Stress Inoculation Training Supported by Physiology-Driven Adaptive Virtual Reality Stimulation

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Abstract. Significant proportion of psychological problems related to combat stress in recent large peacekeeping operations underscores importance of effective methods for strengthening the stress resistance of military personnel. Adaptive control of virtual reality (VR) stimulation, based on estimation of the subject’s emotional state from physiological signals, may enhance existing stress inoculation training (SIT). Physiology-driven adaptive VR stimulation can tailor the progress of stressful stimuli delivery to the physiological characteristics of each individual, which is indicated for improvement in stress resistance. Therefore, following an overview of SIT and its applications in the military setting, generic concept of physiology-driven adaptive VR stimulation is presented in the paper. Toward the end of the paper, closed-loop adaptive control strategy applicable to SIT is outlined.

Keywords. Physiology-driven adaptive virtual reality stimulation, stress inoculation training, adaptive control, physiological measurements

Introduction

Large peacekeeping operations, and assessment that 10–50% of operational injuries are psychological [1], emphasize importance of mental care for military personnel. Mental readiness training [1], which builds on SIT [2], is one aspect of such care, focused on making individuals more resilient to adverse psychological effects of combat. On the other end of the spectrum, various therapeutic approaches exist [3] for healing the individuals who already suffer from combat-related psychological disorders. VR and physiological measurements are being applied both in the treatment of psychological consequences of combat, like posttraumatic stress disorder (PTSD) [4], and in SIT for military personnel [5]. Their application in PTSD therapy may potentially be enhanced by physiology-driven adaptive VR stimulation [6], [7]. In VR exposure therapy, a treatment method for PTSD and other anxiety disorders, the therapist operates a user interface to deliver gradually to the patient the virtual stimuli of anxiety-provoking situations [8]. Physiology-driven adaptive VR stimulation attempts to optimize and customize the therapy by relieving the therapist of repetitive interface manipulation and monitoring of the patient’s physiology. Considerable similarities of SIT for tactical

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decision making to exposure therapy [9] suggest possibility of applying physiology-driven adaptive VR stimulation to SIT.

1. Stress Inoculation in the Military Setting

SIT attempts to improve stress resistance by training a set of skills that make an individual capable of responding more favorably when confronted with stressors in real life. It is described as “a flexible individually-tailored multifaceted form of cognitive-behavioral therapy” [2]. As such, SIT has been successfully used in a variety of clinical settings, including PTSD treatment [10]. Furthermore, SIT has been successful in non-clinical context, e.g. with individuals who need to cope with death of a beloved person or unemployment, and professional groups who experience high levels of stress during their regular work [10].

SIT is conducted through three overlapping phases, as expounded in reference [2]. In the initial, conceptualization phase the trainees receive stress education, including explanations regarding the nature and effects of stress etc. In the second phase of SIT, related to skill acquisition and rehearsal, the trainees learn the stress coping skills and acquire them through repeated practice. The third and final phase of SIT entails the trainees’ application of the acquired stress coping skills over a sequence of increasingly intense stressful experiences relevant for their real-life situation.

This paper is concerned with SIT for high-stress professional groups, like military personnel. There have been calls for emphasis on explicit training of stress coping skills, through integration of emotional, cognitive and behavioral control practice with realistic military training [1]. Mental readiness training approach is aligned with SIT, but has the focus shifted from lectures concerning stress to techniques directly integrated into more intense and operationally relevant training situations [1]. Thus, the third phase of SIT seems accentuated in mental readiness training.

Investigations have been conducted to ascertain the most appropriate protocol of stressor delivery for task performance in the military setting. One hypothesis has been that training of tasks while being simultaneously exposed to stressors may possibly produce undesirable mutual interference between task acquisition and stressor familiarization [11]. The authors have compared combined training, including simultaneous task acquisition and exposure to stressors, to phased training, in which the two are temporally separated [11]. In the authors’ several experimental settings, effectiveness of phased training has been equal or superior to combined training [11].

Another available publication in the military context is a book written on the experiences and lessons learned from the Tactical Decision Making under Stress (TADMUS) project [12]. The project strived to develop training, simulation and decision support principles that would help mitigate the impact of stress on decision making. Significant agreement is noticed when comparing the TADMUS findings to the findings of the cognitive-behavioral therapy [9], including that skills acquired during the TADMUS training generalize to novel tasks and stressors, and that gradual increase in stressors is preferred to initial high-stressor delivery.

Recent review of VR applications for SIT [5] finds several studies within the military context. The reviewed studies show that training in VR with stressors may result in better performance during testing, than training in VR without stressors. Likewise, psychological and physiological stress may be lower when training in VR with versus without stressors. The review also provides support for the expectations
that SIT may provide protection against stress-related psychological disorders after encountering real-life stressors. Altogether, using VR technology for SIT holds promise for stress reduction and performance enhancement, warranting further research.

Physiology-driven adaptive VR stimulation in this paper will specifically target the third phase of SIT, applying only exposure-to-stressors part of the phased training [11], in hope to improve resistance to stress-related psychological disorders.

2. Physiology-Driven Adaptive VR Stimulation

Adaptive systems using physiology in a feedback loop have been around at least since the mid 1990’s (e.g. [13]). Further examples of adaptation of computer systems based on emotions of their users, where emotion indicators are obtained from physiology, may be found in the affective computing field [14]. Concept of physiology-driven adaptive VR stimulation is related to influencing the emotional state of the “subject” (“patient”, “trainee”) in a controlled manner by display of stimuli in various media forms, like static pictures, sounds and synthetic virtual stimuli combined with real-life video clips. To this end, the concept includes time-synchronized stimuli generation to the subject, acquisition of the subject’s physiological response, subject’s emotional state estimation, and adaptive closed-loop control that leads to subsequent generation of new stimuli [6]. Any potential application of the concept may be derived by specifying the application-specific control strategy, with appropriate stimuli and emotional state estimation; the next section will outline the application to SIT.

Physiology-driven adaptive VR stimulation is decomposed into four logical subsystems: Stimuli Generator, Emotional State Estimator, Adaptive Controller, and Graphical Interface. The Stimuli Generator receives control signals from the Adaptive Controller and generates the corresponding stimuli. Control signals may specify the semantics (e.g. keywords), and/or emotional properties of the stimuli (e.g. valence/arousal values in line with the dimensional model of emotions [15]), together with the desired media forms. Control signals are resolved into concrete stimuli by comparing them against semantically and emotionally annotated stimuli database [16].

The Emotional State Estimator estimates the subject’s emotional state in real time from the acquired physiological signals, e.g. in the form of valence/arousal values [17]. Generally, the subjects may also occasionally rate their emotional state, which can be provided to the Emotional State Estimator in addition to physiology.

The Adaptive Controller holds the decision-making logic regarding the best stimuli to deliver based on the subject’s estimated emotional state. Thus, the Adaptive Controller needs from other subsystems all information potentially relevant for decision making. It is also the most appropriate subsystem for storing this information permanently into the Subject’s Aggregated Knowledge Database (SAKD), for subsequent use. In particular, internal state of the Adaptive Controller at the end of each session can be serialized into SAKD, in order to be reloaded at the beginning of the next session. Reference Knowledge Database (RKD) is based on relevant data from literature, or integrates SAKDs of the previous subjects. The Adaptive Controller may use RKD in the beginning of the first session, for educated guess regarding the subject’s characteristics when no other information is yet available, and in any decision making that needs to compare the individual subject to a larger sample of subjects.

The Graphical Interface is necessary in applications that may require collaboration between the “supervisor” (“therapist”, “trainer”) and the Adaptive Controller during the
session. Prominent example is VR exposure therapy for PTSD [6], [7], as the patients may be very sensitive to the potential mistakes by the Adaptive Controller. In such applications, the Adaptive Controller should by design have its decision making subordinate to the supervisor’s decision making. It also needs to supply the supervisor with information useful for making appropriate decisions.

3. Adaptive Control Strategy for SIT

This section presents control strategy aligned with the third phase of SIT, to the best of the authors’ knowledge. Whenever the stressful stimuli are delivered by the strategy, the subject may practice application of the stress coping skills learned in earlier SIT phases. The strategy is focused on delivery of stressors only, not on any professional task skills acquisition, thus corresponding to a particular part of the phased training approach [11]. The stressors are presented with the purpose of improving the subjects’ resilience to stress-related psychological disorders that may occur after experiencing similar real-life stressors. According to the literature presented in section 1, it is advised to progress with intensity of stimulation gradually, rather than to jump immediately to the expected most stressful stimuli.

At the beginning of any session other than the first one, the information from the subject’s earlier sessions is retrieved. This also includes initializing the state of the Adaptive Controller from the state stored at the end of the previous session. Every session contains several minutes of baseline physiological measurements, to allow for day-to-day differences in the subject’s physiology.

The session then proceeds with multiple cycles of exposure and training stages. In the exposure stage, the subject is presented with various stimuli from the stimuli database, according to the currently unspecified search algorithm in the stimuli space. Durations of the stimuli may generally be time-limited and/or depend on behavior of the acquired physiological signals. Estimated emotional state from physiology, regardless of its actual representation in this application, may be used for ranking the stimuli based on their impact on the subject’s physiology. Following the exposure to any particular stimulus, ranking of the stimuli is performed and a predicate that guards the initiation of the training stage is checked. For example, the training stage may be allowed to commence only after sufficient number of stimuli that elicit significant physiological reactions has been found.

In the training stage the subject tries to lower physiological reactivity to the high-reactivity stimuli from the exposure stage. Repeated exposures to these stimuli may be needed. The training stage may end when adequate success has been achieved, e.g. measured by the percentage of achieved habituations over the stimuli delivered in this stage. If the subject cannot achieve the required percentage of habituations, restrictions on the maximum number of repeated exposures allowed per stimulus may be needed to avoid infinite loop in the training stage. Exact definition of habituation to a stimulus is left unspecified at this point. However, it is expected to be defined in terms of change in the physiological reactivity relative to the first exposure to the stimulus, taking into account baseline differences if the stimulus is used across sessions.

After the training stage has been completed, various checks may be performed to determine if the session should end, e.g. whether maximum allowed time per session or maximum allowed number of stimuli per session has been exceeded. If the session should continue, new cycle of exposure and training stages is performed. Otherwise,
the internal state of the Adaptive Controller is serialized into the SAKD just before the session ends, to be retrieved when the subsequent session starts.

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References


