Physiological Evaluation of Stress during Virtual/Immersive Combat Training

David A. Kobus, Dr. Erica D. Palmer, Jason M. Kobus, Jared R. Ostertag

Pacific Science & Engineering

San Diego, CA

DavidKobus@pacific-science.com, EricaPalmer@pacific-science.com, JasonKobus@pacific-science.com, JaredOstertag@pacific-science.com

ABSTRACT

This paper reports upon the physiological monitoring of stress effects from individual infantrymen during immersive combat related scenarios demonstrated during the Future Immersive Training Environment- Joint Capability Technology Demonstration (FITE JCTD). Immersive training environments provide the opportunity to expose infantrymen to some of the stressors that they may experience in theater. In theory, exposure to realistic stressors may provide a degree of inoculation to the stress of the environment before it is experienced in theater, leading to better performance under stress and a reduction in the long term effects of combat stress. The goals of this study were to 1) identify whether the FITE immersive environment could provide a level of stress that could be measured physiologically, and 2) determine whether physiological measures could be used to objectively measure presence – or a sense of being ***in*** the environment rather than the sense of ***watching it***. During this study Army and Marine Corps infantry squads participated in multiple virtual scenarios. Each participant wore an Expedition Dismounted Infantryman (ExDI) suit which allowed him to control an avatar within a Virtual Battlespace 2 (VBS2) scenario. Individual movements and actions taken by the participants were replicated by their avatars within the scenario. Each participant also wore a Threat-Fire™ system that provided negative feedback (electrical shock) to their thigh should they be shot or killed in some manner (e.g., IED, fall off building) during a scenario. Heart rate (HR) was collected from members of four squads (2 USMC, 2 USA) during each of the four scenarios. HR and HR variability were used to identify changes in stress level experienced by each infantryman throughout each scenario and were correlated to perceived level of readiness (Cooper's Color Code). Individual HR data was also correlated to scenario event time markers (e.g., sniper shot) to denote individual level of presence, and was correlated to subjective measures of perceived realism for each scenario.

ABOUT THE AUTHORS

Dr. Kobus is Director of Warfighter Performance at Pacific Science & Engineering Group (PSE). He holds an MS and PhD from Syracuse University and has been involved in human performance research and project management for over 25 years. He has served as the principal investigator, or as program manager, on over 30 research projects related to enhancing human performance. These studies incorporated a wide variety of measures including cognitive psychophysiological techniques and various measures of human performance. He has extensive teaching experience at both the graduate and undergraduate level and is a retired professor from San Diego State University.

Dr. Palmer is a Senior Scientist with PSE. She has significant experience in individual assessment and performance measurement, using behavioral, psychophysiological, and neurophysiological metrics. She is also experienced in functional and cognitive task analyses, scenario based training, and modeling human cognition. Her recent work has focused on enhancing Warfighter performance. She holds a BA degree in Cognitive Science and Psychology from Johns Hopkins University, and a PhD in Psychology (Cognitive Neuroscience emphasis) from Washington University in St. Louis.

Mr. J. Kobus is a Research Analyst with PSE. He has several years' experience working with the military in scenario based training and immersive environment training. His recent work has been in enhancing Warfighter performance. He holds an AA from Grossmont College.

Mr. Ostertag is an Operations Analyst with PSE. He is a United States Air Force Reserve Major with significant experience in Intelligence, counter-Improvised Explosive Device (IED) operations, and special operations. He holds a BA degree in Psychology from the University of Arizona, and a M.A. in Educational Psychology (Special Education emphasis) from the University of Texas at San Antonio.

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INTRODUCTION

The Future Immersive Training Environment (FITE) Joint Capability Technology Demonstration (JCTD) Management and Transition Plan (MTP) dated 26 Feb 2010 asked in Critical Operational Issue (COI) number 3 "Will the JCTD capabilities generate a realistic and interactive training environment which assists the unit in meeting established training standards?" (ONR 2010, pg.20).

While it is currently neither possible, nor feasible, to replicate a realistic battlefield environment, it is still possible to create a system that replicates many of the characteristics of combat or patrols in the area of operations. The general hypothesis is that the more realistic the training environment, the greater the immersion, providing more of a sense of presence to the trainee. One goal of Spiral 1 of the FITE JCTD was to develop an immersive training environment that could present a realistic patrol environment to trainees. The methods identified and used in the work reported here were specifically targeted at evaluating whether participants demonstrated a sense of presence within the training environment.

The goal of the FITE JCTD is to create an immersive environment, but how should immersion be operationally defined? Ijesselstein and Riva define immersion, in technical terms, as the technology that sets the environment by producing cues that make an individual sense that they were part of the environment. The actual sensation experienced by the trainee working in the environment indicates their level of presence (Ijesselstein & Riva, 2003). In other words, immersion is produced by technology to induce the sensation of presence. Witmer and Singer define presence as "the subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer & Singer, 1998, pg. 225).

One way to measure the experience of presence is to collect subjective data from presence questionnaires (or surveys). Presence questionnaires ask questions of the participant about their experience using the virtual system, post-immersion. These questionnaires may provide some good information, but a major disadvantage of using these questionnaires is that they are post-immersion, meaning that the questionnaires do not measure the time-varying qualities of presence and they may be more influenced by events that occurred near, or at the end of the immersion, which is closer to the administration of the questionnaire (Insko, 2003).

Further, Slater argues that the use of presence questionnaires alone is an "unsafe" methodology since it is difficult to rule out the possibility that the phenomenon being measured is influenced by simply asking questions about it (Slater, 2003). The questionnaires themselves may be influencing the responses of the participant whether they sensed presence or not. Therefore, other measures need to be identified to compliment the presence questionnaires.

Insko (2003) describes two additional categories of measures that can be used in concert with subjective measures. The first is behavioral observations; the premise is that the greater the sense of presence in the virtual environment, the more similar trainees' responses to stimuli in the virtual environment will be to behaviors they would exhibit in an identical real environment. The second set of measures is physiological indicators. Insko suggests three common and minimally intrusive ways to measure presence physiologically: heart rate, skin conductance, and skin temperature.

Mandryk (2006) found that while subjective data (surveys and questionnaires) do yield valuable quantitative and qualitative results, they do not provide sufficient information when used alone. Mandryk's team recorded users' physiological, verbal, and facial reactions to game technology to evaluate their experience. They found a significant correlation between subjective ratings and physiological responses. They suggest that by using multiple techniques to

evaluate participants' experience, presence can be measured in a more objective manner.

Based on the findings of these studies, the Pacific Science & Engineering (PSE) team proposed two methods to complement the survey results of the Independent Assessor in evaluating presence of individuals in the FITE immersive environment. The first method was recording observations of individuals performing real-world actions in response to stimuli in the virtual environment (behavioral method). Participants may be unaware of these actions, and by recording this information and linking it to scenario events, a sense of presence may be inferred if the action is similar to what an individual would do in the real world. The second method was measuring heart rate (physiological method) during each Virtual Battlespace 2 (VBS2) scenario. If a participant does have a sense of presence in the environment and a stressful event occurs, a physiological response should be triggered. Bangay and Preston (1998) used a similar technique in their experiment and measured heart rate to determine stress levels. Their goal was to use a virtual environment to lower the stress level of individuals.

The goals of introducing these methods during the FITE JCTD Operational Demonstrations were to 1) identify whether the FITE immersive environment could provide a level of stress that could be measured behaviorally and physiologically, and 2) determine whether behavioral data and physiological measures could be used as indicators of presence, that is, a sense of being ***in*** the environment rather than a sense of ***watching it***. The technology demonstrated in Spiral 1 of the FITE consisted of the Expedition Dismounted Infantryman (ExDI) and VBS2 software, both technologies identified by the FITE JCTD to create an immersive virtual environment.

The ExDI is an individually worn virtually reality system consisting of a head mounted display, a body-worn computer, and individual position and weapon tracking systems. Movement is via a weapon-mounted joystick. For the FITE JCTD Operational Demonstrations, a Threat-Fire™ system was worn by each individual to provide negative feedback if he was shot or in the blast zone of an explosion. The capabilities of the ExDI suit and VBS2 for Spiral 1 were demonstrated during two Operational Demonstrations (ODs). OD-1A was conducted February 23 - March 5, 2010 with two squads of U.S. Marines at Camp Lejeune, NC, and OD-1B was conducted March 16-25 2010 with two squads of U.S. Army Soldiers at Fort Benning, GA. A detailed description of methods and all analyses are provided elsewhere (Kobus, Palmer, Kobus, and Ostertag, 2010).

METHOD

Behavioral observation and physiological data (heart rate) were collected during each of four scenarios completed by each of the four squads. Scenarios 0 and 1 were designed as non-kinetic scenarios, while Scenarios 2 and 3 involved kinetic attacks near the end of the scenario. All squads went through the scenarios in order, except Squad 2 for OD-1B. Squad 2 performed Scenario 0 first, then performed Scenario 2 and 3 before performing Scenario 1. Further, Squad 1 for both OD-1A and OD-1B had the opportunity to do a "Free for All" at the end of Scenario 3. The "Free for All" was set up as an "every man for himself" period where each individual participant hunted their fellow squad members in the virtual environment to be "King of the Mountain/Last Man Standing."

During each scenario, observers from PSE's team simultaneously observed the physical actions of each participant and watched the events and actions in the virtual world via display monitors. Behavioral observation data collection focused on what actions, movements, etc. the participants made, or tried to make, in response to stimuli in the virtual world. An example of an action showing presence would be if a participant communicated to others on his team using hand signals, even though the action could not be seen by his team members in the virtual environment. Startle responses, such as jumping during an explosion, would be another observation indicating the participant was experiencing presence. Training and other factors that had either a positive or negative effect on squads using the ExDI suit were also noted. Additional observations were made to note unique training opportunities presented during the scenarios. Lastly, observations were also recorded whenever conditions were presented that appeared to disrupt the sense of presence, or that were likely to cause a break in immersion.

Participants' heart rates (HR) were recorded during each scenario using Suunto Dual Comfort Belts®. The belt is minimally invasive, requiring the user only to wear a lightweight strap around the chest. Participants were informed that their wearing of the HR monitor belt was voluntary. These belts used a Suunto wireless technology called ANT® to transmit HR to the Suunto Team Pod® receiver which is an antenna that connects to a laptop through a USB port. The Suunto Team Pod receiver was connected to a Lenova ThinkPad T60© laptop using the Windows XP© operating system to collect the data in real-time. The Suunto Monitor® version 1.1.2 software and the Suunto Team Manager®

version 2.3.0 software were also used during data collection. The Suunto Monitor® software provides real time monitoring of all participants' HR and allows the manual time stamping of events when they occur. At the completion of each scenario, the HR data were saved to the Suunto Team Manager® software for further analysis. The data files were then exported to Microsoft Excel© to complete the analysis.

Mean HR for each scenario was computed. Further, during each scenario key events (IED located, explosion, etc) were timed stamped to serve as event markers and to identify time spans for pre- / post-event comparisons. Increases in HR to a kinetic event would be indicative of the individual having a sense of presence. In addition, the amount of time spent in HR zones with postulated relationships to levels of Cooper's Color Code (CCC) was determined. CCC is broken into four conditions (white, yellow, orange and red) that indicate an individual's level of engagement or readiness. A fifth condition, often referred to as black, has been adopted by the United Stated Marine Corps. Heart rates were classified into zones based on a composite of CCC and work done by Grossman (Grossman & Christensen, 2004). The postulated HR zones are: White: < 80 beats per minute (bpm); Yellow: 81-100 bpm; Orange: 101-120 bpm; Red: 121-140 bpm; Black: >140 bpm. These HR zones were entered into the Suunto® software and provided real time monitoring of participant CCC HR zone. Figure 1 shows the Suunto® software display of CCC HR zone for each participant at a given moment during the scenario.

Figure 1. Real-time screen shot from OD-1A showing HR and the associated level of Cooper's Color Code.

RESULTS

Behavioral Observations

Behavioral observations were recorded for both OD-1A and OD-1B to provide examples of positive and negative presence actions while also noting factors that may have interfered with the sense of presence for the participants. Notes were also kept to reflect training and system-related issues that either helped or hindered the participants while using the ExDI suits, and could have had an effect on the sense of presence.

Presence

For OD-1A, a common indicator of presence was the observation of participants making actions (behaviors) in the real world to reflect events occurring in the scenario without realizing they were performing these actions. These actions included using hand gestures when speaking, pointing directions (even though no one could see where they were pointing in the virtual world), startle responses, excitement in the participant's voice, and warning others of threats. Pointing directions was a common observation throughout the scenarios but unfortunately was not one that was mimicked in the virtual world, becoming a source of frustration at times for the squad when they realized no one could tell where they were pointing. Participants quickly learned that they could use their weapons as a way of pointing within the virtual environment. Another demonstration of presence was that a squad's movement and route planning activities changed over time as they gained more information regarding what to expect in the village. Lastly, one observation was made in which an individual ran out of his real-world training space (almost into a wall) as he was trying to change locations quickly during a fire fight.

There were also several observations made during OD-1A that indicated a lack of presence. This included behaviors such as participants talking to each other or gesturing in the real world to get someone's attention (waving hands, tapping on shoulders, etc.) even if they were separated by a few hundred meters or their line of sight was obscured by a building in the virtual world. Another negative presence aspect was that when a participant was "killed" or was taken out of the scenario for other reasons (e.g., equipment failure), they sometimes continued to provide feedback and/or assisted the remaining squad members. During one of the scenarios an external stimulus (vacuuming) may have also affected the sensation of presence of the participants by distracting or drawing participants' attention away from the scenario. An interesting observation that indicated both positive and negative aspects of presence was when the Squad Leader called for the Team Leaders to come to him, there was confusion over whether he meant in the virtual world or in the real world or both. This reflects that the participants may have wanted to maintain a sense of

presence, but at the same time realized the existence of the real world in which they were also interacting.

For OD-1B similar observations were made for the sensation of presence. Again, participants used hand gestures in the real world to point out direction, location, etc. There was also an instance where a Squad Leader reported feeling "nervous" while the squad was near an Improvised Explosive Device (IED) site, even though it was not a really a physical threat, except for the possibility of getting shocked by the Threat-Fire™ system if the IED went off. There was also an incident between a Squad Leader and his Team Leader in which the Squad Leader told the Team Leader "I can't talk to you - you're too far away. We have to use radios." This simple exchange is again reflective of how the Squad Leader attempted to maintain a sense of presence in the scenario, even though he was standing close enough to the Team Leader to hold a conversation. Another interesting reaction occurred during the "Free for All" event when an aircraft flew overhead in the virtual world and the soldiers reacted by ducking as if they had to hide or find cover.

There were also several observations made during OD-1B that indicated a lack of presence. For example, the Squad Leader often needed to look at a real-world hard-copy map of the village which meant that he had to raise his visor to look at the map, likely breaking the sensation of presence in the virtual world. During the scenarios there were also some technical issues (e.g., freezing of the system) that affected only a few of the participants, but served as a distraction if the scenario needed to be paused. Unfortunately, sometimes the affected participant would speak loudly to voice their issue and frustration, which may have affected the sensation of presence for other participants still operating in the virtual world.

A general observation for both demonstrations that affected the sensation of presence was the ambient lighting in the demonstration rooms. To help reduce some of the external visual distractions with movement seen in their periphery, the ambient lighting needs to be set to a low level. In both ODs, the lights were dimmed slightly after the scenario began but due to other considerations, such as needing lighting during video capture, the lights were often turned back up.

Heart Rate Results

Initial analysis was conducted to investigate HR changes between a baseline period (average HR over the period two minutes before and after the scenario start time) and an end phase (average HR over the last 15 minutes of each scenario). Figures 2 and 3 display the average HR differences between these time periods for each of the scenarios during OD-1A and OD-1B respectively. While these results do show that the participants were engaged, they do not necessarily reflect a sense of presence since they are not associated with specific behavior.

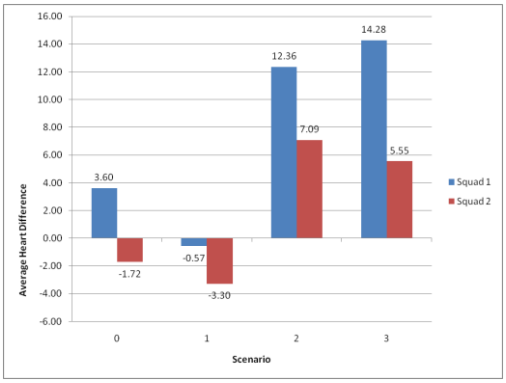

Figure 2. Difference in heart rate between baseline and end of scenarios for OD-1A

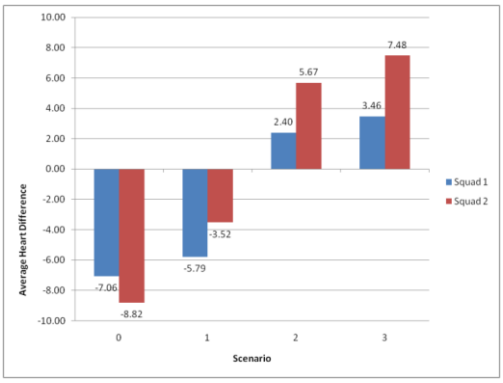

Figure 3. Difference in heart rate between baseline and end of scenarios for OD-1B

To evaluate presence, specific scenario events were identified and pre-to-post (PTP) HR measures were collected for analysis. Average HR values were determined for the three minute period prior to each event (Pre) and over a three minute period after each event (Post). Statistical analyses (paired *t*-tests) were conducted independently for each event. To select the events for analysis, time markers for each event were identified on the HR data displays for all participants. Visual reviews of changes in HR were then observed for each of the events. Only events that displayed large increases in HR as a group were selected for statistical analysis. This technique helped reduce the number of analyses that needed to be conducted while maximizing the opportunity of demonstrating presence.

Event-based Heart Rate for OD-1A

For OD-1A, eight events were selected for analysis of PTP heart rate differences. The only events with a common theme between the two squads were the "Initial Attack" event that occurred in Scenarios 2 and 3, and the "RPG Attack/Identification" that occurred in Scenario 3. All other events were unique to a squad within a given scenario. Table 1 shows which analyses were conducted and the statistical results. Analyses were only conducted in cells containing symbols.

No HR changes related to specific events were apparent during Scenario 1. Therefore, no analyses were conducted for this scenario. In addition, HR for Squad 2 did not increase during events in Scenario 0. Table 1 displays the statistical results of PTP HR analyses during OD-1A.

Table 1. OD-1A statistical results for *t*-tests pre/post significant scenario events

Event	Contact	Initial Attack	Shots – Small Arms	Engage	RPG Attack	Taking Fire	RPG Gunner	Free for All
Squad 1								
Scenario 0	** (83%)							
1								
2		** (80%)	* (80%)	** (80%)				
3		*** (92%)			** (75%)			*** (100%)
Squad 2								
Scenario 0								
1								
2		** (69%)						
3		*** (92%)			** (83%)	*** (92%)	*** (100%)	

*** (p<0.1); ** (p<.05); *** (p<.01)**

Statistically significant increases in PTP HR were found for all analyses conducted for the OD-1A participants. Table 1 shows the percentage (in parentheses) of squad members that demonstrated an increase in HR. At least 75% of all participants whose data were recorded for the scenarios showed an increase in HR for events identified. Further, all of the participants displayed an increase in HR for two events, "Free for All" for Squad 1 and "RPG gunner to the north" for Squad 2. The high percentage of Marines that demonstrated an increase in HR related to each of the specific events indicates that the statistical results are driven by group data rather than an individual outlier.

To illustrate how the HR varied due to specific events during OD-1A, representative data are displayed in Figure 4 for participants from Fire Team 2 for Scenario 2. Each participant's HR over the course of the scenario is identified by a different line as noted in the figure legend. At the top of the figure are three event titles that were identified for that scenario, and the period of time when the event either occurred. One of the three individuals showed a very large increase in HR for the events. The squad as a whole also indicated significant increases in PTP HR for each of the events. Figure 4 shows how individuals respond differently to each of the events. However, during each of these events, 80% of the squad did display an increase in HR.

Cooper's Color Code OD-1A

HR data were tracked to provide an estimate of how much time during a scenario an individual's HR was within each condition of Cooper's Color Code (CCC). As a whole, the two squads averaged HR in the yellow condition across all scenarios. However, as shown earlier, there were individual differences.

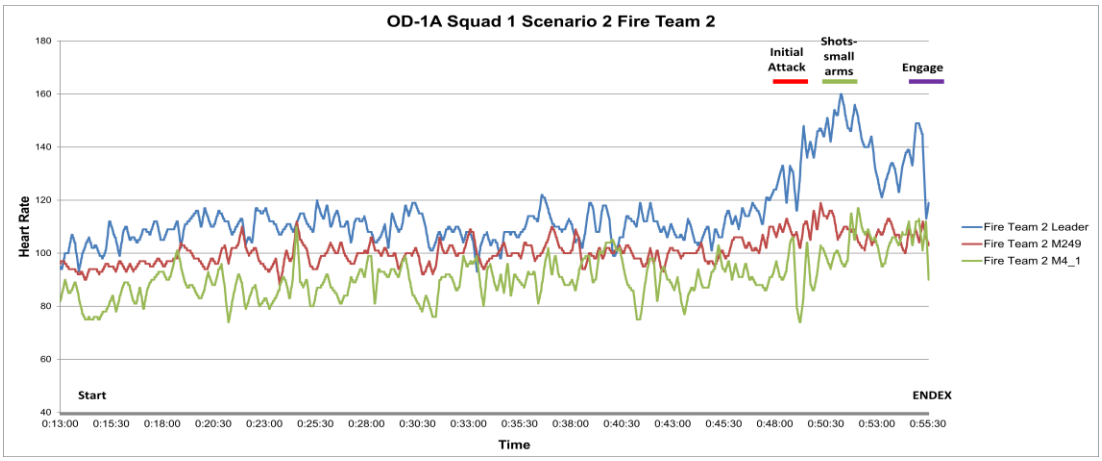

Figure 4. Heart rate data recorded during OD-1A for Fire Team 2 for Scenario 2

Table 2 shows percentage of time participants spent in each condition of CCC during each scenario. The condition in which participants spent the most time is highlighted for each scenario. Scenario 0 was Squad 1's first scenario wearing the ExDI suit and most of the squad was in either condition orange or yellow, suggesting that they were engaged or excited to be in the event, probably anticipating kinetic activity. Scenario 1 consisted of a non-kinetic patrol and most of the participants spent the majority of their time in the yellow condition. Scenario 2 was the first fully kinetic scenario and the majority of participants showed a HR increase and spent most of their time in condition orange. Scenario 3 was also a kinetic scenario but now the majority of participants spent most of their time in condition yellow. Such a result may reflect a reduction in general stress level (or uncertainty) due to having already experienced kinetic events within the system.

Table 2. OD-1A: Squad 1 - Percentage of time in CCC conditions

Scenario 0	**FTL1**	**FT1-1**	**FT1-2**	**FT1-3**	**FTL2**	**FT2-1**	**FT2-2**	**FT2-3**	**FTL3**	**FT3-1**	**FT3-2**	**FT3-3**	**SL**
Black	--	--	--	--	--	--	--	--	--	--	--	--	--
Red	1%	5%	--	--	14%	--	--	--	--	10%	--	6%	--
Orange	**82%**	**57%**	9%	1%	**77%**	27%	4%	7%	--	**90%**	**53%**	**90%**	11%
Yellow	17%	38%	**88%**	46%	8%	**73%**	**57%**	**62%**	--	--	43%	4%	**87%**
White	--	1%	4%	**53%**	--	--	39%	31%	--	--	4%	--	2%

Scenario 1	**FTL1**	**FT1-1**	**FT1-2**	**FT1-3**	**FTL2**	**FT2-1**	**FT2-2**	**FT2-3**	**FTL3**	**FT3-1**	**FT3-2**	**FT3-3**	**SL**
Black	--	--	--	--	--	--	--	--	--	2%	--	--	--
Red	--	--	--	--	--	--	--	--	--	3%	--	--	--
Orange	6%	28%	**60%**	--	10%	11%	--	--	--	**75%**	24%	**69%**	5%
Yellow	**88%**	**72%**	30%	--	**80%**	**87%**	21%	15%	--	9%	**75%**	31%	**67%**
White	5%	--	9%	--	10%	2%	**79%**	**85%**	--	11%	2%	--	27%

Scenario 2	**FTL1**	**FT1-1**	**FT1-2**	**FT1-3**	**FTL2**	**FT2-1**	**FT2-2**	**FT2-3**	**FTL3**	**FT3-1**	**FT3-2**	**FT3-3**	**SL**
Black	--	6%	--	--	5%	--	--	--	--	--	--	2%	--
Red	--	8%	33%	--	28%	--	--	--	--	15%	3%	32%	1%
Orange	**55%**	24%	**46%**	--	**56%**	**52%**	9%	--	--	**85%**	**66%**	**59%**	36%
Yellow	45%	**52%**	19%	--	11%	48%	**80%**	--	--	--	31%	8%	**62%**
White	--	9%	2%	--	--	--	12%	--	--	--	--	--	1%

Scenario 3	**FTL1**	**FT1-1**	**FT1-2**	**FT1-3**	**FTL2**	**FT2-1**	**FT2-2**	**FT2-3**	**FTL3**	**FT3-1**	**FT3-2**	**FT3-3**	**SL**
Black	1%	17%	--	--	2%	--	--	--	--	--	--	11%	--
Red	5%	9%	17%	--	8%	--	5%	--	--	26%	14%	17%	5%
Orange	22%	16%	**57%**	--	29%	--	15%	--	--	**63%**	25%	**42%**	20%
Yellow	**68%**	**49%**	24%	20%	**57%**	**57%**	**51%**	22%	--	11%	**59%**	31%	**69%**
White	3%	8%	1%	**80%**	5%	43%	29%	**79%**	--	--	2%	--	6%

One interesting note is that the Squad Leader always spent a majority of his time in condition yellow regardless of the scenario.

Event-based Heart Rate for OD-1B

Eight scenario events were also identified for OD-1B. PTP HR analyses were conducted for each of these events and statistical results are displayed in Table 3. As in OD-1A, no specific events were identified during Scenario 1. There were unique events between squads and across scenarios such as Squad 1's "Hands up, don't move" event during Scenario 0.

Again not all the participants showed an increase in HR during each key event (percentage of participants indicated in parentheses). However, Table 3 shows that at least 56% of participants displayed increases in HR for the scenario events identified. For eight of the events all members of the squad displayed increases in HR.

Table 3. OD-1B statistical results for *t*-tests pre/post significant scenario events

Event	"Hands Up"	Initial Attack	Suspect Spotted	Man Down	Meet w/ local	Shots Fired	"Truck!"	Free for All
Squad 1								
Scenario 0	*** (100%)							
1								
2		ns	*** (88%)	*** (80%)				
3		** (89%)		* (56%)	** (78%)			*** (100%)
Squad 2								
Scenario 0								
1								
2		*** (100%)	*** (100%)	*** (100%)				
3		* (78%)		** (100%)		* (78%)	*** (100%)	

*** (p<0.1); ** (p<.05); *** (p<.01): NS (Not Significant)**

Table 4. OD-1B: Squad 2 - Percentage of time in CCC conditions

Scenario 0	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	SL_11
Black	--	--	--	--	--	--	--	--	--
Red	--	--	--	--	--	--	--	--	--
Orange	28%	1%	14%	--	4%	14%	--	4%	18%
Yellow	72%	74%	86%	6%	84%	78%	5%	93%	82%
White	--	25%	--	94%	12%	8%	95%	3%	--

Scenario 1	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	SL_11
Black	--	--	--	--	--	--	--	--	--
Red	2%	--	--	--	3%	33%	--	1%	--
Orange	58%	5%	3%	--	7%	28%	--	31%	26%
Yellow	39%	90%	76%	34%	38%	28%	30%	32%	59%
White	--	6%	21%	66%	52%	11%	70%	37%	15%

Scenario 2	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	SL_11
Black	--	--	--	--	--	--	--	--	--
Red	5%	1%	1%	--	5%	--	--	--	2%
Orange	73%	13%	42%	--	37%	4%	--	7%	68%
Yellow	22%	73%	57%	6%	57%	59%	33%	77%	30%
White	--	12%	--	93%	1%	37%	67%	16%	--

Scenario 3	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	SL_11
Black	--	--	--	--	--	--	--	--	--
Red	51%	--	--	--	1%	--	--	--	13%
Orange	48%	11%	4%	--	42%	15%	--	65%	81%
Yellow	1%	78%	95%	25%	56%	77%	48%	34%	6%

White	--	**10%**	**1%**	**74%**	--	**7%**	**52%**	--	--

Cooper's Color Code OD-1B

Heart rate data were tracked to provide an estimate of how much time during each scenario an individual spent within each condition of CCC during OD-1B. As a whole, the two squads averaged HR in condition yellow for all scenarios. The distribution of individuals in both squads was six men with average HR that placed them in condition yellow, two men in condition orange, and one individual in condition white.

Table 4 shows the percentage of time participants from Squad 2 spent in each condition of CCC during a scenario, with the condition in which the participant spent the most time for that scenario highlighted. For Scenario 0, participants tended to remain in either condition yellow or white with minimal time spent in the other conditions. The data for Scenario 1 show that the majority of participants had heart rates that placed them in condition yellow or white, with two individuals spending a majority of their time in orange or red. Although Scenario 2 was a kinetic scenario, only two members of the squad spent the majority of their time in orange, while the rest were in yellow or white. Scenario 3 had three members spend a majority of their time in conditions red or orange while the rest of the squad remained in condition yellow or white. For all the scenarios, no member of Squad 2 was ever in condition black.

Of note, the Squad Leader displayed HR data indicating that he spent most of his time in condition yellow for the non-kinetic scenarios (Scenarios 0 and 1) but was in condition orange for the kinetic scenarios (Scenarios 2 and 3).

DISCUSSION

While it is impossible to completely simulate a real-world patrol situation that includes gunfire, explosions, and the risk of injuries and death, the FITE JCTD was designed to create an immersive virtual environment that closely represents what a Marine or Soldier could encounter while on patrol. The question of how close to reality the virtual environment is to combat conditions and situations infantrymen face in theater can be addressed by using different methods tied to measuring the sensation of presence. These methods include subjective (questionnaires/surveys), behavioral (observations) and physiological (e.g., changes in heart rate). The results displayed here clearly demonstrate that the ExDI/VBS2 Spiral 1 system did provide sufficient immersion to produce the sensation of presence.

Behavioral observation results revealed that participants clearly performed specific actions and behaviors that might have been expected if they were in the actual real-world environment. These actions included making hand movements while talking, or indicating direction by pointing to other squad members. Further, these scenarios provided many additional unique opportunities for training in situations to which few infantrymen are exposed before experiencing them in theater. One example that arose in one of the scenarios addressed what actions to take while under attack in a school with children present. Multiple learning/training opportunities arose during the AARs where the participants could view their behavior via replay and learn from their actions. The participants used these talking points to discuss how to make better decisions in future scenarios and in real-world situations.

Heart rate increases were found across scenarios for all squads. However, to more specifically evaluate presence, event-based HR results were analyzed. These results show that a when an event occurred in the virtual world that would normally be expected to produce an increase in HR in the real world, the HR of the participants did increase. There were individual differences, but the majority of the squad members showed similar results. A compelling investigation for future work would be analysis of how HR changes may reflect a participant's proximity to the event, their level of situation awareness, their experience level, or a host of other factors.

Survey data were collected by the Independent Assessor to provide subjective reports of the participants' sense of presence in the scenarios. Overall, although the correlations between survey data and HR data were not statistically significant, participants did show that they were exhibiting a sensation of presence for events within a scenario based on observed actions and HR. The lack of correlation is probably related to the fact that all participants indicated a moderate level of presence based upon the survey data. One key to these data is that HR measures must be linked to event-based activities that occur within a scenario. The linking of events to changes in observed actions and HR served as a method to show that presence did occur. Subjective reports may have been based primarily on overall experiences, rather than tied to specific scenario events. One needs to be aware that subjective reports do not always match objective data.

An example of this disconnect occurred during the FITE JCTD Technical Demonstration. During a scenario, the Squad Leader was killed and removed from the scenario. One of the Fire Team Leaders, Davis (not his real name), was forced to take over as Squad Leader around the 20 minute mark (blue square marker on graph in Figure 5). Soon after Davis took over as Squad Leader, a rapid increase in his HR was recorded (green line in Figure 5), exceeding 174 bpm by the end of the scenario run. When asked afterwards what he thought when it became clear that he needed to take over as Squad Leader, he stated that "it was nothing" indicating that he experienced little stress when moved into a position of higher responsibility. His physiological data, in contrast, suggest otherwise. This example illustrates that there can be a disconnect between what someone experiences and what they report.

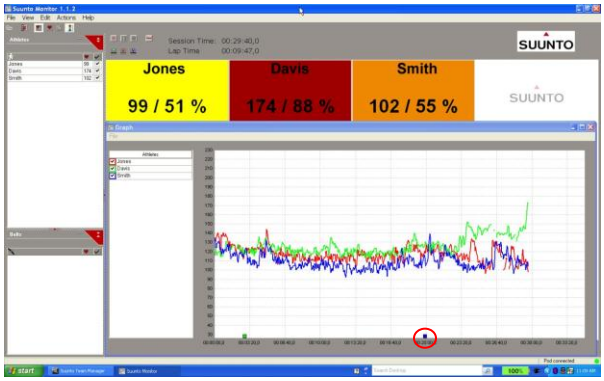

Figure 5. Real-time graph of Technical Demonstration 1 Team Leaders' heart rates

The results from the Cooper's Color Code data also demonstrate a sense of presence across the scenarios. Although there are individual differences, the participants' heart rates generally placed them in CCC conditions appropriate for the scenario events. In other words, when patrolling and observing they were in the yellow, and when faced with threats or engaged in combat they spent more time in orange or higher. These data demonstrate modulation of physiological responses in the virtual world that are similar to what would be expected in the real world.

Potential Caveats

The demonstration overall was not a controlled experiment and confounding variables may have influenced the results. Participants were not monitored for variables like caffeine and nicotine use, athletic ability, and naturally high or low heart rates. These could all have an effect on participants' starting HR or baseline, which could affect results. For future studies, more control should be employed.

CONCLUSION

The FITE JCTD was designed to show that a system can be created in which an infantryman can receive immersive, realistic small unit training with minimal risk of harm. One important aspect of this effort was to demonstrate that the technology produced a sensation of presence within participants. In this limited investigation, PSE showed through observational data and recording of participants' heart rates during scenarios, that participants did experience a sensation of presence. The key to these findings is the use of event-based activity as the independent variable, analyzing HR changes prior to and immediately following specific events. While confounding variables may have been present, these data suggest that the FITE system holds promise as an immersive training tool.

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