

LEARNING
IN
AFFECTIVELY INTENSE VIRTUAL ENVIRONMENTS

by

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ABSTRACT

The main purpose of this research was to examine the impact of the degree of affective intensity of a virtual reality training environment on learning, as demonstrated by performance within a “real life”, affectively intense environment. The research was based on a model that took into consideration learner variables such as immersive tendency and affect intensity, coupled with virtual reality induced conditions of autonomic arousal and presence, and their cumulative effect on task performance in the corresponding affectively intense “real” world. Twenty-two individuals recruited from the university completed a “training” scenario in which they were required to locate victims of a terrorist attack either in an “affectively intense” or “affectively neutral” version of the virtual environment. This virtual environment was a model of the University’s Computer Science building, created to support this scenario. Following the training, participants were required to locate the rooms that contained the victims within the actual computer science building as they listened to an affectively intense audio track. The major findings were: 1) Those in the affectively intense environment performed substantially better at identifying the location of injured victims; 2) The two environments did not differ with respect to the autonomic arousal of the participants or with respect to their perception of presence, nor did autonomic arousal or presence predict performance in the “real” environment; 3) Those more experienced with computer games reported a higher degree of presence in the virtual environment and performed better in the “real” environment (and males tended to have more experience with computer games).; 4) Those who scored high on individual difference measures representing an immersive focus tendency and a tendency to respond intensely to affective events performed worse in the “real” environment.

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1. INTRODUCTION

1.1. OVERVIEW

With the support of the U.S. Army's Tank-automotive and Armaments Command (TACOM, grant # DAAE07-02-C-L068), a virtual reality system is being developed by the University of Missouri-Rolla (UMR) to help train first responders in dealing with terrorist attacks involving the use of weapons of mass destruction. The participating factions at UMR are Virtual and Rapid Prototyping Laboratory (VRPL), which provides hardware and infrastructure support, the Virtual Environment and Object Modeling (VENOM) lab, which provide software and system integration facilities and the Laboratory for Information Technology Evaluation (LITE), whose role is to evaluate the impact of the system on learners. An important evolving component of this project is a focused and systematic examination of the basic factors that account for learning within affectively intense learning environments.

The purpose of this research is to examine basic psychological and physiological processes associated with virtual reality based training for learning in affectively intense environments. Affectively intense learning refers to learning in which the task to be learned is to be performed in a highly stressful, emotionally intense environment (such as first responders to weapons of mass destruction) (Hall et al., 2004). There is very little research on the factors that contribute to effective learning in these types of environments. The main goal of this research was to examine the optimal degree of affective intensity within the virtual environment that lead to the most effective learning in a "real world" affectively intense performance environment. The research used a first responder scenario for training and testing. An experimental environment was developed, based on a virtual model of the University of Missouri – Rolla's Computer science building, adding special affectively intense effects that would be associated with a terrorist attack to facilitate this research. Both the scenario and experimental environment are described in more detail below.

1.2. VIRTUAL REALITY IN EDUCATION

Traditionally, virtual reality presents information in a dynamic 3-dimensional form with the participant viewing the world from an immersed viewpoint with the ability to interact with the information or world (Byrne, 1993). Virtual reality's style of presentation can mimic the ways that we, as humans, have learned to interact with our physical world. Through the use of this technology in education, the requirement of learning abstract concepts in order to understand data can potentially be significantly reduced. Virtual Reality can be used for an advantage in places where it becomes difficult to convey certain concepts that rely heavily on metaphors or abstract principles. Learning in the real world is mostly from experience, but trying to recreate some of the experiences in the real world might be dangerous or too costly for constructive learning. For example, in the virtual world, the internal working of a nuclear reactor can be shown without one having to step into the actual location or for that matter anywhere near the reactor, something which is not humanly possible without adequate shielding.

Technological advances have taken virtual reality and augmented reality environments into schools as tools for education and for training in the military (Hays & Vincenzi, 2000), aerospace, and medical fields (Stansfield, 1998). Unfortunately, there is much more focus on the technology of virtual reality than there is evaluation of its impact on learning. The efficacy of the VR systems developed, and what factors mediate this effectiveness are seldom studied.

One ambitious example of the use of virtual reality in education is Project ScienceSpace, which is a collection of immersive virtual worlds designed to aid students in mastering the challenging concepts in science (Hall, Stiles, & Horwitz, 1998; Salzman, Dede, Loftin, & Cheng, in press). ScienceSpace consists of three separate worlds. NewtonWorld provides an environment for investigating the kinematics and dynamics of one-dimensional motion. MaxwellWorld supports the exploration of electrostatics, leading up to the concept of Gauss' Law. PaulingWorld enables the study of molecular structures via a variety of representations. A formative evaluation of MaxwellWorld was conducted by Dede and Salzman to examine its effectiveness as a tool for learning. The students tested for their study found the virtual environment an effective means to learn about electric fields as compared to textbooks and lectures. But certain abstract, though

creative, representations (such as size of the ball representing mass) were not readily understood by the students, which leads to the conclusion that maximizing interaction aspects can sometimes hamper learning. Pre and post knowledge tests were conducted to determine if there was an increase in learning and retention. There were significant pre to post gains in learning outcomes for MaxwellWorld, but nothing conclusive could be drawn with respect to NewtonWorld. A direct comparison of MaxwellWorld with a popular non-immersive 2-D learning tool called EM Field was also carried out. Although results were mixed, the group of students who used MaxwellWorld scored higher on measures of comprehension of conceptual knowledge and ability to describe 3-D fields as against EM Field. Tests were conducted to determine five month retention which yielded no significant differences between the groups (Salzman, Loftin, Dede, & McGlynn, 1996).

Another example to illustrate the use of virtual reality based systems for training is a study conducted to evaluate knowledge retention at the Air Force Research Laboratory, Brooks Air Force Base, San Antonio, Texas as part of the Virtual Environments for Training (VET) program funded by the Office of Naval Research (Hall et al., 1998). The study involved training two groups, one on conventional desktop systems and the other on immersive 3D virtual reality environment with 6 degrees of freedom in a life size virtual room with scale 3D objects. The purpose of the training was to determine if the spatial experiences involved in learning in the virtual reality environment enabled them participants to recall a procedure better than the group which was trained on the conventional 2D desktop systems. The procedure involved operating several devices distributed around a room. The devices were associated with a compressor used by the navy on some of its ships. The tasks were conducted more effectively in the VR environment as compared to the Desktop environment, which was seen in the mean scores, but the difference was not significant enough to warrant an assertion that VR systems are superior for training. Knowledge retention was also slightly higher in the VR systems but the times spent in the environments to accomplish the tasks were considerably higher in the VR environment than in the Desktop environment.

Other comparisons of Virtual Reality and learning methods often fail to find an advantage for immersive Virtual Reality environments. For example, Mania and

Chalmers conducted experiments using head mounted displays and traditional desktop systems (Mania & Chalmers, 2001). Students were required to watch a seminar using the two technologies and a memory test was administered, the group using the desktop systems performed better than the group using the head mounted displays.

In addition, Pausch R., and Proffitt D., at the University of Virginia conducted an experiment where users were to determine the presence or absence of an alphabet in comparable virtual rooms using desktop systems and head mounted systems respectively (Pausch, Proffitt, & Williams, 1997). They found: a) HMD users did not find targets in camouflaged scenes faster than traditional users; b) HMD users were substantially faster when no target was present; c) Desktop VR users needed to re-search portions of the scene to be confident there was no target; and d) Users who practiced first with head mounted displays positively transferred that experience and improved their performance when using the traditional display. On the other hand, users who practiced first with the traditional display negatively transferred that experience and performed worse when using VR. This negative transfer may be relevant in applications that use desktop 3D graphics to train users for real-world tasks. These findings illustrate the fact that varying levels of immersion (HMD vs. desktop) can significantly impact performance, but the impact is complex, not specifically favoring one modality over the other.

There is little information on how the efficacy of current virtual reality systems can be improved for educational purposes. Research on the effectiveness of these systems in comparison to traditional learning is mixed. This lack of effectiveness is due, in no small part, to a lack of systematic examination of the component factors that make up VR environments. This has resulted in a general lack of knowledge as to what factors are most important for learning, and how these are mediated by other important variables such as the learner and information representations used in virtual reality systems.

1.3. FIRST RESPONDER TRAINING

An area where virtual reality offers great potential as a training tool is for the training of First Responders. The military could employ the technology for providing situational and task training for certain scenarios which are highly dangerous to reproduce terrorist attacks involving Weapons of Mass Destruction (WMD). The users could be trained using a varying array of situations, which could be studied and altered to

determine the best response and tactics to deal with the situation. In this regard, the advantage of using virtual reality is that the situation could be modeled as closely as possible without endangering the user. The variables can be altered in the environment to simulate different scenarios or different degrees of threats.

There are a number of examples in which virtual reality has been applied for the training of military and medical personnel for responding to emergency situations. One of these provides the context for the current research – FiRSTE (First Responder Simulation and Training Environment). This is a system developed at the University of Missouri – Rolla, in collaboration with the Army’s Tank Automotive and Armaments Command (TACOM) for the training of first responders in event of WMD usage (Berry & Hilgers, 2004; Hall et al., 2004; Leu et al., 2003; Misra, Decker, Barker, & Hilgers, 2004; Tichon, Hall, Hilgers, Leu, & Agarwal, 2003). The project is aimed at determining the effectiveness of virtual environments for training first responders and emphasized WMD survey training. The FiRSTE environment supports 3 core features:

WMD event simulation: It provided a virtual simulation to facilitate chemical survey operations with its ability to model the release of toxic gases in enclosed structures.

Sensor simulation: The array of sensors that first responders use when entering a site suspected of a WMD event are quite complex. The photo ionization detector (PID) is the primary tool that measures gas concentrations and volatility in the environment and has been modeled into the simulation to provide feedback to the user in a heads up display (HUD).

Complex Structures: The gas release simulations that are commercially available as common off the shelf (COTS) products mainly cater to diffusion in open environments. Complex structures related to building have corners, partially closed doors, ventilation ducts to define gas diffusion boundaries. Such indoor gas diffusion simulations have been realistically simulated using FiRSTE.

A modified version of the FiRSTE environment was developed for the purposes of systematically examining affectively intense learning (Hall et al., 2004), and this is described later in the thesis in more detail.

Another example of using virtual reality for first responder training is Medisim (Stansfield, 1998). MediSim, developed at Sandia National Laboratories, is a virtual environment targeted primarily at training battlefield medical personnel whose responsibility is to assess and stabilize multiple casualties for evacuation. Medic trainees are represented in the virtual environment as full graphical figures that provide a high fidelity representation of the actions and motions of the medic they represent. Within this environment, they are presented with simulated casualties on a virtual battlefield. The goal of MediSim is to train rapid situation assessment and decision-making under highly stressful conditions.

The system underwent an evaluation study (Stansfield, 1998). Although the groups tested on the system requested more visual and tactile cues, the system acceptability was rated highly by the test subjects as an augmentation to currently existing medical mission rehearsal and training approaches. In totality, the system proved to be quite successful as a situational training tool, though it did not perform as well on individual task training.

Another virtual reality trainer that deals with training first responders to weapons of mass destruction is BioSimMER also developed at the Sandia National Laboratories (Stansfield, A., & D., 1998). BioSimMER is a prototype virtual reality (VR) system for training first responders to nuclear, biological, and chemical acts of terrorism. The initial application is to medical emergency response and focuses on the training of personnel who might be called upon to provide emergency triage at the scene of an act of terrorism involving both an explosion and the release of a BW biotoxin. The system consists of an immersive, multi-modal user interface and a dynamic casualty model that both changes over time and responds to the actions of the trainee. The system is built upon Sandia's open, distributed VR platform and leverages previous development of the MediSim system discussed above. The VR platform allows multiple users (displays, trackers, etc.) and multiple, heterogeneous simulation modules to be networked together to create a common, shared virtual environment. A dynamic casualty simulation provides realistic cues to the patient's condition (e.g. blood pressure and pulse change over time as a patient's condition worsens.) The casualty simulation also responds to the actions of the trainee (e.g. a change in the color of a patient's skin may result from a check of the

capillary refill rate.) The current prototype does provide a fairly detailed simulation with regard to virtual casualty depiction but user comments and feedback indicate that multi-sensory perceptual cues (visual, auditory and tactile) require improvements as they are critical to patient-management simulations. Naturalistic handling and improved audio were other aspects that users indicated could augment realism in the environment

Another example is the virtual reality simulation called the Firefighter Command Training Virtual Environment developed at Georgia Tech in collaboration with the Atlanta Fire Department using the Simple Virtual Environment (SVE) library, an extensible framework for building VE applications (Julien & Shaw, 2003). The VE allows the user to navigate around the environment, view the house from multiple angles and allows for collaboration and team execution. The VE user is essentially built to train a commanding officer trainee to direct a team of fire fighters to put out the fire with minimum damage to the house in the simulation.

Although the research above illustrates various creative and important uses of virtual reality as a tool for training first responders, important questions still remain unanswered. Most of the systems have only gone through minimal evaluation, so it is still not clear that these systems are significantly better than traditional forms of instruction. Moreover, even though the Medisim system underwent a more thorough evaluation as a whole, there was still no systematic variation of factors that may mediate the systems effectiveness. The fact remains that it is logistically impractical to create a “real life” learning scenario for emergency situations, so these are important questions to address. In addition, the immersive environment would seem intuitively to be an ideal alternative tool for modeling the affective intensity of these situations.

1.4. AFFECTIVE COMPUTING

In the last decade, an area within computer and information science has emerged, which is related to the current study. This area is commonly referred to as “affective computing”. Affective computing is computing that relates to, arises from, or deliberately influences emotions (Picard, 1998). Recent research in psychology indicates that emotions play an essential role in decision making, perception, and more (Norman, 2003). Not only too much, but too little emotion can impair decision making. Research in the field of affective computing deals with the understanding of mechanisms of emotion

that will be needed to build "human-centered" machines, which are able to respond intelligently and sensitively to the complex and unpredictable situations common to human-computer interaction.

This area became popular in the last decade (Picard, 1997). Emotional responses have been identified and are related to characteristics of the interface and computer system. For example, Riseberg and colleagues (Riseberg, Klein, Fernandez, & Picard, 1998) purposely created frustration in users by offering them a cash reward for performance on a video game, and then purposely creating a "stuck mouse" effect during the game. Physiological measures of autonomic arousal differentiated between frustrated and non-frustrated states in users. Similarly, in a recent study, increased autonomic arousal was found in response to video and audio that was not properly synchronized (Ali & Marsden, 2003).

One of the most interesting manifestations of the affective computing area, which relates to learning, is a study which combined biofeedback mechanisms and affective computing (Bersak, 2001). Users were provided with feedback in a virtual reality based race game. The participant's dragon would increase in speed if the person relaxed. The relaxation level of the person was interpreted from his/her change in galvanic skin response. The game provided a much appealing and effective "reward" for the correct "bio-state". The affective feedback helped people to gain better control over their emotional state. Competitive games are normally associated with tension and stress, so the player must learn how to override this tendency and learn not only to relax, but also how to relax in a tense environment.

1.5. AFFECTIVELY INTENSE LEARNING

As an individual difference, "affect intensity" can be defined as the stable individual difference in the strength with which individuals experience their emotions (Diener, Larsen, Levine, & Emmons, 1985). A study conducted on consumer psychology using Affect Intensity as an individual difference measure confirmed that high affect individuals respond with significantly higher levels of emotion when exposed to affectively charged advertising, but not when exposed to non-emotional advertising (Moore & Homer, 2000). Affect Intensity Measure (AIM) developed by Larsen & Deiner was used to measure this construct in the present research (Diener et al., 1985).

As an outcome measure, the term “Affectively Intense Learning” was coined by researchers at the University of Missouri – Rolla (Hall et al., 2004; Tichon et al., 2003) to denote the type of learning associated with strong emotional states where the environments tend to be stressful such as military training. Intuitively, it would seem that this type of learning would be particularly difficult to teach effectively using a traditional classroom approach. Presumably, training would be much more effective in an environment where stress conditions are heightened. Such affectively intense environments are very difficult to recreate and control in a systematic manner without virtual reality technologies. Virtual Reality engines can be used to construct affectively intense scenarios to help train and understand the underlying parameters that influence learning in such environments. Computer gamers would readily agree that 3D visualizations that are integral to most of today’s first person shooter genre of games can impart a feeling of intense emotion. And psychologists have often cited the important relationship between the emotional context for learning and subsequent execution of the task

Some support for the hypothesized relationship between affective intensity in training and performance is provided by the “mood congruence” and “state-dependent learning” effects. Mood congruence refers to the aspect of human memory where persons are more likely to remember facts that coincide with their mood. In other words, if the person were in a good mood, then she would be more likely to remember pleasant information (Eich & Macaulay, 2000). The same pertains to unpleasant information. If the person is in a bad mood, then she will be more likely to remember unpleasant information. A similar phenomenon called State-dependent learning refers to the phenomenon in which people recall information easier if they can return to the same emotional and physical state when they learned the information. A basic contention of the present research is that this phenomenon can be extended to include affectively intense situations - the research addressed the effects of high affect training environments and subsequent performance in a corresponding high affect real world environment. Would subjects trained in an affectively intense environment display better performance compared to those trained in a control environment, where affective intensity was lower, while other factors remained the same?

1.6. VIRTUAL REALITY AND PRESENCE

A common and widely cited outcome measure of virtual reality is “presence”. The term presence has been given a variety of definitions in relation to its use with virtual reality and is in constant evolution as research in the field progresses. One definition that has been widely accepted is:

“Presence is a psychological state or subjective perception in which even though part or all of an individual’s current experience is generated by and/or filtered through human made technology, part or all of the individual’s perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at some level and to some degree, her/his perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience.” (Witmer & Singer, 1998)

Simply put, this means the degree to which a user of a virtual environment feels that the experience is **not** mediated by any technological interface. Presence is believed to be a subjective perception and is generally measure by survey instruments. A questionnaire developed by Slater – the Presence Questionnaire (Slater & Steed, 2000), which consists of 5 items, has been used extensively in research as a measure of presence, and will serve as the presence measure in the present research.

Although there is a lack of empirical data to support the positive effect of virtual reality on learning, as discussed above, there are quite a few studies that have found a relationship between VR components and presence. For example, in a study conducted by Mania and Chalmers on the effect of learning botany in immersive environments as compared to live and desktop systems, the users of the immersive environments experienced increased presence but not significantly increased rates of learning (Mania & Chalmers, 2001). In addition, a number of factors have been identified that seem to increase presence, such as vividness and interactivity. For example, the CAVE leads to a higher degree of presence, as compared to traditional desktop virtual reality (Cruz-Neira, Sandin, & Defanti, 1993). In addition, increased visual detail and realism, high refresh rates, stereoscopic sound effects, naturalistic interaction and collaboration are factors that contribute to a rich virtual reality experience with high degrees of presence (Axelsson,

Abelin, Heldal, Schroeder, & Widestrom, 2000; Schuemie, Vanderstratten, Krijn, & Vandermast, 2001; Welch, Blackmon, Lie, Mellers, & Start, 1996).

Presence has also been related to an individual difference measure in the form of “immersive tendencies” (Witmer & Singer, 1998). Witmer and Singer’s immersive tendency measure consists of 3 sub scales - Involvement, Focus, and Games - and have been found to be significantly related to presence (Witmer & Singer, 1998). Involvement denotes the tendency to become involved in activities. Focus is the sub scale that represents the tendency to maintain focus on current activities. Sub scale Games is the sub scale that relates to the tendency to play video games.

Although presence is traditionally assessed via self report, researchers have also explored physiological measures of autonomic nervous system responses with respect to presence. For example, Meehan and Insko propose that a virtual environment can be viewed as “realistic” if it evokes a physiological response, which is, comparable to that evoked in the real world for a real life experience (Meehan, Insko, Whitton, & Brooks, 2002). They conducted an experiment with consisted of 2 rooms in which a user is supposed to pick up books and deposit them in a particular location in the other room, which is at a virtual 20 feet drop. The environment is thus created to evoke a reaction of fear in the user. Presence, heart rate change and skin conductance change were measured during the experiment. The study concluded that multiple exposures to the environment reduced the presence score. The use of passive haptics (in this case, a ledge where the toes cannot touch the floor below to simulate the feeling of being on the edge of the room) tended to increase the presence score. Presence was measured by the use of the questionnaire developed by Slater (Usoh, Catena, Arman, & Slater, 2000). The study found a positive correlation between the presence score and the change in skin conductance among other autonomic nervous system measures (Meehan et al., 2002).

1.7. PILOT EXPERIMENT: VIRTUAL TERRORIST ATTACK ON THE COMPUTER SCIENCE BUILDING

For our research on affectively intense learning, a research model and methodology was developed to systematically examine factors that will lead to effective, affectively intense learning. The main goal was to examine what leads to most effective learning in affectively intense environments. This model is based on using a first

responder scenario for training and testing. The research methodology model was tested in a pilot study that comprised of 5 subjects (Hall et al., 2004).

1.7.1. Preliminary Research Model. This pilot research was based on a model, which posits four important classes of variables as influencing the virtual reality and learning outcome relationship: learner variables, virtual environment factors, perception of presence, and affective intensity (Figure 1.1).

This pilot research was based on a model, which posits four important classes of variables as influencing the virtual reality and learning outcome relationship: learner variables, virtual environment factors, perception of presence, and affective intensity (Figure 1.1). A basic assumption of the model is that the learner's perception of presence will grow in importance, in terms of learning, with the degree of affective intensity. The research also takes into account the mood state dependence of memory. That is, training in an affectively intense environment would yield better performance in the real world which is affectively intense as compared to training in an affectively neutral environment.

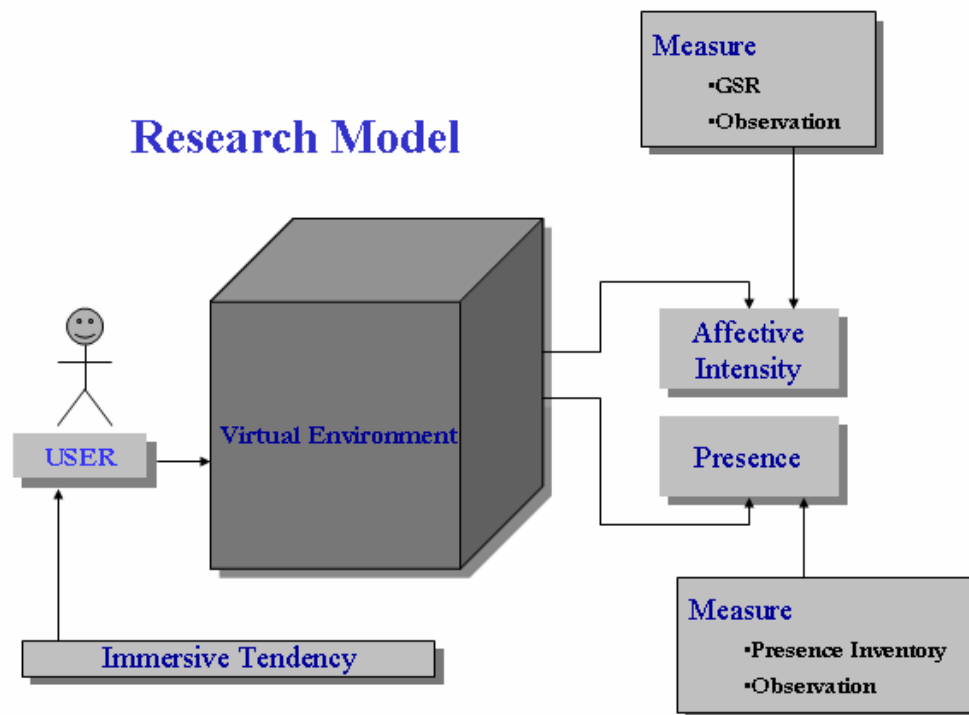


Figure 1.0. Preliminary Research Model

An experimental environment was developed, based on a virtual model of the University of Missouri – Rolla’s Computer science building, adding special affectively intense effects that might be associated with a terrorist attack. The environment was meant to serve as the foundation environment for a research program on affectively intense learning.

The environment was a “modification (mod)” created using the game engine *Half-Life*© in accordance with their licensing agreement. The environment consists of a 3 floor building, which includes classrooms, offices, computer labs with appropriate furniture and textures to match the actual computer science building at the University of Missouri – Rolla. Affectively intense effects were added such as random fires and explosions which would be triggered in the general vicinity of the avatar controlled by the user. The building included fire extinguishers located at each end of the floor. The objective of the user was to locate the fire extinguishers and put out the fires and trigger fire alarms located around the building. There was limited foam in the fire extinguishers and the user would “die” if he/she stood close to the fire for too long. “Death” was signified by a 30 second idle time when the user’s control over the avatar was immobilized. Another feature was that the lights in the various rooms could be toggled between on and off.

This environment had the potential to be affectively intense with random fires explosions and the capability of posing “danger” to the user and constraints on the equipment used to combat the situation. The *Half-Life*© game engine allowed for easy modification of the virtual reality components.

1.7.2. Pilot Research Goals. In order to evaluate the research methodology and tools, an exploratory experiment was carried out with 5 participants. The main goals of the experiment were: a) to determine the measures of perceived affective intensity corresponding to the affectively intense events in the environment, through quantitative comparisons of GSR response. b) to determine the degree of presence experienced in the environment through survey tools, qualitative observation and participants’ self report; and c) to identify methodological problems and/or other issues involving the efficacy of the research environment, via collection of qualitative data.

1.7.3. Pilot Research Method. Five participants were presented with a scenario where they were to assume the role of a first responder, which for the experiment was a fire fighter. Their task was to check all the rooms in the virtual computer science building and put out any fires during the course of their inspection of the building. Galvanic skin response was recorded as they completed their task and a “think aloud” procedure was used to elicit any comments from the participant during the test session, which lasted 10 minutes. Following their experience, a presence questionnaire was administered to determine the degree of presence experienced in the environment. A post test interview was conducted in order to obtain insight into the users’ thoughts and opinions on the virtual environment and testing procedure.

1.7.4. Pilot Test Results. The study showed that there was a marked increase in the GSR readings associated with explosions in comparison to periods when explosions were not occurring. There was also increased GSR activity due to frustration caused by inhibited locomotion and lack of lighting after it was turned off by a user in the virtual environment. Most participants stated that they recognized rooms where they had classes; one student found the environment so realistic that he was reluctant to put out the fires because “I never much liked the computer science building anyway”. One subject who had experience with computer games found the controls counter intuitive since all the controls were on the 5 button mouse (Hall et al., 2004).

1.7.5. Pilot Study Conclusions. The quantitative analysis of GSR levels indicated that arousal levels were dramatically higher following affectively intense events (explosions) in the environment as compared to the rest of the time participants were in the environment. There was a reasonably high level of presence detected in the participants with regard to the virtual environment. There was a methodology related issue with respect to the use of the task performed in the virtual environment as a measure of learning. There was a need for a criterion measure that was independent of the virtual environment. We developed such a measure for the present experiment.

1.8. THESIS EXPERIMENT

1.8.1. Overview. The present research followed similar methodologies and extended the pilot study in various ways. Some of the fundamental differences were: a) The training environment was experimentally manipulated and participants randomly

assigned to one of two conditions (affectively intense vs. affectively neutral); b) five times more subjects participated; c) A performance/testing component was added where users were tested in a non-virtual environment (i.e., the “real” computer science building); d) Participants used a head mounted display; e) The task to be performed in the virtual environment was more clear-cut and result oriented.

The research focused on finding the factors that influenced affective intense learning (Figure 1.1).

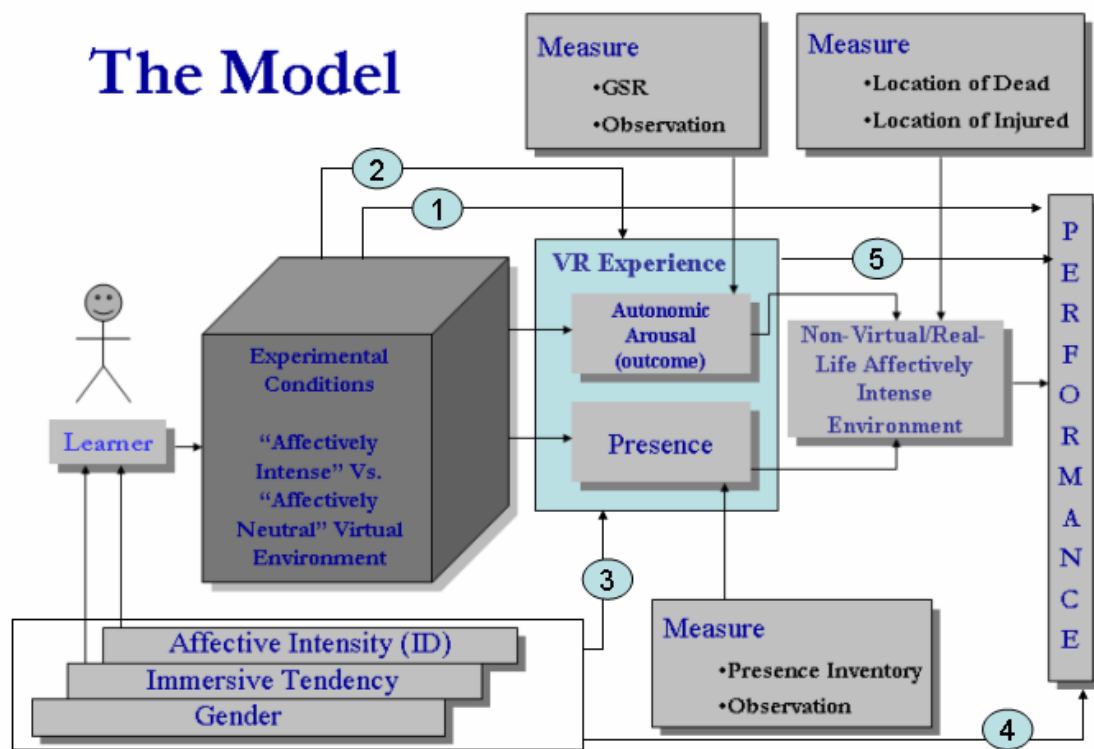


Figure 1.1. Research Model for Current Research

1.8.2. Experimental Questions. This research addressed eleven experimental questions representing five categories as follows:

1.8.2.1 Learning Outcomes as a function of experimental condition

Do learning outcomes (location of dead and location of injured correctly identified) differ as a function of experimental condition (affectively intense vs. affectively neutral)?

1.8.2.2 VR Experience as a Function of Experimental Condition

Does autonomic arousal, as measured by GSR, differ as a function of experimental condition?

Does presence, as measured by the presence inventory, differ as a function of experimental condition?

1.8.2.3 Relationship between individual differences and VR experience

What is the relationship between affective intensity (as id measure) and measures of VR experience (GSR and presence)?

What is the relationship between immersive tendency and measures of VR experience?

What is the relationship between gender and measures of VR experience?

1.8.2.4 Relationship between individual differences and learning outcomes

What is the relationship between affective intensity (as id measure) and learning outcome measures?

What is the relationship between immersive tendency and learning outcome measures?

What is the relationship between gender and learning outcome measures?

1.8.2.5 Relationship between VR experience and learning outcomes

What is the relationship between autonomic arousal and learning outcomes?

What is the relationship between presence and learning outcomes?

2. METHOD

2.1. PARTICIPANTS

The participants were 30 subjects selected from the University of Missouri – Rolla mostly recruited from an undergraduate class in Web Development and Design, rewarded by extra credit. Twenty two participants completed the entire experiment. Five participants did not complete the experiment due to equipment failure and three participants did not complete due to VR sickness.

2.2. MATERIALS AND EQUIPMENT

2.2.1. Measures (Questionnaire items are included in Appendix A & B).

Individual Difference measures included Affective Intensity and Immersive Tendency (gender was also recorded). The virtual reality experience measures included galvanic skin response (GSR) and the Presence Questionnaire. The learning outcomes metric was based on the dead correct count and the injured correct count after the participant had completed the inspection of the actual computer science building at the University of Missouri – Rolla (see procedure). Following is a discussion of each measure in more detail.

Immersive Tendency (Witmer & Singer, 1998): Immersive tendency is the psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences. The general capability or tendency of individuals to be immersed in the environments is measured by the 29 item immersive tendency questionnaire. The scale consists of three subscales: Involvement, Games and Focus. Subscale Involvement deals with the tendency to be involved in activities and it consists of 7 items. Subscale Focus consists of 7 items and deals with the tendency to maintain focus on current activities. Subscale Games determines the tendency to play video games and the degree of involvement in them.

Affective Intensity (Larsen & Diener, 1987): Affect Intensity is defined as the stable individual differences in the strength with which individuals experience their emotions. Affect Intensity is generally measured using the 40 item Affect Intensity

Measure as developed by Larsen & Diener (1987). A 20 item version of the Affect Intensity questionnaire developed by Geuens and Pelsmacker was used (Geuens & P., 2002) in the present research.

Skin Conductance (Galvanic Skin Response, GSR): The skin conductance is one of the fastest responding measures of stress response and has been found to be one of the most robust and non-invasive physiological measures of autonomic nervous system activity (Helander, 1978). In this experiment it was measured by means of a *Biopac*[®] device, which has been calibrated to detect change in the galvanic skin response. Two electrodes were strapped by means of Velcro to two fingers on the participant's non-dominant hand, the fore finger and the middle finger to which conducting gel was applied. The gel was applied to improve conduction and the GSR change output was displayed on the Biopac software by means of a continuous graph. The software can be manipulated to calibrate the gain, the amplification and other factors like filters to the input signal obtained.

A baseline GSR was established for each participant before they entered the virtual environment. During the Virtual Reality experience readings were taken for the duration of 12 minutes for the experiment at 200 samples a second. For the purpose of analysis, the output was divided into quarters. The data points used in the analyses consisted of the change in GSR for each quarter (Δ GSR). This was the mean GSR for that period minus the mean GSR baseline.

Presence (Slater & Steed, 2000): Presence, as discussed previously, is the degree to which a participant feels that a virtual environment is not mediated by any technological interface. A five item questionnaire, developed by Slater and colleagues, was used in this experiment.

Dead/Injured Count Correct: This represented the number of rooms in the "real/non-virtual" computer science building that were correctly identified by the participant during testing as containing a "dead" or "injured" person in the virtual environment.

2.2.2. Virtual Environment

2.2.2.1 Acclimation Environment. Acclimation Environment consists of 2 virtual rooms built using the *Half-Life*© game engine, a modification in accordance with their licensing agreement. The two rooms are connected to each other. The participant starts out in one room which is equipped with a fire extinguisher. The second room has a fire burning in it. The objective of the participant in the acclimation environment is to get familiar with the controls. Basic navigation, moving through doors, fighting fires, triggering alarms are some of the functions that are required to be performed. The simulation ends when the participant is sufficiently familiar with the controls.

2.2.2.2 Training Environments. Two versions of a virtual reality environment were used in this experiment, affectively intense and affectively neutral. Both environments were virtual simulations of the computer science building at the University of Missouri – Rolla, built using the *Half Life*© game engine. Again, these were modifications in accordance with the licensing agreements. The affectively intense environment was interspersed with explosions and fires that occurred at random around the avatar controlled by the user. The time of the explosions was based on a random number generated such that explosions occurred within 0 to 25 seconds of one another. There were also bodies of dead and injured people located in the virtual computer science building. The locations of the bodies were generated at random to spawn at 18 locations throughout the building. During the course of the simulation, at any point of time there would be 9 injured and 9 dead bodies in the virtual simulation. The affectively neutral environment lacked the fires and explosions with all other parameters maintained the same.

2.2.3. Equipment. The bulk of the experiment was conducted in the Laboratory for Information Technology Evaluation (LITE) at the University of Missouri – Rolla. LITE is especially equipped to support Usability testing. The lab schematic is shown in the Figure 2.0.

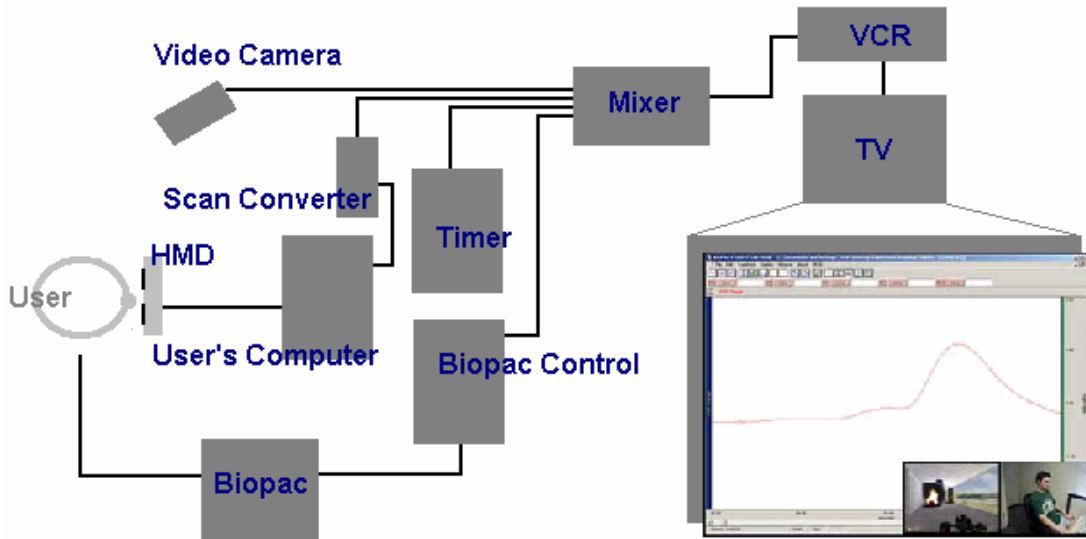


Figure 2.0. LITE Usability Lab Schematic

The various inputs from the video channels like the Head mounted display, the graphical representation of GSR change on the Biopac control computer, the camcorder output, and the auditory effects are mixed by the mixer which is output to the VCR for recording purposes and displayed on a television for the tester in the experiment room.

Hardware used for the experiment:

Virtual Reality Host computer – Pentium 4 2.8 GHz, 512Mb RAM, 19” Display, GeForce 4 MX440 with 128MB.

Immersive Head-mounted display (i-glasses SVGA-3D, <http://www.i-glassesstore.com/>).

Biopac© (<http://www.biopac.com/>). This is a device designed to measure various nervous system parameters.

Computer to display Biopac output graph – Pentium 3 1.0 GHz, 384Mb RAM.

Dazzle (Pinnacle Systems, <http://www.pinnaclesys.com/>) PCI card (video format converter and digital video recorder)

Computer to convert Biopac graphical output to S-Video hosting *Dazzle* – Pentium 3 533Mhz, 256 Ram

Camcorder (Panasonic, MiniDV Palmcorder).

Videonix© video mixer (FOCUS Enhancements, Inc.,
<http://www.focusinfo.com/>) (4 video and 4 audio input mixer)
VCR, TV and videotapes.

2.3. PROCEDURE

The participants were briefed on the rationale behind the test and the basic testing procedure and presented with a consent form. It was made clear to participants that the experiment may be uncomfortable for people who have a past history of motion sickness. It was specifically emphasized that the participant can withdraw at any point of time for whatever reason. An informal interview was then carried out, to ascertain general information on the individual gaming backgrounds, their gaming interests, gaming experience, virtual reality experience, and any relevant history of motion or VR sickness. Subsequently the Biopac electrodes were strapped on to the participant's fingers. Baseline GSR measurement was taken while the participant completed the Immersive Tendency and Affect Intensity questionnaires.

On conclusion of the questionnaires, the baseline was ended and the graphical output was saved to a file using the Biopac data analysis software package. The participants were then presented with instructions on how to operate in the virtual environment (Appendix C). The head mounted display was adjusted into place on the participant and the acclimation VR environment was started up. The participants were encouraged to navigate in the virtual environment using the 5 button mouse and perform the steps to complete the acclimation process. The steps involved were:

- Practice moving in the environment
- Locate the Fire extinguisher
- Enter the other room by opening the door
- Locate a fire
- Locate fire alarm
- Set off the fire alarm
- Return to initial room and pick up the fire extinguisher
- Put out the fire.

On successful completion of the acclimation environment, the participant was asked to assume the role of first responder fire fighter and presented with a scenario and task directions (Appendix E). Prior to the virtual reality simulation the participant was asked to “think aloud” while carrying out their tasks. This technique is used to gain insight into the thoughts and immediate goals and perspective of the participant (Nielsen, Clemmensen, & Yssing, 2002). Participants were randomly assigned to either the affectively intense or affectively neutral environments with the constraints that: a) An effort was made to counter-balance the order as much as possible; and b) An effort was made to have an equivalent number of participants in the two groups. GSR measurement was started and the video of the session recorded.

The participant was required to enter the virtual computer science building and complete an inspection to try and locate the dead and injured personnel in the building. The inspection was to be conducted while the participant defused situations occurring around her such as fires and explosions (note that the explosions only occurred for those in the affectively intense group). The virtual reality session lasted 12 minutes and the video of the session, used for observational analysis, consisted of 3 separate videos merged into one via the mixer – facial expressions of the participant with the head mounted display, continuous graphical GSR readings and the virtual reality simulation of the computer science building.

Towards the end of the session at 20 seconds left for completion, the participant was given instructions to exit the virtual building. The simulation ended at 12 minutes, and recording of GSR and video were stopped. The participant then completed the presence questionnaire. On completion, an informal interview was conducted to ascertain the state of the participant, the impact of the virtual environment and what possible improvements could be made to it.

The next phase of the experiment was conducted at the actual computer science building at the University of Missouri – Rolla, which is located approximately 200 yards from the LITE laboratory. The participant was given a CD player with headphones, which played tracks that correspond to random explosions recorded from the affectively intense VR session. This was used to recreate as closely as possible an affectively intense environment in the real world with as little inconvenience to other users of the building.

The participant was given 12 minutes to locate the rooms where they found dead/injured personnel to the best of their memory and asked to record this on a piece of paper. At the end of 12 minutes in the affectively intense environment afforded by the explosions on the headphones of the CD player, the participant returned to the tester with the sheet of paper containing data relating to room numbers and the type of body in the room – “dead” or “injured”. That concluded the experiment. The tester compared the data on the sheet to a file generated by the *Half-Life*© mod (modification). The generated file corresponding to the participants VR experience gave the actual room numbers and what they contained. A comparison yielded the Correct Dead Count and Correct Injured Count metrics which served as the learning outcome measures for the experiment.

2.4. TIMELINE

Table 2.0 details the time spent for the activities involved in the experiment.

Table 2.0. Experiment Timeline

Time(Minutes)	Task
0-10	Briefing, Consent Form, Informal Interview
10-20	GSR Baseline, Immersive Tendency Questionnaire, Short Affect Intensity Questionnaire
20-25	VR Instructions
25-30	VR acclimation environment
30-40	VR scenario and Instructions
40-57	VR test environment of computer science building, GSR measurement, Video Recording
57-60	Stop Recording, Removal of electrodes
60-65	Presence questionnaire
65-70	Debriefing, Informal post interview
70-82	Inspection of computer science building

3. RESULTS

3.1. QUANTITATIVE RESULTS

3.1.1. Learning Outcomes as a Function of Experimental Condition. In order to compare the effect of experimental condition, affectively intense vs. affectively neutral, on the learning outcome measure of Dead Count Correct, a Univariate Analysis of Variance was computed with experimental condition (affectively intense vs. affectively neutral) as the independent variable and dead correct count as the dependent variable. The analysis of variance was not statistically significant.

In order to compare the effects of experimental condition on Injured Count Correct, a Univariate Analysis of Variance was computed with experimental condition as the independent variable and the injured correct as the dependent variable.

This Analysis of Variance was marginally significant $F(1, 20) = 3.178, p = .09, eta^2 = 0.137$. Note that an eta^2 of .137 is a medium to large effect size based on Cohen's criteria (Cohen, 1969). The descriptive statistics associated with these analyses are displayed in Table 3.0

Table 3.0. Mean Learning Outcomes as a Function of Experimental Group

	Affectively Intense	Affectively Neutral	Significance
Dead Correct	2.250(0.462)	3.100(0.506)	Not significant
Injured Correct	3.250(0.397)	2.200(0.435)	$p = .09, eta^2 = .137$

(Standard deviation in parentheses)

3.1.2. VR Experience as a Function of Experimental Condition

3.1.2.1 GSR. The effect of experimental condition was studied with respect to the GSR response. The GSR response (Δ GSR) refers to the difference between the mean skin conductance levels for all quarters of the virtual reality simulation (4 minutes per quarter) and the baseline skin conductance levels. A two-way mixed analysis of variance was conducted with group (intense vs. neutral) as a between-subjects independent

variable and quarter (first vs. second. vs. third vs. fourth) as a within-subject independent variable and Δ GSR as the dependent variable. No effects were found to be statistically significant. The descriptive statistics associated with this analysis are displayed in Table 3.1.

Table 3.1. Δ GSR as a Function of Experimental Condition and Quarter

	Quarter			
	1	2	3	4
Affectively Intense	-.049(.032)	-.021(.027)	.016(.022)	.009(.026)
Affectively Neutral	.001(.035)	-.010(.030)	.004(.024)	.011(.028)

(Standard deviation in parentheses)

3.1.2.2 Presence. In order to compare the effect of experimental condition on presence, a Univariate Analysis of Variance was computed with experimental condition (affect vs. not) as the independent variable and the Presence scale score as the dependent variable. The results were not statistically significant. The means for intense group in terms of Presence score was $M = 4.736$ ($SD = .437$), while the mean for the neutral group was $M = 4.660$ ($SD = .478$), which is based on the mean of a series of questions scored on a 7 point Likert scale used in the Presence Questionnaire.

3.1.3. Relationship between individual differences and VR experience

3.1.3.1 Affective Intensity. In order to determine the degree of relationship between the individual difference measures of Affect Intensity with the outcome measure Presence and GSR, two Pearson's correlations were calculated, affective intensity with Δ GSR and affective intensity with presence. These correlations were $r = .257$ and $r = -.116$ respectively, neither was statistically significant.

3.1.3.2 Immersive Tendency. In order to determine the degree of relationship between Immersive Tendency and the VR Experience parameter presence, Pearson's correlations were calculated pairing each of the Immersive Tendency sub scale scores with Presence. These correlations and statistical significance are displayed in Table 3.2.

Table 3.2. Pearson Correlations between Immersive Tendency and Presence

	<i>r</i>
Involvement	.34 ⁺
Focus	.329 ⁺
Games	.54 ^{*++}

* $p < .05$; ⁺ medium to large effect size; ⁺⁺ large effect size

3.1.3.3 GSR. In order to determine the degree of relationship between individual measures of Immersive Tendency and the VR Experience parameter GSR, Pearson's Correlations were calculated pairing each of the Immersive Tendency sub scale scores with Δ GSR. These correlations were not found to be statistically significant and are displayed in Table 3.3.

Table 3.3. Pearson Correlations between Immersive Tendency and Δ GSR

	<i>r</i>
Involvement	.144
Focus	-.038
Games	-.027

3.1.3.4 Gender. In order to compare the effect of gender on the virtual reality experience measure Presence, a Univariate Analysis of Variance was computed with gender (male vs. female) as the independent variable and Presence as the dependent variable. This Analysis of Variance was marginally significant $F(1, 20) = 3.507$, $p = .076$, $\eta^2 = 0.149$ (effect size medium-large). The mean computed for males ($M = 5.082$, $SD = .360$) was greater than the means for females ($M = 3.886$, $SD = .528$) with respect to Presence scores.

In order to compare the effects of gender on the virtual reality experience measure of GSR, a univariate Analysis of Variance was computed with gender as the independent

variable and Δ GSR as the dependent variable. This analysis was not statistically significant. The descriptive statistics for this comparison were as follows: males: $M = -.008$, $SD = .018$; females: $M = -.001$, $SD = .027$.

3.1.4. Relationship between Individual Differences and Learning Outcomes

3.1.4.1 Immersive Tendency. In order to assess the degree of relationship between immersive tendency and learning outcomes a series of Pearson correlations were computed pairing each of the three immersive tendency subscales with both dead correct and injured correct. The results of these analyses are displayed in Table 3.4.

Table 3.4. Correlations of immersive tendency subscales and affective tendency with learning outcomes

Scale	Learning Outcome	
	Dead Correct	Injured Correct
Immersive tendency: involvement	.14	.18
Immersive tendency: focus	-.02	-.57** ⁺⁺
Immersive tendency: games	.55** ⁺⁺	.10
Affective intensity (ID)	-.37 ^{(*)+}	-.37 ^{(*)+}

^(*) $p < .10$; ^{**} $p < .01$; ⁺medium to large effect size; ⁺⁺large effect size

3.1.4.2 Affective Intensity. In order to assess the degree of relationship between the individual difference affective intensity and learning, two Pearson correlations were computed, pairing affective intensity scores with dead correct and with injured correct. These correlations for both dead correct and injured correct were: $r = -.37$, $p = .09$ (effect size = medium to large).

3.1.4.3 Gender. In order to assess the impact of gender on learning outcomes two one-way analyses of variance were computed. In each, gender (male vs. female) was the independent variable and in one dead correct was the dependent variable and in the other injured correct was the dependent variable. The first ANOVA, in which dead correct was the dependent variable, was not statistically significant. However, the second

ANOVA was statistically significant $F(1, 20) = 7.11, p < .05, \eta^2 = .26$. Descriptive statistics associated with these two analyses are displayed in table 3.5.

Table 3.5. Mean Learning Outcomes as a function of Gender

Outcome	Gender	
	Male	Female
Dead Correct	2.73(1.79)	2.43(1.27)
Injured Correct* ⁺⁺	3.27(1.39)	1.71(.95)

(Standard deviation in parentheses)

* $p < .05$; ⁺⁺large effect size

3.1.5. Relationship between VR experience and learning outcomes

3.1.5.1 Presence. In order to determine the degree of relationship between presence and learning outcomes, two Pearson's correlations were computed pairing Presence with Dead Correct and Presence with Injured Correct. These correlations were $r = -.034$ and $r = .024$ respectively. Neither was statistically significant.

3.1.5.2 GSR. In order to determine the degree of relationship between GSR and learning outcomes, two Pearson's correlations were computed: Δ GSR with Dead Correct and Δ GSR with Injured Correct. The correlations were $r = -.338$ (effect size medium to large) and $r = -.215$ respectively, neither of which was statistically significant.

3.2. QUALITATIVE RESULTS

The qualitative data consisted of notes that were compiled based on a pre-experimental interview, observation of the participant during the experiment and video recordings of the experiment and post-experimental interviews.

Different types of information emerged from each of these three sources, so the qualitative results are organized according these overarching themes. Three themes emerged from the observations. They were User Performance, Measurement Tools and Methodology. The sub themes are described in the figure 3.0.

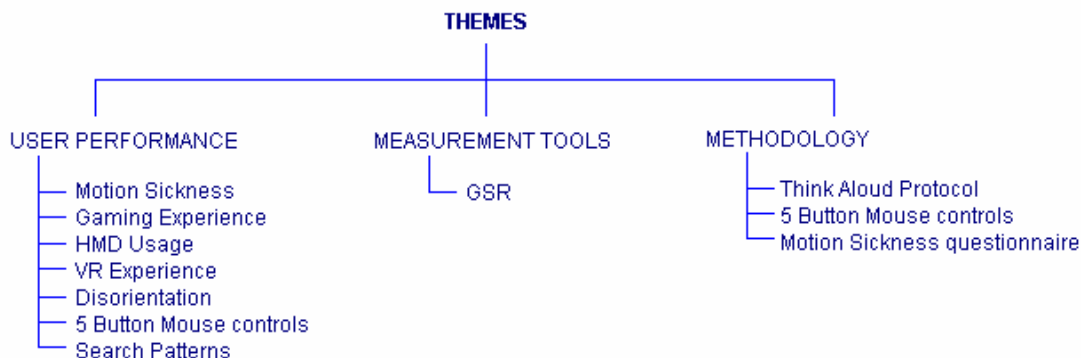


Figure 3.0. Themes

3.2.1. User Performance. This section deals with qualitative data associated with factors affecting user performance in the virtual environment.

Little Evidence of Past Motion Sickness in Participants. Most subjects responded negatively when asked if they had a past history of motion sickness. One female participant complained of experiencing motion sickness on drives but completed the experiment without a hitch.

Most participants experienced some degree of discomfort after 12 minutes with the head mounted display. Most of the participants stated that they experienced momentary discomfort after 12 minutes of immersion in the virtual reality environment using the head mounted display.

Equal distribution of participants who had experience with first person games. There were an even proportion of gamers who had experience with the first person genre of games, which was quite similar to the virtual environment that was used in the experiments vs. those who had not had experience with these games.

Little experience with head mounted displays. Most of the participants had not used head mounted displays prior to the experiment and expressed curiosity in terms of its functioning.

VR task was relative easy for all participants with one exception. Analysis of the video recordings of the participants showed that all of the participants were successful in

reaching the objectives save one female participant who had difficulty with orientation. The objectives were successfully locating the dead and injured personnel in the buildings and countering fires during the process (countering fires is only applicable to the affectively intense virtual environment). One comment made by the participant was “I’m confused as to what I’m looking at – is it the ceiling or the floor.” She had no prior experience with computer games or virtual reality based simulations and fell in the 40-50 age-group.

Disorientation most common on first and third floor of computer science building. Most of the participants who were familiar with the layout of the computer science building at the University of Missouri – Rolla, stated that they got a little disoriented when they visited the first floor since it was normally off limits to students. This section of the building comprised mostly of the server room and assorted offices. There was some disorientation experienced on the third floor of the virtual computer science building. Most participants followed a general path but on the third floor, the participants would sometimes trace back their steps after getting in and out of rooms. Most moved to the end of the corridor to get a better grasp of their current location. The decrease in sense of direction at that point could possibly be due to the large number of doors quite close to each other leading to various student offices on the floor. The second floor of the building was noted as the floor where the participants navigated most confidently. This could be attributed to the fact that the floor held most of the class rooms.

Engaging virtual Environment. Most participants moved their heads during the experiment due to the increased immersion afforded by the head mounted display. Participants tended to move their heads in an attempt to look in the direction where they intended to move their virtual avatars. At 20 seconds to the close of the virtual experience, participants were given voice instructions to exit the building, to which they snapped their heads level to the source of instruction. The instruction was delivered by the tester. This showed a high degree of involvement in the virtual environment due to the use of the head mounted display.

Most participants followed the same search pattern in the “real” computer science building test as they did in their training. The majority of the participants

followed the same search pattern in the Real Life “Affectively Intense” computer science building as they did in the virtual training environment.

Most participants used a systematic search pattern, fighting fires as they searched. Most participants followed a general search pattern, going from floor to floor looking for the dead and injured, fighting fires if necessary along the way.

Alternate search pattern learned better. Participants, who performed best in learning, used an alternative search pattern, locating dead and injured first, and fighting fires after. Two participants followed a slightly different technique, find the dead and injured first and fight fires last. These two participants had the highest cumulative correct count in the “Affectively Intense Group”.

Focus on the injured personnel. There was a general trend among the participants to focus on finding injured personnel instead of both types “dead” and “injured”. This was particularly true for the males. One participant stated “I didn’t bother looking for the dead”. This is augmented by the fact there were two participants who never even attempted to look for the dead. They made a 0 score for Dead Correct Count in the real computer science building testing.

Many participants noted the environment’s realism. Many participants commented on the realism of the computer science building in the experiment.

Participants noted realism would be enhanced with more objects. Participants also stated that it could be better if all rooms and offices contained more objects, or as one participant stated “the rooms could use a little more attitude”.

Participants had difficulty differentiating between dead and injured personnel. The participants tended to get the room numbers of the dead and injured personnel in the building incorrect at times because they did not correctly identify which were dead and which were injured. This could be due to the similarity in the model used to denote “dead” and “injured”. Both were represented by a model of a person in a white lab coat, lying down to signify “dead” and sitting on the ground to signify “injured”.

3.2.2. Measurement Tools. This section deals with the measurement tools employed in the experimental setup.

GSR readings peaked in response to frustration, video, and audio cues. GSR readings peaked from a variety of reasons including increased frustration, auditory cues such as explosions, and visual effects.

Auditory cues were most likely to result in GSR responses. It could be seen that auditory cues were the most significant cause for a peaks on the GSR curve, but few participants responded to visual stimuli more than expected.

For some users with game experience, darkness rather than auditory cues, increased GSR. Dark rooms or corridors tended to increase GSR activity in two subjects both of whom were proficient with games. Interestingly, auditory effects did not seem to have much effect on their GSR curve.

Frustration was a major cause of GSR activity, some of it due to usability issues with the game. Frustration also caused a lot of GSR activity. Doors open in both directions in the virtual simulation to allow for easier navigation; an opened door should close before the door can swing in another direction. And a door swinging to close would push the avatar away, coupled with narrow corridors tended to be frustrating. Most participants experienced increased levels of GSR activity when faced these types of situations.

3.2.3. Methodology. This section deals with some methodology related aspects in the experimental setup.

Minimal use of “think aloud” technique, particularly with males. The “think aloud” technique was emphasized at the onset of testing. But most participants got engrossed in the virtual environment that and forgot to convey their immediate goals or their emotions via the think aloud technique. There was greater response from females in the use of think aloud procedure than males. A female subject commented “hey, I had a class there last semester!”

Most “think aloud” comments related to previous experience with computer science building. Comments related to familiarity with the environment were quite numerous. One male participant commented “I have to turn in an assignment today by 3 and I found a body in the professor’s room”. One subject got so enthusiastic with the virtual environment layout that he went on to state “I had never seen the inside of the ladies restroom before”. Most “Think aloud” comments emanated from people who were

familiar with the computer science building, which formed the majority of the subjects tested.

The five button mouse was difficult to use, particular for those with first-person video game experience. Participants tended to be confused between buttons on the mouse during the course of the experiment. The left and right mouse buttons were used for forward and backward navigation respectively. This is contrary to the way most gamers use their mouse controls and the wrong key click tended to be used. This is evident from the video recording, when erratic backward movement was observed. Most participants who were familiar with computer games, especially the first person shooter genre, expressed dissatisfaction of not being able to use two hands (the less dominant hand was strapped to electrodes connected to the GSR recording device).

VR sickness measures. Measures such as questionnaires that determine the degree of VR sickness experienced during the VR training could have be employed.

4. DISCUSSION

4.1. LEARNING OUTCOMES AS A FUNCTION OF EXPERIMENTAL CONDITION

Those in the affectively intense condition did substantially better at finding the injured personnel in the virtual environment. The mean difference between conditions was marginally significant and the effect size medium to large. This provides some initial indication that the degree of affect in training is, in fact, related to performance within an affectively intense environment. The conditions did not significantly differ in finding dead personnel. This may be due to the fact that most participants did not pay close attention to finding the dead, as noted in the qualitative analysis. One participant commented “Why should I find the dead people, the injured are the ones I can help save...” In addition, as noted in the qualitative analysis, there wasn’t very much difference in the representations of the “dead” and “injured” in the virtual environment apart from their posture. Additional color effects like a bloody corpse to signify “dead” might have stood out more in the minds of the participants.

4.2. VR EXPERIENCE AS A FUNCTION OF EXPERIMENTAL CONDITION

Quantitative data analyses did not indicate a significant difference in the effects of experimental conditions on the GSR readings. One possible explanation for this non-significant finding was that the environments were immersive enough (with or without affectively intense cues). Most participants were quite engrossed in their tasks in the virtual environment. An observation to support this, noted in the qualitative analysis, was the head movement exhibited by the participants. It is quite probable that the environment may have been an intense experience for both the groups despite the explicit affective content for one of the groups resulting in even GSR readings among the groups.

With respect to the impact of experimental condition on presence, it was not found to be statistically significant. However, the mean values for the presence score in the “affectively intense” group were seen to be slightly higher than the “affectively neutral” group. Visual cues that indicate presence like moving in response to the virtual environment were observed to be mostly equal between the groups. The relatively even presence score across the experiment groups could be because, as noted above, the virtual

environment (intense and neutral) was quite engaging enough to afford high degrees of presence for both groups.

4.3. RELATIONSHIP BETWEEN INDIVIDUAL DIFFERENCES AND VR EXPERIENCE

4.3.1. Affective Intensity (ID). It was observed that the correlations between affective intensity and Δ GSR and between affect intensity and presence were not statistically significant. One possible explanation is that this individual difference measure may not have been designed to represent affective response within an engaging context such as this. Note that previous validation studies of this measure were done by relating scores to responses with stimuli such as affectively charged advertising (Moore & Homer, 2000). An examination of the items that make up the affect intensity scale (Appendix A) also indicates that this may not be an appropriate individual difference measure for this type of study, in that the focus is more on happiness and excitement in relation to daily activities, rather than affective response to a high stress life and death scenario. Though the construct's name "affect intensity" would seem appropriate for this research, it may be that the scale is not sensitive to environmental stress as represented in the first responder training environments. The correlation with presence was clearly minimal ($r = -.12$), which may also make sense; given that these results as a whole are indicative that presence and affective response (as indicated by GSR) are somewhat independent. However, with respect to the correlation between affect intensity and GSR, it's important to note the low statistical power provided by such a small sample size. Although the correlation between these two variables ($r = .26$) did not reach the level of Cohen's medium effect size (.30), this same size correlation would be statistically significant for a sample size of 60. (The sample size for this experiment was 22).

4.3.2. Immersive Tendency. There was no relationship indicated by the immersive tendency and Δ GSR correlation, but a strong relationship was established between immersive tendency, particularly game experience, and presence. The sub scale "Games" of the immersive tendency measure showed a very strong correlation with presence. Clearly, those who play games tend to experience presence to a greater degree in the virtual environments. It is interesting to note that the male with the highest presence score was an avid gamer. It's also important to note that we cannot be sure,

based on these findings, whether the experience of gaming “trains” one to better experience presence, or, if those who are more prone to experience presence, gravitate to game playing.

4.3.3. Gender. Males scored approximately 25% higher on presence scores. despite the fact that the sample size for females was very small (7) resulting in very low statistical power, the F score was still marginally significant ($p = .09$) and the effect size was medium to large. The difference was most likely due to the fact that most of the males had greater gaming interest and experience. Studies have shown that Immersive tendency has a positive correlation with presence (Witmer & Singer, 1998), and, in fact, a strong relationship between presence and immersive tendency, especially games, was found in this experiment, as noted above. To explore this explanation further, an additional adjunct analysis was conducted in the form of a Univariate analysis of variance with gender (male vs female) as the independent variable and the game portion of the immersive tendency questionnaire as the dependent variable. This analysis was marginally significant $F(1,20) = 4.22, p = .053 \eta^2 = .174$ (medium to large effect size). The mean for males ($M = 3.800$) was 84% percent higher than the means for females ($M = 2.071$).

4.4. RELATIONSHIP BETWEEN INDIVIDUAL DIFFERENCES AND LEARNING OUTCOMES

4.4.1. Immersive Tendency. Quantitative analysis of the experimental data show that Immersive tendency sub scale “Focus” is negatively correlated with Injured Correct Count while the sub scale “Games” is positively correlated with Dead Correct Count. Both of these correlations are very strong. This implies that the participants that are more focused have a lower tendency to find injured people than those that are less focused. One explanation for this could be that, the more focused people tend to get very much drawn in by the environment, and the basic task of locating the dead or injured people in the building eludes them. On the other hand, the people who play more computer games tend to find more dead people than others as indicated by the significant correlation between Dead Correct Count and immersive tendency sub scale “Games”. This may be possible because the objective of many first-person computer games is increasing the death count during the course of the game. Identifying people as dead

during the course of such games may be common place for a gamer lest the “dead” game based opponent should return to “kill” the computer player. In any case, it’s very interesting to note that these two subscales showed a high degree of discriminate validity, in that their predictions of similar variables were very different. Based on these results, it appears that different types of immersive tendency have very different effects on a learner’s ability to learn effectively in immersive environments. In one case the tendency to become immersed is very positive and in the latter case it is equally negative.

4.4.2. Affect Intensity (ID). Statistically it may be noted that the higher the affect intensity score, the lesser the probability of finding bodies or injured personnel in the virtual environment. Based on the nature of the affect intensity construct, those with high affect intensity scores tend to react highly emotionally. Taking that nature into consideration, the virtual simulation with the head mounted display might have provided an affective environment both physically and virtually in which the ability to respond to the experiment objectives were lessened. Most of their emotions would have been directed to the environment and to the unnatural or new experience of wearing a head mounted display that sufficient energies were devoted to accomplishing the task at hand. Given the similar results, it appears that affect intensity is related to the focus component of the immersive tendencies questionnaire.

4.4.3. Gender. There was virtually no difference between males and females on the location of dead bodies. However, the mean for males almost doubled the female mean ($M = 3.267$ vs. 1.174) for successful identification of the location of an injured persons. This is in accordance with the observations that males focused more on identifying the injured as noted in the qualitative analysis. This aim of saving the injured fueled the males to narrow their search and yielded better results compared to females who had a broader objective. It may be noted that the instructions to locate the dead and injured personnel in the building was common for both males and females.

4.5. RELATIONSHIP BETWEEN VR EXPERIENCE AND LEARNING OUTCOMES

4.5.1. Presence. Statistical data showed that the presence scores are largely unrelated to the learning outcomes of Dead Correct Count and Injured Correct Count. This could be because the environment may have afforded a high degree of presence due

to which the participants were caught up with the virtual experience that the assigned task in the virtual environment was sidelined. Sufficient attention to the task could not be devoted by the participants. It is possible that, had the environment not been as realistic, the participants would have been more focused on the task instead of the environment and there would have been a greater range in presence scores, resulting in better prediction.

4.5.2. GSR. The correlations between mean GSR and outcome measures also did not reach statistical significance. However, the strength of the correlation was substantially stronger than with presence, and in the case of dead correct, the effect size was medium to large. With greater statistical power, these correlations could well have been statistically significant. Also, interestingly, the correlation was negative, as GSR increased learning decreased. This might be explained if increased GSR was associated with a state of heightened emotion where the participants lose perspective of their objectives and performance drops. The better the participant is in control of his/her emotional state; the better would be the task performance.

4.6. ADDITIONAL INSIGHTS

The qualitative data assessed were categorized into 3 major themes User Performance, Measurement tools and Methodology. These themes encompassed various observations that were classified based on their impact on the various aspects of the experiment.

Motion sickness, VR and gaming experience, levels of disorientation, search patterns and observed levels of immersion in the environment were factors that contributed to user performance. Most of the sub themes had an influence in either increasing or decreasing the user performance. Increased motion sickness would only lead to poor performance in the virtual environment. Past gaming experience and VR familiarity tend to help the participants in focusing on the task at hand instead of being intimidated by the technological interface and the VR environment. Some of the participants found it difficult to distinguish between the dead and injured in the VR environment. This could arise from the use of a very similar human figure used to represent both, with the difference being their pose in the virtual environment. The representations could have been more contrasted by the addition of indicative colors like

red to signify blood for a body. Performance could also have been affected in the first and third floors due to reduced usability of the narrow hallways and doors. Familiarity of the actual building contributed to lesser disorientation. The understanding of these factors can help develop a better virtual environment and gives a better insight into how they affect the performance of the participant.

The arousal measurement tool which was GSR for the experiment did not function as expected due to its extreme sensitivity. A more reliable measure would be heart rate for such experiments. Another aspect that could be measured by means of a questionnaire is the degree of motion sickness experienced. This can be classified under the theme Methodology as well as a measurement tool.

Some methodological issues were uncovered during the course of the experiment. The “Think Aloud” protocol did not yield benefits as expected due to the fact that the participants found themselves too involved in the virtual environment that they forgot to give emphasis on feedback. The “think aloud” protocol may also be a hindrance to task execution in the environment. The usage of the 5 button mouse for control and navigation in the virtual environment was also noted to be counter intuitive under most circumstances. A majority of the participants had some experience with computer games and both hands are generally used for control and navigation. The normal multimodal usage of controls for the virtual environment had to be shifted to the mouse, since GSR sensor electrodes were attached to the non-dominant hand of the participant. This restricted movement on one hand and the other hand had to be used to control the avatar in the virtual environment by the specially configured mouse functions. It was noted that the wrong buttons were clicked during the experiment sometimes and a conscious effort was required to work the mouse. Most complaints came from gamers who had past experience in operating in similar virtual reality based games. Apart from that, sudden movements on the non-dominant hand due to cramps or fatigue results in an erratic GSR curve which induced error in the readings. It is concluded that a lesser obstructive mode of affect measurement such as heart rate would be more appropriate for the experiment.

5. CONCLUSION

There is evidence that the degree of affective intensity within a training virtual environment is, indeed, related to learning performance within a “real world” affectively intense environment. Though this was found to be true for only the Injured Correct Count as the learning outcome, it may be explained by the “reality factor” associated with it. Participants formed a very realistic and practical approach to finding the injured personnel over the dead. This goal very much translates into the real world in what is required of a learner from an affectively intense environment. For example, if fire fighters were trained in a virtual environment and they did not give precedence for an injured person as far as evacuation action or first aid is concerned, then the practical purpose of such simulations would be lost.

The affective intensity of the environment did not affect perceived presence or autonomic response, as measured by GSR. A few possible explanations: 1) The individual differences effected presence so much that they overwhelmed any effect for experimental condition; 2) Users in both the experimental conditions had a high level of presence; 3) Factors like frustration effected GSR so much that it overwhelmed the effects of explosions and other characteristics of the affectively intense environment; and 4) GSR turned out to be a less than optimal measure of autonomic arousal (to be described in more detail below).

Immersive tendency and gender had a substantially strong impact on presence. All of the immersive tendency measures, especially games, were strongly related to presence. In addition, males rated their degree of presence substantially higher than females. Adjunct analyses indicated that males tend to have a much greater preference for computer games than do females. This preference for video games, which is in fact quite similar to the virtual reality simulations, causes them to be more receptive to the virtual world. Computer games today are modeled quite closely to a perceivable world to make gaming as realistic an experience as possible. Most games try to increase the feeling of being there and having performed in that fantastic world. There is a general tendency of males to have a greater affinity for games, which can be noted from the increased

“Games” score.. This tendency was correlated with presence. Hence males, tend to exhibit increased presence over their female counterparts.

On the other hand, the affective intensity ID measure was not significantly related to either of these VR experience measures, and none of the individual difference measures were related to GSR. Possible reasons: The affective intensity measure may not have been appropriate for this type of experiment as discussed above. Variations in GSR could have been flawed or sometimes misleading due to various error inducing factors. External factors such as ambient humidity, temperature and other factors such as recent physical activity among others can change the physiology of the skin which in turn can change the GSR readings. GSR readings are taken by means of electrodes attached to the tips of two fingers; the equipment measuring it is extremely sensitive and erratic hand movements can cause sharp peaks. From a practical stand point, heart rate may be better measure of autonomic arousal, which will be noted for future research.

Some immersive tendency subscales strongly related to learning outcomes, though in somewhat unusual and sometimes unexpected ways. With immersive tendency, focus was very strongly negatively related to injured personnel located, while games was strongly positively related to dead correct. This brings out distinct dimensions of the tendency to be present. Focus deals with the ability to focus on the task at hand while sub scale “Games” refers to the tendency to be present within the context of video games. In both cases, the total score determines the tendency of one to be immersed. This can be explained if one were to assume that the group scoring high on “Focus” got extremely involved in the environment that the environment parameters such as visual detail, affective cues (only in the affectively intense virtual environment), navigation complexity were so overwhelming that the simulation objective eluded them or did not hold their required attention. Computer games today seem to emphasize increasing one’s kill count to win. Such games often require one to “kill” a lot of “bad guys” or “be killed”. Although avid gamers may have a tendency to become highly immerse, they would know how to distinguish a “dead person” so that he/she would not have to “waste ammunition on it” or “would know, ‘its going to stay dead and not come after me to kill me’”. Therefore it would follow that avid gamers or subjects who score high on the immersive tendency subscale “Games” would find more dead personnel in the virtual environment.

The individual difference, affective Intensity was fairly strongly and negatively related to both learning outcomes. This may also help to explain the negative “Focus” relation with learning outcomes, in that one can picture a person who tends to react in a very affectively intense manner and tends to be very focused on the reality of the environment and, as a consequence, is distracted from the learning task.

Males performed substantially better than females in what appeared to be the most important learning outcome (injured correct). Their mean is almost twice as high as the females. This is consistent with qualitative observations, where they adopted a practical objective to save the injured first and their general tendency to avoid locating the dead altogether.

Degree of presence perceived was largely unrelated to learning outcomes. This is consistent with previous studies (Mania & Chalmers, 2001; Moreno & Mayer, 2002), so it appears that this finding extends to affectively intense learning, based on this experiment.

Autonomic response was not significantly related to learning outcomes, though the correlations were much stronger than with presence and effect size for the correlation between GSR and dead correct is medium to large. So, there is some evidence that the affective intensity experienced in the VR environment, as represented by GSR, is more strongly related to performance in an affectively intense environment, than is presence. If there had been a large sample (more power) these correlations would very likely have been statistically significant.

There are a number of possible ways that these results could be extended in future research. First, work could include feed back of autonomic nervous system measures to the participant in the affectively intense virtual environment to try and get them to regulate or control their current emotional state and then determine the impact that such loop systems have on the learning process. Second, this can be further extended where the task such as fire fighting effectiveness is regulated by conscious regulation of one’s ANS measures through a process of affective biofeedback. Third, other measures to monitor autonomic nervous systems activity like heart rate can be used instead of GSR. Fourth, augmented reality systems can be used, with first responder gear to give a more enhanced feel for virtual reality based training.

APPENDIX A.
INDIVIDUAL DIFFERENCE MEASURE: AFFECT INTENSITY ITEMS

1. When I feel happy, it is a strong type of exuberance
 2. My happy moods are so strong that I feel like I'm in heaven
 3. If I complete a task I thought was impossible, I am ecstatic
 4. When I'm feeling well, it's easy for me to go from being in a good mood to being really joyful
 5. When I'm happy, I feel like I'm bursting with joy
 6. When I'm happy, I feel very energetic
 7. When things are going good, I feel "on top of the world"
 8. When I'm happy, I bubble over with energy
 9. Sad movies deeply touch me
 10. When I talk in front of a group for the first time, my voice gets shaky and my heart races
 11. When I do something wrong, I have strong feelings of shame and guilt
 12. When I do feel anxiety, it is normally very strong
 13. When I feel guilty, this emotion is quite strong
 14. When I am nervous, I get shaky all over
 15. When I'm happy, it's a feeling of being untroubled and content rather than being zestful and aroused*
 16. When I succeed at something, my reaction is calm and contentment *
 17. When I know I have done something very well, I feel relaxed and content rather than excited and elated *
 18. When I feel happiness, it is a quiet type of contentment *
 19. I would characterize my happy moods as closer to contentment than joy *
- When I am happy, the feeling is more like contentment and inner calm than one of exhilaration and excitement *

The participant responds to the questionnaire based on a 7 point agree-disagree Likert Scale.

* Reversed Scaled in scoring

APPENDIX B.
INDIVIDUAL DIFFERENCE MEASURE: IMMERSIVE TENDENCY ITEMS

1. Do you ever get extremely involved in projects that are assigned to you by your boss or your instructor, to the exclusion of other tasks?
2. How easily can you switch your attention from the task in which you are currently involved to a new task?
3. How frequently do you get emotionally involved (angry, sad, or happy) in the news stories that you read or hear?
4. How well do you feel today?
5. Do you easily become deeply involved in movies or TV dramas? ^F
6. Do you ever become so involved in a television program or book that people have problems getting your attention? ^I
7. How mentally alert do you feel at the present time? ^F
8. Do you ever become so involved in a movie that you are not aware of things happening around you? ^I
9. How frequently do you find yourself closely identifying with the characters in a story line? ^I
10. Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen? ^G
11. On average, how many books do you read for enjoyment in a month?
12. What kind of books do you read most frequently? **(CIRCLE ONE ITEM ONLY!)**
 - a. Spy novels
 - b. Fantasies
 - c. Science fiction
 - d. Adventure Historical novels
 - e. Romance novels
 - f. Westerns
 - g. Mysteries
 - h. Other fiction
 - i. Biographies
 - j. Autobiographies
 - k. Other non-fiction
13. How physically fit do you feel today? ^F
14. How good are you at blocking out external distractions when you are involved in something? ^F

15. When watching sports, do you ever become so involved in the game that you react as if you were one of the players?
 16. Do you ever become so involved in a daydream that you are not aware of things happening around you? ^I
 17. Do you ever have dreams that are so real that you feel disoriented when you awake? ^I
 18. When playing sports, do you become so involved in the game that you lose track of time? ^F
 19. Are you easily disturbed when working on a task?
 20. How well do you concentrate on enjoyable activities?
 21. How often do you play arcade or video games? (OFTEN should be taken to mean every day or every two days, on average.) ^G
 22. How well do you concentrate on disagreeable tasks?
 23. Have you ever gotten excited during a chase or fight scene on TV or in the movies? ^F
 24. To what extent have you dwelled on personal problems in the last 48 hours?
 25. Have you ever gotten scared by something happening on a TV show or in a movie? ^I
 26. Have you ever remained apprehensive or fearful long after watching a scary movie? ^I
 27. Do you ever avoid carnival or fairground rides because they are too scary?
 28. How frequently do you watch TV soap operas or docu-dramas?
- Do you ever become so involved in doing something that you lose all track of time? ^F

This questionnaire is based on a 7 point Likert scale

Note. Subscales: I = Tendency to become involved in activities (INVOLVEMENT), F = Tendency to maintain focus on current activities (FOCUS), G = Tendency to play video games (GAMES)

APPENDIX C.
HOW TO USE CONTROLS AND NAVIGATION IN THE ACCLIMATION
VIRTUAL ENVIRONMENT

The 5-Button Mouse is the only navigational tool to be used in the test environment.

Left Button: Moves the person in the VR environment forward

Right Button: Moves the person backward.

Shifting the mouse to the right, shifts the view on the screen to the right; likewise shifting to the left moves the view to the left.

If you move over a fire extinguisher, you will pick it up.

To turn on a light switches, or enable a door with an entry switch push the thumb button closest to you.

To spraying foam from the fire extinguisher, press the middle mouse button

Moving in front of doors that do not have an enabling switch, causes them to open.

APPENDIX D.
PRESENCE QUESTIONNAIRE

1. Please rate your sense of “being there” in the virtual environment, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place.

1 Not at all ... 4 Somewhat ... 7 Completely

2. To what extent were there times during the experience when the virtual room became the “reality” for you, and you almost forgot about the “real world” of the laboratory?

There were times during the experience when the virtual room became more real or present for me compared to the “real world”...

1 At no time ... 4 Sometimes ... 7 Almost all the time

3. When you think back about your experience, do you think of the virtual room more as images that you saw, or more as somewhere that you visited?

The virtual room seems to me more like ...

1 Images that I saw ... 4 About 50/50 ... 7 Somewhere that I visited

4. During the course of the experience, which was stronger on the whole, your sense of being in the virtual room, or of being in the real world of the laboratory?

I had a stronger sense of being in ...

1 The real world in the lab ... 4 About 50/50 ... 7 The virtual room

5. When you think about the virtual reality, to what extent is the way that you are thinking about this similar to the way that you are thinking about the various places that you have been today?

I think of the virtual room as a place in a way similar to other places that I have been today...

1 Not at all ... 4 Somewhat ... 7 Very much so

APPENDIX E.
SCENARIO

The year is 2004, it is three years since the gruesome attack on the World Trade Center. Today it is happening again, this time – the target is an educational institution. It was apparently easy to take over due the relaxed security in a campus environment; the consequences are often devastating.

The University of Missouri – Rolla is suddenly faced with a situation. The computer science building has been taken over by terrorists. The only information received on the situation is that the building has been booby trapped with explosive devices. Police arriving at the scene managed to kill one of the members of the operation during an attempt to escape, the remaining managed to flee. The current death toll is put at 4 dead including 3 graduate students and a professor. There are also a number of injuries. The building has been cordoned off and is off-limits until your team of first responders can defuse the situation.

According to the latest reports, there are no terrorists remaining in the building. But the fires and explosions continue to rage. This situation needs to be neutralized. You are a first responder- primary profession – fire fighter. It is your responsibility to enter the building, to check the different floors for any possible threats and eliminate them. You are required to remember the locations of each dead/wounded civilian trapped inside the building to report to paramedics that would arrive in 12 minutes.

Experiment directives:

1. Move around in the VR environment of the computer science building. Explore all three floors.
2. Enter rooms to locate dead/wounded people and remember the locations to report to paramedics after the expedition. (THIS IS YOUR PRIMARY OBJECTIVE)
3. On event of fire:
 - a. locate the nearest fire alarm and set it off;
 - b. locate the nearest fire extinguisher and pick it up (if you aren't already carrying one)

- c. put out the fire.
4. At the end 12 minutes the experimenter will give you a signal and you should exit the building as quickly as possible.

Note:

The fire extinguisher has a limited amount of foam, so once it is empty a new one must be located. (A counter on the lower right of the screen will indicate amount of foam remaining).

Fires grow rapidly, so it is advised to put them out quickly. If you are exposed to the fire too long – health points are reduced, the health monitor, located on the lower left, on reaching 0 will result in a 30 second “death” period during which time you will be unable to move. Therefore, exercise caution when approaching fires.

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