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Virtual Reality Applications for Stress Management Training in the Military

Federica Pallavicini; Luca Argenton; Nicola Toniazzi; Luciana Aceti; Fabrizia Mantovani

INTRODUCTION: Stress Management Training programs are increasingly being adopted in the military field for resilience empowerment and primary stress prevention. In the last several years, advanced technologies (virtual reality in particular) have been integrated in order to develop more innovative and effective stress training programs for military personnel, including soldiers, pilots and other aircrew professionals. This systematic review describes experimental studies that have been conducted in recent years to test the effectiveness of virtual reality-based Stress Management Training programs developed for military personnel. This promising state-of-the-art technology has the potential to be a successful new approach in empowering soldiers and increasing their resilience to stress.

METHODS: To provide an overview from 2001 to 2016 of the application of virtual reality for Stress Management Training programs developed for the military, a computer-based search for relevant publications was performed in several databases. Databases used in the search were PsycINFO, Web of Science (Web of Knowledge), PubMed, and Medline. The search string was: (“Virtual Reality”) AND (“Military”) AND [“Stress Training” OR (“Stress Management”)].

RESULTS: There were 14 studies that met the inclusion criteria and were included in the review.

DISCUSSION: The main observation to be drawn from this review is that virtual reality can provide interactive Stress Management Training to decrease levels of perceived stress and negative affect in military personnel. This technology appears to be a promising tool for assessing individuals’ resilience to stress and for identifying the impact that stress can have on physiological reactivity and performance.

KEYWORDS: stress management training, virtual reality, military.

including coping strategies to implement before deployment to a combat zone, during deployment, and when returning home.\textsuperscript{22}

Although few, if any, individuals are likely to be completely immune to the effects of stress on performance, there are intervening variables known as “moderators” that can reduce the performance decrement caused by stress.\textsuperscript{27} One of the most studied and most effective moderators is training.\textsuperscript{27} Stress training can help military personnel handle emotional and physiological responses to stressors in order to maintain optimum performance even in situations of high stress.\textsuperscript{25,37,44}

In psychiatric literature, the term “Stress Management Training” (SMT) is not a single and selective concept. Most approaches usually contain elements of both relaxation and cognitive coping skills for preventing and managing stress.\textsuperscript{18} In general, SMT can be defined as the application of any set of techniques (e.g., relaxation, biofeedback, and cognitive behavioral therapy) with the intent to improve the way people cope with stress.\textsuperscript{1} Most research on the effects of SMT programs focuses on two main types of training: Stress Inoculation Training (SIT) and Resilience Training (RT). While SIT programs aim to build stress tolerance through exposure, RT programs teach stress management techniques.

SIT was born from clinical psychology as a cognitive-behavioral treatment\textsuperscript{47–49} to help individuals cope with the consequences of being exposed to stressful events. In the military field, the purpose of SMT programs is to repeatedly expose soldiers to specific stressors and ask them to perform a target task while under the stress. Hence, SIT can gradually lessen an individual’s physiological response to a stimulus by reducing its novelty.\textsuperscript{22} Through training, individuals may also learn how to manage uncertainty\textsuperscript{22,49} and maintain high levels of performance despite its presence.\textsuperscript{19,33,60} Several military programs incorporate SIT techniques. Examples include: 1) Survival, Evasion, Resistance and Escape (SERE)\textsuperscript{26,82,83} which provides U.S. military personnel, U.S. Department of Defense civilians, and private military contractors with training in survival skills, evading capture, and the military code of conduct; and 2) Mental Readiness Training (MRT),\textsuperscript{84} which was developed for the Canadian Armed Forces.

Resilience training (RT), i.e., the instruction of stress coping mechanisms while in a nonstressful setting, has been shown to reduce subjective stress assessments and increase performance of individuals.\textsuperscript{26,64,74} While the term “resilience” is conceptualized in a number of different ways in the academic literature, the term broadly refers to an individual’s capacity to maintain a functional equilibrium or display positive adaptation following or in spite of risks to normal development or psychological health.\textsuperscript{7} Some of the most important programs developed in this area are the Comprehensive Soldier & Family Fitness Program (CSF2, U.S. Army),\textsuperscript{20,34,64} designed to build resilience and enhance the performance of soldiers, their families, and U.S. Army civilians, and the Army’s Resilience Training Program (Battlemind Training, U.S. Army)\textsuperscript{2,17} built as an integration of resiliency training for support populations throughout existing soldier, leader, and unit strengths.

In recent years the use of virtual reality (VR) has been extended to different traditional SMTs, including SIT and RT programs.\textsuperscript{29,56,61} SIT programs have been recently implemented in cyber-interventions (cyber-SIT), which through advanced technologies recreate simulations to teach individuals how to effectively cope with psychological stress.\textsuperscript{70,79,86} With respect to RT, VR can help stressed or anxious individuals acquire effective coping skills, such as relaxation strategies\textsuperscript{29,31,62} and biofeedback training.\textsuperscript{55,57,71}

By definition, VR is an application that lets users navigate and interact with a three-dimensional computer-generated (and computer-maintained) environment in real-time.\textsuperscript{62} Research studies have compared the efficacy of VR in inducing an emotional response with that of other media and/or real-life reactions, reporting that exposure to virtual stimuli produces emotional and behavioral responses similar to those that occur in the real world.\textsuperscript{32,45} In addition, VR has recently been proven able to elicit emotions related to complex real-life stressors.\textsuperscript{56,57}

In the military field, the use of VR for SMT is increasingly common.\textsuperscript{16,66,76} Until a few years ago this technology had been used in a military context almost exclusively for the treatment of disorders associated with exposure to stressful situations, especially PTSD\textsuperscript{23,24} and for flight simulation\textsuperscript{3,5,46}.

VR has become a topic of increasing interest to the military because it simulates highly stressful and complex scenarios in a safe environment. In addition, this technology is customizable, dynamic, and less expensive than other methods.\textsuperscript{42,66,67}

In the current review we will describe experimental studies that have been conducted since 2001 to test the effectiveness of VR-based SMTs developed for military personnel in order to show how this emerging state-of-the-art approach can improve soldiers’ resilience to stress.

**METHODS**

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.\textsuperscript{51}

To provide an overview of VR-based SMT programs developed for military personnel, a computer-based search for relevant publications was performed in several databases. Databases used in the search were PsycINFO, Web of Science (Web of Knowledge), PubMed, and Scopus. The search string was: (“Virtual Reality”) AND (“Military”) AND [ (“StressTraining”) OR (“Stress Management”) ].

To avoid the risk of bias, PRISMA recommendations for systematic literature analysis have been strictly followed. Three authors independently selected paper abstracts and titles, analyzed the full papers that met the inclusion criteria, and resolved any disagreements through consensus. The articles were individually scanned to examine whether they fulfilled the following inclusion criteria: 1) research article; 2) provide information about the used sample; and 3) provide information about measures.

In the current systematic review, we aim to analyze experimental studies (from 2001 to 2016) focused on the use of VR
for SMT programs geared toward military personnel to provide crucial indications for future studies and interventions. To this end, several aspects of the selected studies will be fully reviewed and discussed: 1) participants; 2) experimental design; 3) type of task used; and 4) the main outcomes for each study.

RESULTS

The flow chart of the systematic review is shown in Fig. 1. Our initial search in PsycINFO, Web of Science (Web of Knowledge), PubMed, and Scopus yielded 76 nonduplicate citations. After the application of the inclusion criteria, 20 articles remained. A deeper investigation of the full papers resulted in the exclusion of another 6 articles. In the end, only 14 studies met the full criteria and were included in this review.

The first important application of VR-based SMT programs for the military is cyber-interventions (cyber-SIT) programs, developed to expose soldiers to high-stress situations in order to improve their responses and performance under stress (Table I).

In the first study, Stetz et al. tested 25 soldiers (first responders or “medics”) with VR training that consisted of a virtual environment being shown while the soldiers performed tasks in a stressful combat casualty environment. Participants were divided into four groups: virtual scenarios only, relaxation techniques only, both, or neither. Participants received feedback on their psychological and physiological stress levels and practiced coping strategies (e.g., combat breathing). Results showed that participants who learned coping techniques during the VR training generally enjoyed the environment and experienced little to no discomfort while navigating within the environment. Comparative analyses indicated that the virtual environment did increase levels of posttreatment anxiety and dysphoria.

In a second study, the same author investigated the usefulness of a cyber-SIT program to increase levels of stress in medical military personnel. Sixty-three volunteers who were attending a combat medical class (e.g., Flight Medic, Joint En-route Care Course, Ranger First Responder) were placed in groups to practice combat medical skills with virtual scenarios only, relaxation techniques only, both, or neither. Higher levels of hostility were observed in the VR group than in the rest. Also, participants practicing relaxation techniques while exposed to the virtual scenarios showed higher levels of sensation-seeking. Interestingly, further analyses showed higher levels of both anxiety and dysphoria in those previously deployed who participated either in the VR or the relaxation group. Results suggested that exposure to VR scenarios involving medical skills could be a promising way to prepare soldiers for combat stress.

Some years later, Hourani et al. conducted a controlled pilot study to compare the efficacy of a cyber-SIT program called PRESIT with Combat and Operational Stress Control (COSC), the current best practice. The purpose of the study was to use a Multimedia Stressor Environment (MSE) to induce a psycho-physiological arousal response during a simulated training mission and to assess the ability of participants to respond quickly and accurately to visual stimuli presented during the mission. The MSE (a moderate-sized Iraqi village developed as a virtual scenario) was presented to a viewing group of 20 participants. Results showed that participants with deployment experience demonstrated improvement, which was measured as greater relaxation during the MSE when it was shown again in a follow-up session. In addition, participants with more PTSD symptoms showed more capability for improvement, as was true for participants who were more anxious about their next deployment.

Four other papers have recently reported on experimental studies conducted during a 5-yr partnership between the Department of Psychiatry and Combat Stress (DP&CS) at the Military Institute of Medicine in Warsaw with the Virtual Reality Medical Center (VRMC) of San Diego. The training program consisted of...
of physiological control exposure to a virtual stressor while maintaining physiological control.

In the first study, Zbyszewski et al. conducted a study investigating the impact of personality, temperament, and stress coping factors in a cyber-SIT program in soldiers preparing for their first deployment to Afghanistan (ISAF). There were 120 soldiers that were split into two groups of 60 people each: the Experimental (EG) and the Control (CG) Group. Soldiers from the EG, split into four subgroups of 15 each, took part in 10 SIT sessions. Both main groups filled out self-report questionnaires assessing coping skills, personality, and anxiety level. Results showed that before the SIT program, in the EG there was a negative correlation between values in anxiety and briskness, sensory threshold, and endurance; there was a positive correlation between anxiety levels and emotional reactivity. After the SIT program, in the EG there was a correlation between trait anxiety values and emotional reactivity. These results can be taken into account when analyzing individual susceptibility to SIT programs.

In the second study, Maciolek et al. evaluated the influence of this type of cyber-SIT on the anxiety levels of ISAF soldiers. There were 118 soldiers who were selected randomly from the 1500-strong contingent that took part in the research. The soldiers were split into two groups: the EG and the CG. Both groups listened to a lecture on the nature of stress, its symptoms, and coping with stress. Soldiers from the EG were split into four subgroups, each taking part in ten SIT sessions over the next 5 d. At the same time, soldiers from the CG took part in the scheduled training in their military area. Results of self-report questionnaires showed that, after training, anxiety values in the EG were significantly lower than in the CG. Participants who learned coping techniques during the VR training enjoyed the environment, and experience minor to no discomfort while navigating within the environment.

Table I. Information About the Selected Studies on VR-Based Stress Inoculation Training Programs.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>SAMPLE</th>
<th>DESIGN</th>
<th>CONDITION(S)</th>
<th>VIRTUAL STRESS INOCULATION TRAINING</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stetz et al. (2007)</td>
<td>25 soldiers</td>
<td>Between subjects design</td>
<td>Four conditions</td>
<td>Combat Medic Scenario; Individual training</td>
<td>Participants who learned coping techniques during the VR training enjoyed the environment, and experience minor to no discomfort while navigating within the environment.</td>
</tr>
<tr>
<td>Stetz et al. (2008)</td>
<td>63 soldiers</td>
<td>Between subjects design</td>
<td>Four conditions</td>
<td>Combat Medic Scenario; Individual training</td>
<td>Exposure to VR scenarios where to practice medical skills could be a promising way to prepare warfighters for combat stress.</td>
</tr>
<tr>
<td>Hourani et al. (2011)</td>
<td>77 marines</td>
<td>Between subjects design</td>
<td>Two conditions:</td>
<td>PRESIT; Multimedia Stressor Environment (MSE) scenario</td>
<td>Participants with deployment experience and who were in the experimental group showed greater relaxation during the MSE scenario;</td>
</tr>
<tr>
<td>Zbyszewski et al. (2013)</td>
<td>120 soldiers</td>
<td>Between subjects design</td>
<td>Two conditions:</td>
<td>Physiological control exposure to virtual stressor; Training was delivered in subgroups of 15 soldiers</td>
<td>After the training there was a correlation between anxiety trait values and emotional reactivity.</td>
</tr>
<tr>
<td>Maciolek et al. (2013)</td>
<td>118 soldiers</td>
<td>Between subjects design</td>
<td>Two conditions:</td>
<td>See Above; -Training was delivered in subgroups of 15 soldiers</td>
<td>After training, anxiety values in EG group were significantly lower than in the CG.</td>
</tr>
<tr>
<td>Kosinska et al. (2013)</td>
<td>4 soldiers</td>
<td>Within subjects design</td>
<td>One condition:</td>
<td>See Above; -Training was delivered in subgroups of 4 soldiers</td>
<td>Two participants achieved better results in relaxation during final exposition, when compared to the initial session;</td>
</tr>
<tr>
<td>Ilnicki et al. (2012)</td>
<td>118 soldiers</td>
<td>Between subjects design</td>
<td>Two conditions:</td>
<td>See Above; Training was delivered in subgroups of 15 soldiers</td>
<td>Short-term effectiveness of the training as a method of tension reduction. In the long-term results were ambiguous.</td>
</tr>
<tr>
<td>Winslow et al. (2015)</td>
<td>40 novice participants</td>
<td>Between subjects design</td>
<td>Two conditions:</td>
<td>Five military-relevant training tasks under stress within Virtual Battlespace 2 (VBS2)</td>
<td>Utility of adding stressors external to the virtual training environments.</td>
</tr>
<tr>
<td>Bouchard et al. (2011)</td>
<td>1,319 soldiers</td>
<td>Within subjects design</td>
<td>A review and analysis of the available literature and of data collected post-deployment from respondents, recruited within Canadian Forces</td>
<td>Three sources were included</td>
<td>Identification of several stressful situations that could be used in VEs.</td>
</tr>
</tbody>
</table>
were significantly lower compared to values before training. Authors stated that, given the equivocal results of the experiment, further study and deeper analysis were necessary.

In the third study, Kosinska et al.\textsuperscript{36} evaluated the effectiveness of the same cyber-SIT program on four ISAF soldiers and then assessed whether the soldiers’ temperament structure was related to successful training. Soldiers took part in 10 SIT sessions over 5 d. The initial and final arousal/relaxation in response to VR exposition was assessed using heart rate (HR) indexes, while the temperament traits and structure were assessed using a self-report questionnaire. The analysis of HR indexes showed that three soldiers succeeded in reducing their arousal during the final session. Two of them achieved better results in relaxation during the final exposition when compared to the initial session. Three of the soldiers could effectively reduce arousal after the exposition as an effect of the training. Regarding the temperament structure, greater harmony was found in soldiers who achieved weaker results in training.

Finally, Ilnicki et al.\textsuperscript{36} investigated the effectiveness of a short collective cyber-SIT program conducted according to the same methodology developed by the VRMC. There were 118 soldiers from the 1500-strong Polish military contingent in Afghanistan that were split into two groups: the EG and the CG. Results showed short-term effectiveness of the cyber-SIT program as a method of tension reduction. However, in the long term, results were ambiguous and authors suggested the need for further research.

In another recent study, Winslow et al.\textsuperscript{87} investigated how stress induction through a virtual environment compares to and is influenced by the gold standard of socio-evaluative stress, the Trier Social Stress Test (TSST).\textsuperscript{38} There were 40 novice participants divided into Experimental (EG) and Control Groups (CG). Participants’ physiological and psychological stress levels were assessed. After the collection of baseline measurements, the EG was exposed to the TSST, while the CG was not. Then, all the participants performed five military-relevant training tasks under stress within Virtual Battlespace 2 (VBS2, Bohemia, Orlando, FL), a VE used for military training. Results showed that virtual stressors alone may not be sufficient to induce a significant stress response (i.e., cortisol levels did not increase significantly after the exposure to stressful virtual scenarios). Indeed, analysis indicates the utility of adding stressors external to virtual training environments. Interestingly, baseline stress measurements were predictive of individual resilience to stress, including the impact stress had on physiological reactivity and performance under stress.

Only one study focused on the procedures followed to identify several stressful situations that could be used in VEs designed to train military personnel in stress management techniques.\textsuperscript{11} The aim was to list VEs that are significantly stressful and specific enough to allow a reduction in the likelihood of developing PTSD. A review and analysis of the available literature and of data collected post-deployment from 1319 respondents (recruited by the Canadian Forces) about the frequency of stressors and their association with psychological injuries were pulled together to propose potential virtual stressors. Stressor selection was based on a few criteria, such as a frequency of occurrence of at least 50% among military personnel who were involved in active combat and the feasibility of recreating the stressor in VR. After submitting stressors to these criteria, eight stressful situations stood out (e.g., seeing dead bodies or uncovering human remains and knowing that someone has been seriously injured or killed).

Another area of extreme interest to the military related to the field of VR-based SMT programs is Resilience Training (RT), which aims to teach stress management techniques to soldiers to increase their stress tolerance (Table II).

The first study conducted in this field was to test receptivity to stress management techniques taught through virtual scenarios by military service members.\textsuperscript{75} There were 60 soldiers were randomly assigned and equally distributed to either an Experimental Group (EG) or a Control Group (CG). For three consecutive days, the EG looked at a video of a virtual island zone that contained an embedded script explaining how to practice relaxation techniques (e.g., progressive muscle relaxation). Analyses of surveys and a focus group suggested that EG participants not only liked practicing relaxation techniques, but would also continue practicing these after the completion of the study.

In a second study, Bosse et al.\textsuperscript{10} investigated the impact of virtual training on the subjects’ experienced stress responses. Driven by the goal to develop a virtual environment capable of training for mental readiness, the main research question was whether it is possible at all for such an environment to obtain a learned effect of successfully lowering subjects’ stress responses in future situations. There were 10 healthy adults who participated in the experiment and were randomly assigned to either the EG or the CG. The CG participated in two rounds separated by a 6-h break. In these rounds participants were shown 150 images from the IAPS picture set.\textsuperscript{40} After each image, participants were asked to rate the emotional intensity of the picture. The EG also participated in these rounds. However, in between these two rounds, the EG participated in a virtual training session. The virtual training used the same pictures as the other rounds. But instead of rating them with a grade, the participants were asked to view the pictures while actively reducing their emotional response until they felt comfortable looking at the picture. The training resulted in significantly lower ratings of the images in the second test. In particular, the overall drop in emotional ratings of the training group was significant, while the change in emotional ratings for the control group was not significant.

The same authors replicated this study on a different sample in a second experiment\textsuperscript{11} to investigate what type of VR-based RT could be the most appropriate in order to obtain a successful decrease of emotional responses toward negative stimuli. There were 15 healthy adults who participated in the experiment and were randomly assigned to 1 of 3 groups: a first group performing a session of virtual training in between these time points (EG 1), a second group performing virtual training thereby applying reappraisal strategies (EG 2), and a group without any training session (CG). In these rounds, 150 images from the IAPS picture set\textsuperscript{40} were shown to the participants following the
Table II. Information About the Selected Studies on VR-Based Resilience Training Programs.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>SAMPLE</th>
<th>DESIGN</th>
<th>CONDITION(S)</th>
<th>VIRTUAL RESILIENCE TRAINING</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stetz et al. (2009)</td>
<td>60 soldiers</td>
<td>Between subjects design</td>
<td>Two conditions: 1) VR-based training group (EG); 2) no training group (CG)</td>
<td>&quot;Dream Island&quot;, a virtual environment that embedded script explaining how to practice Progressive Muscle Relaxation and Controlled Breathing</td>
<td>- Participants not only liked practicing relaxation techniques through VR scenarios but would also continue practicing these after completion of the study</td>
</tr>
<tr>
<td>Bosse et al. (2012)</td>
<td>10 healthy adults</td>
<td>Between subjects design</td>
<td>Two conditions: 1) VR-based training group (EG); 2) no training group (CG)</td>
<td>Emotional pictures were shown while participants were asked to actively reducing the emotional response until they felt comfortable looking at the picture</td>
<td>- The VR-based training resulted in significantly lower ratings of the images supporting the hypothesis that reappraisal-based virtual training can be used to reduce subjects’ emotional responses to negative stimuli at later times</td>
</tr>
<tr>
<td>Bosse et al. (2013)</td>
<td>15 healthy adults</td>
<td>Between subjects design</td>
<td>Three conditions: 1) VR-based training group 1 (EG1); 2) VR-based training group 2 (EG2); 3) no training group (CG)</td>
<td>Emotional pictures were shown while participants were asked to actively reducing the emotional response until they felt comfortable looking at the picture or to apply reappraisal strategies</td>
<td>- The VR-based training applying reappraisal strategies could be the most appropriate in order to obtain a successful decrease of emotional responses toward negative stimuli with a long-term effects of training</td>
</tr>
<tr>
<td>Morie et al. (2011)</td>
<td>27 healthy adults</td>
<td>Within subjects design</td>
<td>One condition: Virtual Biofeedback</td>
<td>A virtual jogging path, developed within Second Life™, where control of the avatar is done via rhythmic breathing</td>
<td>- The virtual jogging activity tends to help participants feel more relaxed and calm. While there was a decline in some positive emotions such as inspired and enthusiastic, there was a significant decline in the negative emotions as well</td>
</tr>
<tr>
<td>Stetz et al. (2011)</td>
<td>60 military medical warriors</td>
<td>Between subjects design</td>
<td>Two conditions: 1) VR-based training group (EG); 2) no training group (CG)</td>
<td>For three consecutive mornings a virtual calming environments was presented while practicing relaxation techniques</td>
<td>- The VR-based relaxation techniques were successful in reducing overall anxiety levels</td>
</tr>
</tbody>
</table>

same procedure of the previous study. Both EGs also participated in these rounds, just like the CG. However, in between these two rounds, the EGs performed a virtual training session. In addition to the above, the participants in all three groups participated in a second part of the experiment that afternoon and then 6 mo after the first part. Results showed that the EG 1 resulted in a significant increase of emotional ratings for negative images, while EG 2 significantly decreased emotional ratings for those images.

Morie et al. conducted a preliminary study that measured mood and arousal effects produced by engaging in a biofeedback (virtual jogging) scenario where control of the avatar is achieved via steady, rhythmic breathing. There were 27 participants, not specifically selected from the veteran population, who used a male avatar wearing Army fatigues and were tested at the same virtual location within Second Life. Results on self-report questionnaires showed that participants’ experiences using the jogging path had effects on these measures, resulting in a significant decline in mean scores for all three scales. Overall, results indicate that the virtual jogging activity, in its totality, tended to help participants feel more relaxed and calm.

Stetz et al. conducted another study with the aim to test the effectiveness of a VR-based RT based on progressive muscle relaxation (PMR) and controlled breathing (CB) techniques. There were 60 military medical warriors who participated in the study and were divided in 2 groups: the EG and the CG. For three consecutive mornings, participants in the EG were presented with virtual calming and relaxing environments while practicing PMR and CB techniques. The participants also engaged in two stressful hands-on tasks (simulations of surgery). Results on self-report questionnaires showed that participants in the EG were less anxious post-immersive relaxation training compared to the CG. In addition, even if the VR-assisted relaxation techniques were unable to be evaluated during stressful situations (i.e., the stressful tasks failed to increase participants’ anxiety levels), they were successful in reducing overall anxiety scores.

**DISCUSSION**

SMT programs are increasingly being adopted in the military field for soldiers’ and aircrew professionals’ resilience...
empowerment and primary stress prevention. \textsuperscript{16,74} Stress can worsen the performance, affecting individuals’ cognitive and emotional processes. Thus, knowing how to manage stress is a fundamental skill for military personnel that can have an impact on job performance, as well as on emotional and physical health. \textsuperscript{12,37,54} In recent years, advanced technologies including virtual reality have been included in SMT in order to develop more innovative and effective training. \textsuperscript{29,65} Here, we focused specifically on SMT programs for military personnel that integrated virtual reality in order to describe this emerging and promising approach to improving resilience to stress.

The main observation to be drawn from this review is that VR-based SMT programs (both developed on SIT and RT programs) can reduce subjects’ emotional responses to negative stimuli, \textsuperscript{35,39} even at later times. \textsuperscript{9,10} This type of training, therefore, can help military personnel handle emotional and physiological responses to stressors in order to maintain performance even in situations of high stress.

Interestingly, VR also appears to be a promising tool to assess individuals’ resilience to stress and to identify the impact that stress can have on physiological reactivity and performance. \textsuperscript{57} Virtual stressful scenarios can be used to assess the physiological response to stressors and correlate that response to task performance, making it possible to train practitioners to identify resilient individuals or those at risk for stress-related performance issues.

The third important observation that emerges from this review is that VR can also be used to provide interactive SMT programs useful for decreasing levels of perceived stress and negative affect in military personnel. \textsuperscript{9,52,76} In particular, the review showed that virtual environments combined with arousal reduction strategies (e.g., systematic desensitization through exposure to stressful scenarios, traditional relaxation and biofeedback techniques) effectively increase military resilience to stress.

According to the results of this systematic review, SMT programs based on VR applications appear to be a promising approach; there are even studies that have effectively combined traditional SMT protocol with VR technology. However, there are some methodological challenges.

The first challenge is the number of studies carried out in this research field. Because it is an emerging field of research, there are still relatively few studies in the literature that meet the requirement of using VR in SMT programs. Most of the studies, in fact, have VR-based SMT programs only in theory, without providing data about trials conducted to test the effectiveness of the proposed approaches. In particular, we could not include in the review important programs developed in recent years for SMT that integrate VR as a “virtual reality adaptive stimulation” (VRAS) or “Stress Resilience in Virtual Environments” (STRIVE). VRAS is a predeployment mental stress resistance training, based on the use of virtual reality that was developed for the assessment of emotional and behavioral control of International Security Assistance Force (ISAF) soldiers, whose mental health is an important indicator of NATO’s readiness. \textsuperscript{20,21,68} The STRIVE project builds on the Virtual Iraq/Afghanistan simulations developed for VRET\textsuperscript{63,68} to create a series of immersive virtual interactive narrative episodes that present examples of the types of emotional challenges soldiers may face during deployment. It has developed and disseminated training that aims to improve the emotional coping skills and resilience of soldiers. \textsuperscript{57} Although VRAS and STRIVE are both complex and innovative programs that may provide important new elements to SMT programs for military personnel, the lack of experimental studies significantly limits their impact. As VR and, more generally, the adoption of advanced technologies (e.g., augmented reality, serious games) play a greater role in the future SMT military field, \textsuperscript{58} it will become crucial that future studies be methodologically and numerically stronger to enhance the adoption of these technologies.

The second challenge, closely related to the first, is that the experimental studies conducted to date have used few and heterogeneous measures to assess the effectiveness of the VR-based SMT programs that have been developed. Several studies included in this systematic review (e.g., Bosse et al \textsuperscript{9,10}) do not include specific measures of individuals’ stress levels before and after the VR-based training, making it very difficult to understand differences before and after SMT. In the future it will be important to define a set of standard measures for the evaluation of the training. These measures should include: 1) individuals’ subjective stress levels (e.g., self-report questionnaires); 2) individuals’ objective stress indexes (e.g., cortisol and HRV data); and 3) individuals’ experience of the VR system (e.g., self-report, interviews, and observational data).

The third main challenge is that studies conducted to date have included only very small numbers of subjects, in some cases even recruited among military personnel. \textsuperscript{52}

A fourth and final fundamental challenge is the lack of standardized procedures used in the definition of SMT protocols based on the use of VR. This challenge regards all the ideation and development phases of this type of training. The following should be included: 1) the definition of the specific objectives of the training on the basis of the sample concerned; 2) definition of VR scenarios both for the gradual exposure to stressors and for the training of coping skills and resilience; and 3) the test of the effectiveness of the VR-based SMT program through the execution of clinical trials. To define a series of “best practices” to be used in the development process of VR-based SMT could increase the ultimate effectiveness of any program developed.

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