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# Characteristics of successful technological interventions in mental resilience training

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## 1 Abstract

In the last two decades, several effective virtual reality-based interventions for anxiety disorders have been developed. Virtual reality interventions can also be used to build resilience to psychopathology for populations at risk of exposure to traumatic experiences and developing mental disorders as a result, such as for people working in vulnerable professions. Despite the interest among mental health professionals and researchers in applying new technology-supported interventions for pre-trauma mental resilience training, there is a lack of recommendations about what constitutes potentially effective technology-supported resilience training. This article analyses the role of technology in the field of stress-resilience training. It presents lessons learned from technology developers currently working in the area, and it identifies some key clinical requirements for the supported resilience interventions. Two processes made up this research: 1) developers of technology-assisted resilience programs were interviewed regarding human-computer interaction and system development; 2) discussions with clinicians were prompted using technology-centered concept storyboards to elicit feedback, and to refine, validate and extend the initial concepts. A qualitative analysis of the interviews produced a set of development guidelines that engineers should follow and a list of intervention requirements that the technology should fulfill. These recommendations can help bridge the gap between engineers and clinicians when generating novel resilience interventions for people in vulnerable professions.

## 2 Introduction

Military personnel, police, firefighters and other personnel exposed to traumatic events on the job have a high prevalence of stress-related disorders such as post-traumatic stress disorder (PTSD), anxiety disorders, and depression. Apart from subjective suffering, these disorders present a financial societal burden[1,2]. It is estimated that as many as 15% of U.S. veterans returning from the Afghanistan and Iraq wars suffer from PTSD[3].

Much research has been targeted at developing treatments for PTSD and stress-related disorders[4]. These are increasingly incorporating technology [5]. For example, there are several virtual reality-assisted programs for exposure therapy, the most well-known being Virtual Iraq for returning soldiers [6].

Whereas much progress has been made in the area of technological support for PTSD *treatment*, training programs that would strengthen mental resilience prior to a traumatic event are only starting to emerge. This time of creative innovation creates a willingness to experiment with new technologies, because they can provide forms of stimuli and measurement beyond the therapist’s traditional tools. Currently, technology such as virtual reality, physiological interaction (technology that uses physiological signals as inputs or outputs) and biofeedback is being examined. General stress-resilience is a more practical, detectable metric to use than the prevention of PTSD, and is often used in studies [7,8]. The rationale behind focusing on general stress-resilience is that higher levels of resilience have been proposed as a protective factor against PTSD and other forms of psychopathology [9].

As yet, several questions regarding the development of effective resilience programs remain unclear. First, what kind of pre-trauma resilience intervention will lower the chance of developing trauma-related stress disorders?

What critical requirements must be met when enhancing pre-trauma resilience interventions with technology? What have we learned from the technology projects currently being explored? And finally, what can engineers do to respond to the need for novel stimulus and measurement techniques in this field? As can be seen from these questions, intensive study by both clinical psychologists and engineers is necessary. This article studies both what technology should strive to achieve and how it can be successfully delivered in the field of PTSD prevention and stress resilience. It describes key requirements for technological resilience interventions, obtained through experts. It also presents lessons learned from technology developers currently working in the area. Finally, it discusses how the two can combine and provide a basis for communication within development teams, and with stakeholders. In Section 4 we describe a few resilience training technologies, including lessons learned from interviews with their developers. We then describe in Section 5 how intervention requirements were elicited from a number of subject-matter experts through concept sketches and mock-ups. There are two main parts to this work: Section 4 contains the analysis of interviews with developers and ensuing guidelines; and Section 5 contains the analysis of clinician feedback regarding the development of a new resilience intervention, leading to a list of key requirements. These were both analyzed for influential themes and then tied together in Section 6. The developer interviews produced guidelines for resilience technology development. The feedback sessions produced design goals for technology-assisted resilience interventions. Section 6 also includes a discussion on how development teams can use these to better engage with stakeholders in the field to create new solutions. This paper aims at informing effective future intervention designs.

# 3 Background

## 3.1 PTSD and Resilience

PTSD is an anxiety disorder that develops in some individuals after being exposed to traumatic events, either directly or indirectly. Traumatic events might be due to crime, accidents, natural disasters or war. Symptoms include the following, lasting more than a month and causing significant distress to the individual: intrusive memories or re-experiencing or the trauma; avoidance of internal or external reminders of the trauma; persistent negative cognitions about the events; hypervigilance or hyper-arousal associated with the traumatic event [10].

Potentially traumatic wartime events might include seeing dead bodies or uncovering human remains, knowing someone being seriously injured or killed; being under fire, being unable to help civilians in harm’s way because of the rules of engagement, seeing destroyed homes and villages; clearing and searching homes, caves or bunkers, patrolling in dangerous conditions [11].

Exposure therapy appears to be the most effective therapeutic treatment for PTSD [12]. During exposure therapy, individuals intentionally confront feared external situations or objects or internal sensations (memories, emotions or bodily sensations) with the aim of reducing fear reactions in the future.

As stated above, a protective factor against the development of PTSD is psychological resilience. Resilience has been defined as the ability to adapt and cope successfully despite threatening or challenging situations [13,14]. However, the constructs of resilience one encounters are often inconsistent, poorly defined or not yet scientifically grounded. There is still no single satisfactory conceptualization of resilience, with some authors defining resilience as a set of characteristics, a trait, an outcome, a process or all of the above. Southwick and Charney [15] describe resilience as the complex outcome of genetic, biological, psychological, social and spiritual factors. It is unclear why certain individuals recover and “bounce back” from a psychological trauma while others develop PTSD. Clinical psychologists may study notable cases of resilient individuals to help define the construct of resilience. In the future, such a construct should be defined in terms of necessary and sufficient aspects. Smith et al. [16] propose a six-item brief resilience scale based on a definition of resilience that most closely matches the original meaning of the word—the ability to recover from stress. This may more directly measure resilience itself, as opposed to the resources that promote it (e.g., optimism and faith).

## 3.2 Lessons from medical systems

Several studies in the more general field of medical systems can offer insights into the introduction of technology in psychological training [17-19]. From these the success factors from the point of view of technology acceptance most commonly mentioned are system reliability and ease of use, followed by safety, appropriate functionality and a supporting infrastructure. The populations studied in the above studies are mainly doctors and other clinicians, making a study on military populations necessary. Even within the medical domain, this pointed customization of training to different settings and populations is imperative, as illustrated by [20].

Previous work can also give insight into the evaluation of self-led programs for skill training, [21]. One review provided a comprehensive study of monitoring and behaviour-change applications in the form of smartphone apps, including a discussion of benefits and risks [22].

## 3.3 Training strategies

Often resilience training programs seem to rely on one or combination of the following three  fundamental strategies : Stress Inoculation Training (SIT) [23], other forms of Cognitive-Behavioral Therapy (CBT), and arousal control. They teach and rehearse coping and self-regulation skills that may improve outcomes in those exposed to traumatic stress.

SIT is described as a three-phase training. It involves cognitive restructuring that includes, first, psychoeducation and preparation for the process; second, coping-skills acquisition, where new coping skills are taught and rehearsed; and the application of these coping-skills in the presence of stressors, which are gradually intensified [23]. The trainees become “inoculated” toward traumatic stress by practicing managing their response to lower levels of stress. The main goal of SIT is usually to reduce arousal in response to stress. SIT can be categorized as one technique based on CBT. Generally CBT is based on the understanding that psychological problems can be a consequence of cognitively distorted views of experiences and events, and be maintained by faulty thinking and behavior patterns. Accordingly, changing faulty patterns of thinking and behavior can improve psychological functioning [24]. CBT uses various techniques, including self-talk, relaxation and the development of coping strategies, but generally tries to address maladaptive thoughts and behaviors through goal-directed action. Biofeedback is the real-time display of a person’s physiological indicators (e.g., heart rate variability, skin conductance) so as to help him or her to consciously control them. The induced changes feed back to the display, and the person learns to self-regulate through trial and error. A common model is to use deep breathing to relax and increase heart rate variability, which is visually displayed showing the level and acceptable range.

# 4 Study I: Developer lessons

More and more attention is directed toward the development of technology for resilience training. Because the findings reported from these projects usually focus on efficacy, little is known about the design and development process of these systems. The experience acquired and lessons learned are also valuable for future developers, and these are the focus of this section. We asked developers for their input and finished with a set of guidelines.

## 4.1 Methods

A flexible research strategy was followed in this mainly explorative study, since a theoretical foundation is yet to be developed in this area. It consisted of a combination of interviewing and literature review. We spoke with several developers of technology-assisted resilience programs. The systems were chosen via literature search or referral, and selected if their intended purpose was to prevent PTSD-related symptoms. This criterion excluded therapy systems. A review was compiled and the systems were characterized based on the prevention strategy they supported. The development teams behind the systems were contacted to participate in a semi-structured interview about the system design and development.

Since the focus is on technology development, the interview questions (Appendix A) followed two main threads: (1) Human-Computer Interaction (HCI) technology and (2) system development phases. HCI questions covered topics related to automation, agents and artificial intelligence, physiological interaction, affective computing, virtual reality, biofeedback, and games. Questions about the phases of system development were also covered, including problem definition, analysis and design, construction, testing, and deployment [25]. Further project-specific questions were asked where appropriate. The time allowed varied between 30-90min.

Key lessons were extracted from these interviews as well as the descriptions of the systems in the literature. This was done by applying a Grounded Theory clustering analysis. It integrated the results with an aim of establishing empirically testable guidelines embedded with the collected data. This approach has often been used as a qualitative analysis method for text-based data in the social sciences as part of theory development [26]. The key insights from published research and interviews were extracted, clustered and coded. Frequently occurring insights were clustered into categories, and these categories provided the basis for a set of guidelines grounded in the data. Before discussing these insights, the next section will first summarize each system to provide a context for the interview data and analysis.

## 4.2 Review of systems

Hourani, Kizakevich et al. [8] developed a Predeployment Stress Inoculation Training, called PRESIT, that has marines practice stress-coping skills in a multimedia stressor environment (MSE). PRESIT includes biofeedback-based breathing retraining, as well as attentional control training for staying in the moment. The training is conducted in groups, such as squads. Following a SIT protocol, marines practiced these skills using the MSE; they were 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 explosions) and suspicious things trainees were asked to look out for. The MSE simulated operational mission conditions while inducing stress. Target identification tasks measuring speed and accuracy tested for any effects of the training on performance. A controlled study showed improved relaxation, with PRESIT, as measured by HRV, for previously deployed marines, especially those with PTSD symptoms.

STRIVE, the Stress Resilience in Virtual Environments [27] system is a multi-episode, interactive, cinematic simulation of deployment. The trainee's experience is similar to that of being inside a movie, with the ability to move and look about, as a first-person perspective of a US marine in Afghanistan. In the roughly 10-minute episodes, cinematic devices, such as narration, character development and backstories, build up an emotional backstory. This includes setting up relationships with other virtual characters. At some point an emotionally challenging event occurs at which time a virtual mentor steps in to guide the participant through appraisal of the experience and the acquisition of emotional coping skills. The mentor sessions include various CBT-based lessons on cognitive stress coping, and incorporate material from existing classroom training programs. The STRIVE environment is distinct in maintaining free-agency of the trainee within the environment. In this way, trainees are actively engaged while exposed to stressful virtual events and learn in an experiential way. A battery of physiological measures is used to measure Allostatic Load, a measure of how environmental stressors contribute to the wearing down of the stress response. Allostatic Load is meant to predict the trainee's acute stress response to the virtual environment.

Cosic, Popovic et al. [28] have described a conceptual system for physiology-driven, adaptive affect stimulation. It uses adaptive automation to select and present images and video of graded intensity for exposure training. The exposure levels are controlled to maintain physiological inputs at a safe but effective level. They describe the components of such a system, potential applications, and engineering design issues. Three main components are as follows: 1) a stimulus generator contains images and videos that have been rated and categorized in machine-readable dimensions; 2) the emotional state estimator monitors the trainee's physiological as well as subjective experience by sampling emotion measures and analyzing them according to a model; and 3) the adaptive controller uses this estimate to select the appropriate items to present from the stimulus generator. The authors describe a stimulus delivery algorithm for SIT, based on a trainee's habituation to stimuli.

ImPACT, Immersion and Practice of Arousal Control Training, [29,7] is a SIT-based biofeedback game for soldiers that provides SIT-based practice in relaxation and attentional focus while under stress. Soldiers were taught to practice deep breathing while under attack in a virtual reality first-person shooter game. The visual field of the trainee contracts if physiological measures (i.e., skin conductance and heart rate) crossed stress thresholds. It would reopen when physiology returned within sufficiently relaxed limits. The use of biofeedback makes performance in the game depend upon successful application of relaxation strategies.

**Table 1 Technology-assisted mental resilience programs characterized according to prevention strategies.**

| System name | Prevention Strategy Use |
|---|---|
| PRESIT+MSE [8] | Biofeedback breathing and attentional training, with SIT-based practice in a multimedia stressor environment; group-based delivery. |
| STRIVE[27] | Cinematic VR immersion with free-agency, including CBT-based cognitive restructuring with a virtual human coach. |
| ImPACT[29,7] | SIT-based, stressful VR game requiring successful biofeedback as a performance tactic. |
| Physiology-Driven VR[28] | SIT-based exposure training using automated, computer-driven physiology regulation. |

The above is a description of the systems whose developers we interviewed for advice. Below, we describe how we processed the interview data to uncover insights into the process of creating technological support for PTSD prevention.

## 4.3 Development Guidelines

As mentioned above, a Grounded Theory analysis was applied to understand the themes underlying the interview data as a whole. Insights were extracted from interview notes and literature about the systems, and a common theme—or code—was identified within each cluster. The clustering analysis revealed four codeable factors describing the insights: Resource-, Cultural-, Effectiveness-, and Engineering-related (Table 2). These four codes seem to identify the constraints—or limiting factors—characterizing the course of the system developments. Next, two coders used these four codes to jointly tag all the insights that were abstracted from the interviews (Appendix B). 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 of the 66 insights, coded the remaining insights independently. Agreement between first two coders and the third could be classified as fair to good (according to [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 all the insights, 58% were only assigned a single code. In the remaining 42%, there was no strong indication that specific codes tended to be assigned together; the proportion of dual coding of two specific codes ranged from only 4% to 17% (in 2-by-2 crosstabs). This low co-occurrence suggests that the four factors describe the collected interview data fairly independently.

**Table 2 Code definitions describing limiting factors.**

| Code | Definition |
|---|---|
| Culture | Refers to a social aspect with the parties or stakeholders involved in the development |
| Effectiveness | Refers to the ability of the system to achieve its goals |
| Engineering | Refers to ingenuity required to solve problems, design, or implement; includes development processes, methods, design principles |
| Resource | Refers to the use of a resource, e.g., time, money, information, expertise |

Table 2 defines the four codes defining the limiting factors. A first general guideline emerges from these, stating that developers should be aware of such potentially constraining factors. Besides these, the interviews revealed some insights voiced by more than one system developer: resilience training should not interfere with the operational job-effectiveness of the trainee[30] [31]; technology is positively seen by soldier-trainees and stakeholders [31] [30]; buy-in and user-centered design is important [31] [32] [33]; stress and emotion estimation are complex challenges [33] [32]; and that there is some degree of stigma toward addressing psychological problems in the military [33] [30]. In Table 3, these are related to the four limiting factors. Together these form a basic set of guidelines for future developers. Identifying the relevant limiting constraints helps them understand potential sources of problems.

**Table 3 Guidelines for developers of technology-assisted mental resilience programs, related to project constraints.**

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

# 5 Study II Requirements and clinician feedback

Although a review of existing technology-assisted programs resulted in a set of development guidelines, an investigation into the requirements for future technology-assisted mental resilience programs also required exploring concepts beyond the existing programs. We therefore sketched several concepts to create discussions with experts, such as clinicians, engineers and scientists working in the field. The purpose was to understand what technology-supported resilience training might entail. The result was a set of ten requirements that any training should consider.

## 5.1 Methods

To elicit requirements from experts, concept sketches and storyboards were used to start the idea generation process. The sketches and storyboards provided the starting context for discussion. Concept sketches are a single image accompanied by a brief explanation, used to convey a possible solution approach. They require little resources to create, but give a starting point for the conversation. Figure 1 shows two examples of concept sketches, meant to show a range of possibilities:


**Figure 1 Concept sketches used to start conversations. At left is a smartphone app with a stress coach. At right, the idea of focus retraining is presented.**

Concept storyboards also have the advantage of requiring little resources to create, while providing an easy way to present, adapt and circulate ideas [34]. The storyboards depicted more detailed concepts than sketches. They were shown and explained to experts, pausing at each frame for discussion. Below are two frames from a storyboard:

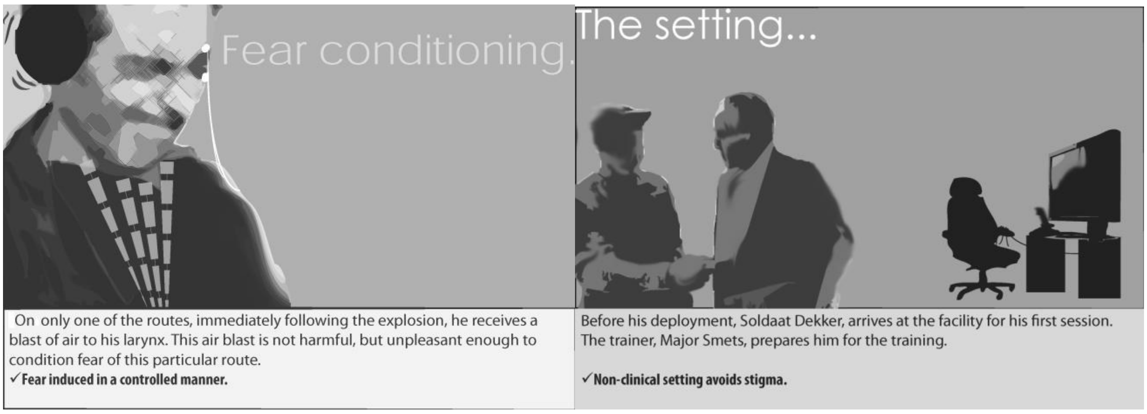


**Figure 2 Two storyboard panels for a resilience intervention that uses a divided attention task in the presence of fear.**

A disadvantage of our process of requirements elicitation was that it could limit the range of responses obtained from experts. We also had few conversations with target users, who would have been servicemen with an upcoming deployment, preferably with some previous combat experience.

In the beginning we conducted interviews using six high-level sketches: a sleep hygiene watch; a VR exposure environment with graded levels of control; a family storytelling game; a biofeedback device; a mobile app with a virtual buddy; and a memory retraining involving cognitive tasks during induced fear. Later, a new set of sketches depicting four types of interventions, derived from a review of existing resilience training systems, were used to start discussions. This next set of sketches included the following approaches: cognitive training; SIT behavioral training with exposure; SIT relaxation training with biofeedback; and SIT with focus retraining or mindfulness. Twenty-four experts were interviewed, including seven psychiatrists, five clinical psychologists, ten cognitive or social psychologists, an internist studying PTSD and a military sniper. They were asked to reflect on these suggested concepts, consider underlying assumptions, foresee potential weakness and strengths, and imagine other resilience interventions.

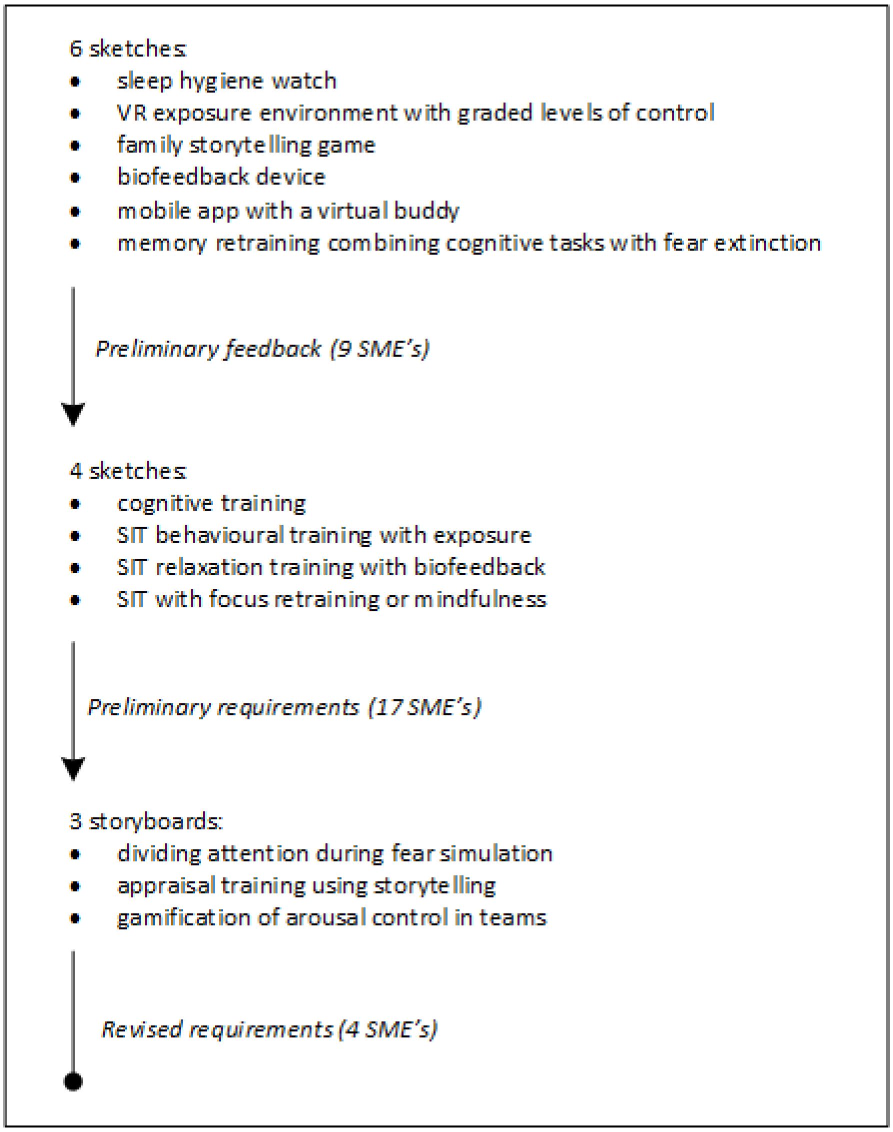


**Figure 3 Requirements elicitation process and conceptual materials.**

We then gathered the notes, transcripts or transcript summaries from these interviews and marked all the insights that had to do with intervention design. We made a list of the most common remarks, as well as less common remarks that introduced new ideas. From these we extracted a set of themes which became the initial requirements, using a process aligned with Interpretative Phenomenological Analysis [35].

Next we created three detailed storyboards of concepts that formed as a result of the discussions, and based on these requirements. We showed these to clinicians to gather feedback. From the notes and transcripts we highlighted all remarks that had to do with intervention requirements. We checked if these fit under the existing list requirements, and if not we modified or added new categories. This procedure allowed for flexible categorization of the qualitative data with the goal of creating a set of requirements. After the categories were chosen, the texts were scanned again and important insights were listed under each category. When an insight did not fit a category, a new requirement was added.

## 5.2 Requirements for technological mental resilience programs

Table 4 is a list of requirements that can guide the design of technological mental resilience programs. In the following sections we describe the requirements in more detail, and include some important insights we gathered from the subject-matter experts.

**Table 4 Training requirements gathered from interviews with experts.**

| Requirement |
|---|
| 1. The training should achieve cognitive, affective or behavioral change that enhances resilience |
| 2. The training should be personalized to individual needs and differences |
| 3. Training effects should be durable |
| 4. Training effects should be transferrable to operational domain and not interfere with operational performance. |
| 5. Training effects should be measureable |
| 6. Training should be relevant to its cultural context |
| 7. Training should be economical |
| 8. Training should be safe, and should be safe to use in the operational domain. |
| 9. Training should be engaging and motivating. |
| 10. Training should address the entire soldier life cycle |

### 5.2.1 Achieving change that enhances resilience

Subject-matter experts (SME's) spoke of affective, cognitive and behavioral types of change to enhance resilience. Affective change involves an increase in emotion regulation skills. This process involves arousal as a necessary component to activate emotional processes in order to change them, as in the case of exposure therapy for anxiety disorders. For soldiers this an important issue. For example, one of the experts suggested focusing also on the emotion of disgust, as this can also be traumatic at high intensity. In this context experts also argued for devices such as HMD's for their ability to be more immersive and believed to deliver more arousing experiences.

Arousal control was one of the most mentioned approaches to resilience training. Reducing arousal while staying on task is considered by experts to be a valuable skill to train, and many resilience training programs do train relaxation skills, sometimes under stress. This kind of training can be graduated, with increasing levels of stress. Besides arousal reduction, one expert mentioned the skill of competitive imagery whereby the person re-attributes the feeling of arousal from a negative cause, to a positive one. For example, when aroused by a memory of a negative experience like falling off a cliff, the person re-attributes the arousal to a fun, arousing experience of riding a roller coaster.

Some SME's are cautious about the use of the arousal control paradigm. They point to the ability of soldiers to still perform well under extremely high arousal. As an example, they contrast soldiers who are trained to shoot a gun with high accuracy even while highly aroused, with a person suffering from a panic attack, who is both highly aroused and having distorted thoughts about dying. These SME's claim the more important cause of trauma is cognitive distortions in combination with high arousal. They recommend a cognitive training approach. Changing the cognitive distortions may be more helpful than focusing on arousal control. For this, they suggested addressing the cognitive triggers of negative emotion. The experts also put forward other potential cognitive approaches including changing core beliefs, broadening perspectives, and seeing situations from different angles.

The role of memory is important in cognitive approaches. Negative memory activations may be triggered by a variety of sensory stimuli, including audio, visual, olfactory, taste and touch. Negative memory activation is important in learning to deal with negative cognitions under stress. Furthermore, one expert mentioned the role of the hippocampus in short-term memory and pointed to evidence that changes in the hippocampus might be used as a means of measuring the efficacy of a resilience training [1].

The experts pointed to attention as another cognitive function where changes may benefit resilience. For example, a technique like mindfulness can help one focus attention on the present moment [36]. One SME proposed training soldiers to divide their attention between danger stimuli and environmental stimuli, speculating that this may reduce overconsolidation of fear leading to traumatic memories. However, the idea brought up some caveats with other SME's: will distraction from the danger really benefit the soldier? It may also oppose their usual training skills, in which they look for and attend to potential dangers.

Finally, capitalizing on things, such as social support, that might facilitate behavioral change was also regarded as important. One often mentioned behavioral strategy was talking about their emotions with fellow servicemen or with family. The stigma surrounding talking about emotions should be attacked.

A more general observation also made by some of the experts was the idea of positive psychology, and the broadening of the definition of resilience from PTSD prevention, to include coping skill enhancement or the power to recover. This would include, for example, boosting a soldier's feelings of self-efficacy. Another example is changing people's perception of threats into challenges.

### 5.2.2 Personalization

A recurring theme in discussions with the experts was personalization, meaning adjustments for both personal experiences and stable personal characteristics. A person's history and specific experiences was often seen as an aspect that would make a difference in how a soldier would react to specific stimuli, and some types of training would not work unless they were adapted for a person's triggers. Experts reaffirmed that cognitive training is more successful when the trainee applies it to his or her own personal memories.

Emotional characteristics such as temperament and emotional reactivity are factors that training personalization might target, according to a research group that paid specific attention to these [37]. They also pointed out that imagination is a trait that varies in individuals, and will need to be considered in any training that uses VR or substitutes it with imaginal exercises. Another research group said that individual cognitive factors such as an orientation toward global impressions vs. details could bias attention in simulated environments. With reference to behavioral training, they suggested that factors like preferred coping styles may be tested before selecting the appropriate coping mechanisms to train.

Some experts felt that simply allowing trainees to apply their preferences to a training could improve engagement, for example, by allowing neurofeedback trainees to control the sound quality of their favorite music [38].

### 5.2.3 Durability

Whatever the training seeks to achieve, experts agree that it should produce affective, cognitive or behavioral reactions that are automatic, and that the appropriate number, duration and intensity of sessions, as well as the duration of the training program, should be determined experimentally. Some suggested that self-practice can be encouraged with mobile apps that can be taken into the field to keep skills current.

### 5.2.4 Transferability and performance

Experts agree that any training program must consider how learned skills will transfer from the classroom to the operational domain—whether the training will interfere with performance or even jeopardize the safety of the individual. Potential training programs should focus on a better way of coping with negative emotions like anxiety, without being distracting so servicemen can effectively focus on duty.

It goes without saying that the situations a soldier will experience in theatre will be novel. Therefore a training that uses specific situations and stimuli may be weaker than one that trains reactions to more general events, as was pointed out by one focus group. The idea of state-dependent learning is that people will be able to remember or perform skills best in a physiological state that was similar to where they learned it [39]. It may, for example, be necessary to have soldiers practice learned skills while under extreme stress [29]. Also, one expert said that any kind of support tool used during the training should be phased out, since this will not be available in theatre.

A target user recommended that resilience skills be trained simultaneously with actual skills required in theatre, for example, a faster magazine change, scanning the environment for danger, or firing a gun at a target. This same source said that one should also consider the different types of stresses that occur at different stages of deployment. For example, soldiers are most anxious before deployment, and most fatigued toward the end at which point they may be most vulnerable to PTSD. Boredom was reiterated by another expert as a very difficult thing soldiers have to deal with often during deployment. Resilience training may want to focus on these stages and types of stressors.

#### 5.2.5 Measurability

It is obviously important to test the effectiveness of a training, which requires a measure of resilience. Resilience can be seen as a multi-faceted construct with multiple aspects, and one group of researchers has found family-, team- , organization-, individual-related markers [40]. As discussed in Section 3.1, here is no one standard measure, and the exploration of new measures is welcome in the field.

#### 5.2.6 Cultural Relevance

The most frequently mentioned cultural aspect was the stigma of talking about emotions within the military (and police). Being able to talk about emotions was often said to be an important part of a resilience training. One research group found that soldiers have real reasons to be afraid of disclosing emotions, because if they are reported to be weak they may not be deployed again. Their livelihood is threatened by such disclosure and they do not want to risk talking about emotions with psychologists, even, as the researchers discovered, when confidentiality is promised. They found that they do not want to speak with their teammates either, for fear of seeming unreliable, but may be more willing to speak with a priest or a chaplain.

Experts repeatedly emphasized the importance of social support. According to one group it normalizes the experience of the training, and it provides the already familiar group-training format [31]. As mentioned before, families are another source of support that can help resilience. A game that supports talking with a spouse or children, while incorporating emotional regulation was also suggested by one clinician.

For training programs that involve exposure to pain or discomfort, one expert warned of a possibility that soldiers face these with a different attitude than civilians. He said that enduring pain and discomfort can be seen as positive experiences for soldiers, as a way to practice for future physically grueling situations, or even torture. Therefore, using discomfort for conditioning paradigms should be approached cautiously.

According to one clinician, soldiers tend to like clear goals when going through a training. Therefore it may be helpful to set structured goals in the training for usage and performance. Furthermore, for non-English native speakers, one research group said that training programs involving emotional content is best delivered in the soldier’s native language. A military clinician also mentioned that in order to gain acceptance with military stakeholders approving the training one should use action words to describe it, as this would fit with the existing language used in many military cultures.

#### 5.2.7 Economics, Safety, Engagement and Life Cycle

Evidently, cost can be reduced by taking as little time as possible to train trainees. It can also save on development costs to use already developed non-technological training programs as a basis. Another suggestion was to target soldiers as far down the disease phase as possible, in order to reduce cost by training a smaller amount of soldiers. In the case of resilience training, this is difficult to achieve. Reducing the training population would require some kind of prediction about which servicemen are most vulnerable.

It is, of course, important to consider the safety of the training. For example, with exposure-based training, appropriate graduation is necessary to avoid over-exposing the trainee to stress [41]. An expert gave the example of training awareness of heartbeat in HRV control; there is evidence that says focusing on one’s heartbeat can increase the likelihood of panic attacks [42], so this may not be safe to use in theater.

In order to complete any training program, experts agree that soldiers need to feel motivated and engaged. Ways to enhance engagement were suggested, including the creation of experiential sensations, for instance, virtual reality or haptic devices that provide realistic feedback. Team training with interaction is also valuable in creating engagement and avoiding boredom, according to others. One expert emphasized that if the soldiers do not like the training or find it boring, it will only feel like punishment. Other experts agreed that there are many gamers within the soldier population and a gamified training may be one way to engage them. Seeing change and results is also important to engagement, and one expert noted that having a training that is frequent enough for soldiers to notice their improvement is motivating. Finally, one clinician said that something like a doctor's prescription for the training will make a difference to whether soldiers feel it is necessary to follow.

It was often mentioned that resilience training should be targeted at all stages of a soldier's career, and the training should be seen as supporting the soldier life-cycle, from recruitment, to retirement.

# 6 The means-ends matrix for resilience technology

The essential requirements derived from the interviews with experts that seem common to most mental resilience training applications in the military are shown in Table 4, while advice for how developers can manoeuver a project toward these goals is show in Table 3. We discuss here the relationship between the two, and explain how they can be used in practice.

The table **Error! Reference source not found.** shows the relationship of the ten training requirements to the six guidelines for developers. The guidelines are the means by which the requirements, or ends, can be successfully reached. The dots indicate a relation whereby a guideline can help fulfill a requirement.

| MEANS \ ENDS | 1. Change | 2. Personalization | 3. Transferability | 4. Durability | 5. Measurability | 6. Cultural Relevance | 7. Economy | 8. Safety | 9. Engagement | 10. Life-Cycle |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Beware Limiting Factors | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| 2. Keep Operational Priority | | | ● | ● | | | | ● | | |
| 3. Capitalize on High-tech | | | | | | ● | | | ● | |
| 4. Get Stakeholder Buy-in | | | | | ● | ● | ● | ● | ● | ● |
| 5. Prepare for Scientific Challenge | ● | ● | ● | ● | ● | | | | | |
| 6. Acknowledge Stigma | | ● | | | ● | ● | | | ● | |

**Figure 4 The requirements (or ends) of resilience training related to the guidelines (or means) to achieve them.**

How can this relationship work when developing mental resilience training? Here are a few vignettes that demonstrate how to create effective training systems while mitigating project risk. To show their practical applicability they are explained by addressing problems reported by the developers of these systems.

## 6.1 Vignette: Emotion measurement in the military

This vignette is based on a conversation with a leading scientist about something they experienced during a study [30].

A team of scientists tested a new system with soldiers that expose them to stress. They used a self-report instrument to record stress levels. Upon examining the first group of test subjects, they saw that the self-report ratings for stress were lower than what would be expected from a person who is nearly asleep. The requirement at risk was the Measurability of the effect of the new system (requirement 5).

It is clear that the soldiers are not providing honest self-reports of stress. This is due to the stigma associated with expressing negative emotions in military culture. Even with the assurance of confidentiality, soldiers find it too risky, as their next deployment may be jeopardized. The scientists *acknowledge the stigma* (guideline 6) and decide to add objective physiological measures. In doing so, they find much higher stress levels than reported by the soldiers.

## 6.2 Vignette: Engaging marine trainees

A team of scientists is developing a training program for the marines. Stakeholders are skeptical of the relevance of the program and whether marines will find it *engaging* (requirement 9). This situation was faced by developers [30,31].

The scientists introduced virtual reality and gaming to *capitalize* on the appeal of high-tech to their audience (guideline 3). They also decided to hold the training in groups, keeping the existing model that is a *cultural limitation* of the domain (guideline 1). Training in groups incidentally also helps reach requirement 7 of *economy* and requirement 6 of *cultural relevance*.

## 6.3 Vignette: Personalizing a training program

A large team of developers and scientists want to ensure a good fit between the training and the trainee. They would like to ensure that each trainee is receiving the right treatment and they know that there is no one-size-fits-all approach. They try to create a system that is highly *personalized* (requirement 2).

The development team understands the scientific challenge is a large one, and enlists the help of a scientific team focused on the measurement of the built-up effects of stress, using a battery of biomarkers and other measures [32,27]. These measures can help tune the training to the individual's needs, but knowing how to interpret them in a way that would lead to this goal is difficult. By enlisting a team of emotion experts, the development team *prepares for the scientific challenges* of emotion and stress measures (guideline 5).

Real-life system development is often unpredictable. There are many more scenarios that can occur but it would be impossible to enumerate them all in advance. The above scenarios serve only as a few instances of problems to illustrate the use of the guidelines and requirements.

# 7 Concluding Remarks

In this paper we uncovered essential design requirements and development guidelines for mental resilience training applications. Scientifically, this work presents a survey of expert opinion in the field of technology-based mental resilience training. The main contribution of the work is that it offers mental resilience researchers involved in the development of technological solutions a set of the requirements they can use to structure their efforts, and a set of development guidelines that can help them to mitigate risk. The requirements show what the training system must fulfill, while the guidelines describe ways to increase success.

The next step is to see if the findings benefit actual development projects and validate which guidelines are helpful for reaching which means. Also it would be best to include requirements elicited from the target users of these training systems, who are more difficult to access. We hope, at least, that developers can use these findings to prepare for new challenges, as well as serious risks in resilience training innovation. This study lays a groundwork that represents the collected wisdom of seasoned experts, and will hopefully provide a map for developers and stakeholders to find the shortest path to helping at-risk professionals bounce back from trauma.

# 8 Acknowledgement

The authors wish to thank Joris Favié for the background section research on PTSD and resilience. This study was supported by the Dutch Economic Structure Enhancement Fund (FES) "Brain and Cognition: Societal Innovation" program.

# 9 Sources

1. Nemeroff CB, Bremner JD, Foa EB, Mayberg HS, North CS, Stein MB (2006) Posttraumatic stress disorder: a state-of-the-science review. Journal of Psychiatric Research 40 (1):1-21

2. Sabes-Figuera R, McCrone P, Bogic M, Ajdukovic D, Franciskovic T, Colombini N, Kucukalic A, Lecic-Tosevski D, Morina N, Popovski M (2012) Long-term impact of war on healthcare costs: an eight-country study. PloS one 7 (1):e29603
3. Schell TL, Marshall GN (2008) Survey of individuals previously deployed for OEF/OIF. Invisible Wounds of War:87
4. Bisson JI, Ehlers A, Matthews R, Pilling S, Richards D, Turner S (2007) Psychological treatments for chronic post-traumatic stress disorder Systematic review and meta-analysis. The British journal of psychiatry 190 (2):97-104
5. Paul LA, Hassija CM, Clapp JD (2012) Technological Advances in the Treatment of Trauma A Review of Promising Practices. Behavior modification 36 (6):897-923
6. Gerardi M, Rothbaum BO, Ressler K, Heekin M, Rizzo A (2008) Virtual reality exposure therapy using a virtual Iraq: case report. Journal of Traumatic Stress 21 (2):209-213
7. Bouchard S, Bernier F, Boivin É, Morin B, Robillard G (2012) Using Biofeedback while Immersed in a Stressful Videogame Increases the Effectiveness of Stress Management Skills in Soldiers. PloS one 7 (4):e36169
8. Hourani LL, Kizakevich PN, Hubal R, Spira J, Strange LB, Holiday DB, Bryant S, McLean AN (2011) Predeployment Stress Inoculation Training for Primary Prevention of Combat-related Stress Disorders. Journal of CyberTherapy & Rehabilitation 4 (1):101
9. Bonanno GA, Westphal M, Mancini AD (2011) Resilience to loss and potential trauma. Annual Review of Clinical Psychology 7:511-535
10. Diagnostic and statistical manual of mental disorders (2013). Fifth edn. American Psychiatric Association, Arlington
11. Bouchard S, Baus O, Bernier F, McCreary DR (2010) Selection of Key Stressors to Develop Virtual Environments for Practicing Stress Management Skills with Military Personnel Prior to Deployment. Cyberpsychology, Behavior, and Social Networking 13 (1):83-94
12. Bryant RA (2005) Psychosocial approaches of acute stress reactions. CNS spectrums 10 (2):116
13. Agaibi CE, Wilson JP (2005) Trauma, PTSD, and Resilience A Review of the Literature. Trauma, Violence, & Abuse 6 (3):195-216
14. Drozðek B, Wilson JP (2004) Broken spirits: The treatment of traumatized asylum seekers, refugees, war and torture victims. Routledge,
15. Southwick SM, Charney DS (2012) Resilience: the science of mastering life's greatest challenges. Cambridge University Press,
16. Smith BW, Dalen J, Wiggins K, Tooley E, Christopher P, Bernard J (2008) The brief resilience scale: Assessing the ability to bounce back. International journal of behavioral medicine 15 (3):194-200
17. Sclafani J, Tirrell TF, Franko OI (2013) Mobile tablet use among academic physicians and trainees. Journal of medical systems 37 (1):1-6
18. Holanda AA, e Sá HLdC, Vieira APGF, Catrib AMF (2012) Use and satisfaction with electronic health record by primary care physicians in a health district in Brazil. Journal of medical systems 36 (5):3141-3149
19. Franko OI, Tirrell TF (2012) Smartphone app use among medical providers in ACGME training programs. Journal of medical systems 36 (5):3135-3139
20. Ishibashi Y, Juzoji H, Kitano T, Nakajima I (2011) ITU e-Health Training Program for Pacific Island Community with the Support of the Sasakawa Peace Foundation. Journal of medical systems 35 (3):345-351
21. Choi K-S, Chan S-H, Pang W-M (2012) Virtual suturing simulation based on commodity physics engine for medical learning. Journal of medical systems 36 (3):1781-1793
22. Bert F, Giacometti M, Gualano MR, Siliquini R (2014) Smartphones and Health Promotion: A Review of the Evidence. Journal of medical systems 38 (1):1-11
23. Meichenbaum D (1985) Stress Inoculation Training. Psychology Practitioner Guidebooks. Pergamon Press,

24. Hollon SD, Beck AT (2013) Cognitive and Cognitive-Behavioral Therapies. In: Lambert MJ (ed) Bergin and Garfield's handbook of psychotherapy and behavior change. 6th edn. Wiley, New York, pp 393-442
25. IBM (2005) Rational Unified Process: Best Practices for Software Development Teams. http://www.ibm.com/developerworks/rational/library/content/03July/1000/1251/1251_bestpractices_TP026B.pdf. Accessed 28/05/2012 2012
26. Glaser B, Strauss A (1967) The Discovery of Grounded Theory: Strategies for Qualitative Research. Aldine de Gruyter, New York
27. Rizzo A, Parsons TD, Lange B, Kenny P, Buckwalter JG, Rothbaum B, Difede JA, Frazier J, Newman B, Williams J (2011) Virtual Reality Goes to War: A Brief Review of the Future of Military Behavioral Healthcare. Journal of clinical psychology in medical settings:1-12
28. Cosic K, Popovic S, Kukolja D, Horvat M, Dropuljic B (2010) Physiology-driven adaptive virtual reality stimulation for prevention and treatment of stress related disorders. Cyberpsychology, Behavior, and Social Networking 13 (1):73-78
29. Bernier F, Bouchard S, Robillard G, Morin B, Forget H (2011) Enhancing Stress Management Skills in Military Personnel Using Biofeedback and Immersion in a Stressful Videogame: a Randomized Control Trial. Journal of CyberTherapy & Rehabilitation 4 (2):3
30. Bouchard S Personal interview.
31. Hourani LL, Kizakevich PN Telephone interview.
32. Rizzo A Telephone interview.
33. Cosic K Telephone interview.
34. Rankin A, Field J, Kovordanyi R, Morin M, Jenvald J, Eriksson H Training systems design: bridging the gap between users and developers using storyboards. In: Proceedings of the 29th Annual European Conference on Cognitive Ergonomics (ECCE'11), 2011. pp 205-212
35. Reid K, Flowers P, Larkin M (2005) Exploring lived experience. Psychologist 18 (1):20-23
36. Hofmann SG, Sawyer AT, Witt AA, Oh D (2010) The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. Journal of consulting and clinical psychology 78 (2):169
37. Ilnicki S, Wiederhold BK, Maciolek J, L. K, Szymanska S, Zbyszewski M, Siatkowska A, Opalko-Piotrkiewicz E, Ilnicki P, Filarowska M, Glibowska A, Borzetka D, Pleskacz K, Murawski P (2012) Effectiveness Evaluation for Short-Term Group Pre-Deployment VR Computer-Assisted Stress Inoculation Training Provided to Polish ISAF Soldiers. Paper presented at the Annual Review of Cybertherapy and Telemedicine 2012, Brussels, Belgium,
38. van Boxtel GJ, Denissen AJ, Jäger M, Vernon D, Dekker MK, Mihajlović V, Sitskoorn MM (2012) A novel self-guided approach to alpha activity training. International Journal of Psychophysiology 83 (3):282-294
39. Overton DA (1966) State-dependent learning produced by depressant and atropine-like drugs. Psychopharmacologia 10 (1):6-31
40. Kamphuis W, van Hemert D, van Wouwe N, van den Berg C, van Boxmeer L (2012) Een model van mentale veerkracht-Een nieuw ontwikkeld model voor het defensiedomein kan als basis dienen voor het monitoren en beïnvloeden van mentale veerkracht en bijdragen aan een gemeenschappelijke taal en visie binnen de krijgsmacht. Militaire Spectator 181 (11):495
41. Ehlers A, Clark DM, Hackmann A, Grey N, Liness S, Wild J, Manley J, Waddington L, McManus F (2010) Intensive cognitive therapy for PTSD: A feasibility study. Behavioural and Cognitive Psychotherapy 38 (04):383-398
42. Margraf J, Ehlers A, Roth WT (1988) Case studies and clinical replication series: Panic attack associated with perceived heart rate acceleration: A case report. Behavior Therapy 18 (1):84-89

# Appendix A: Common Interview Questions for Developers

The following questions were asked to the mental resilience system developers where applicable. The questions refer either to process and development issues, or the Human-Computer Interaction issues (HCI).

| Question | Theme | Topic |
|---|---|---|
| What is the training paradigm and how did you implement it in your system? (How theoretical concept maps to implementation.) | Process | analysis and design |
| How did you approach the development of your training paradigm? Why this paradigm? | Process | analysis and design |
| What are the concerns and needs of the doctors/trainees/military organization? Are there any other stakeholders? | Process | analysis and design |
| Were there any conflicts found between the needs of various stakeholders? | Process | analysis and design |
| Did you have to make any concessions in your design to make it more acceptable to stakeholders? | Process | analysis and design |
| How did you handle the ergonomics when developing the system? | Process | analysis and design |
| What are the most important technological challenges you faced? (Implementation limiting) | Process | construction |
| What is needed for these systems to be used in large scale? | Process | deployment |
| What were the major difficulties you experienced throughout developing your system? What were the most unexpected problems? | Process | general |
| What advice would you give for someone developing a PTSD prevention technology? | Process | general |
| Can you see this being applicable to non-military domains? If so, what criteria should be met? | Process | problem definition |
| Effect measurement: benchmark? Gold standard for comparison? | Process | testing |
| Did you have challenges using human subjects for testing? How did you prove the safety of your system? | Process | testing |
| Did you look at affect (emotions), as well as stress? Do they interact? | HCI | affective computing |
| How do you deal with uncertainties in the measurement of emotions? | HCI | affective computing |
| How do you propose to prevent the fear exposure aspect from inducing negative feelings/affect toward the training itself? | HCI | affective computing |
| What physiological indicators are you monitoring? Would you have liked to monitor others not included in the system? | HCI | physiological interface |
| Your system tries to induce an emotional/stress response. How does the trainee exert control, if any, on this manipulation? | HCI | physiological interface |
| You used a direct interface between the participant's physiology and the computer. What did you learn from using a physiological human-computer interface (if applicable)? | HCI | physiological interface |

# Appendix B Developer Insights and Related Constraints

The following table summarized the insights extracted from the interviews with developers. The constraints that they are related to were coded by two different judges and validated by a third.

| Text | Culture | Effectiveness | Engineering | Resource |
|---|---|---|---|---|
| When turning over the system to the trainers you need a manual that can be used by non-scientists. | 1 | 1 | 1 | 1 |
| It was suggested we simulate conditions for the marines like wearing full heavy equipment, turning the heat up in the room more closely replicate conditions they will face. I don't know if we will do that. | 0 | 1 | 1 | 1 |
| We used a game, because games are meant to be stressful, and because companies are investing money on the concept of the game. | 0 | 1 | 1 | 1 |

| | | | | |
|---|---|---|---|---|
| STRIVE rests on the experience of "being there" (aka presence). Free-agency adds to that feeling | 0 | 1 | 1 | 0 |
| Have a team of marines as subject-matter experts (SME) who go through developments. The SME's weigh in on all of it, make sure it's realistic | 0 | 1 | 1 | 0 |
| We are using the principle of state-dependent learning: what you learn in a certain state is more likely to transfer to a situation when that state occurs again in the real world | 0 | 1 | 1 | 0 |
| We are using the principle of latent inhibition: you are less likely to experience fear conditioning if you've had similar experiences previously, in a controlled fashion. | 0 | 1 | 1 | 0 |
| We settled for using tactical breathing because we needed something quick and fast that they could practice. Cognitive restructuring is really nice, but it's not really the place to start, or to do cognitive restructuring when you're being fired at. | 0 | 1 | 1 | 0 |
| We strongly believe that personalization to the user is important. For us, the pilot instructor, therapist and commander needed different interfaces. | 0 | 1 | 1 | 0 |
| Estimation of emotion state is very complex and challenging.<br>Challenges include:<br>-what signal to use<br>-filtering signals<br>-feature generation<br>-feature reduction<br>-later select valence and arousal<br>-discrete emotion selection<br>-train neural networks | 0 | 1 | 1 | 0 |
| User-centered design for information requirements leads to changes in:<br>-instruments for different apps<br>-sensors<br>-graphical interfaces, graphical info | 0 | 1 | 1 | 0 |
| Soldiers need time to practice stress-management techniques. These techniques are taught sometimes over just 20 minutes in all in their entire training, sometimes within a few hours. Because it's only theoretical, and they practice in the classroom once, the soldiers don't really master the techniques | 0 | 1 | 0 | 1 |
| On the use of human subjects for testing -- the IRB wanted to know that the MSE wouldn't cause more harm by facilitating arousal. The population needed to be pre-screened for mental health problems. We provided info on where to get help during the training (e.g. hotlines). | 1 | 1 | 0 | 0 |
| To make things more stimulating, we put a counter in the corner of the MSE and told trainees that the better they did the better the score would be as a whole, though this wasn't really measured. We wanted to facilitate group ownership of the training process. This was a kind of sham reward. They like to do things as a group anyways. | 1 | 1 | 0 | 0 |
| We are using the PCLC PTSD screening as standardized instrument to compare scores to other studies using this instrument. | 0 | 1 | 0 | 0 |
| If you have a storyline the user will become engaged on an emotional level. | 0 | 1 | 0 | 0 |
| It's not enough to expose people to stressors. Must get people in a state and give them something to do so they can manage their state. | 0 | 1 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Test with users. | 0 | 1 | 0 | 0 |
| Tactical breathing seems so easy that it seems like soldiers don't need to practice. | 0 | 1 | 0 | 0 |
| There is no well-validated stress-resilience questionnaire to test effectiveness. We are tackling that as part of the project, developing a questionnaire. | 0 | 1 | 0 | 0 |
| Military population is good for testing effectiveness because they will be sent to a potentially stressful situation within a known time-frame. Also true of police officers. | 0 | 1 | 0 | 0 |
| Get input from people who have been in combat. Find out from trauma survivors what kinds of events they've experienced and to understand the subtleties of these experiences, odd things they notice just before and after. User-centered design, essentially. | 1 | 0 | 1 | 1 |
| One of the biggest challenges to large-scale deployment is that the software is licensed and to use it on a large scale would be prohibitively expensive. Need to develop the software in house. | 0 | 0 | 1 | 1 |
| To take the concept of a story and translate it into an interactive narrative experience is challenging. Writing dialogue, creating scenery so user will actually see key events while having some free-agency...it's easier said than done and takes heck of a lot of work. | 0 | 0 | 1 | 1 |
| The ultimate vision is to have dialogue with speech recognition when talking with the virtual mentor. But for now, use a gamepad to select responses. | 0 | 0 | 1 | 1 |
| You need time to establish virtual characters and build their relationship with the user. | 0 | 0 | 1 | 1 |
| You need time (many episodes) to develop an emotional bond between the user and virtual characters. | 0 | 0 | 1 | 1 |
| Ties with Hollywood have driven research that develop credible characters, gestures, and facial expression. | 0 | 0 | 1 | 1 |
| The virtual mentor discusses physiological response to stress in a way military subject matter experts have approved, not in scientific terms. | 1 | 0 | 1 | 0 |
| To create rapport, use a virtual agent that has the qualities of an inspirational leader but with a soft side that makes it seem okay to have feelings. | 1 | 0 | 1 | 0 |
| Had a challenge coordinating and networking groups of computers used as workstations for the MSE. There were some issues with networking and timing to work that out. | 0 | 0 | 1 | 0 |
| The issue with free-agency is that that we are not testing properly if user spends time in a part of the environment where the test stimulus isn't present. | 0 | 0 | 1 | 0 |
| Making the user the driver in a scene keeps them active, which was what we wanted. | 0 | 0 | 1 | 0 |
| Used a slick representation of the human brain and nervous system to help them understand physiology of stress and a simple breathing exercise. | 0 | 0 | 1 | 0 |
| Used voice-over narration to deal with the complexity of an interactive movie. There are too many things to show in 10-15min episodes so need to set the stage efficiently. We are hoping the voice will emulate the user's inner thoughts | 0 | 0 | 1 | 0 |
| Use cinematic strategies to tell a story in a short period of time and constrain the view: for example, narration and video montage (e.g. review dramatic perspective of different characters in scene with first person shots). Cinematic techniques are the biggest challenge | 0 | 0 | 1 | 0 |

| | | | | |
|---|---|---|---|---|
| Physiological measures used in the first test include: EEG (with sophisticated independent component analysis), HR, HRV, SC, Respiration. Also will take bloods, including cortisol. | 0 | 0 | 1 | 0 |
| Physiological measurement equipment should not encumber the user, and allow them to stay engaged in the environment. Test with pilot subjects. | 0 | 0 | 1 | 0 |
| User-centered design and user-testing informed our development. | 0 | 0 | 1 | 0 |
| A steering wheel is not necessary as an input device for driving. Other solutions can be used. | 0 | 0 | 1 | 0 |
| A gamepad is unnatural and distracting input device for a walking task. We used weighted mock weapons and mount thumb controller on it. Direction of travel is where you are looking in the HMD. | 0 | 0 | 1 | 0 |
| Tried a set up where user could turn to look at things while walking in another direction but found it was confusing to do with the hand controller. | 0 | 0 | 1 | 0 |
| Stick to the science and theories of stress response. | 0 | 0 | 1 | 0 |
| We learned that real time estimation of emotion is nonlinear and stochastic. We see different responses between individuals and over sessions. | 0 | 0 | 1 | 0 |
| Years ago we thought to make the presentation system fully automated, but this may be dangerous. Now use different Levels of Automation (LOA) that change for the phase of training/therapy. | 0 | 0 | 1 | 0 |
| Emotions are not measured, they are estimated. | 0 | 0 | 1 | 0 |
| The military organization liked that it was a technological approach and were very supportive | 1 | 0 | 0 | 1 |
| Buy in from stakeholders is important when developing these systems. | 1 | 0 | 0 | 1 |
| Can this training simulation cause PTSD? Can do a cost-benefit analysis and find it's better to bear the risk on the front end, as opposed to on the battlefield… these are ethical issues | 1 | 0 | 0 | 1 |
| The military world is loaded with rules, rules of engagement, things you need to do, things you cannot do, ways of doing things. So if they change a rule you have to redo the environment. So initially we thought we would have a stressful environment that would depict a real situation that the soldier would see, but we were afraid that we would not be able to get something stressful enough, and also realistic enough and also durable enough. | 1 | 0 | 0 | 1 |
| We use an engineering approach (with a mostly engineer team) but working with psychologists, psychiatrists and neuroscientists. | 1 | 0 | 0 | 1 |
| An operational problem was timing the funding of the study together with availability of the troops' deployment schedules. | 0 | 0 | 0 | 1 |
| Group administered training is also practical because it keeps costs down. | 0 | 0 | 0 | 1 |
| We only have funding to build 3 episodes for now. Funders will evaluate these before funding the rest. | 0 | 0 | 0 | 1 |
| Draw on existing stress resilience programs for content. | 0 | 0 | 0 | 1 |
| Using the head direction as rudder and hand control as a "gas pedal" takes about a minute to master | 0 | 0 | 0 | 1 |
| These projects, where the goal is the reduction of PTSD, take time and are long term | 0 | 0 | 0 | 1 |
| The trainees really like the training; it's tech-y which they like. | 1 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| One of the big selling points was that it was group administered and they could train as a unit, which in the marine corps was a strong point, because in the marines they do everything as a unit and they could support each other in the training. | 1 | 0 | 0 | 0 |
| Working with a geographically distributed project team. | 1 | 0 | 0 | 0 |
| Building this for front line soldiers and the issues they face, and most of them are male. Women soldiers face some different challenges. | 1 | 0 | 0 | 0 |
| Don't give up [in the face of ethical criticism]. This is a noble pursuit, even though it involves war. We are doing this to help the soldiers who get sent out. | 1 | 0 | 0 | 0 |
| Military culture is such that soldiers don't like to do things where psychologists are involved. | 1 | 0 | 0 | 0 |
| Virtual reality and gaming is cool and fun for soldiers and fits their culture. | 1 | 0 | 0 | 0 |
| There is a stigma facing users that they are not allowed to have mental issues. | 1 | 0 | 0 | 0 |
| PTSD is a societal problem (e.g. causes suicides and divorces). We believe prevention is very important to society, as well as psychology and engineering sciences. | 1 | 0 | 0 | 0 |
| | 20 | 21 | 36 | 22 |