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Lessons Learned from the Development of Technological Support for PTSD Prevention: A Review

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Abstract. This review [2] describes the state-of-the-arttechnologiesthat support mental resilience training for PTSD prevention. It characterizes four current systems across training approaches; seeks insights via interviews with the systemdevelopers; and extracts from thesea set of essential guidelines for future developers. The guidelines include four distinct project-limiting factors, which were found to constrain the reviewed developments. These were Culture, Effectiveness, Engineering, and Resource constraints.This research is novel in reviewing technologiesfor PTSD prevention as opposed to treatment, and in analyzing from the perspective ofsystem development and designissues.

Keywords. System development, PTSD, prevention, mental resilience

Introduction

The training of mental resilience is gaining increasing importance as a way to prevent post-traumatic stress disorder (PTSD). Such training can include technological supports as an essential tool. These systems train resilience to traumatic stress in healthy persons, to preventdevelopment of pathology, in contrast to treatment systems which aim to reduce the symptoms of patients diagnosed with PTSD,such as (1)VRET for PTSD and (2)the 3MR memory reconstruction system [3]. This review of PTSD prevention systems focuses on emerging lessons for their design and development. Four systems are profiled. A focus on design and development issues was chosen, rather than on preventioneffectiveness—the design and development process is important for success but less covered in the scientific literature. Training strategies are characterized, andpractical issues and solutions uncovered for the benefit of future developers.

1. Method

Systems were selected based on their intention for primary prevention of PTSD symptoms, via literature search or referral, and excluding therapy systems. Five key

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personswere contacted, and, those who agreed participated in semi-structured interviewsabout system design and development. Key lessons were extracted from these as well as literature descriptions. A Grounded Theory clustering analysis integrated the results.Grounded Theory provides a method for the discovery of empirically testable theories by interpreting data in the social sciences [6]. It is often used as a qualitative analysis method for text-based data. Different theories can emerge depending on the data collected, and can be later validated using other methods.

Since the focus is on technology development, the interview questions followed two main threads: (1) Human-Computer Interaction (HCI) technology and (2) system development phases. HCI questionscovered automation, agents and artificial intelligence, physiological computing, affective computing, virtual reality, biofeedback, and games. Questions relating to the phases of system development were covered, including problem definition, analysis and design, construction, testing, and deployment [9]. Applicable questions were selected for each interviewee, appropriate for the time allowed (30-90min).

2. Results

This section contains a characterization of the reviewed PTSD prevention systems, giving a framework for comparison. A brief review of each system provides a context for understanding the ensuing analysis. The interview analysis comprises of a coding scheme developed by clustering key insights.The insights and resulting codes lead to a grounded set of guidelines.

2.1. Characterization

Table 1 characterizes the prevention strategies of the systems. It shows three key underlying prevention strategies that are currentlyused: Stress Inoculation Training (SIT), Cognitive-Behavioral Therapy (CBT) and biofeedback training.These methods teach and rehearse coping and self-regulation skills that may improve PTSD outcomes in those exposed to traumatic stress.

SIT is a three-phase training which involves cognitive restructuring, coping-skills acquisition, and coping-skills application in the presence of graduated stressors[10]. CBT is a therapeutic restructuring of negative thoughts and behaviors based on conscious awareness of these and their relationship to feelings. Biofeedback is the display of one or more of a person's physiological indicators to him or herself. The display of the indicator allows a person to consciously influence his or her physiology, which feeds back to the display.

Table 1. PTSD prevention systems with prevention stage and strategy.

System	Prevention Strategy
PRESIT + MSE [8]	Biofeedback breathing and attentional training, with SIT-based practice in a multimedia stressor environment; group-based delivery.
STRIVE[12]	Cinematic VR immersion with free-agency, including CBT-based cognitive restructuring with a virtual human coach.
Game-based Biofeedback[1]	SIT-based, stressful VR game requiring successful biofeedback as a performance tactic.
Physiology-Driven VR[5]	SIT-based exposure training using automated physiology-driven regulation.

2.2. Review of systems

Hourani, Kizakevich (RTI International) et al.[8] developed a pre-deployment stress inoculation training (PRESIT) for the practice of stress-coping skills using a multimedia stressor environment (MSE). PRESIT is done in group format with members of the same squad, and includes biofeedback-assisted breathing retraining, as well as attentional control training for staying in the moment. Following a SIT protocol, marines practiced these skills using the MSE. Here they are seated in groups in front of a screen displaying a scripted first-person journey through a virtual Iraqi village. The MSE included sudden stressful events (such as IED explosions) and suspicious things trainees were required to notice. This simulated potential mission conditions while providing stress. In addition, a target identification task requiring joystick responses was included in order to measure any effects of the training on performance. A controlled study was carried out to evaluate the effectiveness of PRESIT, and showed improved relaxation, as measured by heart-rate variability, for previously deployed marines, especially those with PTSD symptoms.

The Stress Resilience in Virtual Environments, or STRIVE system [12] of the Institute for Creative Technologies is a multi-episode narrative of interactive combat simulations. The trainee's experience is similar to that of being inside amovie as a marine in Afghanistan. In the roughly 10-minute episodes, cinematic devices build up an emotional backstory, setting up relationships with other virtual characters. At some point, an emotionally challenging event occurs—for example the accidental death of a civilian child—at which point a virtual mentor appears to guide the participant through cognitive-behavioral appraisal of the experience and the acquisition of emotional coping skills. The mentor sessions include various lessons on cognitive stress coping, which incorporate material from existing classroom-based training programs. The STRIVE environment is distinct in maintaining free-agency of the trainee within the environment. In this way trainees areactively engaged while exposed to stressful virtual events, and learn in an experiential way.A battery of physiological measures are used to measure Allostatic Load (AL), taken from multiple systems including immune, cardiovascular and metabolic. It is a measure of how environmental stressors contribute to the wear of the stress response. AL will be studied for its ability to predict the trainee's acute stress response to the stresses of the virtual environment.

Cosic, Popovic et al.[5]of the University of Zagreb describe an concept for a physiology-driven, adaptive virtual affect stimulation system. It usesadaptive automation to select and present graded images and video for exposure training. The exposure levels are controlled according to physiological input levels. They describe the components of such a system, applications and engineering strategies for their implementation. Three main components are elaborated. First, a stimulus generator contains various multimedia stimuli that have been rated and categorized in machine-readable dimensions. Second, the emotional state estimator monitors the trainee's physiological and subjective experience, by sampling emotion indicators during a fixed interval before the estimation is required. Third, the adaptive controller uses this estimation to apply a strategy for the control of the stimulus generator. The original paper describes a stimulus delivery algorithm for SIT, based on a trainee's physiological habituation to stimuli.

Bernier et al.[1]developed a SIT-based biofeedback training game for soldiers that involves relaxation and attentional focus simultaneous with exposure. Soldiers were required to practice deep breathing while under attack by zombies in a virtual reality first-person shooter game. The visual field of the trainee would close in if physiological measures (e.g. heart-rate variability) were outside acceptable ranges. It would reopen when returned to acceptable levels. Via such biofeedback, performance in the game depends upon successful application of relaxation strategies. The game itself is stressful, characterizing this as a SIT application. The authors evaluated the effects of the training by physiological responses during a live first-aid training simulation.

2.3. Analysis of Interviews

To understand common threads underlying the interview data as a whole, a Grounded Theory analysis was used. This meant that insights, issues and lessons gathered from interview notes and papers were clustered, leading to a coding scheme. The clustering analysis revealed four code-able factors describing the insights: Resource-, Cultural-, Effectiveness-, and Engineering-related (Table 2). These four codes seem to refer to the constraints, or limiting factors, that characterize system developments. Next, two coders used these four codes to jointly tag all 66 insights that were abstracted from the interviews. To study the reliability of their coding and the clarity of the coding scheme, a third coder, after being trained on a sample of 15 insights, coded the remaining insights independently. Agreement between the third coder and first two coders could be classified as fair to good [9] for all codes except for Effectiveness—the calculated Cohen Kappa values were: Culture, 0.58; Engineering, 0.68; Resource, 0.65; and Effectiveness, 0.25. Of the 66 insights, 58% were assigned with only a single code. In the remaining 42% that received multiple codes, there seems to be no strong indication that specific codes were often assigned together—the proportion of dual coding in 2-by-2 crosstabs of two specific codes ranged from only 4 to 17%. This suggests that four clearly distinct factors underlie the collected interview data.

Table 2.

Code	Definition	Example
Culture	Refers to a social aspect with the parties or stakeholders involved in the development	*Building this for front line soldiers and the issues they face, and most of them are male. Women soldiers face some different challenges.*
Effectiveness	Refers to the ability of the system to achieve its goals	*There is no well-validated stress-resilience questionnaire to test effectiveness.*
Engineering	Refers to ingenuity required to solve problems, design, or implement; includes development processes and methods, design principles	*A steering wheel is not necessary as an input device for driving. Other solutions can be used.*
Resource	Refers to the use of a resource (time, money, information, expertise)	*An operational problem was timing the funding of the study together with availability of the troops' deployment schedules.*

The first guideline this analysis provides is that developers should be aware of these four potential constraining factors. Besides these, interviews revealed some insights shared by more than one system: resilience training should not interfere with operational effectiveness[2][7]; technology is seen positively by trainees and stakeholders [7][2]; buy-in and user-centered design is important [7][11][4]; stress and emotion estimation are complex challenges[4][11]; and there is some degree of stigma toward addressing psychological problems in the military[4][2]. These form a basis on which to complete anessential set of development guidelines (Table 3).

Table 3. Guidelines for developers of PTSD prevention systems, related to project constraints.

Guideline	Constraints
1. Beconscious of project-limiting factors Culture, Effectiveness, Engineering, and Resources	
2. Beware that the training does not negatively affect operational effectiveness of the trainee	Effectiveness, Engineering
3. Capitalize on the positive regard for high-tech approaches	Culture
4. Ensure stakeholder buy-in and employ a user-centered design process	Culture, Effectiveness, Engineering, Resource
5. Prepare for the challenges of using stress and emotion measures	Effectiveness, Engineering
6. Acknowledge the stigma toward psychological and emotional topics in military settings	Culture

3. Discussion

Of the four systems studied[3], the PRESIT+MSE of Hourani, Kizakevich et al. is perhaps the farthest along in the development cycle, having stepped toward large-scale deployment. The issues faced by developers can be mostly described as affecting at least three project-limiting constraints: Culture, Engineering and Resources. It may be that the current definition of Effectiveness does not fit the meaning of a project-limiting constraint, and it might be reworked to better describe the dataset. A set of initial guidelines was completedfrom shared insights, which may represent an essential, if not yet comprehensive, list—besides the issues noted by multiple developers, a number insights made by a single developer seemed to berelevant as well. The generalizability of these might be validated by concisely asking other developers if they concur.

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