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A Continuum of Care: Pre-Deployment Medical and Tactical Stress Inoculation Training Using Virtual Reality.*

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RESUME

Continuité des soins : la réalité virtuelle dans l'entraînement médical et tactique aux situations de stress.

Les récentes auditions du Congrès à Washington suggèrent que le nombre de syndromes de stress posttraumatique et de blessures cérébrales liés aux opérations en Irak et en Afghanistan dépasse le nombre de 500 000. Parmi ceux-ci, et dans la cohorte certes beaucoup plus âgée des membres des services, on s'attend à une morbidité et une mortalité cardiovasculaires significativement plus élevées. Il faut y ajouter une très forte incidence de troubles associés au stress qui a submergé les services de soins aux Anciens Combattants. Partant de ces préoccupantes considérations, il est important de redoubler d'efforts tant dans le domaine de la prévention des troubles liés au stress par la formation et l'entraînement que dans le développement de méthodes proactives telles que l'exposition et l'endurcissement au stress. Nous faisons la synthèse de notre expérience aux Etats-Unis et en Europe dans l'application de ces programmes au profit des troupes devant être déployées en zone de combat.

KEYWORDS: Stress Inoculation Training (SIT), Posttraumatic Stress Disorder, Virtual Reality, Injury Creation Science (ICS), Pain syndromes.

***MOTS-CLÉS :** Entraînement par exposition au stress, Syndrome de stress post-traumatique, Réalité virtuelle, Simulation de blessures, Syndromes douloureux.*

INTRODUCTION

Stress Inoculation Training (SIT) is often the umbrella term used to represent a collection of coping strategies provided to the trainee. Developed in the late 1970s by Donald Meichenbaum, SIT was originally designed for use with multiple populations of individuals[1]. Often thought of as «mental armour,» Sit helps to «inoculate» individuals to future potentially traumatizing stressors, teaching them to psychologically deal more effectively with the stressors[2, 3].

In 1988, a National Research Council study on enhancing military performance found that when a person is given knowledge of future events, stress surrounding those events is then reduced[4]. In general, this occurs because stress is associated with a new, novel task. Stress training therefore renders the task less novel and improves the trainee's self-efficacy, which in turn improves performance.

1. Pre-deployment

To improve the success rate of emergency medical interventions, Virtual Reality Medical Center (VRMC) developed the Injury Creation Science (ICS) as a way to simulate injuries – bullet, tissue and bone wounds – with scientific accuracy as close to reality as possible. Moreover, we also developed VR-SIT for highly stressful situations. After the mistaken shooting down by the U.S. Navy of a commercial Iranian airliner, a study entitled Tactical Decision-Making Under Stress project (TADMUS) was done. We have adapted these lessons learned to improve troops' responses under stress.

1. 1. Injury Creation Science

A 1998 report from the Government Accountability Office (GAO) revealed that, in peacetime, combat medics have very little practice with battlefield trauma care skills. A second report by the National Library of Medicine's Institute of Medicine estimated that approximately 98,000 U.S. patients die each year due to medical errors. The commonly used medical simulation training techniques all involve serious limitations: plastic forms and computerized mannequins lack realism, animals do not offer the proper anatomy, and cadavers can only be used once. Moreover, all of these techniques are expensive and fail to replicate many of the injuries encountered on the battlefield[5].

The Injury Creation Science (ICS) technology was developed as an injury simulation capability giving both the program and prosthetics necessary to train medical professionals in interventions such as bypassing a compromised airway, inserting an intravenous port, preventing blood loss due to arterial and venous wounds, dressing burns, and expanding a collapsed lung.

The limited realism of combat medics' simulation training does not prepare them for trauma care in the field. Moreover, many civilian-trained medical personnel are not sufficiently prepared psychologically to cope with wartime traumatic injuries. Our ICS Stress Inoculation Training program develops these skill sets through highly realistic training under increasingly stressful conditions. This helps improve the performance in actual battlefield conditions.

Combat medics' current training has an extensive curriculum, and the ICS is to be seen as an adjunct to this training, not as a replacement. The initial ICS technology was able to realistically simulate a large number of battlefield injuries (from amputations to burns and blast injuries); it has now been expanded into wearable «part-task trainers», which not only simulate injuries, but also allow medics to practice common battlefield procedures. The VRMC developed these «trainers» with the U.S. Army Research and Engineering Command – Simulation and Technology Training Center (RDECOM – STTC).

According to a paper given at the first symposium on Modelling and Simulation for Computer-Aided Medicine and Surgery[6], a perfect medical simulation would occur in a realistic setting with actual perspiration, increased heart rate, and coherent reaction from the participant. Such a reaction is possible through virtual reality (VR) combined with other realistic forms of simulation.

For over eighteen years, The Virtual Reality Medical Center (VRMC) has been pioneering the use of VR in medical procedures, with training and assessment objectives, coupled with physiological feedback. We have been able to provide the military with immersive training benefits to build psychological resilience and to prepare troops for their missions. ICS is the result of the joint work of VRMC and Department of Defence personnel. To increase the realism of injuries, movie-making techniques and special effects were added, and combat injuries as well as surgical procedures identified.

A new type of artificial skin was created after a thorough study of the microanatomic structure of the components of the layers of the skin. We also analysed how the microelastic viscous and other important physiological attributes of living tissue are integrated together. In order to use this information in our technology, we examined both materials and expertise involving selection of potential substances from nanotechnology substrates. Currently, we are further developing and looking for appropriate nanotechnology materials.

Two options exist for the use of these prosthetics. First, they can be applied to mannequins. Perceived as credible by trainees, their major drawback is that they do not bleed convincingly, and according to the injury, body type or age group, different mannequins must be used[7]. Second, prosthetics can be applied to a trainee or an actor. This allows the injured person to behave like a real patient, complaining, speaking, moving, giving wrong medical information, etc. Mantovani *et al.* (2003) underline VR as potentially enhancing skills that take into account the individual aspects of patient care, which are often difficult to recreate. When a human wears the simulator, it goes beyond basic VR and creates more realistic interaction in simulations of emergency conditions as seen in augmented reality scenarios[8].

Since 1834, with the first paintings of injuries on soldiers' bodies for casualty exercises, reproduction techniques of injuries have continuously improved. Whereas these initial «moulages» were not very realistic, Hollywood make-up

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techniques now allow a great level of realism, though the scientific accuracy may not always be replicated. Forensic science simulations focus more on realism and use simulated tissue and bones and synthetic body parts.

Experience and skills are crucial in the successful care of injured patients. A lack of training opportunities makes it hard to learn and maintain the skills. Skill decrement has been linked to poor outcomes in delivery of clinical care.

Significant drawbacks, like realism, however, have to be reported with current state-of-the-art medical simulators. A comparison between the ICS wearable synthetic skin and common simulation methods is given in the table below.

Four objectives were at the origin of the ICS prosthetics. First, it should provide an immersive training experience by being as realistic as possible. Second, it should limit to the fullest extent both the application and the removal time. Third, it should maximize the durability and be reusable. Finally, it should increase comfort. The prosthetics are assembled in kits, providing injuries and supplies to apply and improve the look, feel and smell of wounds. These four aspects of ICS's prosthetics improve upon current simulation techniques, being either too difficult to put in place, not reusable or not durable enough. The ICS prosthetic is physiologically accurate, highly durable, very comfortable to wear, and totally ready-made, rendering it extremely easy to use.

It is an effective tool for training the U.S. Army combat medics and is deployed to all the Medical Simulation Training Centers (MSTC) around the world. It is also used in the civil sector for Emergency Management, Disaster Management, and First Responder personnel. Further collaboration between VRMC and RDECOM-STTC led to laboratory research and products which developed materials able to mimic the smell and feel of human tissues and fluids.

1. 2. Stress Inoculation Training (SIT)

Under the term Stress Inoculation Training (SIT), one can often find many different coping strategies given to trainees. According to its first development in the 1970s by Donald Meichenbaum, SIT was designed for multiple populations of individuals[1]. By «inoculating» potential traumatizing stressors, trainees learn psychologically to better deal with them[2, 3]. This was confirmed by a 1988 study of the National Research Council, which found that having knowledge of future events diminishes the stress caused by such events when they do occur[4]. While stress is related to a new task; with SIT, the task is better known, enhancing the trainee's self-efficacy, and thereby the performance.

In preventive SIT, individuals are exposed to stressful situations through VR while their physiological feedback is monitored. Military personnel become progressively desensitized as they repeat exposures to situations that may trigger extreme physiologic arousal and psychological trauma. Personnel are trained using a set of coping strategies among which they can choose those that best suit their needs in a specific occasion. SIT is divisible in three distinct stages: conceptualization, skills acquisition and rehearsal, and application and follow-through.

SIT virtual environments include an Iraqi village, a shoot house, a battlefield medicine clinic, a hostage rescue scenario and a ship. VR can be experienced on computer screens, with a head-mounted display (HMD), or with a 3-wall CAVE (Computer Automatic Virtual Environment) projection system. After success in the virtual environments, a transition to real-world exercises are then practiced in structures intended for tactical training. This ensures a transfer of training from the virtual to the real world setting.

1. 3. Combining SIT and Medical Training for Combat Medics

VRMC's Student State Assessment, a 3-year study funded by Defense Advanced Research Projects Agency (DARPA), included a combat medic training scenario in which medics received SIT training using VRMC's Injury Creation Science (ICS) simulator prototype. In these scenarios, we

Table 1: Comparison of Surgical Simulation Methods. Adapted from Kaufmann, C.R. (2001)[(9)].

1.1.1.1. Model	1.1.1.2. Strengths	1.1.1.3. Weaknesses
Animal	Bleeding, individually inexpensive	Ethics/animal rights, anatomy incorrect, single use, logistics
Cadaver	Anatomy correct	Expensive, storage issues, single use, no bleeding
Plastic model	Inexpensive, convenient, repeat use	Realism, needle tracks
Computerized mannequin	Multiple applications, repeat use	Realism, very expensive, pre-cut holes
Virtual reality (VR)	Unlimited use, practice without instructor, multiple scenarios, control degree of difficulty, reset	Realism variable, expense variable, haptic force limitation
ICS Wearable Synthetic Tissue	***Inexpensive, multiple applications, repeat use, "bleeding," safe and easy to put on, behaves like real patient***	***Future challenge: train in SIT scenarios → test on mannequin or human → refine SIT scenarios***

simulated bleeding resulting from «dynamic» injuries. In addition, trainees were able to cut the «skin,» insert a chest tube, and stitch the wound closed. (A lightweight metal plate and Kevlar plate underlying the suit protected the «patient.») The feedback received from trainees was that it was the most intense, realistic training they had ever received.

Figure 1: VRMC is experienced at creating highly realistic scenarios to train combat medics. Here, trainees work on a simulated "dynamic" wound, which bleeds and reacts to treatment.

During the combat medic training, VRMC was able to experiment with simulations that went beyond moulage, or static make-up techniques. For example, we created a wound complete with active bleeding that stopped when a tourniquet was applied. In other cases, where compression was more difficult and bleeding continued, we were able to fill large IV bags with special-effects blood and deliver tubing to the injury site so as to create brisk bleeding from the wound. In another case, we created a chest wound and hid a tube that delivered air to the chest injury site. The «wounded» soldier could squeeze a bulb hidden in his hand to simulate air bubbles at the chest wound site with each breath. While we were able to try other types of injuries, it became clear to us that the tubing and other pieces that add to the special effects really need to be properly engineered, as in some cases the devices became detached.

In addition to providing state-of-the-art training for military. law enforcement and first responders, other uses for this approach include trauma care training for the civilian population and scenarios for mental health care delivery.

We have studied lessons learned from the tactical decision-making under stress (TADMUS) exercise, which resulted from the mistaken shooting down by the U.S. Navy of a commercial Iranian airliner. The study has some important information about training in virtual worlds and other types of simulated environments. Essentially, trainees must learn under stress and complexity conditions similar to what they will encounter in real life. This may seem obvious, but transitioning training from simulators to the real world is still an active issue under intense investigation. Table 2 is a comparison chart that contrasts the lessons learned from the TADMUS study with lessons learned from our clinical experience and from our previous contract with DARPA. The last column focuses on the application of a VRMC SIT paradigm based on TADMUS and applied to medical training. We believe that this theoretical model will be useful in constructing and then validating the most effective model in the training of medical personnel. Implicit in developing this new technology is the ability to weave in the important lessons we are learning from SIT.

It is our opinion that the SIT component may be equally important to the acquisition of appropriate medical triage and trauma training skills. Most medical training does not include a stress-hardening component, even though reports of high levels of stress and PTSD in medical personnel makes evident the need for improved attention to this growing problem. Although other groups are developing training programs for psychological resilience in military personnel (e.g. Battlemind, Army Center for Enhanced performance/ACEP, Warrior Reset), there remains a division between these concepts and skills-based (hands-on) medical training. Our approach is to blend SIT with skills-based medical training with the added component of novel, highly realistic injury simulation technology (e.g., ICS). Our intent is not to replace other programs but to build upon and potentially integrate our technologies for a more comprehensive and effective medical training experience. In addition to TADMUS, our investigation will bring together findings from Meichenbaum's work on SIT and Stanley Rachman's work on synchrony vs. desynchrony as they relate to training effectiveness.

1. 4. Objective Measurements of Training Transfer

It has been demonstrated that skills developed through virtual training strongly impact real-world exercises. Military populations can achieve peak performance as they are repeatedly exposed to stressful stimuli and physiologically monitored.

Additional measurements should include prediction of percentage of improved performance, reduction in the number of errors, and the overall efficiency of the training program. In the DARPA Student State Program, we established comprehensive and accurate transfer metrics. The program places the trainee in an Iraqi city. We measured specific goals like sketching a house, identifying the weapons or clearing the room through objective metrics in the virtual environment as well as in the real world. Table 3 includes examples of this kind of objective measure.

It is clear that virtual training can result in significant improvement in real world task performance. Several interesting associated findings were seen in our data analysis. Overall VR training improved performance speed and accuracy in urban warfare skills. In these first studies, the virtual shoot house was an exact replica of the «real world» shoot house. In other experiments, we provided an inaccurate VR representation of the real world. We wanted to reproduce a scenario where either incomplete or inaccurate intelligence was obtained. In these studies the VR trained group still performed better than the non-VR trained group. The findings suggest an additional cognitive benefit of VR training above and beyond simple 3D knowledge. We are further studying this finding.

CONCLUSION

VR appears to be useful in helping to prevent or attenuate stress-related reactions through Stress Inoculation Training (SIT), a type of training used to prepare individuals for stressful situations (such as combat). Large-scale studies have revealed that VR-enhanced SIT is more effective than real world training in terms of time expenditure and helping participants adapt to stressful stimulus and perform efficiently. As access to VR technology and techniques for this type of training improves, it is hoped that the incidence of stress-related psychological reactions like PTSD will diminish.

Table 2: Application of VRMC SIT Paradigm Based on TADMUS and Applied to Medical Training.

	TADMUS	VRMC (Civilian)	VRMC (DARPA)	VRMC (RDECOM)
	Stress Exposure Training	Cognitive Behavioral Therapy	Student State Individual Training	Combat Medic Training
Education	Information provision	Patient education	Individual training	Skills training
Skill Bulding	Skill acquisition and practice	Physiological feedback and training	Stress inoculation, skill acquisition and practice	Improved performance under stress
Cognitive Schema	Confidence building – application and practice	Cognitive coping techniques, desensitization in virtual reality, then *in vivo* (real life)	Cognitive thought processes – expected behaviours, sequence of procedures	Correctly follow medical algorithms
Degree of Exposure	Over-learn	Over-learn	Over-learn	Over-learn
Training Generalization	Training generalizes to real-life missions	Therapy generalizes to real-life situations	Training generalizes to real-life tasks and missions	Training generalizes to real-life tasks and missions
Content Generalization	Skills generalize to novel tasks and novel stressors	Other phobias not specifically trained show improvement	Skills generalize to multiple missions and tasks	Skills generalize despite unique anatomic attributes
Method of Exposure	Gradual increase in stressors results in skill building	Gradual exposure is important	Train in neutral environments, then in tactical situations	Train in increasingly difficult environments
VR Advantages	Virtual reality simulations crucial in allowing for a gradual increase in stressors	Virtual reality simulations allow for over-learning and gradual exposure to increasingly intense situations	Training on simulators is as effective as training in real-world settings	Virtual training for medical applications is underdeveloped
Internal Belief	A sense of control and mastery occurs	Self-efficacy and a sense of mastery occurs	Sense of confidence and mastery of skill sets occurs	Sense of confidence and mastery of skill sets occurs
On-going Support	Refresher sessions provide maintenance of skills	Booster sessions provide maintenance of skills	Strong user acceptance and portability prevent skill decrement	Refresher training and recertification are possible
Pace of Exposure	Initial exposure to high-demand/ high-stress conditions does not result in skill development and generalization	Flooding does not result in development of skills	Temporal contiguity of simulation training to real-world training is important in skill building	Gradually increase the complexity of medical complications for mastery
Order of Exposure	Develop basic physiological control strategies first to control stress/reduce attention allocated to emotions	Teach physiological control first	Complete the cognitive and associative phases of learning first	Pairing of cognitive and stress hardening skills is preferred
Quality of Exposure	Absolute fidelity is not necessary or desirable	Virtual reality simulations better than real video	Face validity and low fidelity are requirements for successful completion of the cognitive and associative phases of learning	Fidelity and continuous improvement in physical characteristics is important

Lessons Learned	**Take-home message**: "an effective method for reducing anxiety and enhancing performance in stressful environments. The results of this analysis should clearly encourage further application and research" (Cannon-Bowers and Salas, 1998).	**Take-home message**: CBT reduces anxiety, results in higher levels of functioning, and increases quality of life.	**Take-home message**: The laptop simulator is an effective method of training individuals to carry out mission-specific tasks.	**Take-home message**: Combining both medical skills and stress hardening is crucial not only for optimal performance but the prevention of PTSD

Table 3: VRMC / DARPA DARWARS Results.

Activity Performed	VR Trained Scores	Non-VR Trained Scores
Proper ID & Breach Technique	Utilized proper breaching tool 100% of the time. Identified outward door 27.8% more effectively.	Utilized the proper tool 80% of the time.
Room Clearing	5-man team took an average of 9 seconds to clear the room.	Took an average of 11 seconds.
Take Down Objective	Took 21 minutes to secure the objective with 100% accuracy.	Took 23 minutes with only 93.8% accuracy.
Sketching the House	Exhibited 80% accuracy and sketched house in 4 minutes.	Exhibited 50% accuracy and sketched house in 6 minutes.
Identify Contraband, Weapons, and Other Significant Materials	Correctly identified and collected 50% of these materials.	Only identified and collected 30% of these materials.
Fastrope	Total time of 1256 seconds. (17.2% faster)	Total time of 1517 seconds.
Caving Ladder	Total time of 1657 seconds. (8.3% faster)	Total time of 1807 seconds.

ABSTRACT

Recent Congressional hearings in Washington DC suggest the number of individuals with Posttraumatic Stress (PTS) and Traumatic Brain Injury (TBI) from the Iraq and Afghanistan wars exceeds 500,000 individuals. In this admittedly much older cohort of service members, projections for numbers of individuals with associated cardiovascular morbidity and mortality are significant. In addition, very high incidence of associated stress disorders has currently overwhelmed the Veterans Administration healthcare delivery system. Based on these sobering trends it is important that renewed efforts and interests in both prevention of stress disorders through education and training combined with proactive methods such as stress inoculation training and stress hardening be implemented. We will review some of our experience in both the U.S. and Europe applying these programs to troops pre-deployment to combat zones.

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