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Training Capabilities of Wearable and Desktop Simulator Interfaces

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14. ABSTRACT *(Maximum 200 words)*:

The use of game-based simulations (GBS) for dismounted infantry training has considerable potential. One method of training employs a wearable computer interface that simulates the Soldier's load bearing equipment. At present, the advantages of wearable interfaces have not been validated by research. Therefore, the TRADOC Capability Manager Virtual Training Environments requested that ARI conduct a study to determine the training advantages of wearable and desktop interface simulators for dismounted infantry training. Ninety-eight participants were trained in U.S. Army warrior skills using one of three methods; a GBS using a wearable interface, a GBS using a desktop interface, and, the standard U.S. Army training video. To measure skill retention, participants were asked to watch a series of short (8-16 second) video captures of an avatar in a VE performing the same warrior skills and free recall both correct and incorrect procedures demonstrated by the avatar. Results showed there were no significant differences among the three groups as far as recall of correct and incorrect steps of the warrior skills. However, the desktop and the wearable groups reported significantly more Presence, Engagement, and Interest/Enjoyment than the control group, with no differences being found between the desktop and wearable groups.

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Game-based simulations, training, simulation, training transfer

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Army Project Number 665803D730	**Personnel and Training Analysis Activities**

TRAINING CAPABILITIES OF WEARABLE AND DESKTOP SIMULATOR INTERFACES

EXECUTIVE SUMMARY

Research Requirement:

The use of game-based simulations (GBS) for training has considerable potential, particularly for dismounted infantry training. However, there are a number of different methods available to present the training, including traditional desktop computer interfaces, or newer wearable computer interfaces that simulate the Soldier's load bearing equipment. The wearable interface employs a helmet mounted display (HMD), sensors positioned on the Soldier's body, and controls mounted on a simulated rifle. This type of interface is expected to provide the Soldier a better sense of immersion in the environment and potentially better training transfer than more common desktop interfaces. However, since wearable interfaces are considerably more expensive than desktop interfaces, they must provide better transfer of training than desktops to justify their expense. At present, the advantages of wearable simulator interfaces for training are merely theoretical and have not been validated by research. A report conducted by ARI (Knerr, 2007) discussed the need for, and expected benefits of, dismounted Soldier training in virtual environments. One of the recommendations included in the report was to evaluate the cost effectiveness of fully immersive and desktop simulations for dismounted infantry training. As a result of this report, the TRADOC Capability Manager Virtual Training Environments (TCM Virtual) requested that ARI conduct an experiment to determine the relative advantages, from a training standpoint, of wearable interface simulators and desktop interface simulators for dismounted infantry training. The present experiment seeks to answer questions about training merits of both wearable and desktop GBS interfaces.

Procedure:

Ninety-eight participants with no prior military training were trained in a number of U.S. Army warrior skills using one of three methods; a GBS using a wearable interface, a GBS using a desktop interface, and, as a control, the standard U.S. Army animated training video. Participants in both GBS conditions controlled an avatar in a virtual environment (VE) and watched an instructor avatar demonstrate each of the warrior skills. After each demonstration, the participant was able to practice the skill in the VE with guidance from the instructor (a researcher). Participants in the control condition simply watched the training video. To measure skill retention, participants were asked to watch a series of short (8-16 second) video captures of an avatar in a VE performing the same warrior skills. After each video clip, the participants were asked to free recall both correct and incorrect procedures demonstrated by the avatar.

Findings:

There were no significant differences among the three groups as far as recall of correct and incorrect steps of the warrior skills. This suggests that, for this type of learning (i.e., recalling correct and incorrect steps of warrior skills), using either GBS interface is no better than the current training video. One caveat of this finding is that after the data analysis we realized the experimental method may have measured recall of declarative knowledge (memorization), but may not have addressed procedural knowledge (performing procedures or

skills). Therefore, it is possible there may have been differences between the training methods if skills involving more procedural knowledge had been used. Other findings included:

- The Desktop and the Wearable groups reported significantly more Engagement (from the Dundee Stress State Questionnaire) and Interest/Enjoyment (from the Intrinsic Motivation Inventory) than the control group, with no differences being found between the desktop and wearable groups.
- The Desktop and Wearable groups reported significantly more Presence than the control group, with no differences found between the Desktop and Wearable group.
- The Wearable simulator evoked significantly higher levels of Simulator Sickness.

Utilization and Dissemination of Findings:

These findings can be used to help make decisions about fielding GBS for U.S. Army training. The most cost effective training would be that which provides the most transfer of training for the least cost. The costs associated with simulator alternatives include not only the monetary cost of the simulator system, but also the costs to the students in time, frustration, and boredom, as well as training time lost through simulator sickness.

The evidence presented does not support the position that the Wearable, immersive interface trains declarative knowledge better than the Desktop interface. Indeed, in this experiment there is no evidence that either simulator interface provides better training than the current training videos. However, both Wearable and Desktop interfaces are more engaging, are more interesting and enjoyable to use, and also provide a better sense of presence. These factors should motivate the student to learn the material, and would suggest that for these reasons a simulator should be used for training where feasible.

If cost is the principle consideration, the desktop interface seems to be the best choice. A Desktop computer costs far less than the Wearable interface, but, according to the evidence in this experiment, the Wearable does not provide better training than the Desktop. In addition, there is a higher probability of simulator sickness with the Wearable interface. This evidence should be taken into consideration when deciding how to employ simulators for training.

These findings were presented to TCM Virtual on 3 June, 2010.

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TRAINING CAPABILITIES OF WEARABLE AND DESKTOP SIMULATOR INTERFACES

The relationship between the amount of training transfer versus the cost of the training is known as training efficiency (Wickens, 1992). Training efficiency is especially important in the U.S. Army's current operating environment. The goal of efficient training is to get the most learning for the least cost, with costs usually being expressed in terms of time and money. The Soldier's job is becoming a more and more complex one, and Soldiers therefore require more training to perform their jobs well. At the same time, deployment schedules leave less time for training than was available in the past. Therefore, any training technique that can train Soldiers better or in less time is valuable.

Simulators offer the promise of training efficiency (Taylor, Lintern, Hulin, Talleur, Emanuel, & Phillips, 1999). Tasks that are normally trained in a live setting (range, field, or using actual equipment) can often be trained in simulators at reduced cost. Simulated environments do not have the same scheduling, safety, transportation, or logistics concerns that training ranges have. Simulated environments can often be modified at far less cost than traditional training ranges. Also, sometimes there are things that can be done in simulators that would be dangerous or costly to do in live training. Thus, although simulated virtual training environments cannot replace live training, they are sometimes more appropriate for certain training situations than live training. However, the expected advantages of virtual training environments are based on the assumption that training in virtual environments can provide effective training. If simulators do not provide effective training, then the other advantages are somewhat irrelevant.

In addition, there are often multiple simulated environments and multiple interfaces with those environments. Each environment and interface combination may provide more or less effective training than others. Obviously, training managers would want to employ the training environment and interface match that provides the best training at the least cost. Measuring the relative training effectiveness of different systems can help training managers choose the best training simulation for the situation. The most appropriate means to measure training effectiveness is to measure training transfer from the simulator to the real world task.

The present research investigates how well two interfaces for a game-based simulator facilitate learning basic military skills. One interface is the traditional desktop keyboard-and-mouse interface similar to a PC game, while the other is a wearable computer and interface that simulates a weapon and load bearing equipment an individual Soldier would wear and use in the field. The wearable interface uses body motion as input and allows the Soldier to interact with the virtual environment in a more natural way than using a desktop interface. However, whether the wearable interface produces better training than the desktop, or than traditional classroom training, is unclear. The present research seeks to compare the training transfer of the two training methods: the desktop interface, the wearable interface, with traditional classroom training as a control.

Background

A review conducted by Knerr (2007) analyzed the need for, and expected benefits of, dismounted Soldier training in virtual environments. One of the recommendations of this experiment was to evaluate the cost effectiveness of fully immersive simulators versus desktop simulators for dismounted infantry training. Based on the recommendations in this report, the

TRADOC Capability Manager, Virtual Training Environment (TCM Virtual) requested that ARI conduct a further experiment to determine the relative advantages and cost effectiveness of wearable interface simulators and desktop interface simulators for dismounted infantry training.

Simulation Training

The essence of training is to introduce learners to declarative and procedural knowledge related to certain skills and then give them the opportunity to correctly practice and improve those skills. Simulators give learners the opportunity to practice skills in situations that otherwise would be difficult or dangerous. It is much safer for a student pilot to practice landings in a simulator where the penalty for failure is much less catastrophic than with a real aircraft. Training Soldiers in a simulated environment allows them to use weapons and tactics that would be dangerous to practice in the real environment.

A key question in simulator training and the use of virtual environments is how realistic must practice be to improve performance. Ideally, the procedures practiced in the simulator should be exactly the same as those for the real environment. However, for practical reasons some actions in a simulated environment cannot be exactly the same as in real life. For example, if a game-based simulator uses a desktop computer as an interface, the avatar in the simulated environment is moving through the environment controlled by the learner's mouse and keyboard, but the learner is normally seated in a chair and not moving. Is the student in this simulator still learning, even if they aren't moving? The answer to this question often depends on the type of skills to be learned.

Skills are often divided into motor skills and cognitive skills. Motor skills involve bodily movement and fine muscle coordination, such as those that are used in sports such as golf or tennis. Hitting a golf or tennis ball and having it go where you want involves training groups of muscles to make very fine movements. Typically, this level of skill requires a considerable amount of practice. Cognitive skills involve remembering procedures required to perform a task and sometimes problem solving. Cognitive skills involve memory more than musculature. For example, remembering how to change a flat tire on a car is more of a cognitive skills than motor skill. It is more important, for safety and practical reasons, to remember how to perform the steps in the correct order than how to physically operate the tools, such as the jack. The tire wrench, jack, and other tools do not require fine motor skills; rather, almost anyone who has the strength to operate the tools has the ability to use them correctly. Soldier tasks often require the performance of both motor and cognitive skills. For example, a Soldier operating a checkpoint must have a thorough understanding of the Rules of Engagement and Escalation of Force procedures in order to know when it is necessary to fire on an suspected threat or enemy, and they must also be well trained on the physical operation of their weapon in order to effectively eliminate the threat.

Thus, learning motor skills through simulation requires the simulation to be an accurate representation of the physical operation of the real world system. On the other hand, learning cognitive skills requires the learner to remember and think through the correct procedures, while the exact physical movements are less important (Wickens, 1992).

Training Transfer

How well skills learned via a simulator or other training device improve performance of the same skills in the real world is termed transfer of training. Generally, if the behaviors practiced in the simulator are similar to the behaviors required to perform the real world skill, the transfer of training is high (Wickens, 1992). Often, though, practical considerations prevent the simulator behaviors from being exactly like those in the real world. For example, a driving simulator may have a steering wheel and pedals similar to a real automobile, but “driving” the simulator will not include the acceleration and deceleration forces of driving a real car. If those forces are important for learning how to drive, then the training transfer may be poor, however, if experiencing acceleration and deceleration forces is not important to learning to drive, then training transfer should not suffer.

Ideally, training in a simulator or simulation should improve the performance of skills in the real world. This is known as positive transfer of training. If the training did not improve or worsen those skills, it would be considered zero transfer. However, sometimes poor or inappropriate training can interfere with the performance of real world skills. This is known as negative transfer. For example, learning to type using an atypical keyboard layout, such as the Dvorak keyboard, would make it more difficult to learn to type on another keyboard layout, such as the common QWERTY layout. Obviously, any training, especially simulator training, must have positive training transfer to be useful. Zero transfer would be a waste of valuable training time, and negative transfer would make the student worse at performing the skill. Transfer of training is an important consideration when developing training and selecting training systems.

With many training systems it is not as simple as positive, zero, or negative overall training. Often, a training system will produce different levels of positive (or sometimes negative) transfer for different skills. Therefore, in most practical situations, training developers are looking for a system that can produce some level of positive transfer of training for the majority of skills, with little or no negative transfer.

Training Efficiency

Another consideration for training development is the cost of the training, normally measured in money and time. More time spent training in most circumstances improves performance, but also increases costs. The relationship between the amount of training transfer versus the cost of the training is known as training efficiency (Wickens, 1992). The goal of training developers is to get the most training for the least cost. This is the most efficient use of the training.

Training efficiency is often measured by determining the amount of time it takes to reach a criterion level of learning for different training methods. The training method that takes less time to reach the same criterion is considered more efficient. This efficiency can be expressed as a Transfer Effectiveness Ratio (TER) (see Wickens, 1992 for a discussion of TER).

Immersive Simulators

A virtual environment that has a greater sense of immersion should produce higher levels of presence, that is, the subjective feeling of being in one environment when actually being in another (Knerr, et al., 1998). While immersion is primarily a mental state, the physical analog is fidelity. A training system has high fidelity if it matches the real world system very closely. Although it is logical to believe that a simulator with high fidelity will train better than a lower fidelity system, research has shown that this is not always true (Wickens, 1992). In some cases, the added realism of high fidelity simulators may not provide enough training improvement to justify the increased costs. In other cases, simulators with high fidelity, but which are not an exact match to the simulated system, can force users to learn simulator-unique actions that are incompatible with the real system. These simulator-unique behaviors can actually interfere with the learning of skills needed for the real system. Wickens (1992) suggests it is important to know which components of training have to be similar to the target task and which are less important to learning.

The use of wearable simulators for dismounted Soldier training is a relatively recent development. Initial studies investigating their effectiveness found that although early systems did allow Soldiers to perform basic Infantry tasks, they were too bulky and lacked the fidelity in their visual and weapons systems necessary to be truly useful (Lockheed Martin, 1997; Pleban, Dyer, Salter, & Brown, 1998). Over the past decade, simulation technology has continued to advance, and researchers have continued to investigate their usefulness for the training of dismounted Soldiers (see Knerr, 2007). However, this research has been limited (due in no small part to the costs associated with wearable simulators), and the research that has been done has primarily revolved around subjective questionnaires to assess how effective users felt the systems were, rather than objective measures of their training effectiveness. Of the few studies to objectively measure training, only one (Loftin et al., 2004) compared the immersive system to a standard desktop simulation, but they used a CAVE (CAVE Automatic Virtual Environment; a simulator that projects images onto large fixed screens) rather than a wearable system. Their results showed a minor improvement in training from the CAVE over the desktop, but not enough to justify the tremendous increase in cost.

This experiment continues the research previously conducted on the use of wearable simulators for training of dismounted Soldiers. Specifically, the systems will be evaluated by empirically measuring the knowledge obtained from tactical training with wearable simulators. As a reference, the wearable systems will also be directly compared to the knowledge gained from two current standards in military training technology: Interactive Multimedia Instruction (semi-interactive training slideshows), and desktop computer simulation.

Method

Participants

Participants were university undergraduates who were compensated with course credit. A total of 98 students participated (66 males, 32 females), with a mean age of 18.9 years.

Apparatus

Software. The simulation software, Game Distributed Interactive Simulation (GDIS), was developed by the Research Network Inc. (www.resrchnet.com) and is based on the Half-Life graphics engine developed by Valve (see Figure 1). GDIS is a first-person shooter developed for a U.S. Army research and development program. The software allows for the use of customized interactive environments complete with buildings, terrain, vehicles, and friendly, enemy, and civilian characters (which can be fully automated or controlled by other live role-players). In this experiment, participants utilized a virtual representation of the McKenna Military Operations in Urban Terrain (MOUT) training site located in Fort Benning, GA.

Desktop simulator. The desktop simulator was powered by a Dell XPS computer (2.67 GHz Intel Core 2 Duo processor, 3 GB RAM) with a 20 inch widescreen monitor.

Wearable simulator. The wearable simulator was powered by an ExpeditionDI system developed by Quantum3D (see Figure 2). The system was comprised of a Thermite 1300 Tactical Visual Computer (1.4 GHz Intel Pentium processor, 1 GB RAM), which was worn on the back of a load-bearing vest. The computer presented the same GDIS simulation used on the desktop computers on a helmet-mounted eMagin Z800 SVGA OLED display. The system was fully self-contained and the user was not tethered to any external equipment, providing them an unhindered range of motion. The user's movements were tracked via three tri-axis motion sensors connected to the head (helmet), simulated weapon, and thigh.

Figure 1. Screenshot of the GDIS virtual environment.

Interactive Multimedia Instruction. These training tools are currently in use by the U.S. Army to assist in the presentation of the information from the corresponding training publications. A total of three were used: 071-326-0541 ("Perform Movement Techniques during an Urban Environment"), 071-326-0557 ("Select Hasty Firing Positions during an Urban Environment"), and 071-440-0031 ("Employ Hand Grenades during an Urban Operation"). Each contained a series of slides, which the trainee can advance through at their own pace using a mouse. Information was presented by a recorded voice with animated images demonstrating the principles being discussed.

Controls. A standard keyboard and optical mouse were used to control the desktop simulation. The controls used for the simulation were fairly typical of other PC-based first-person shooters (see Figure 3). In the wearable simulator, the user controlled their avatar through a combination of their own natural movements along with a weapon-mounted joystick and series of buttons on the front handgrip of the simulated M4A1 rifle (see Figure 3). The user's head movements were used to control their view within the simulation, movement of the simulated weapon controlled the aim and position of the weapon within the virtual environment, and the leg tracker detected the user's posture (standing or kneeling) and adjusted the avatar's position accordingly.

Figure 2. Soldier wearing the wearable interface.

Action	**Desktop**	**Wearable**
Move	W, S, A, D	Thumbstick
Look	Mouse Movement	Head Movement
Aim	Mouse Movement	Weapon Movement
Run	Shift + Move	Thumbstick Threshold
Kneel	Control (hold)	Kneel (leg tracker)
Prone (lie down)	X	Kneel + 3[a]
Weapon Select	Mouse Scroll	2[a]
Fire	Mouse Click	Trigger

Figure 3. Controls for the desktop and wearable simulators.
[a] The numbers indicate one of four buttons located on the front handgrip of the wearable system's simulated rifle.

Questionnaires

All questionnaires were administered on desktop computers within an internet browser. These were the same computers used for the Flash-video and desktop simulation training conditions.

Demographics Questionnaire. A simple questionnaire was used to collect each participant's age, gender, dominant hand, and to ensure that they had normal sensory abilities and did not have prior military experience.

Game Experience Measure: First Person Shooter. The Game Experience Measure (GEM) is an assessment of the participant's experience and knowledge of video games (Taylor, Singer, & Jerome, 2009; Appendix A). The original measure has been modified to specifically assess the participant's knowledge of first-person shooter video games, a departure from the original measure's attempt to assess knowledge of all video games. This alteration was made in light of the original measure's apparent shortcomings in its measurement of general video game knowledge, as well as the hypothesis that only first-person shooter knowledge/experience will contribute to participants' performance with the system.

Game-based Performance Assessment Battery (GamePAB). GamePAB was developed to be used in conjunction with the Game Experience Measure to assess video game skill in a first-person shooter environment (Taylor, Singer, & Jerome, 2009; Chertoff, Jerome, Martin, & Knerr, 2008). The assessment occurs in a first-person shooter environment, and consists of two sections: a follow phase and an aiming phase. The follow phase has the participant following a leader at a set distance while mimicking their actions (crouching, jumping, running, etc.) and verbally responding to questions about their virtual surroundings. The aiming phase has the participant remain still and aim at a moving target with the mouse, shooting it whenever its color changes to green. GamePAB scores the participants' gaming skill on the amount of time they spend following the leader at the correct distance and aiming their weapon at the target, reaction times to both posture changes and shooting the target, and the speed and accuracy with which they respond to the questions.

Immersive Tendencies Questionnaire. The Immersive Tendencies Questionnaire (ITQ; Witmer & Singer, 1998) is a trait measure of a person's natural tendency to become highly involved in artificial environments (such as movies, video games, books, etc.). The questionnaire yields three subscales (focus, involvement, and games) along with a total score. The focus and involvement subscales can both range from 7 – 49, the games subscale can range from 2 – 14, and the total score can range from 18 – 126.

Presence Questionnaire. The Presence Questionnaire (Witmer & Singer, 1998; Witmer, Jerome, & Singer, 2005) is used to measure the participant's feeling of presence, or sense of "being there" within the simulation. The 29-item questionnaire results in four subscales: involvement, sensory fidelity, adaptation/immersion, and interface quality. The involvement scale can range from 12 – 84, sensory fidelity ranges from 6 – 42, adaptation/immersion ranges from 8 – 56, and interface quality ranges from 3 – 21.

Simulator Sickness Questionnaire. The Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993) rates the participant's subjective experience of nausea, oculomotor, and disorientation symptoms individually, and is used to assess the degree of simulator sickness experienced with the different simulators. The nausea scale can range from 0 – 200.34, oculomotor ranges from 0 – 159.18, and disorientation ranges from 0 – 292.32.

Dundee Stress State Questionnaire (DSSQ). The DSSQ (Matthews et al., 1999) measures the participant's subjective stress associated with the various task components. The short (20-item) version of the DSSQ is used (Helton 2004), which measures task engagement, distress, and worry. The scales for task engagement and distress both range from 0 – 28, and the worry scale ranges from 0 – 24.

NASA-TLX. The NASA-Task Load Index (TLX; Hart & Staveland, 1998) is a workload measure designed to assess the mental demand, temporal demand, physical demand, effort, subjective performance, and frustration level associated with the use of the simulator for training, with each of these scales ranging from 0 - 500.

Intrinsic Motivation Inventory (IMI). The IMI (McAuley, Duncan, & Tammen, 1987) measures six separate subscales of task-related motivation. Two of these subscales were used to evaluate motivation with respect to the training: interest/enjoyment and perceived competence. Interest/enjoyment can range from 7 – 49, and perceived competence can range from 6 – 42.

User Interface Questionnaire. The User Interface Questionnaire was developed specifically for this experiment. It was used to assess the ease of use of the two different simulators (Appendix B). Questions focus on the effort needed to learn and use the controls, the realism of the environment and the avatar's capabilities, and provides a free-response section for participants to discuss any specific aspects of the system that they found particularly good or bad.

Training Content

The tasks trained in the simulators were tactical movement in an urban environment, selecting fighting positions in an urban environment, and the use of hand grenades in urban environments. The tasks were taken from Soldier training publications 071-326-0541 (Department of the Army 2004a) and 071-326-0557 (Department of the Army 2004b), and field manual 071-440-0031 (Department of the Army, 2002). Each task was parsed into discrete procedural steps (Appendix C). In the references, some of the steps were phrased as both errors of commission and errors of omission. For example, the procedure "do not silhouette yourself in windows" is the same as "stay below windows," but phrased as an error of commission rather than omission. Where a procedural step was described both ways, both descriptions were considered to be the same procedural step rather than different steps.

Training Retention Test Video

To measure the participant's learning of the tasks, a series of videos were created showing a Soldier avatar in an urban environment performing the same tasks on which the participants had been trained. The avatar performed some of the tasks correctly, and some incorrectly. A total of 14 videos were created, each between 10 – 26 seconds. Each video showed the Soldier avatar performing 2 – 8 tasks, for a total of 53 actions that the participant could potentially comment on. After each video was shown, the participant was given time to freely recall and record correct and incorrect tasks of the avatar by typing them into a computer program. When the participant finished recording correct and incorrect tasks, they viewed the next video.

The experimenters created the videos by using video capture of the actions of an experimental confederate controlling a Soldier avatar in a virtual environment (similar to a "machinema" video). The virtual environment used for the assessment video was OLIVE (www.forterrainc.com), a different but similar environment from that used in training by the participants. While the training was conducted in a virtual environment that replicated the McKenna MOUT site, the performance assessment video showed a Soldier avatar operating in a virtual environment that simulated parts of the city of Baghdad, Iraq.

Procedure

Participants were randomly assigned to one of three groups, either the Desktop group, the Wearable group, or the Control group. Participants first completed the informed consent, demographics questionnaire, and pre-tests (SSQ, DSSQ, GEM, GamePAB, ITQ). Participants were briefed on the experiment and allowed to ask questions.

Next, participants in the two experimental groups (Desktop and Wearable) were trained on the simulator controls and allowed approximately five minutes to practice on their own. They were then trained on the procedural tasks in the simulators. The training consisted of the participant's avatar following an avatar controlled by an experimental confederate (the trainer). The trainer explained and demonstrated each procedural task and then prompted the participant to practice the task. The tasks were logically grouped into similar task groupings. The experimenter provided feedback on correct and incorrect performance of the tasks. The entire training process lasted roughly 20 minutes.

Participants in the control group viewed portions of U.S. Army interactive multimedia instruction that presented the same tasks as the experimental conditions. These are standard training tools that are currently in use. The presentations described the tasks and showed an animated Soldier performing the tasks. The same verbal instructions were used in the Control group presentations and by the trainer in the Desktop and Wearable groups' training.

Once the training was completed, all participants completed relevant post-test measures (SSQ, DSSQ, NASA-TLX, Presence Questionnaire, IMI, User Interface Questionnaire), and then completed the training retention measure. For the training retention measure, they viewed a video of an avatar in the virtual world performing the tasks that had just been trained. The video continued for a short time (10-26 seconds) and then paused. During the pause the participant was asked to free recall and record both correct and incorrect procedural steps performed by the avatar. Participants typed a short description of the correct or incorrect task into a software-based form on a computer workstation. Once the participant finished rating the procedures, they were able to view the next portion of the video. They continued to view and rate segments of the assessment video until all 14 of the segments were rated.

In the assessment video, most procedural steps were presented twice, as either the correct or incorrect step. The participant was graded on how many times they correctly identified correct/incorrect actions performed in the video, out of a total possible score of 53. Errors, such as incorrectly identifying a procedural step were recorded and analyzed independent of the participant's correct responses.

Once participants completed the training assessment measure, they were thanked for their time and allowed to leave. The entire procedure lasted 1.5-2 hours.

Results

Training Retention

Training Retention was measured as the total number of movement procedures correctly identified from all of the videos. A reliability analysis was first conducted to ensure that the method used to measure Training Retention maintained an acceptable level of internal consistency. Cronbach's Alpha was computed from the participants' scores on each of the 53 total movement procedures presented in the videos, and was found to be sufficient at $\alpha = 0.742$.

A one-way Analysis of Variance (ANOVA) found no significant differences between the groups ($F(2,90) = 0.184$, $p = .832$), with the Control group correctly identifying an average of 18.13, the Desktop group correctly identifying 17.38, and the Wearable group correctly identifying 17.37 (Figure 4).

The frequency with which participants made errors in their responses was also evaluated. An error was defined as claiming that a specific aspect of the Soldier's movement was correct, when it was actually incorrect, or claiming it was incorrect when it was actually correct. Failing to comment on a particular action at all was not considered an error, it simply did not contribute to their total correct score. It was a relatively rare occurrence for a participant to commit an error, regardless of training condition, which lead to the ANOVA conducted to report no significant group differences ($F(2,90) = 2.204$, $p = .116$).

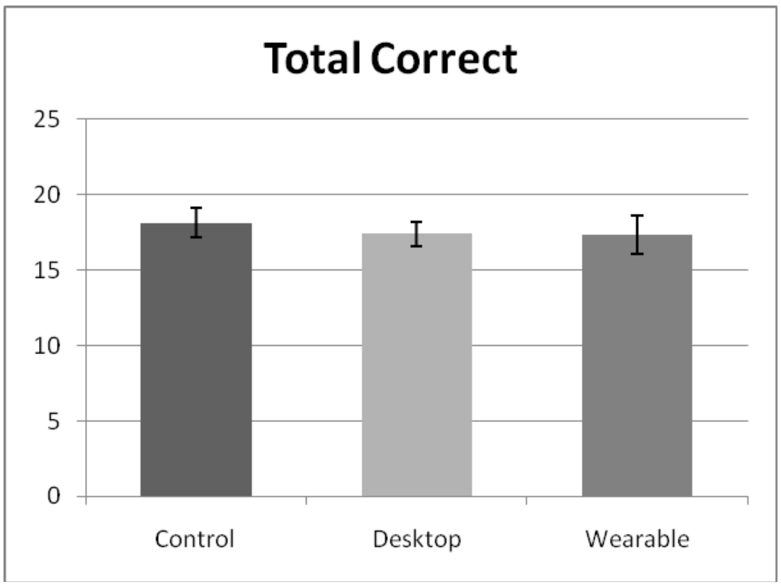

Figure 4. Total number of correct responses on the training retention test.

Although no significant group differences were found, several correlations were found to be significant between training retention and other measured variables. Training Retention was found to be negatively correlated with the Disorientation subscale of Simulator Sickness ($r = -.291$, $p = .005$), as well as both the Distress ($r = -.248$, $p = .017$) and Worry ($r = -.304$, $p = .003$) components of the DSSQ. Training Retention was also significantly correlated with GEM measures of Gaming Experience ($r = .245$, $p = .018$) and First-Person Shooter Knowledge ($r = .338$, $p = .001$), as well as the GamePAB measures of Time on Follow ($r = .528$, $p < .001$) and Posture Reaction Time ($r = -.489$, $p < .001$; note that the negative correlation implies shorter/faster reaction times are related to greater Training Retention). Positive relationships were also found between Training Retention and the Interface Quality subscale of the Presence Questionnaire ($r = .350$, $p = .001$) as well as the Perceived Competence subscale of the Intrinsic Motivation Inventory ($r = .226$, $p = .029$).

Simulator Sickness

A series of one-way ANOVAs were conducted to determine whether the participants in the different training conditions experienced different levels of simulator sickness. The measure used (SSQ: Kennedy, Berbaum & Lilienthal, 1993) reports simulator sickness on three subscales:

Nausea, Oculomotor, and Disorientation. Scores on each of these scales were calculated using the method described by the original authors. The ANOVAs reported significant group differences in each of the subscales – Nausea ($F(2, 91) = 10.024$, $p < .001$), Oculomotor ($F(2, 91) = 8.422$, $p < .001$), and Disorientation ($F(2, 91) = 4.518$, $p = .013$).

Post-hoc analyses determined that the participants in the Wearable condition reported significantly higher levels of simulator sickness than those in the Control and Desktop groups for each of the three subscales. For the Nausea subscale the Wearable group reported a higher level ($M = 13.42$) than both the Desktop group ($M = 3.39$, $p < .001$) and the Control group ($M = 7.69$, $p = .013$). For the Oculomotor subscale, the Wearable group again reported a higher level ($M = 22.50$) than both the Desktop group ($M = 6.60$, $p < .001$) and the Control group ($M = 11.49$, $p = .007$). For the Disorientation subscale, once again the Wearable group reported a higher level ($M = 15.23$) than both the Desktop group ($M = 4.04$, $p = .006$) and the Control group ($M = 5.84$, $p = .021$). Somewhat surprising in these findings is the fact that the Control group's ratings were consistently higher than the Desktop group's, though these differences were never statistically significant (Figure 5).

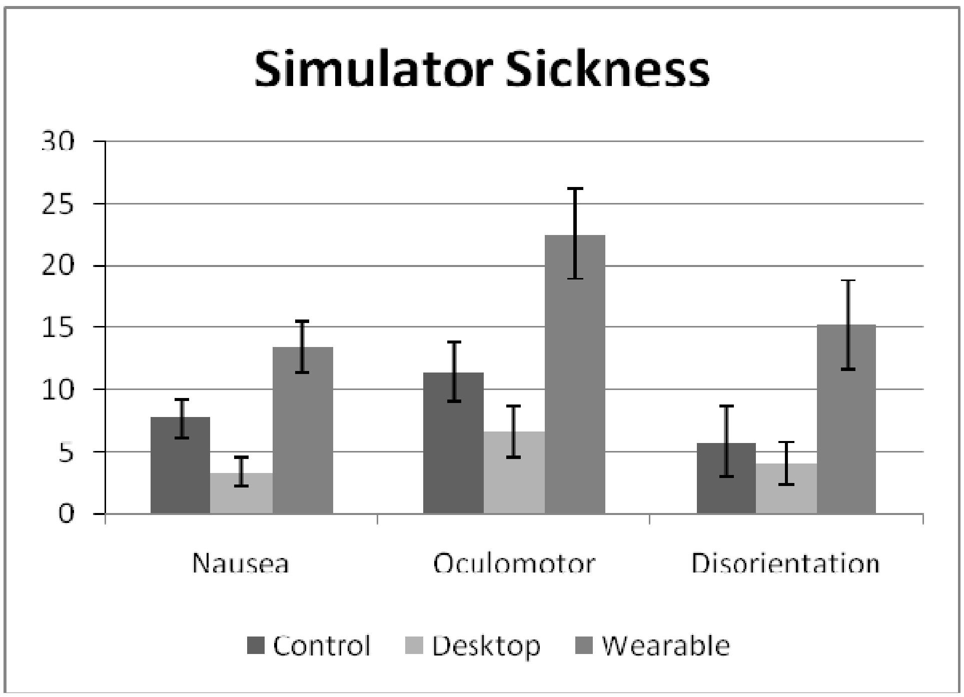

Figure 5. Simulator sickness results

Stress

A series of one-way ANOVAs were conducted to determine whether the participants in the different training conditions experienced different levels of stress. The measure used (DSSQ: Matthews et al., 1999) reports stress on three subscales: Engagement, Distress, and Worry. Of these, Engagement was the only subscale found to report significant group differences ($F(2, 95) = 13.156$, $p < .001$). Post hoc tests determined that the Control group reported significantly less Engagement ($M = 3.97$) than both the Desktop group ($M = 10.25$, $p < .001$) and the Wearable group ($M = 8.37$, $p = .001$).

Workload

Workload, as measured by the Task Load Index (NASA-TLX: Hart & Staveland, 1998) showed mixed results among the subscales. One-way ANOVAs found significant group differences for the Mental Demand ($F(2, 91) = 4.686$, $p = .012$), Physical Demand ($F(2, 91) = 33.240$, $p < .001$), Performance ($F(2, 91) = 3.590$, $p = .032$), and Frustration ($F(2, 91) = 3.373$, $p < .039$) subscales.

Post-hoc comparisons showed the Wearable group to have reported less Mental Demand ($M = 121.9$) than both the Control ($M = 204.0$, $p = .007$) and Desktop groups ($M = 195.2$, $p = .014$). The Wearable group was also found to have reported more Physical Demand ($M = 185.5$) than both the Control ($M = 6.0$, $p < .001$) and Desktop groups ($M = 33.5$, $p < .001$). The Desktop group reported higher scores (indicating that they believed they performed worse) on the Performance Concern subscale ($M = 207.3$) than both the Control ($M = 117.0$, $p = .020$) and Wearable groups ($M = 122.8$, $p = .027$). The Control group was also found to have higher scores on the Frustration subscale ($M = 58.83$) than both the Desktop ($M = 18.8$, $p = .018$) and Wearable groups ($M = 24.5$, $p = .042$).

Presence

ANOVAs found significant group differences on each of the four subscales of the measure used (Witmer & Singer, 1998): Involvement ($F(2, 92) = 28.505$, $p < .001$), Sensory Fidelity ($F(2, 92) = 13.716$, $p < .001$), Adaptation Immersion ($F(2, 92) = 6.971$, $p = .002$), and Interface Quality ($F(2, 92) = 5.285$, $p = .007$).

Post-hoc comparisons found the Control group to have experienced less Involvement ($M = 43.71$) than both the Desktop ($M = 61.72$, $p < .001$) and Wearable groups ($M = 62.22$, $p < .001$). The Control group also experienced less Sensory Fidelity ($M = 21.84$) than both the Desktop ($M = 28.91$, $p < .001$) and Wearable groups ($M = 28.31$, $p < .001$), as well as less Adaptation Immersion ($M = 36.52$) than both the Desktop ($M = 41.81$, $p = .005$) and Wearable groups ($M = 42.91$, $p = .001$). However, the Control group did report higher levels of Interface Quality ($M = 16.87$) than the Wearable group ($M = 14.16$, $p = .002$).

Motivation

The IMI (Ryan, 1982; McAuley, Duncan, & Tammen, 1989) was used, with only the Interest/Enjoyment and Perceived Competence subscales included. Of these, one-way ANOVAs found significant group differences only in the Interest/Enjoyment subscale ($F(2, 92) = 16.276$, $p < .001$). Post-hoc comparisons showed that the Control group reported less Interest/Enjoyment ($M = 3.659$) than both the Desktop ($M = 5.147$, $p < .001$) and Wearable groups ($M = 5.563$, $p < .001$).

User Interface

There was no difference between the groups on the User Interface questionnaire. There were statistically significant correlations between User Interface and simulator sickness, stress, GEM/GamePAB, Immersive Tendencies, workload, and presence, however, they were all fairly weak correlations. No further analysis were computed with these data.

Discussion

Surprisingly, no differences were found between the three groups in terms of knowledge acquired from the training. This may have been the result of several factors. First, in an effort to ensure consistency across the training conditions, the training procedure used in both the

Desktop and Wearable conditions was adapted from that used in the Control condition, as it is the currently accepted standard. However, the standard training consists of verbal instruction as a series of animated images are displayed on the screen. Therefore, when this was adapted to the Desktop and Wearable conditions the training was still heavily lecture-based, with the experimenter explaining and demonstrating procedures as the participants passively watched and listened. This left relatively little time to take advantage of the ability to actively practice the tasks, which is these systems' greatest advantage, without skewing the total amount of time spent within the different training conditions (another variable that was necessary to keep consistent). Consequently, in an attempt to maintain consistency for the sake of validity, the Desktop and Wearable systems were partially crippled of the very feature that is their greatest benefit.

Several other possibilities for these results should be mentioned. First, all three training methods trained what was essentially declarative knowledge, that is, students were expected to memorize and recall lists of good and bad behaviors. The training did not address procedural knowledge, which is learning to perform procedures such as driving an automobile or landing and aircraft. It is possible the control method is better for training declarative knowledge, while the desktop and wearable training methods would be better for training procedural skills. Further research is necessary to address this question.

Another factor to consider is the measure used to determine training transfer. It consisted of students observing and evaluating the actions of others, rather than performing the skills themselves. Again, the control training method may be more effective given this type of measure than the desktop or wearable training. Unfortunately, practical and safety considerations restricted participants to observing the skills they learned rather than performing them.

Although no group differences were found for Training Retention, the correlations between Training Retention and the other measured variables, as well as the group differences found on several of the secondary variables, still serve to better understand the distinction between the simulators. For example, the Wearable simulator evoked significantly higher levels of Simulator Sickness on all of the subscales. Although the measured levels of Simulator Sickness were not excessively high, it is important to consider that these levels were reached after only 20 minutes in the simulation. Obviously, this alone is a problem with the Wearable simulator and must be considered before it is implemented into use, as the wellbeing of trainees must always be of utmost importance. However, when it is considered that the Disorientation subscale of Simulator Sickness was found to be negatively related to Training Retention, this compounds the problem in that not only does the Wearable simulator lead to higher levels of Simulator Sickness, but that increase in Simulator Sickness may in turn negatively impact not only the trainee's comfort during their time in the simulator, but also the knowledge they retain from the training.

A positive relationship was also found between the Interface Quality subscale of the Presence Questionnaire and Training Retention. A previous usability analysis has found the Wearable system to have poorer usability than the Desktop system (Barnett & Taylor, in preparation), which is related to Interface Quality and may therefore lead to another decrement in the Training Retention for those trained in the Wearable system.

Other group differences expose potential disadvantages of the traditional training methods used with the Control group. The Control group reported significantly less Engagement (from the DSSQ) and Interest/Enjoyment (from the IMI) than both the Desktop and the Wearable groups, with no differences being found between the Desktop and Wearable groups. Although neither of these variables were found to be significantly related to Training Retention in this experiment, the concepts of engagement and interest have been considered important aspects in training for many years (Lepper, Woolverton, Mumme, & Gurtner, 1993; VanLehn et al., 2007).

While significant results were found for several of the workload subscales, the patterns were too inconsistent to make any general statement about any of the training conditions. Further research will be necessary to fully understand the complex relationship between simulated training and workload, and whether this relationship has any impact on Training Retention.

With the exception of the Interface Quality subscale, the Control group consistently reported less Presence than both the Desktop and Wearable groups, with no differences found between the Desktop and Wearable group. Presence is one aspect that has long been considered an important part of simulation-based training, but evidence of a direct link between presence and training retention from virtual environments has been weak (Jerome & Witmer, 2004; Mantovani & Castelnuovo, 2003). This still gives an additional advantage to both the Desktop and Wearable systems in that the increase in Presence they provide should lead to an increase (albeit a minor one) in the knowledge retained by those who train with them.

Conclusion

Previous research indicates Soldiers believe they received effective training from simulators (Knerr, 2007). However, with previous research based entirely around subjective, non-comparative ratings, the current experiment was necessary to objectively evaluate the effectiveness of simulation-based training. While we found no significant difference in training retention between simulators and watching videos, the simulators had other benefits the videos did not have. The simulators were rated higher in Engagement, Interest/Enjoyment, and Presence. This suggests the simulators were a more enjoyable way to learn, meaning trainees may likely be more motivated to learn the material using simulators.

While employing simulators may be a more engaging way to learn, there is no evidence that the Wearable interface provides better training than the Desktop. Indeed, participants using the Wearable simulator reported increased simulator sickness symptoms, and previous research has shown it to have poorer usability (Barnett & Taylor, in preparation).

For the type of skills that dismounted infantry normally train in the field, skills such as tactical movement, use of grenades, choosing hasty firing positions, etc., the Wearable provided no better training than the Desktop interface. Although there are procedural and motor skills that are difficult to train with the Desktop interface, the Wearable interface does no better in training these types of skills. As it stands, there is no evidence to justify the acquisition of the more expensive Wearable simulator interface over the Desktop interface.

Future research should consider measuring the transfer of procedural skills. The present research measured primarily declarative knowledge. It may be that the Wearable simulator interface may be better for training procedural skills. Research which measures military procedural skills may answer important questions regarding the relative training effectiveness of the Wearable and Desktop simulator interfaces.

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Appendix A: Game Experience Measure: FPS

Answer the questions below to characterize your previous experience with video and computer games. For each question select the appropriate choice that most accurately describes your experience. Answer questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

1. What is your level of confidence with video games in general?

- ☐ Very Low
- ☐ Low
- ☐ Average
- ☐ High
- ☐ Very High

2. How many hours per week do you currently play video games (average of the past 6 months)?

- ☐ 0-9 hours
- ☐ 10-19 hours
- ☐ 20-29 hours
- ☐ 30-39 hours
- ☐ 40+ hours

3. What is the maximum number of hours per week you've ever spent playing video games?

- ☐ 0-9 hours
- ☐ 10-19 hours
- ☐ 20-29 hours
- ☐ 30-39 hours
- ☐ 40+ hours

4. About how many times have you read a video game magazine or website to find out tips to improve your gaming skill?

- ☐ 0-9 times
- ☐ 10-19 times
- ☐ 20-29 times
- ☐ 30-39 times
- ☐ 40+ times

5. How often do you play the following types of games

	Never	**Rarely**	**Monthly**	**Weekly**	**Daily**
Action (e.g., Street Fighter, Contra)	☐	☐	☐	☐	☐
Adventure (e.g., Myst, Fable)	☐	☐	☐	☐	☐
Music (e.g., Guitar Hero, Dance Dance Revolution)	☐	☐	☐	☐	☐
Platform (e.g., Mario Bros., Sonic the Hedgehog)	☐	☐	☐	☐	☐
Puzzle (e.g., Minesweeper, Tetris)	☐	☐	☐	☐	☐
Racing (e.g., Need for Speed, Test Drive)	☐	☐	☐	☐	☐
Role-playing (e.g., Final Fantasy, Pokemon)	☐	☐	☐	☐	☐
Shooter (e.g., Doom, Halo)	☐	☐	☐	☐	☐
Simulation (e.g., Flight Simulator, SimCity)	☐	☐	☐	☐	☐
Sports (e.g., Madden Football, FIFA Soccer)	☐	☐	☐	☐	☐
Strategy (e.g., Command and Conquer, Civilization)	☐	☐	☐	☐	☐

6. List your recent favorite 5 game titles in the blanks

A: ______

B: ______

C: ______

D: ______

E: ______

7. Indicate your experience with each game you listed in question 6 above:

	None	**Very Little**	**Average**	**High**	**Expert**
A	☐	☐	☐	☐	☐
B	☐	☐	☐	☐	☐
C	☐	☐	☐	☐	☐
D	☐	☐	☐	☐	☐
E	☐	☐	☐	☐	☐

8. Indicate your experience with the following types of game controllers:

	None	**Very Little**	**Average**	**High**	**Expert**
A.					
B.					
C.					
D.					
E.					
F.					
G.					
H.					

A. 

B. 

C. 

D. 

E. 

F. 

G. 

H. 

The next section consists of a series of multiple-choice questions designed to assess your knowledge of First-Person Shooter video games. There is no penalty for incorrect answers, so if you are unsure of the correct response just make your best guess.

9. On PC first person shooter games, what set of controls are most often used to control the *movement* of your character?

- ☐ Mouse movement
- ☐ 8546
- ☐ WSAD
- ☐ UJHK

10. On console first person shooter games, what set of controls are most often used to control the *view* of your character?

- ☐ Trigger buttons
- ☐ Right analog stick (thumbstick)
- ☐ Left analog stick (thumbstick)
- ☐ Directional pad

11. What does the term “strafe” mean?

- ☐ Run
- ☐ Side-step
- ☐ Excessive force
- ☐ Automatic fire

12. What does the term “reticle” mean?

- ☐ Exploding round
- ☐ Safe firing position
- ☐ Aiming crosshair
- ☐ Helmet

13. On a PC first person shooter, what action would you most likely take to execute a weapon's secondary fire?

- Enter
- Backspace
- Space bar
- Right mouse button click

14. What game is generally regarded as being the first first-person shooter game?

- Halo
- Doom
- Quake
- Wolfenstein 3D

15. Doom takes place primarily on what planet?

- Mars
- Earth
- Mercury
- Na Pali

16. What is the melee weapon used in Half-Life?

- Crowbar
- Chainsaw
- Fist
- Baseball bat

17. GoldenEye 007 was originally released for what gaming system?

- [ ] GameCube
- [ ] PlayStation
- [ ] Sega Saturn
- [ ] Nintendo 64

18. What is the name of the alien enemies in the Halo series?

- [ ] Skaarj
- [ ] Zebes
- [ ] Covenant
- [ ] Chthon

19. What is the name of the main character from the Metroid series?

- [ ] Link
- [ ] Chozo
- [ ] Samus
- [ ] SRX-1

20. What character is shown in the image below?

- Gordon Freeman
- Prisoner 849
- Master Chief
- Duke Nukem

21. The logo shown below is for what game?

- Deus Ex
- Quake
- Crysis
- Halo

22. Rainbow Six is a series of games based on novels by what author?

- Stephen King
- Tom Clancy
- Michael Crichton
- Robert Ludlum

23. The Medal of Honor series of games take place during what war?

- Vietnam
- WWI
- Gulf
- WWII

24. Which of the following games does NOT have the main character wearing a protective/high-tech suit?

- Unreal
- Halo
- Metroid
- Crysis

25. Who are the primary enemies in Far Cry?

- Ghosts
- Soviet soldiers
- Aliens
- Genetically modified humans and animals

Appendix B: User Interface Questionnaire

Was the overall User Interface easy to understand and use?

- ☐ Very Difficult
- ☐ Somewhat Difficult
- ☐ Average
- ☐ Somewhat Easy
- ☐ Very Easy

The User Interface seems like a good design for this kind of simulation:

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither agree nor disagree
- ☐ Disagree
- ☐ Strongly disagree

How difficult was it to learn the following controls?

	Very Difficult	**Somewhat Difficult**	**Average**	**Somewhat Easy**	**Very Easy**
Movement	☐	☐	☐	☐	☐
Posture (kneel, prone)	☐	☐	☐	☐	☐
View	☐	☐	☐	☐	☐
Aim (note: on the desktop system view and aim are the same control)	☐	☐	☐	☐	☐
Selecting a weapon	☐	☐	☐	☐	☐
Firing a weapon	☐	☐	☐	☐	☐

How difficult was it to perform the following actions once you learned the controls?

	Very Difficult	**Somewhat Difficult**	**Average**	**Somewhat Easy**	**Very Easy**
Movement	☐	☐	☐	☐	☐
Posture (kneel, prone)	☐	☐	☐	☐	☐
View	☐	☐	☐	☐	☐
Aim (note: on the desktop system view and aim are the same control)	☐	☐	☐	☐	☐
Selecting a weapon	☐	☐	☐	☐	☐
Firing a weapon	☐	☐	☐	☐	☐

How realistic were the avatar's capabilities in these areas?

	Completely Artificial	**Somewhat Artificial**	**Average**	**Somewhat Realistic**	**Completely Realistic**
Movement	☐	☐	☐	☐	☐
Posture (kneel, prone)	☐	☐	☐	☐	☐
View	☐	☐	☐	☐	☐
Aim	☐	☐	☐	☐	☐
Selecting a weapon	☐	☐	☐	☐	☐
Firing a weapon	☐	☐	☐	☐	☐

How realistic was the environment?

- Completely Artificial
- Somewhat Artificial
- Average
- Somewhat Realistic
- Completely Realistic

Was there any noticeable latency in the simulation?

- The system was very fast
- The system was fast
- The system was adequate
- The system was slow
- The system was very slow

Can you describe the worst interaction you had in the system? What were you doing?

(Free response)

Please provide a short description of any controls that did not work as you expected.

(Free response)

What is your overall impression of the system? Please provide details for aspects of the system that you feel need improvement.

(Free response)

Appendix C: List of Tasks Trained From Each Manual

- 071-326-0541: "Perform Movement Techniques during an Urban Environment"
    - Avoid silhouetting in all areas (minimize exposure)
    - Avoid moving in open areas (streets, alleys, parks)
    - Make visual reconnaissance and plan movements ahead of time
    - Select a route with cover and concealment, if possible
    - Move rapidly
    - Don't stick weapon out beyond corner (flagging)
    - When looking around corners, lay down and expose head at ground level. Don't expose head from standing position
    - Expose head slowly
    - Move parallel to walls
    - Stay about 12" away from walls to avoid ricochets
    - Don't silhouette self in windows (move under or over windows, remain 12" away from wall)
    - Move while crouched
    - Use smoke where appropriate for concealment
    - Move in the most direct route
    - Do not fire while moving
- 071-326-0557: "Select Hasty Firing Positions during an Urban Environment"
    - When firing around corners or walls, use the right shoulder when on the right side and the left shoulder when on the left side
    - Fire from crouch or prone position. Don't fire while standing
    - Fire around side of walls. Only fire over walls that don't have an end, or if you can't see enemy position otherwise)
    - Stand back from windows when inside of buildings (don't extend barrel out of window)
    - Fire from kneeling position out of windows
- 071-440-0031: "Employ Hand Grenades during an Urban Operation"
    - Use frag grenades before entering doorway if enemies may be inside
    - When throwing a grenade up a stairwell, maintain observation to ensure the grenade doesn't roll back down. Take cover if it does
    - Break upper story windows before throwing a grenade through them to avoid having it bounce off
    - Start at the top of a building (with grenades) and work down when clearing a multi-story building
    - Take cover after throwing a frag grenade. If no cover is available, lay down with your stomach to the ground with the top of your head facing the blast