to undergo a wider release in 2013. Although this project represents an early effort in this area, it is our view that the clinical aims selected can still be usefully addressed within the limits of current technology. However, we expect that SimCoach will continue to evolve over time based on data collected from ongoing user interactions with the system and advances in technology, particularly with improved voice recognition.

Along the way, this work will afford many research opportunities for investigating the functional and ethical issues involved in the process of creating and interacting with VHs in a clinical or health care support context. While the ethical challenges may be more intuitively appreciated, the

functional technology challenges also are significant. As advances in computing power, graphics and animation, artificial intelligence, speech recognition, and natural language processing continue to develop at current rates, we expect that the creation of highly interactive, intelligent VHs for such clinical purposes is not only possible, but probable.

CONCLUSIONS

This article detailed a range of applications that illustrate the current use of clinical VR to address the behavioral health care needs of those suffering from the wounds of war. If

Innovations that emerge in military health care typically have a lasting influence on civilian health care.

one reviews the history of the impact of war on advances in clinical care, it could be suggested that clinical VR may be an idea whose time has come. For example, during WW I, the Army Alpha/Beta Classification Test emerged from the need for better cognitive ability assessment; that development later set the stage for the civilian intelligence testing movement during the mid-20th century.

As well, the birth of clinical psychology as a treatment-oriented profession was borne from the need to provide care to the many veterans returning from WW II with “shell shock.” The Vietnam War then later drove the recognition of PTSD as a definable and treatable clinical disorder. In similar fashion, one of the clinical “game changing” outcomes of the OEF/OIF conflicts could derive from the military’s support for research and development in the area of clinical VR

that could potentially drive increased recognition and adoption within the civilian sector.

As we have seen throughout history, innovations that emerge in military health care, driven by the urgency of war, typically have a lasting influence on civilian health care long after the last shot is fired.

However, such impact will only occur if positive efficacy and cost-benefit outcomes are generated from research with these military-based VR applications. As in all areas of new technology design and development, it is easy for one to get caught up in the excitement that surrounds the potential for innovative clinical opportunities, while casting a blind eye to the pragmatic challenges that exist for building and disseminating useful and usable applications. Thus far, rational minds have prevailed among clinical VR developers and clinicians, most of whom have approached this area with an honest measure of enthusiastic vision, good science, and healthy skepticism. This has led to a growing interest in VR within the health care community as clinical tests are incrementally demonstrating that VR can be implemented safely, at a reasonable cost, and that it has now begun to yield clinical outcomes that are at the least equivalent to, and sometimes more effective than, the more traditional approaches. Thus, any rush to adopt VR should not disregard principles of evidence-based and ethical clinical practice.

In the end, technology is really no more than a tool. The technology in and of itself, does not “fix” anybody. Rather, these systems are designed to either train or extend the skills of a well-trained clinician, and in the case of SimCoach, to help a person to anonymously find the treatment they may benefit from with a live human provider.

These systems, 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 and professional appreciation of the complexity of these important behavioral health care challenges.

Note: Space limitations preclude the presentation of rich visual imagery of the work described in this article. The reader is invited to access Internet links provided in the Sidebar (see page 135) to view approximately 60 videos that are available for learning more about these projects.

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