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Perception of Presence in a Mixed-Reality Training Environment

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Abstract

Ground troop training within the Army typically involves three kinds of training: live mission rehearsal, virtual or simulated training exercises (e.g., within a Humvee simulator), and constructive training, in which warfighters battle artificially intelligent enemies in a video game format. Some leading edge training missions merge these formats to offer full LVC training (live, virtual, constructive) in a mixed-reality environment in which trainees rehearse in a physically immersive setting that is augmented with simulated constructive entities and integrated with virtual entities controlled by trainees at other locations. In this pilot study, a number of human factors that contribute to a sense of immersed presence were evaluated by 12 ROTC cadets engaged in a scenario within a mixed-reality training environment. Participants were evaluated via survey, interview, and After Action Review (AAR). Participants reported reasonably high levels of involvement on several measures, and the AAR offered meaningful objective measurements. The combined results provide a rich dataset that establishes a baseline for the participants’ sense of presence and provides useful insights into the environment’s human-system interactions, thus guiding future development.

Keywords
Mixed-reality training, presence, human factors, virtual reality, augmented reality

1. Introduction

With funding by the United States Army, the Virtual Reality Applications Center (VRAC) at Iowa State University has created a live, virtual, and constructive (LVC) environment (“the Veldt”) [name changed for double-blind review] to support research on military-style training activities. The Veldt exists in a physical room (approximately 40’ x 40’ x 30’ tall) with modular walls that can be moved and reconfigured for different training environments. Integrated into these modular walls are television screens (both projection and flat screen) for displaying the virtual environment, and tracking systems (optical, ultrasonic, and wireless) to capture the movements of trainees through the Veldt environment. The Veldt supports multiple trainees simultaneously using ambient displays, head-mounted displays, and augmented reality systems (see Figures 1 and 2).

The underlying concept behind the Veldt is to meet LVC training needs that are not met by current Army training technology. Specifically, the Veldt addresses five interrelated issues:

• The requirement for multiple warfighters to experience a virtual training environment that contains both real and simulated elements simultaneously;
• The requirement for a modular, reconfigurable virtual training environment;
• The requirement for a training mission database to work smoothly across multiple devices, including emerging embedded and mobile technologies;
• The requirement for accurate position tracking of participants and their weapons within a virtual training environment; and
• The requirement for validated assessment of the effectiveness of a new synthetic training environment.
This paper first reviews the literature pertaining to virtual military training and defines “presence” as an important factor. Next, the methodology of the pilot study is explained, particularly with regard to the training scenario, evaluation of participants, and the methodology and literature that informed the survey’s construction. Finally, we present the results for each of the three categories of evaluation (survey, interview, and AAR), followed by a discussion and summary.

2. Literature Review

The Veldt system has been designed to integrate live, virtual, and constructive elements to provide soldiers an advanced immersive virtual simulated training environment [1]. In the past, the method of choice for training soldiers took place in live, in-person settings. A more cost-effective approach uses a mix of live, virtual, and constructive simulations [2-4]. One of the first virtual reality projects that offered this type of environment was the FlatWorld Project at the University of Southern California’s Institute for Creative Technologies (ICT). Users interact with both real and virtual elements, walking among rooms with props and “digital flats” (large rear-projection screens that employ digital graphics). FlatWorld technologies, such as the projection of virtual characters and the implementation of sounds and smells, are at use in the Infantry Immersion Trainer on Marine Corps Base Camp Pendleton, California [5]. In evaluating and further developing FlatWorld technologies, ICT researchers are working on a comprehensive, standardized, norm-based VR cognitive performance assessment test battery [6] and “Virtual Iraq/Afghanistan,” an exposure therapy for combat-related PTSD [7].

Virtual training offers numerous advantages. The first is no restriction on the use of ammunition or fuel. In addition to these cost savings, potentially dangerous training tasks such as close air support or call for fire can be accomplished without hazard. Virtual training is also not restricted in the type of environment, landscape, or real-world area it can mimic. Lastly, timely lessons learned from combat can be quickly employed in virtual scenarios, thereby adding realism and relevancy to the training [4]. According to Knerr [3], “The Army now recognizes a need to train Soldiers and leaders to be adaptable, capable of responding to rapidly changing situations, and attuned to cultural conditions, in addition to being proficient in high-intensity combat operations” (p. 2). This new context of warfare makes live, virtual and constructive training crucial for the advancement of training initiatives.

The effectiveness of a virtual or mixed-reality environment relies on users’ experience of presence [8]. Slater [9] distinguishes between "immersion" (the measurable objective level of sensory fidelity provide by a system) and "presence," the sense of "being there" that occurs when a simulated environment is sufficiently perceptually convincing that users interact with the environment as if it were real, even though users know it is not. While the technical and systems aspects of a simulated environment are of obvious consequence, the interplay of social context and users’ emotions are also important elements in achieving presence [10, 11].

In the case of this specific study, our goal is to perform an initial evaluation of the perceptual cues of the Veldt to determine if the level of presence is sufficient. Battle simulations are one type of application in which a feeling of physical presence is critical [12]. While this pilot study uses self-reports to measure presence (drawing heavily from the Presence Questionnaire [13]), future plans include physiological measurements. Meehan et al. [14] found that heart rate satisfied their requirements for a measure of presence, as did (to a lesser extent) change in skin
conductance. They also found that inclusion of a passive haptic element in the virtual environment significantly increased presence.

2.1 Evaluation design
The evaluation design for this study was informed by a series of studies conducted by the United States Army Research Institute for Behavioral and Social Sciences [1-4, 15-16]. These studies identify several best practices, and thereby recommend the following implementations:

1. Virtual exercises lasting approximately 16 minutes
2. A web-collection approach in soliciting input from a significant number of users
3. Realistic representation of terrain with different conditions (night, rain, sandstorm) and dynamic terrain that shows structures, rubble, trees
4. Locomotion devices that provide realistic perception of movement
5. Realistic weapons
6. Computer-generated enemy, friendly, and neutral forces
7. Accurate portrayal of solider movements
8. Systems that provide adequate feedback

At the time of this study, the design and evaluation of the Veldt incorporated practices identified in numbers 1, 2, 3, 5, 6, 7, and possibly 8, depending on the threshold for “adequate.”

3. Methodology
The research team evaluated 12 participants who took part in the “Clear a Room” military training scenario. Participants were chosen from the ISU Reserve Officer Training Corps (ROTC) program. The study focused on three research topics: 1) the effectiveness of LVC training technologies used in the day-to-day military context; 2) opportunities for improving LVC training technologies; and 3) appropriate assessment methods for matching performance of one or more individuals in a training mission to learning objectives and skill outcomes.

The Veldt’s composition at the time of the pilot study was of a single street-view level with multiple walls capable of being reconfigured into various room structures and alleyways. A large-area tracking system comprised of 24 Motion Analysis cameras provides accurate tracking of all individuals, guns, and props within the space. Five reconfigurable constructs incorporate windows and doors that contain displays, which allow users to experience the virtual world beyond. All areas of the Veldt were designed for quick reconfiguration to the requirements of any specific training scenario.

3.1 Training scenario
Twelve Marine and Navy ROTC students, two with combat experience in Iraq, volunteered to perform the scenario. Six teams of two ROTC participants were taken through the Veldt over two days. Each participant completed the following steps in order:

- Walk-through: Participants were oriented to the Veldt environment. During this time participants put on their helmets and practiced firing their weapons. (5-7 minutes)
- Mission briefing: Participants were shown a briefing presentation that provided details for the Clear a Room scenario. Participants were told that opposing forces included two virtual enemies and one real enemy. (5 minutes)
- Mission: Participants took part in a live Clear a Room scenario. Each team ran through the scenario two times. (5-7 minutes each)

A brief video showing an excerpt of one team's progress through the mission can be seen at http://www.youtube.com/watch?v=tdOgwnrUN4k.

3.2 Participant evaluation
Immediately after completing the training scenario, each team of two ROTC participants was taken to a separate room outside the Veldt to be evaluated by researchers. Each participant completed the following:

- Survey: Participants completed a survey instrument about their experiences in the Veldt. The survey was a web-based survey administered electronically via a laptop computer. See Section 3.3 for further information on the survey methodology. (10-15 minutes)
Interview: Participants were asked questions about their experiences in the Veldt. Teammates (two participants per team) were interviewed together. (10-15 minutes) Questions included:

- What stands out to you regarding your experience in the live-virtual environment?
- Could scenarios, such as the one you experienced here, be used in this type of environment to practice decision-making skills? Please explain.
- To what extent did events occurring outside the virtual environment distract from your experience in the virtual environment?
- Were there moments during the virtual environment experience when you felt completely focused on the task or environment?
- Do you think this type of environment could be beneficial if you were training for military activities, such as practicing Rules of Engagement, making decisions in a stressful environment, and practicing shoot/don’t shoot situations?

Additionally, the After Action Review (AAR) system of the simulation engine recorded the time it took teams of participants to clear the scenario and the number of hits and misses for both participant teams and enemy forces. Finally, location tracking recorded participants’ location within the Veldt as well as weapon movements, using infrared sensitive tracking balls placed on the helmets and faux weapons. For more information about the technical construction and engineering of the Veldt, see AuthorOfThisPaper [17].

3.3 Survey methodology
The survey for the Veldt evaluation was developed following a review of the literature on military training in virtual environments. Particular attention was paid to previous research on gaming as training, as well as assessments of decision-making skills, situational awareness, and presence in virtual settings [13, 18-20]. The Veldt survey used for this report draws heavily from the Presence Questionnaire developed by Witmer and Singer [20]. The Veldt survey uses repeated measures to verify participants’ presence within the virtual environment and to gauge the effectiveness of the system in improving combat skills. By asking the same question in different ways, the survey also helps determine what elements of the Veldt system require improvement. Furthermore, we used these previous studies to guide our selection of a web-based survey and in-person semi-structured interviews for our evaluation.

The theory used to develop the Veldt survey centered on work conducted by Witmer, Jerome, and Singer [13] on the factor structure of the presence questionnaire. Factors that contribute to presence include:

- Involvement – The consequence of focusing one’s mental energy and attention on a set of related activities or tasks.
- Adaption/immersion – When one feels involved in their environment. Within virtual environments this occurs when extraneous distractions are limited.
- Sensory fidelity – How the auditory and sight experiences contribute to the overall experience.
- Interface quality – The ease with which participants interacted with the virtual environment.

Witmer et al. [13] found that Involvement is the most dominant dimension measured when using a presence-based questionnaire. A presence-based questionnaire poses questions about the virtual environment as it relates to users’ perceptions of experiences of the interfaces, involvement in the task(s), nature and quality of their interactions, and time required to adjust to the experience [13]. Given the importance of presence and the strengths of a presence-based questionnaire, we believed this approach was best suited for our evaluation of the Veldt.

4. Results
The results from the combined survey instrument, participant interviews, and AAR data provided a rich set of data that helped us understand the Veldt’s performance related to learning objectives, skill outcomes, and human-system interactions. The survey offered participant perspectives on their presence in the environment as well as their degree of involvement in the training scenario. Interviews gave participants the opportunity to reflect on the experience and assess the overall usefulness of the training exercise. Lastly, the AAR tracked and recorded participants’ actual movements and weapons use in the Veldt.

4.1 Survey results
The following themes emerged from the survey results.
Aspects of physical environment were highly rated. All participants (100%) rated the following items as Good or Very Good: the ability to identify enemy combatants, maneuver around obstacles (see Figure 3), maneuver around corners, scan from side to side (see Figure 4), move quickly to the point of attack, engage targets within a room, coordinate with team members, determine other team member’s positions, and execute the assault as planned.

Difficulty locating enemy fire. Most participants (67%) rated the ability to determine the source of enemy fire by sound as Poor or Very Poor, with none rating it as Good or Very Good (see Figure 5). Additionally, 59% of participants rated the ability to determine the direction of enemy rounds as Poor or Very Poor and only 8% rated the ability as Good or Very Good. Conversely, 58% of participants indicated the ability to visually locate the source of enemy fire was Good or Very Good (see Figure 6).

Poor accuracy of weapons. While 75% of participants rated the ability to aim their weapon as Good or Very Good, (see Figure 7) 75% rated the ability to fire their weapon accurately as Very Poor while the remaining 25% of participants rated it as Poor (see Figure 8). Likely related to problems of weapon tracking within the early version of the Veldt, 67% of participants reported No improvement in marksmanship based on their training experience.
Ability to engage opposing forces. While participants had difficult hitting enemy combatants, all participants (100%) rated as Good or Very good their ability to both identify (92% selected Very good) (see Figure 9) and engage the enemy (58% selected Very good) (see Figure 10). It is important to note that civilians were not used in the scenario and, if employed, could potentially confound participants’ ability to identify enemy combatants.

Potential for meeting learning outcomes. When asked how their ability to meet training objectives had changed based on their Veldt experience, 84% of participants reported Moderate or Vast improvement in their ability to engage enemy combatants (see Figure 11). Similarly, 75% reported Moderate or Vast improvement in their ability to make quick decisions in a stressful environment (see Figure 12) and 67% reported Moderate improvement in their ability to identify and evaluate challenges in complex situations.
Potential for creating an involving experience (part of presence). Even though the inability to fire weapons accurately and the absence of sound appeared to diminish participants’ suspension of disbelief, participants gave fairly high marks to the Veldt’s ability to involve them in the training scenario. All participants (100%) agreed (indicated either Agree somewhat or Agree completely) that the visual aspects of the Veldt environment involved them (see Figure 13). Eighty-three percent agreed that their senses were completely engaged (see Figure 14). Eighty-four percent agreed that they felt involved in the virtual environment, and 67% agreed that their interactions in the Veldt environment seemed natural or true to life.

4.2 Interview results
The following themes emerged from the interviews. With regard to training in a mixed-reality environment, participants liked their ability to move about the Veldt’s rooms and, for example, kick in doors. The windows, alleyway, and feeling of close-quarters provided a useful likeness to actual scenarios. Participants suggested incorporating some larger rooms, ceilings, and furniture. Regardless, they found the ability to move around and interact to be extremely helpful.

Participants were distracted by “unreal” elements while also desiring more “real” distractions. Thus, ambient noise, friendly fire, and other realistic, confusing stimuli would add to the participants’ experience of decision-making and communication under such conditions. Similarly, adding sound and recoil to fired weapons was suggested. Conversely, it would be useful to better incorporate or disguise the virtual elements that belie the intended experience.

Participants liked the system’s ability to track users and provide feedback. However, problems with the Veldt’s tracking system resulted in some shots not being registered as hits even though they were fired on target.

The participants’ comments provide guidance for further development of the Veldt as a flexible, interactive, immersive training system. Longer, more developed scenarios that mimic actual situations can be developed alongside the live and virtual elements to provide experience and feedback, thus maximizing soldier preparedness.

4.3 After Action Review (AAR) results
We have AAR data which are releasable to government parties through proper channels.

5. Discussion and Summary
The Veldt consists of a purposeful integration of both physical and virtual environments. Based on feedback from the initial group of participants and evaluator observations, the physical aspects of the Veldt worked well. These physical elements include the modular walls that form the configurable urban environment, the faux weapons, and the integration of the different simulation displays throughout the environment. However, the virtual environment will require further modification to fulfill its potential as an effective training environment.

Most of the problems reported by participants seemed to stem from issues with the tracking system. For example, the ability to fire a weapon accurately depends on the Veldt’s ability to track the weapon’s location and orientation
at all times during a training exercise. Sometimes the system successfully tracked both weapons and shots fired. Other times participants were unable to “kill” a virtual enemy despite firing dozens of shots while standing a few feet away from the projection screen. Issues with tracking also seemed to prevent, at times, opposing forces from “locating” participants and engaging them in weapons fire. At the time of publication, the tracking system has been improved. Other parts of the virtual environment worked well. The Veldt’s interface with the VBS2 simulation engine, another important component of the virtual environment, did not have any noticeable problems. Opposing forces could move independently, fire at participants, and be fired upon by participants.

Despite these difficulties, participants reported reasonably high levels of involvement in the Veldt environment and indicated good learning outcomes on several measures. The participants’ level of presence was encouraging, and their suggestions for improving the Veldt environment (e.g., including non-combatants, adding furniture to rooms, providing rich background sound) will likely enhance the experience. Also, previous research on presence by Bowman [21] suggests that stereoscopic 3D displays can be useful, especially for tasks that require fine motor accuracy (such as aiming a weapon). Furthermore, the AAR data suggest that the Veldt has considerable potential for recording and automatically measuring training outcomes.

Finally, it is important to note that integrating virtual simulations and constructive training environments is a newer and rapidly evolving field. Many of the challenges identified in this study reflect the inherent challenges of implementing diverse technologies and do not detract from the advantages of virtual simulation as a training tool. Indeed, this pilot study demonstrates the effectiveness and potential of a system like the Veldt.

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References


