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Research Report 1742

Dismounted Warrior Network Enhanced Restricted Terrain (DWN ERT): An Independent Assessment

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14. ABSTRACT *(Maximum 200 words)*:

This research encompassed the second in a series of experiments on the functional capabilities of a collection of four Virtual Individual Combatant (VIC) simulation technologies linked in the Dismounted Warrior Network (DWN). These experiments (user and engineering) provided enhanced restricted terrain (ERT), an improved database and VIC systems. The intent was to demonstrate a reliable low cost easy to use way to insert Dismounted Infantry into synthetic virtual environments. Multiple agencies collaborated over several months; experimentation occurred in July 1998. Data collection occurred at the U.S. Army Infantry Center's Dismounted Battlespace Battle Lab Land Warrior Testbed and the Fort Benning McKenna Military Observations on Urban Terrain (MOUT) site. The four VICs were networked and the individual soldiers in their VICs appeared (visually) to each other in the virtual environment. User exercises measured the VICs' ability to support the individual soldiers as part of a team performing a collective virtual task of room clearing. The MOUT data collection was an attempt to observe the soldiers in actual room clearing. The U.S. Army Research Institute provided man-in-the-loop observations, results of questionnaires and structured interviews.

15. SUBJECT TERMS

Virtual Independent Combatant (VIC), Virtual Environments, Dismounted Warrior Network, Dismounted Infantry Simulation

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FOREWORD

This report describes an assessment of the capabilities of selected Virtual Individual Combatant (VIC) simulators, linked in the Dismounted Warrior Network Enhanced Restricted Terrain (DWN ERT) database, to support military operations on urban terrain. A follow on to earlier work, the DWN ERT evaluation is a part of a research effort conducted by the U. S. Army Research Institute's (ARI) Infantry Forces and Simulator Systems Research Units under the Work Package VERITAS: Virtual Environment Research for Infantry Training and Simulation. The assessment was part of a cooperative effort between ARI and the Dismounted Battle Space Battlelab, U.S. Army Infantry Center, Fort Benning, GA and its Land Warrior Test Bed contractor, Lockheed Martin Information Systems.

The primary focus of this research was to identify the strengths and weaknesses of four virtual reality training simulators from the Dismounted Infantryman's user perspective and to assess the capability of these VICs to support collective training for squad level missions. The findings from this research were provided on a real-time basis to personnel from the U.S. Army Infantry Center (USAIC), and the Simulation Training and Instrumentation Command (STRICOM), and formally to Mr. Jan Chervanak, Chief, Simulations Branch, Dismounted Battlespace Battle Lab, USAIC, and to LTC Tom Coffman, Project Director, Office of the Product Manager, Synthetic Environments and Advanced Distributed Simulations (PMSEADS), STRICOM, in March of 1999.

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The authors wish to thank a number of others, without whose contributions the DWN ERT assessment could not have been conducted. In addition to the assistance provided by ARI colleagues Dr. Gene Fober and Dr. Bob Pleban, and Consortium Fellows Mike Martin and Jan Jackson, Mr. Leon Rodgers, formerly assigned to ARI, provided invaluable help, especially in the evaluation of the data obtained at the Fort Benning McKenna MOUT site.

The Lockheed Martin Information Systems personnel (especially Billy Potter and Brian Plamondon), the technicians who supported the Virtual Individual Combatant systems, and most especially, the test soldiers, all contributed to this effort. The DWN ERT was a cooperative venture, and all are responsible for its success.

DISMOUNTED WARRIOR NETWORK ENHANCED RESTRICTED TERRAIN (DWN ERT): AN INDEPENDENT ASSESSMENT

EXECUTIVE SUMMARY

Research Requirements:

In a cooperative effort with the U.S. Army Infantry Center Dismounted Battle Space Battlelab and the Simulation Training and Instrumentation Command, the U. S. Army Research Institute conducted an independent assessment of four prototype Virtual Individual Combatant (VIC) simulators. Simulation is recognized as a part of the future of Infantry training, especially for military operations on urban terrain (MOUT). The VICs were designed to enable Dismounted Infantry (DI) soldiers to perform typical tasks in the virtual world. Virtual reality is increasingly used for military training, but the VIC characteristics necessary to permit the Infantry soldier to perform the necessary tasks and acquire new individual or collective skills are not fully defined. This assessment was a further attempt to identify requirements, and to provide man-in-the-loop feedback on prototype systems.

Procedure:

Over a two-week period, eight soldiers, organized as two DI fire teams, trained using each of four VIC simulation devices, and participated in engineering experiments and a set of user exercises/training scenarios. They also completed questionnaires and engaged in structured interviews. The engineering experiments explored the ability of the VICs to support performance of basic Infantry tasks such as movement and search and engagement. User exercises focused on squad room clearing. Test soldiers navigated through a real building at the Fort Benning McKenna MOUT site and the virtual building designed to represent it.

Findings:

As far as the test soldiers were concerned, the virtual systems had both strengths and weaknesses. Although each prototype VIC could support some aspects of the Dismounted Infantry set of tasks, no VIC was good at all of those tested. Each system had fatal flaws, primarily because of the difficulty involved

in producing reliable aiming and target engagement behaviors. The networking of individual VICs to permit fire team collective behaviors in support of the room clearing mission was problematic at best. Technical difficulties precluded full VIC integration and limited test soldier involvement in the collective mission. In the limited testing undertaken, performance in the real world was considerably better than performance in the VICs.

Utilization of Findings:

Data collected from this research will provide important information to developers interested in training integrated Dismounted Infantry squads through simulations. The VIC devices, still not mature enough to support squad missions, showed potential for integration of new personnel, and building squad cohesion. The DWN ERT research also provides a continuing positive step toward defining DI requirements for simulations.

DISMOUNTED WARRIOR NETWORK ENHANCED RESTRICTED TERRAIN (DWN ERT): AN INDEPENDENT ASSESSMENT

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Introduction

Virtual Reality (VR) technology is beginning to have an impact on military training. No longer is a unit always required to spend scarce resources (time and money) in preparation for and travel to large-scale training events and exercises. Soldiers are frequently able to train in simulators and experience many of the same effects as if they had actually "gone to the field."

Although sophisticated simulations can enhance military training, the technology still lags the real world. Many but by no means all of the events on a unit's training calendar can be replicated in simulation, and these vary in fidelity. Additionally, some mission essential tasks that can be done in simulation need not be. Their simulation does not represent an effective use of a training device, or of the unit's time.

There is an ongoing and relatively continuous effort to determine exactly which individual and collective military tasks can be represented well or adequately, if at all, in simulation. The Institute for Defense Analyses (IDA) responded to a 1996 Defense Science Board Summer Study request with research to explore the use of simulation for concept evaluation. This work, Small Team Portal into the 21st Century (STP21), focused on dismounted Infantry performance. STP21 was a collaborative effort by IDA, and a team of research psychologists from the U.S. Army Research Institute (ARI). The STP21, as reported in Coe (1997); Coe, Madden, Mengel & Wright (1997); and Salter, Knerr, Lampton, Fober & Dressel (1996), was a preliminary effort to couple actual (live) military personnel and prototype equipment on a virtual battlefield. It provided numerous lessons learned about the use of simulation, and the value of considering the effects of what is frequently called inserting the "man-in-the-loop."

VR, sometimes known as a Virtual Environment (VE), has also been used by other researchers for concept evaluation (e.g., Ehrlich, Knerr, Lampton & McDonald, 1997; Singer, Ehrlich, & Allen, 1998). A multi-year program involving the ARI and the Institute for Simulation and Training in Orlando has defined potential opportunities for and limitations of VR research, and some of the effects of immature technologies (Knerr, Lampton, Singer, Witmer, Goldberg, Parsons & Parsons (1998a).

There have been many attempts to portray realistic looking entities on virtual databases. This effort is sometimes difficult in the military environment. The Simulation Networking (SIMNET) device and its follow-on Close Combat Tactical Trainer (CCTT) have succeeded with fairly rudimentary portrayal of vehicles on the simulated battlefield. Aviation simulators do very well at portraying aircraft and aviators rehearsing on virtual terrain are able to transfer the knowledge to real world terrain (Johnson & Wightman, 1995). Some navigation skills, acquired in a VE by individuals, have been shown to transfer to the real world (Witmer, Bailey, Knerr & Parsons, 1996).

However, portrayal of the complex behaviors of an Infantry soldier, either alone, or together in a nine-man squad, is more problematic. Levinson and Pew (1993) provided a wide-ranging overview of the potential for VR for military training, with a focus on dismounted Infantry (DI). They looked at near and far term (more than five years in the future) technology solutions. Selected aspects of mission planning and rehearsal can be trained in the virtual world; some aspects of combat proficiency (unit) training can also be modeled. However, they cautioned that even in the far term, some of the "difficult problems to be resolved concern mission-specific training, urban and close-in operations, control and manipulation of weapons and equipment, and whole body movement" (Levinson & Pew, 1993, p. vii).

Another extremely comprehensive but also relatively early report by Jacobs, Crooks, Crooks, Colburn, Fraser, Gorman, Madden, Furness, and Tice (1994) noted that despite an Army organizational structure that emphasizes light forces, at the time of their research (1992-1993) few attempts had been made to model behaviors of individual soldiers. They noted that individual combatant simulations (ICS) are needed to adequately portray the roles of dismounted personnel in the virtual battle, and to indicate their concomitant vulnerability. Without some sort of ICS, it is difficult to determine the contributions of individual soldiers either alone or in squad size elements. Jacobs et al. also provided a taxonomy of tasks and offered suggestions for further research based on VE applications. Their suggestions provided a foundation for numerous more recent attempts to bring dismounted Infantry to the VR simulations.

The Jacobs et al., 1994 overview of the kinds of tasks that show a potential to benefit from virtual training is still valid, as are the views and task lists provided by Levinson and Pew in 1993. Unfortunately, the technology to portray an Infantryman has not progressed as well as they might have hoped. As succinctly noted by Ehrlich et al., "the major drawback to the use of VE is its relative technological immaturity" (1997, p. 15).

Stansfield and Sobel (1998) identified other issues inherent in studying human behavior in an immersive environment, including the requirements for fidelity. In using VR for training, however an individual is represented, it is critical that the depiction of the human figure be capable of performing actions with "reasonable" fidelity. High and relatively lower fidelity systems can and should be combined if needed. Users engage in complex tasks in the virtual world in two ways. "Transparent" participants can see the virtual world and move in it, but are not represented in it. They cannot see themselves and typically use external devices like joysticks or keyboards for interaction with this environment. "Active" participants, however, can impact on the environment and influence the course of events by their activities in the simulation. In military training, both approaches can be used, but maintaining the distinction between the two methods is important. Active participants appear to require more simulation fidelity (Stansfield & Sobel, 1998).

However, Wann and Mon-Williams (1996) have posed questions as to the requirement for faithful depictions of the real world in a virtual medium. The degree of "reality" that can be provided to a viewer in a commercial setting (theatre or video arcade) may not really be necessary. The virtual environment must provide the user with information needed while in that setting, for the tasks that need to be accomplished, but need not offer everything that might ever be needed. They suggest that VR be thought of as a medium to provide a user with "access to information that would not otherwise be available at that place or time" (Wann & Mon-Williams, 1996, p. 833). Their focus echoes the need to define the intended purpose of a simulation environment, to determine what aspects of reality are essential, desirable or optional.

A further question, posed by, among others, Helms, Nissman, Kennedy and Ryan-Jones (1997) and Knerr, et al. (1998a), is whether the soldier, immersed in the virtual environment, is in fact, immersed. Does the simulation induce the same kinds of stresses as a real world mission does? Does the simulation provide different (and perhaps unwelcome) sensory feedback that impacts on and detracts from the intended effects of the simulation? Knerr et al. examined the individual's ability to feel involved in or a part of the VE. They defined the construct *presence* to mean "the subjective experience of being in one place or environment (the computer-generated environment), even when one is physically situated in another (the actual physical locale)" (Knerr et al., 1998a, p. 31). The VE must create a sense of presence.

An excellent overview of lessons learned and results derived from work in simulations in the virtual environment is found in two recent summaries (Knerr, et al., 1998a; and Knerr, Lampton, Singer, Witmer, Parsons & Parsons 1998b). As noted therein, the field of virtual reality in application to training is still in flux. Preliminary conclusions and recommendations have been made about certain aspects of soldier performance that can be represented in simulations; other efforts are beginning to determine the scope of the tasks that can be portrayed, and the best ways in which to do so. Others (Witmer, et al., 1996; Helms, et al., 1997; Ford & Andre', in preparation) have shown the potential usefulness of VE trials in military operations on urban terrain (MOUT). The increasingly prevalent trend toward other than war missions in cities and buildings provides further justification for this tactic. The effort to insert the dismounted Infantryman in a virtual MOUT environment is continued in the present research, which describes use of prototype simulation devices and soldier performance.

Background

In May 1997, the ARI Infantry Forces Research Unit at Fort Benning and the Simulator Systems Research Unit in Orlando began a collaborative VR research program with the Simulation, Training, and Instrumentation Command (STRICOM) and its contractor Lockheed Martin Information Systems (LMIS). The overall plan and intent of the program, as noted on the STRICOM Web site, is to "provide a reliable low cost easy to use way to insert DI into synthetic virtual environments." The research encompassed a series of experiments on the functional capabilities of a collection of Virtual Individual Combatant (VIC) simulation technologies linked together in what was called the Dismounted Warrior Network (DWN). ARI personnel provided man-in-the-loop observations.

Part of the DWN research was conducted at the Lockeed Martin facility in Orlando, and other portions in the U.S. Army Infantry Center's Dismounted Battlespace Battle Lab (DBBL) Land Warrior Test Bed (LWTB) (also an LMIS facility) at Fort Benning. This research, initially described by STRICOM (Jones, 1995), was fully reported in Pleban, Dyer, Salter, and Brown, 1998a, 1998b, and in Lockheed Martin Corp., 1997. The term DWN has become an all encompassing label to describe the efforts to link the disparate entities representing individual soldiers combined in a virtual world, and in the context of this paper, will be used to represent the 1997 research efforts.

The Dismounted Warrior Network Enhanced Restricted Terrain (DWN ERT) exercises conducted July 6-24, 1998 are another aspect of the DWN initiative and are the focus of this report. Since this entire program is among the few enterprises actively investigating simulation opportunities for dismounted Infantrymen, the DWN ERT user exercises (USEX) and engineering experiments were again of special interest to ARI.

The DWN ERT research described in this report, like the 1997 DWN research, was also a multi-agency collaborative effort. DWN ERT was conducted under the Force XXI Program Advanced Distributed Simulation Technology II, ADST II. It used some of the same equipment and procedures as were used in the previous DWN effort. STRICOM, LMIS, DBBL, and ARI were repeat participants, and were able to build on the results obtained in the first set of experiments. Many of the same technical and research personnel were involved in both the DWN and the DWN ERT programs. This provided not only continuity, but also the ability to incorporate multiple lessons learned.

Purpose

A primary intent of these two related research programs is to show the benefits of simulation, and the effective use of the synthetic environment. Additional benefits accrue from the experimental determination of which tasks can be supported by simulations. In recent years, distributed interactive simulation (DIS) has developed sufficiently well to be viewed as a fully accepted instructional tool for the military. Many training devices are based on DIS, both as standalone trainers and in conjunction with live or field exercises. Simulation offers opportunities to try different approaches without the risk of casualties to personnel or equipment, and is frequently far more time and cost-effective than actually conducting field exercises. The aviation community has long used simulations in lieu of actually flying; ground forces have just recently incorporated simulation into most aspects of military training. Live (Combat Training Centers), constructive (JANUS) and virtual (CCTT or SIMNET) simulations are now commonly used as foundations for Army training.

The newly fielded CCTT, a comprehensive multi-echelon training device based on the decade-old SIMNET, has been characterized as "the Army's most ambitious attempt to create a realistic simulated battlefield" (Lane, 1994, p. 18). For CCTT, soldiers have been a part of testing from the start, and have worked with system developers to provide immediate user feedback, based on their expertise and knowledge of training device requirements. In the process of development of the CCTT, however, the dismounted soldier's requirements have not received the same amount of attention as those of the mounted force. Both the tank and the Bradley Fighting Vehicle (BFV) are represented in SIMNET and in CCTT; the individual dismounted soldier, accompanying these vehicles on the battlefield, is not well portrayed in the simulations.

The lack of attention to the DI is not mere oversight; the challenge has proven very difficult. The DWN experiments, both 1997 and 1998, are, however remotely, helping to address this deficit. Until very recently "the number and complexity of models required to represent even a modest force of individual combatants exceeded the capability of affordable real time computing resources" (Pleban et al., 1998b, p. 1). Research in virtual environments, however, has recently begun to focus on simulation of individual combatants. These simulations involve representing individual soldier participants in the virtual environment to the extent that their own actions in the real world are mimicked in the virtual environment. This "immersion," through direct sensory experience, provides the individual a sense of control of his own behavior, even as an avatar in the virtual environment represents him (Jacobs, et al., 1994; Pleban, et al., 1998b). As much as is possible, the individual's performance in the virtual world should provide the same cues as in the real world (Knerr et al., 1998a).

A continuing problem, however, is to decide how actually to represent the individual, in this case the dismounted Infantryman, as well as to decide which tasks he can and should do in the VE. For vehicles, these decisions are not particularly difficult. The tank and the BFV are expensive to operate; ammunition is also costly. These vehicles can also move very rapidly, and therefore, require vast expanses of terrain to accomplish meaningful training maneuvers. These factors combine to make decisions about simulations relatively uncomplicated. Any task that can possibly be simulated should be simulated.

For Infantry, small and sometimes independently moving entities on a very crowded battlefield, these decisions are not so simple. Some tasks may be better left to real world practice. Simulation may not be cost-effective, nor is it necessary. There is a continuing need, therefore, to develop a set of requirements for the simulation of dismounted Infantry. There are many claimants for emerging technologies, and a coordinated effort is mandatory.

The background efforts to the 1998 DWN ERT experiments were extensively coordinated with participants from many disciplines as well as industry representatives. Interested agencies included the Infantry Center's DBBL, Force XXI Land Warrior programs, the MOUT Advanced Concepts Technology Demonstration, the Army Research Laboratory and personnel from the various CCTT programs. These agencies were therefore, however indirectly, participants in defining the DWN ERT requirements.

The DWN ERT experiments, both the technically based engineering experiments, and the structured but more nearly free play user exercises, provide a way to better understand and refine the requirements of simulation under controlled conditions. The intent is to provide a series of reports on analyses of specific tasks (what can and should be done in simulation) and how the tasks can be accomplished through simulation. A not incidental byproduct includes analyses of the capabilities of the computer generated semi-automated forces (SAF) that are virtual combatants along side the real soldiers.

<u>Framework</u>

The most recent DWN project, described in this report, is the DWN ERT. It builds upon the lessons learned from the previous DWN effort and focuses on so-called "restricted terrain," specifically the urban operations collectively referred to as MOUT. The virtual MOUT database was modeled after the Fort Benning, GA, McKenna MOUT site, and was one of two databases used in the 1997 experiments. (The alternate 29 Palms, CA, desert database environment also tested at that time was not used for the DWN ERT exercises.)

Prior to the DWN ERT effort, the 1997 MOUT database was "enhanced" - refined, updated and made visually richer. Colors and texture were improved, and a "breachable" building was added to allow Infantry soldiers to operate in a more nearly tactical manner as they enter the simulated building. The database is still, by comparison to commercially available simulations, rudimentary, but easily adequate for the intended purpose. The experiment plan is found in Lockheed Martin Corp., 1998a and 1889b; the information on the previous experiments (DWN) can be found, as noted, in Lockheed Martin Corp., 1997, and Pleban, et al., 1998a and 1998b.

The DWN ERT experiments compared and contrasted the characteristics and capabilities of four simulation technologies. The representations of these technologies are, as before, called Virtual Individual Combatants, or VICs. The functional fidelity requirements for the four VICs were based on considerable previous research. They were, as in the past, integrated into one network for the DWN ERT exercises. This sometimes caused technical problems, as it forced each VIC to conform to a common denominator, and to operate seamlessly with other similar but not identical systems.

All of the VICs, although by no means in their first iterations, could and should be considered prototypes. They were not "hardened," nor were they reliable from the traditional criterion of mean time between failures. The effectiveness of each of these VIC technologies (described in detail below) was assessed over a series of specific Dismounted Infantry tasks as performed in a virtual MOUT environment. The final intent was to balance existing technologies and capabilities against simulation requirements, and to identify areas where future technology developments might be required. No VIC as utilized in the DWN ERT engineering experiments and user exercises is a final product; all are considered to be systems still under development.

Method

Overview

The original 1997 DWN exercises were conducted over a six-week period, the engineering experiments at the LMIS facility in Orlando, the USEX at the LWTB at Fort Benning. In contrast, the 1998 DWN ERT effort was conducted over two and one-half weeks, entirely at Fort Benning. There were three kinds of experiments. The engineering and user exercises used the virtual database and the VIC simulators. A third experiment measured soldier performance in the real world.

From July 8-10, the soldiers reported for training at the McKenna MOUT Site and then at the LWTB. They were briefed on the purpose of the DWN ERT and on operations at both locations. They also practiced squad building clearing operations at McKenna's Building L and performed some initial familiarization training activities using VIC simulators. On July 10, the soldiers participated in a special VIC demonstration. By the time the engineering experiments started the soldiers were beginning to be comfortable with VIC operation.

The engineering experiments took place July 13-17, with one morning dedicated to live data collection at the MOUT site. The LWTB engineering experiments measured individual performance, with independent measures from each VIC. The intent was to collect data on the specific performance characteristics of each of the four separate VICs. The MOUT data collection was an attempt to observe the soldiers in actual room clearing.

The second week, July 20-23, covered user exercises and fire team (collective) performance. The four VICs were networked and the individual soldiers in their VICs appeared (visually) to each other in the field of view as presented on their own VIC screens. The USEX measured the VICs' ability to support the individual soldiers as part of a team performing a collective task of room clearing in the virtual environment. The final day of the USEX week was limited to brief final data collection, a post-experiment debrief and structured interviews for all eight soldiers and the squad leader.

Test Subjects and Research Personnel

The test soldiers were nine active-duty BFV Infantryman from the 3d Brigade, 3D Infantry Division (Mechanized) at Fort Benning. A sergeant served as squad leader. A corporal, three specialists, two privates first class, and two privates comprised the two fire teams. Ages ranged from 20 to 25 years old, with time in service from 9 months to 5 years 11 months. An additional soldier, a sergeant first class, served as platoon sergeant to provide an informal chain of command and conduct AARs.

All soldiers (except the platoon sergeant) were from the same company, but from different platoons, and had not worked together before. Additionally, although it was intended that the same soldiers be available throughout the experiments, including a few days prior for familiarization, there was some within-group turnover in the first few days and an extra test soldier was recruited. Those unable to continue participation (for reasons unrelated to the experiments) were replaced, and the group was sufficiently homogeneous to make the turbulence irrelevant to the results. During the engineering and user exercise weeks, the eight primary soldiers were paired into two fire teams. The fire teams alternated sessions on the VICs to minimize fatigue. The order of presentation of targets within the engineering experiments, and the order of usage of each VIC was counterbalanced to the extent possible.

The Lockheed-Martin and VIC contractors provided technicians to keep the VICs operational. A test director and site managers provided continuity. At each VIC there were from two to four personnel who were extremely well experienced with the individual technologies, and the VIC integration. Most had participated in the DWN experiments.

The ARI observer/data collectors were either full or part-time research psychologists. The team structure comprised up to eight personnel, of whom at least four were on site at all times. One full time researcher was from the ARI Orlando Research Unit and the remainder were from the Fort Benning Research Unit. Three ARI personnel had also participated in the 1997 DWN and were therefore familiar with the VICs and the LWTB facilities and personnel.

Data Collection

The work performed for STRICOM under the ADST II (Lockheed Martin Corp., 1997, and 1998a and 1998b) provided data on the VICs and semi-automated systems. Parameter data were based on actual soldier activities and on the results of engineering measurements. These data comprised time and hits, as well as information on locomotion, target engagement, and search behavior. The ARI personnel collected human performance data, through first hand observations, and by means of paper and pencil questionnaires and structured interviews. The engineering and modeling data are available through Lockheed Martin Corp. (1998b); the ARI data collection instruments and results are discussed below.

Questionnaires

Demographic. Each participant soldier was administered a one time only demographic information questionnaire before the start of the first week of testing. (This questionnaire and all others can be found at Appendix B.)

Comfort. Each day before training participants completed a "Comfort Questionnaire." Developed by the Orlando ARI Research Unit (see Knerr, et al., 1998a), this questionnaire was intended to assess the soldier's overall daily fitness. Information included the number of hours of sleep the previous night, and reports of fatigue, dizziness, or visual difficulties prior to beginning that day's trials.

Symptom Checklist. A related questionnaire developed by Kennedy, Lane, Berbaum, and Lilienthal (1993) was used to measure "simulator sickness." In some previous experiments, prototype VR systems have tended to cause some individuals to experience fatigue, nausea, blurred vision, or vertigo after they have participated in immersive simulations. These symptoms, not unlike those of motion sickness, interfere with the intent of the simulation, and may provide safety concerns. (Reviews of the area, itself outside the scope of this report, can be found in Kolasinski, 1995 and in Kennedy and Stanney, 1996). Checklists were administered to determine if simulator sickness was evident, and to ensure soldier stability after the experiments. These questionnaires were administered immediately after each trial during the Engineering Experiments and occasionally during the USEX if it appeared that a test subject was in any physical distress.

Capability Assessment. Each soldier also responded to VIC Capability Assessment Questionnaires. The engineering trials questionnaire asked about movement, shooting, and communication. The soldiers completed this questionnaire once for each VIC. The User Exercise Questionnaire, similar but not identical, asked about those areas as well as room clearing procedures. Again, each soldier completed the questionnaire one time for each VIC, generally after his second experience on the system. Each VIC was rated (on a scale of 1 to 5) on such dimensions as realism, difficulty, speed, and similarity. The soldiers described activities in the VICs compared to the way they would have performed the same task in the real world. They described their actions as, for example, exactly like the real world, very similar, somewhat similar, somewhat different or completely different.

Observations and Structured Interviews

ARI personnel were present throughout the DWN ERT exercises (engineering and USEX), and also accompanied the soldiers to the MOUT site to observe their performance in the real world situation. In addition to administering formal questionnaires, ARI researchers watched as the soldiers performed their tasks in the VICs. They were seated in locations where they could easily monitor the action, and see both the soldiers' views and any external monitor screens. They were also close enough to be able to hear any comments made by the soldiers. ARI personnel made notes on the behaviors and verbal comments, and also kept track of mechanical problems as they occurred. Observers rotated among VICs in order to examine all the systems and all the soldiers. The comments from all the observers were combined for this report.

These same ARI personnel conducted structured interviews with the test soldiers on the final day of the user exercises. The soldiers were divided into groups of two or three, based on their rank and fire team positions, and interviewed in separate groups at various locations on the LWTB site. The interviews were deliberately informal, and encouraged free exchange of information. The soldiers were reminded that every opinion or insight was important, and that there were no "right answers" to any questions. Only the soldiers and ARI were present for these sessions.

The Virtual Individual Combatant (VIC) Simulators

In the 1997 VIC DWN effort, four distinctly different technologies were represented. The VICs provided a cross section of capabilities from different manufacturers, and each was designed from a different perspective, and with a different purpose. After the fact, these technologies were made interoperable. The DWN ERT approach was similar. Four VR systems that represented changes or enhancements to the original four systems were selected. For each of the VICs, in part based on the results of the DWN experiments, known shortfalls were corrected and specific areas enhanced before the start of the current experiments. (Photographs of the VICs are shown at Appendix A.)

In the 1997 exercises, each of the four VICs, labeled Alpha (A), Bravo (B), Charlie (C) and Foxtrot (F), had both positive and negative attributes. Some aspects of each technology proved more useful than other aspects; some VICs were more robust than others were. Specific capabilities, positive features and shortfalls are reported in detail in summary reports by Pleban, 1998a and b, and Lockheed Martin Corp., 1997. Additional information on the VICs can be found in Ford and Andre' (in preparation). Using the simulators in a slightly different context, Ford and Andre' asked experienced soldiers for feedback on the usefulness and realism of the same four systems. The DWN ERT experiments used the technologies represented by VICs Alpha (a variant of the original Alpha), Delta (D), Echo (E), and Golf (G) (a variant of the original Bravo). Delta and Echo (not players in DWN) are very similar to each other. (The technologies represented by Foxtrot and Charlie were not represented in the DWN ERT.)

For comparison purposes, the essential characteristics of the VICs are shown in Table 1. Since the primary concern for ARI was soldier performance, technical information found elsewhere is not repeated. Full descriptions of each VIC are reported by Lockheed Martin Corp. (1998a). All VICs had some features in common.

The only new equipment was the simulated Land Warrior device, the IHAS, the Integrated Helmet Assembly Subsystem. The IHAS consists of a monocular aiming device (except for VIC Golf, which could be monocular or binocular) that provided a camera-view rifle sight. This apparatus was mounted on a head strap in VICs Delta and Echo, or integrated within the head-mounted display of VICs Alpha and Golf. It could be flipped up or down depending on the situational or experimental requirement. The soldier using the IHAS saw a representation of the virtual environment, as would be projected by a video camera mounted on the barrel of his rifle. Scope-like crosshairs were superimposed over the visual display for aiming. The IHAS let the soldiers sight around corners by extending their rifle barrels, rather than their heads, past the edge of the wall or doorframe.

Table 1
VIC Comparison Matrix (adapted from Lockheed Martin Corp., 1998a, p. B-7.)

FUNCTION	VIC A	VIC G	VIC D	VIC E
Movement	Weapon Mounted Joystick	Weapon Mounted Thumbstick or ODT*	Weapon Mounted Thumbstick	Weapon Mounted Thumbstick
Visual Display	45° x 34° FOV*, head mounted display. 230 x 789 resolution	100° x 50° or 65° x 50° FOV, head mounted display. 640 x 480 resolution	90° x 60° FOV, projection display. 800 x 600 resolution	150° x 40° FOV, projection display. 800 x 600 resolution side, 1024 x 768 resolution center
Body Motion Capture	Video (position & orientation)	Harness (body posn/orientation) Inertial (head track/orientation)	Ultrasonic (position only)	Ultrasonic (position only)

Note. *Omni Directional Treadmill (ODT), Field of View (FOV)

VIC Alpha

VIC Alpha was based on the Dismounted Soldier System (DSS) from Veda, Inc. A participant system in the original DWN experiments, it was upgraded for DWN ERT. VIC Alpha tracks body motion through sensors attached to a special uniform and boots. The soldier uses the IHAS for weapon aiming. The IHAS presents a weapon sight (front and rear posts) or scope view on a monocular head mounted display. The soldier in VIC A can stand or assume kneeling or prone positions. The weapon replicates an M16 rifle.

VICs Delta, Echo and Golf

VICs Delta, Echo, and Golf are all based on the Soldier Visualization Station (SVS) developed by Reality by Design (RBD), Inc. The SVS tracks user position and modifies the field of view (FOV) as the user gets nearer or farther from the screen. Aiming is through the IHAS or the actual weapon sights. The SVS consists of two Pentium PCs, proprietary software, and an inertial/acoustic tracker for body position and weapon pointing. VIC D has one flat screen on which images are projected by a rear projection device. VIC E is similar to VIC D, with a greater FOV provided by three screens, with a curved parabolic surface, as if cut from a dome. The center screen has higher resolution than the sides. Soldiers in VIC D and VIC E can assume all normal firing positions.

VIC G also uses an SVS system. A participant in the earlier DWN experiments, VIC Golf (then labeled Bravo) used the Omni-Directional Treadmill

(ODT) developed by Virtual Space Devices, Inc. Originally designed for use with the walk-in synthetic environment (WISE) system, the ODT provides 360° directional locomotion. The IHAS display can be either binocular or monocular. Soldier posture changes (standing, kneeling, and prone) are controlled by a switch on the weapon; the soldier cannot physically kneel or take a prone position while on the treadmill.

Semi-Automated Forces

Both the DWN ERT engineering experiments and the USEX were run with the four VICs as manned subsystems, with computer-generated targets, and other support entities as required. In addition to the VICs, additional fire teams were represented by computer-generated DI SAF (Dismounted Infantry Semi-Automated Forces). The DI SAF provided an Opposing Force (OPFOR) squad during the USEX as well as a BLUFOR (Blue Forces) fire team and squad in support of the VICs. Additional support functions networked to the VICs included a joystick controlled computer station (BAYONET) for the squad and platoon leader role players and a workstation for the OPFOR sniper. Data collection and after action review (AAR) capabilities were transparent to the soldiers operating the VICs. (Information on SAF functions can be found in Lockheed Martin Corp., 1998a and 1998b.)

Since there have been significant enhancements to the DI SAF since the earlier DWN experiments, one object of the current experiments was to assess how well the DI SAF performed as compared to real soldiers. Therefore, the DI SAF performed the same experimental tasks that the soldiers were tasked to perform in the engineering and user exercises. The manned simulators were limited in number to representation of a fire team; since the plan prescribed a platoon scenario, DI SAF filled out the platoon as a second fire team, and as a second squad. The intent was therefore to compare live (simulated live) soldier performance with computer generated SAF behavior. (The DWN ERT DI SAF results are not included in this report but can be found in Lockheed Martin Corp., 1998b.)

Besides the changes required to individual VICs to enable networking, the SAF and supplementary systems were also modified and adjusted as necessary to ensure interoperability and compatible components. This integration of different technologies for locomotion and target engagement forced the lowest common denominator capabilities in an effort to have all systems work together.

Experiments

McKenna MOUT Site

The live MOUT experience occurred one morning late in the week of the engineering experiments but for simplicity, it is described first. The soldiers performed some of the same tasks at McKenna that they were performing in the virtual world. The intent was to establish some level of validation or correlation for the data collected during the simulation experiments and to help assess how well the virtual experience supported execution of the same tasks in the real world. The purpose of taking the soldiers to the McKenna site was to see what transfer (if any) there would be between the virtual environment and the live environment.

One VR research question addresses how closely the virtual world replicates the real world. The fidelity of the McKenna database was tested using two approaches. The first asked a probe question about database fidelity. The test soldiers had trained on virtual building assault in the LWTB. The practiced scenario began at a line of railroad ties about 200 meters south of Building A. After a hole was blown in the side of the building, the soldiers performed an assault, rushing from the railroad ties to the building.

Upon arrival at McKenna, the soldiers assembled at the corresponding point on the ground south of Building A. They were asked to remember what they had done in the virtual database and then told to approach the building. When they reached the side of the building, the soldiers were asked their opinions on the database's representation of distance, relative to the real world. An ARI researcher also questioned the soldiers.

A second attempt to address transfer had the soldiers perform an inside locomotion task in both the virtual world and the real world. The soldiers had practiced two routes through Building A in the VICs. In a typical practice session the soldier was helped when turning by someone familiar with the routes. Practice in the building was limited, but improvement was evident. To the extent that their practice on the VICs in the virtual world represented a task similar to the real world task, real world performance ought to have been improved by the practice.

At the MOUT site, the test soldiers individually performed the locomotion routes from memory. They wore electronic sensor devices so their progress could be tracked in the AAR facility. Each soldier walked through the building, a two-story multi-room town house. The task was performed three times.

For the first two iterations of this task, the soldiers were instructed to complete the route as quickly as possible without making errors. The soldier, followed by a researcher, entered one doorway, passed through several rooms to the stairs, went up the stairs, through another series of rooms across the top floor of the second townhouse, down a second set of stairs, across the bottom of that building section, and out through a second door. This task replicated a task from the engineering experiments (described in the next section). The order was counterbalanced so half entered first at one door (Route A); the other half reversed the direction (Route B). Each soldier repeated the task, with the original entry point and path reversed. During the third trial (tactical locomotion and search), they were told to operate "tactically," and not try for maximum speed, but ensure that a room was clear of snipers before passing through it.

The final activity at McKenna consisted of several room clearing trials. The soldiers rushed as a squad from the side of Building A, entered through a window, into a room, and cleared the first floor of the townhouse. They were required to perform room clearing to the standard documented in FM 90-10-1 *An Infantryman's Guide to Combat in Built-up Areas* (Department of the Army (DA), 1993). The purpose of this exercise was not only to ensure that they knew proper room clearing procedures, but also to serve as a basis of comparison for the USEX room clearing. It was important to see the soldiers clear rooms in the constructive environment in order to observe what could and could not be replicated in the virtual environment. As before, ARI personnel observed performance during the several iterations of the task.

Engineering Experiments

The stated purpose of the DWN engineering experiments was "to compare and contrast ability of key features of the various VICs to support dismounted Infantry (DI) task performance in a virtual environment" (Ferguson, 1997, Slide 20). Using VICs that had been modified based on the results of these experiments, the DWN ERT follow-on engineering experiments assessed the soldiers' ability to acquire and engage man-sized targets, and to move inside and outside of buildings in the simulated environment (Lockheed Martin Corp., 1997). The DWN experiments measured VIC functional capabilities only; in DWN ERT the systems were used for collective task performance.

The following sections provide descriptions of the engineering tasks. They included multiple iterations of movement, aiming, and visual search and target acquisition tasks. They are briefly described here; fuller detail is available in Lockheed Martin Corp., 1998b. In the engineering experiments, although all four soldiers were in the VICs simultaneously, performing the same tasks, their performance was independent, and they could not see each other. Attempts were made to counterbalance order, and to ensure that each soldier performed all tasks on each of the VICs. Occasionally a soldier was unavailable for his turn, or one of the VICs malfunctioned. Some of both the engineering data and the observations were therefore lost. There were sufficient numbers of iterations, however, that this appeared to be of no consequence. Performance data were collected electronically and ARI maintained observers at each of the VICs to note equipment failures or to record soldier comments and behaviors.

Locomotion experiments. The purpose of the locomotion/mobility experiments was to determine how well each VIC could navigate through the VE by maneuvering to and through a building. As noted before, the actual McKenna MOUT training site at Fort Benning has been partially modeled in the database, and the soldiers were able to move into the virtual Building A.

The basic locomotion task was to negotiate inside Building A. The two story building is laid out in such a way that the only way to cross from one section of the building to another is from the second story level. This ability to cross became a critical part of the task. The visual representation of the layout of the building was identical to McKenna in nearly every respect. The basic rooms and the stairwells were represented as in the real world. A noticeable difference, with unknown impact, was that while the actual site has furniture in the rooms, the virtual rooms were empty. The VR doors and windows were in the appropriate locations, but there were no furnishings.

As was replicated at McKenna, the soldier entered the virtual building at one door, passed through rooms on the ground floor, ascended the stairs, crossed the top floor, descended the second set of stairs, crossed the ground floor, and exited the building. Each soldier performed this task several times, starting at each of the doors. This required frequent changes in direction, speed, going up and down stairs, and movement through confined areas, such as through doors and hallways. They were told to negotiate the course as quickly as possible but slowly enough to minimize collisions with walls. Each soldier tried the course on each of the four VICs. Speed and numbers of collisions were recorded, and observers made written comments on soldier behavior. Soldiers also filled out questionnaires after their sessions.

Target search and engagement experiments. These experiments were conducted to assess how well the VIC visual and weapon system components allowed the soldiers to scan and search for, acquire and detect DI targets in the virtual environment. The soldier task was to locate, track if necessary, and shoot at both stationary and moving targets at ranges up to 200 meters. For the visual search engagements, both target distance and speed varied. Again, although four soldiers were in the VICs simultaneously, performing the same tasks, their performance was independent, and they could not see each other although they could often hear simulated gunfire. The database for this task was an otherwise sterile desert-like environment without clutter.

For the locomotion search and engagement tasks, the soldiers moved through the database in an attempt to locate stationary, non-reactive DI targets.

One set of targets was presented as the soldiers maneuvered individually inside Building A. This search task encouraged fast horizontal side-to-side scanning for targets at close ranges, inside rooms, throughout the building. Another set of targets was positioned along the streets and inside and behind other buildings. The soldiers individually walked from one end of a street to another on a predetermined path, acquiring and then shooting at targets. The outside search task involved both horizontal and vertical scanning, since targets were placed on rooftops and at second and third floor windows. Data collected included time to detect as well as time to engage, number of targets successfully engaged, and accuracy (hit location or miss distance). As with the earlier experiments, there were post session debriefs and ARI questionnaires.

Aiming posture experiment. The weapon aiming posture experiments were conducted to assess how well the VIC weapon tracking and visual systems permitted acquisition and engagement of DI targets in the virtual environment. All targets appeared directly in front of the test soldiers, in the primary field of view, so no one had to search for any target. The targets were presented at varying ranges and orientations, and each soldier fired from all VICs, from the standing, kneeling, and prone positions. As before, although all four soldiers were in the VICs simultaneously, their performance was independent, and they had different target presentations. Data were collected on engagement times and accuracy. AARs and questionnaires followed each session.

User Exercises

The purpose of the first DWN USEX was "to evaluate the capability of the DWN systems and the overall system of systems to support the execution of individual and collective tasks and missions within a virtual environment" (Ferguson, 1997, Slide 25). Lockheed Martin Corp., 1998b described two DWN ERT objectives: to assess the operational utility of the VICs when used within a goal oriented mission context, and to see how well improved DI SAF could be used to augment the VICs in mission execution. The USEX evaluated the four VICs in terms of individual and collective (small team) task performance.

The DWN ERT USEX was conducted in the week immediately following the engineering experiments with the same soldiers participating. The soldiers, already trained on the VICs, used the simulators within the context of squad performance in an urban mission. As during the 1997 DWN USEX, the intent was to assess how well each VIC supported individual and fire team performance for specific dismounted Infantry tasks, with a focus on building clearing tasks. DI SAF provided virtual fire team and squad support for the VICs, and also appeared as OPFOR. The interactions between the VIC soldiers (virtual entities) and the DI SAF virtual entities were also assessed.

The engineering experiments evaluated VIC capabilities in isolation; the USEX provided a mission context to move, shoot and communicate. By providing a situation soldiers were familiar with, they could assess the operations of the simulators as compared to the real world (Lockheed Martin Corp., 1998b). Although performance was timed, most data were subjective. The scenario provided a squad assault on a building, followed by a systematic searching and clearing of the building.

The VIC soldiers comprised a fire team acting as a dismount element from a Mechanized Infantry Platoon. The platoon task was to seize, secure, and then clear a building, in this case McKenna's Building A. The first squad was totally comprised of SAF, with a SAF Squad Leader and two SAF fire teams. The second squad was comprised of a Squad Leader with two fire teams. The VIC Fire Team (real soldiers) was Fire Team Alpha; Bravo Fire team was SAF. The squad leader (the Sergeant) sat at a computer terminal and used a joystick to move. His role was to guide the fire team, but not to participate in the VIC technology evaluation per se.

All soldiers could see the VICs, the SAF fire team, and the other SAF squad in their virtual worlds. Individual soldiers were marked according to squad and fire team name by letters and numbers on the backs of their uniforms, e.g., 2A4 to identify the fourth man of Alpha's second fire team. The only limitation was that the VICs could not see themselves (their own virtual bodies) on their screens, although their own hands were occasionally visible.

The virtual squads were equipped with a mix of simulated Land Warrior and conventional weapons. The Land Warrior equipment consisted of weapon-mounted video displayed on the soldier's simulated IHAS. For this experiment, all VIC fire team members were equipped with M16 rifles rather than the M16 in combination with the M203 grenade launcher or M249 Squad Automatic Weapon (SAW) which would have been more representative of a typical DI squad.

Most of the data collection occurred over two days as portions of several days were reserved for demonstrations. Test sessions took approximately one hour, which included the VIC mission and the AAR. As was the case during the engineering week, the soldiers alternated with each other, one team on the VICs, one team filling out questionnaires or otherwise on break. The data collected were similar to those collected during the engineering experiments, as well as the questionnaire data and observations made by ARI.

Results

The technical results of the engineering experiments and user exercises have been published elsewhere (Lockheed Martin Corp., 1998b). This report supplements that information and provides interpretation of the data collection sessions from a slightly different perspective. User and observer comments are incorporated, along with interview data. The results are presented with live MOUT site performance and observations detailed first for a baseline reference; LWTB engineering and user experiments follow. Questionnaire results and soldier structured interview remarks are provided last.

McKenna MOUT Site

Database Confirmation

As the preliminary task at the McKenna MOUT site, the soldiers were asked: "Based on your experience with the MOUT site in the VICs and here on the ground, do you think the simulation distance seems shorter; the simulation distance seems about the same; the simulation distance seems longer?" Generally, they believed that the distance representation in the database was accurate. Six of the nine soldiers said they thought the distance was about the same, one checked shorter and two checked longer. Since they had the opportunity to view the distance from the start point as well as to travel the distance in both the virtual and real worlds, it appears that the soldiers believed the database accurately represented distance outside the buildings.

Locomotion

The next task was locomotion through the building. An ARI researcher followed each soldier, and occasionally, if the soldier was very disoriented, assisted him in regaining his orientation. During both the non-tactical (NT, as quickly as possible) and tactical (T, with care) runs, times were recorded (see Table 2). In Route A (both NT and T) the soldier started with one doorway, went through the rooms and up to the second floor, across and down and out the second (B) door. Route B (NT and T) is the same route, in reverse direction. The ARI observers noted that during tactical movement, several soldiers silhouetted themselves in doorways and windows. Additionally, they did not hug walls or stay low while moving through hallways. Personnel who became disoriented during the non-tactical movement were able to complete the route after redirection by the observers.

The times to complete the routes at McKenna are in great contrast with the times to complete the routes in the VICs at the LWTB. At McKenna, the average time to complete Route A was nearly 74 seconds, with a range of 49 to 94 seconds. The average time to complete Route B was 67 seconds, with a range of 50 to 83 seconds. For the other task, a slower more careful completion of the route using individual movement techniques, the soldiers averaged over two minutes, with a range of 94 to 194 seconds.

Table 2
McKenna Locomotion Times (Seconds)

Soldier	A - N/T	B - N/T	Note	A/B - T	Note
1	79	80	a	B 114	b
2	74	79	c	B 183	b
3	49	67	a	B 104	b
4	89	52	c	A 94	e
5	70	50	c	A 148	e
6	69	83	a	A 120	e
7	84	54	d	A 121	e
8	57	73	a	A 134	b
9	94	59	a	A 194	b
Mean	73.89	66.33		134.67	
S.D.	14.6	12.98		34.38	

Notes. a Performed route as rehearsed; b Used correct tactical search & movement skills; c Entered rooms out of sequence on 2nd floor; d Entered rooms out of sequence on 1st floor; e Did not use good tactical search & movement skills.

Table 3, adapted from Lockheed Martin Corp. (1998b), compares times for the real and virtual locomotion tasks. This table represents the average time for each soldier, in the real and virtual worlds, all non-tactical routes combined. Only eight soldiers are shown as the ninth soldier, the squad leader, participated in the McKenna locomotion exercise, but was not a participant during the LWTB exercises.

Table 3
Comparison of Live (McKenna) and Virtual (LWTB) Mean Times (Seconds) on Locomotion Task

Soldier	McKenna	LWTB
1	80	318
2	76	234
3	69	309
4	58	336
5	70	213
6	65	303
7	60	192
8	76	371
Mean	69.25	284.16
SD	7.91	63.71

Even when the soldiers were instructed to move slowly and check around corners, times at McKenna were much faster than times in the VICs. The VIC times typically ranged from three to five minutes, exceeding even the slowest real world times. The soldiers were clearly unable to do as well in the VICs as they had done on the ground. However it is possible that with more practice, the LWTB and McKenna times could become more nearly comparable.

These findings must be also considered from the standpoint of numbers of data points, and rigor of measurement. Several of the soldiers had previous, albeit limited, experience in the MOUT site building, or in the VICs, and the squad leader, present at McKenna, did not participate in the VIC trials. The virtual database had a scoring protocol to tabulate collisions. However, since no soldiers ran into walls in the real world, scoring at the MOUT site was limited to time, and was by stopwatch, not computer.

Room Clearing

Other non-quantitative behaviors (e.g., wall hugging and searches) were compared with the standards from FM 90-10-1 (DA, 1993). In addition to timing the routes, ARI tracked behavior during the different iterations of the locomotion and the room and building clearing scenarios to see which aspects of room clearing were done in accord with the FM, and which were not. An observer was posted where he could see the soldiers. The scenario consisted of a squad entering a building to clear designated rooms.

Room clearing data are shown in Appendix C. The test soldiers, although not experts at room and building clearing, were sufficiently familiar with the procedures detailed in FM 90-10-1 to be able to perform most of the key tasks in the building at McKenna correctly. The observers felt that the fire control was good, and movement to and through the objective was smooth and fairly well coordinated. They maintained security outside the building, and "stacked" (maintained close formation) inside. However, they were not proficient at within-building security and did not use good tactical positions. Some silhouetted themselves against windows and a few actually stood in front of windows. Since the soldiers had only minimal practice together on any of the clearing tasks, there had been little chance for the leaders to critique individual performance, and no attempt to develop a good squad SOP. Most of the failures to perform to standard can thus probably be attributed to lack of practice.

On the other hand, as will be seen later in descriptions of the room and building clearing in the LWTB, the soldiers did not fare as well in the virtual world. In some cases, non-performance was because of simulation technological limitations; in others, the soldiers were concentrating on how they were performing (locomotion and aiming) rather than what they were doing. However, many of the critical tasks could be performed in the simulation.

Researcher Observations: Engineering and User Exercises

During both the engineering experiments and the USEX, ARI observers watched the soldiers during their VIC activities. The researchers rotated between VICs over the course of the week, and did not watch the same soldier each time. The intent was not to gain information on the individual soldiers, but to see how well suited each VIC was to the different tasks presented. Some comments are based on simple observation of behavior; others are based on notes of spontaneous remarks made by the soldiers, during or after the activity. Occasionally a researcher queried a soldier about specific behavior if it appeared unusual or out of the ordinary. Overall comments and observations from the two-week period are consolidated below, and separated by VIC.

VIC Alpha (Sensor Suit)

The search and engage trials seemed to yield generally positive comments and results regarding target acquisition and firing of the rifle. Accuracy (without the IHAS) was relatively good, compared to the inaccuracy of the other simulators' weapons systems. Outdoor maneuvering and target acquisition in the MOUT environment appeared reasonably good with this VIC. There were some negative comments, however. The soldiers felt that the joystick position was awkward, and said that sometimes their own arm and hand appeared in front of (instead of adjacent to) the rifle in the visual display. A delay between trigger pull and actual rifle firing also caused difficulty in striking targets, particularly at longer ranges. Occasionally, targets stayed up after being killed. This resulted in two targets in view when the new target was released. With this system, the IHAS created more problems in identifying targets than did the use of iron sights. The soldiers said that the IHAS display blurred, the target "jumped around" within the visual display, and the aim was as much as 45 degrees off when using the IHAS.

Most annoying to participants was frequent downtime, as well as the relative difficulty in preparing to use this simulator. Calibration issues (frequency, elapsed time) continued regardless of the type of trial. Battery problems were also a significant detriment to this system, with frequent interruption of trials as batteries went dead in the middle of a trial.

Locomotion was very difficult in VIC A due to the soldier's avatar becoming "stuck" in walls, teleporting through the roof and walls into other areas or buildings, with particular difficulty noted while attempting to negotiate stairwells. These recurrent problems generated many expressions of frustration and disgust by participants. They also produced unrealistic scenarios when the VICs were networked as a fire team and each participant had an area of responsibility to cover. Participants in VIC A frequently broadcast radio communications such as "I'm on the roof again" or "I fell through the wall."

Additionally, the Alpha avatar sometimes simply disappeared from the view of other participants when he teleported. Other fire team members attempted to help VIC A through scenarios by informing him when he was unknowingly stuck in a wall. Before being asked to desist from this behavior, one soldier was observed looking to VIC A's monitor screen, within his field of view, and calling navigational directions to the VIC A soldier. All of these factors contributed to a decline in the overall realism of the vignette being simulated.

VIC Delta (Flat Screen)

Locomotion trials were performed relatively easily in this VIC. Outdoor movement and stacking maneuvers were excellent, in keeping with overall ease of motion. While no VIC was rated as more than somewhat similar to the real world in tactical movement, this VIC rated highest in many. Most soldiers agreed that VIC D was among the easiest to maneuver in, but some difficulties were observed and reported. The position sensors had difficulty picking up the taller soldiers who had to look up at the sensor antenna to check their position. It was also necessary for all soldiers to look down to ensure they had not moved past a tape-line on the floor, beyond which their position would not be accurately registered. Whenever soldiers inadvertently moved beyond this line the visual display became blurred and distorted, rendering it useless. The avatar occasionally jumped through walls or got stuck in the stairwell.

In search and engage trials, soldier position was a major factor affecting the ability to acquire and engage targets. A prone soldier was represented as below ground level, and any rounds fired struck the ground immediately in front of him. The only solution was for the soldier to stretch up on his elbow in an awkward and unnatural manner, so that the sensors could register him as above the ground level. Iron sight aiming was also a major source of frustration for soldiers in VIC D. It was so inaccurate that targets were missed at point-blank range on several occasions. This caused the soldiers to make only cursory attempts to aim the rifle, particularly if the target was presented at long range. Adding to the annoyance was the inability to compensate by using "Kentucky windage" techniques due to the inconsistency in the degree of error from target to target, and trial to trial. However, in trials with the IHAS, accuracy and subsequent participant satisfaction were greatly improved.

There were some complaints voiced about hand and wrist fatigue from thumbstick manipulation, particularly during search and engage trials, but such observations were relatively infrequent. Overall integration with other VICs was fair, although problems were observed when avatars levitated and disappeared and reappeared in the visual display. It was also very difficult for the VIC D soldier to move around or near other virtual soldiers in the visual display.

VIC Echo (Parabolic Dome)

Search and engage and posture trials produced observations similar to those noted with VIC Delta. The ability to aim the rifle accurately and strike the target was severely limited, particularly when the shooter was in the prone position. As with VIC D, the sensors appeared to place the soldier below the horizon. An extremely small percentage of targets fired upon from the prone position were hit. Results were not much improved when the kneeling or standing positions were used, due to poor calibration of aiming sights. Detection of distant targets was very difficult.

When the IHAS was used in VIC E instead of the iron sights, results improved dramatically but unacceptably. When the IHAS was in use, and the target was lined up in the cross hairs, the physical rifle was actually oriented from 45 to 90 degrees away from the target as it appeared on the screen. The degree of inaccuracy was inconsistent, and made it difficult to hit targets. Some soldiers were observed holding the rifle above their heads in a very unrealistic manner in both the kneeling and prone positions.

Locomotion trials produced generally favorable reactions overall regarding VIC E. There were several complaints about locomotion with the IHAS engaged. Most participants stated that it was very difficult to maneuver with the IHAS down, and nearly all flipped the IHAS up when walking, then back down when it was time to aim the rifle. This was time consuming and unnatural, and one individual stated, "In the real world, having to flip this thing up and down all the time would eventually get me killed." (Although this would appear to be a problem with the IHAS concept, it was reported only for VIC E.)

Technical problems occurred with the VIC E projection system on a few occasions, with one of the three panels turning green or going blank. Additionally, vertical lines sometimes appeared between the three screens. Integration of systems was also intermittently problematic. The posture (i.e., standing, kneeling) of the VIC E avatar was often misrepresented on the visual display of the other simulators, including the Bayonet machine operated by the Squad Leader. This misrepresentation resulted in the Squad Leader's impression that VIC E was not following orders, and that the VIC E participant was out of position during fire team exercises, when in fact he was not. This apparently was caused by errors made in tracking VIC E's head position.

VIC Golf (Omni-Directional Treadmill)

A few soldiers were able to develop a relatively high degree of competency on the omni-directional treadmill (ODT), but most had some difficulty becoming accustomed to maneuvering on it. This led them to focus on the physical act of walking and maintaining balance, which diminished their ability to effectively participate in trials. Some participants said they were more concerned with falling than with completing the mission.

The true effectiveness of VIC G is difficult to determine due to the fact that it was so infrequently fully operational. Problems of a technical nature persisted throughout the two-week period. These included the ODT clutch engaging, which effectively stopped trial participation, as well as other glitches that interrupted trials. Soldiers became entangled in the harness apparatus, particularly when they attempted to turn. This frequently necessitated abandonment of ODT usage in favor of joystick controlled movement.

In was quite difficult for VIC G soldiers to determine their own posture (prone, kneeling, or standing). This led to additional problems in maneuvering. One soldier, asking why he was moving so slowly, was told by the technician that it was because he was kneeling. The soldier had thought he was standing. There were other problems when the avatar became stuck in walls, especially when he attempted to negotiate doorways and stairs. The avatar often was transported through walls to the outside of the virtual building, or to underneath the stairs.

There were problems with the weapon and aiming systems. The most immediately apparent was the visual representation of the rifle in the IHAS. The rifle appeared to float at an odd angle in front of the soldier, in a manner patently inconsistent with reality. When aiming the weapon, soldiers were forced to hold the rifle at a difficult angle in order to fire, with the stock extended laterally approximately six inches off the shoulder. The magazine clip caused a recurrent problem. It repeatedly fell out of the rifle and the ODT had to be stopped to retrieve it.

The instability of the ODT contributed additional difficulty in acquiring and aiming at targets. Soldiers reported that they would get a target lined up, then the ODT would jerk, causing them to lose sight of the target. Additional observations were that distant targets tended to flicker, and the IHAS sights were poorly calibrated. Most participants expressed overall dissatisfaction with both the weapon and aiming systems on this VIC.

During integrated fire team exercises, there were problems when VIC G was unable to keep up with the team. When the four VICs were "stacked" in a room, the VIC G visual display often failed to display other fire team members in the room. Inability to determine body position also caused problems in the integrated team mission. This caused fire team members to appear to stand on top of one another's avatars, which led to teleportation and avatar levitation.

Structured Interviews

Another source of data on the VICs was structured interviews. The soldiers were divided into small groups (2-3 personnel) and interviewed by an ARI researcher. The interviews were conducted on the final day, after two weeks of testing. By then the soldiers were quite familiar with, and comfortable with the researchers. They spoke freely, answered specific questions and also volunteered information. Their comments in response to the questions are presented in Appendix D, and summarized below, by VIC. By and large the original wording is retained in the Appendix although soldier identification has been removed. All of the test soldiers, and the squad leader, were interviewed. The sections below provide the essential elements of their answers to each question, with some quotes.

The comments reported here are selective, however, and represent a compilation of what individuals said. Some of the same positive and negative comments could have been made about more than one VIC; the soldiers only mentioned the things they felt most strongly about for each VIC. The first two questions asked about the most and least desirable aspects of each VIC. Not surprisingly, there were fewer positive comments than negative.

Best Features of Each VIC

Alpha. Shooting and aiming were more realistic than with the other rifles. They could hit targets when they lined up the front and rear sight posts with the target. Looking around corners and to the left and right and good peripheral vision was a benefit. The actual weight of the weapon made it feel like carrying a real M-16 rifle. Freedom of motion, and being able to rotate 360 degrees, to kneel and turn head and body left to right, was good.

Delta. VIC D was easiest to operate. The joystick facilitated movement and maneuver and VIC D could glide through doors and up stairs through the building faster than the others. The IHAS had a good field of view. "When I wanted to kneel I really had to take a knee, rather than just push a button to simulate taking a knee…this made it feel somewhat real. " "Your body mimics the real world even though you're not connected. Your eyes are his eyes."

Echo. The IHAS provided good peripheral vision for identifying targets and seeing objects. The wide FOV was helped (enhanced) with sighting and firing with a clear display with 180 degrees of vision. Movement was realistic. "You can pie [move systematically] around a corner and go through doors." They did not get stuck in walls as easily as in the other VICs. The audio was "awesome", and "you can kneel without a button."

Golf. The physical aspect of being able to run and walk through the building made the mission seem more real. It gave a very good sense of actually engaging in physical movement.

Least Desirable Features of Each VIC

Alpha. Head movement caused a delay in the visual display, and it got fuzzy or blurry. The batteries went dead too often and the system went down. The shirt was a hygiene issue when it became sweaty after repeated use. They would have preferred it on top of their own shirts or with the sensors hung off a vest or using snaps and hooks. The equipment was a "hassle". They also did not like to put their feet into the same boots as everyone else. The head display was hard to adjust and difficult to get right over glasses. Bodily motion was limited since they had to stay close to the center of a defined area. They would have preferred to physically walk around and not remain stationary, especially when assaulting a building. It was hard to move about with the joystick and "getting stuck in the wall made it hard to stay focused on the mission." One said he "did not feel in contact with the other guys in my fire team."

Delta. They sometimes had to pull the trigger more than once to fire. Magazine change was unrealistic; the rifle was too light and did not feel like a real one. The screen got blurry and "I had to be careful not to move or drift too close to the screen." "Constantly having to move back and forth to clear my vision made it hard to identify targets." With the IHAS, the small field of view made it hard to see and judge the distance of far targets. The thumb joystick was hard to control. "You had to crouch down to be able to look up on top of buildings." In the prone "I had to push myself up very high on my elbows to see targets. In the real world, this would have left me exposed to enemy fire."

Echo. It was complicated to look at the screen and the IHAS at the same time. "I had to keep flipping my IHAS up and down to move and see targets." The screen kept changing colors and "this made it hard for me to stay focused" and hurt concentration. They suggested a button that brings the IHAS up when needed. It was hard to adjust fire on the sides, and like Delta, you had to crouch to look up. The joystick was less of a problem because of the wider field of view. "When I tried to move fast from left to right, I always got dizzy."

Golf. It was easy to get disoriented. "I couldn't do a 360 without getting tangled up in the harness and wires." It was very hard to walk with the IHAS down - "I had to keep looking down at my feet to keep my balance." The treadmill was very jerky and too sensitive to movement. "If I moved my shoulder slightly, the treadmill would take off." The peripheral view was limited and they could mainly look only straight ahead. Turning the body to see what was going on was a problem. "I always had the feeling that I was going to fall." "At times, I found myself focused more on keeping my balance and not the mission." It was hard to keep up with other VICs and to approach and turn corners. Aiming was poor as "the floating weapon was always off." The head mount should have one large eyepiece instead of two separate ones. It was hard to zero the weapon and line-up targets in the crosshairs. A slight movement while trying to remain stationary would change the view. They did not like using a button to change posture and often did not know what posture they were actually in.

Similarity to the Real World

Visual display. Five of the nine soldiers said that VIC E was most like the real world because the view was wide and clear. Two more chose a combination of D and E, stating that E gave them a sense of being outside. Two chose VIC A. As for least like the real world, three chose VIC G, primarily because the view bounced when they were running. Two chose VIC D because of the one screen view, and two chose A because the view was "distorted." Two said there was no difference, that if the visuals were all working they were all the same.

Movement. Only one selected D as most realistic, because it was faster. The other eight all chose VIC G. They said "if it worked it would be awesome" but it was hard to keep up. Most selected VICs D or E as least like the real world because they were joystick controlled, and more like playing a video game. Moving forward and laterally was hard.

Shooting. Five soldiers said VIC A was most realistic, because they could look and shoot through front and rear sight posts. The front sight post "provided the feel of actually pointing my weapon at targets." Others selected D or E when shooting with the IHAS. Six thought that VIC G shooting was least like the real world. It was hard to line-up the IHAS and sight the weapon, and unexpected treadmill movements made it hard to aim and keep balanced at the same time. Despite the relatively good results from shooting with the IHAS, several noted that in VIC D and E the IHAS and the weapon were not synchronized as if the IHAS was not zeroed properly.

Changes for the MOUT Database

Most of the soldier responses focused on adding mailboxes and cars outside, and adding furniture and obstacles inside the rooms. They noted that in real life they couldn't just run through a room without looking. Furniture would give the OPFOR something to hide behind and also add realism. They thought that different rooms should have different features and should not all be alike. They also requested better contrast between doorways, stairs, openings and the walls. With everything the same color, there is no depth perception. Ideally, soldiers and enemy should be able to cast shadows.

At first it was very difficult to differentiate friendly and enemy fire teams because the uniforms were basically the same color (green) and all weapons were the same shape. When (in the middle of the exercises) the OPFOR uniforms were changed to black it was very easy to identify them. Identifying their own fire team members was easier than in the real world because of the large numbers on their backs.

They thought that when they bumped into the walls they needed a signal or sensory feedback, like in the real world. Another suggestion was that some walls should appear to be dry wall, not concrete, to increase awareness of the danger involved with shooting through walls. They asked that civilians be added to the scenarios, and that soldiers be able to be wounded, have the option to call for a medic, and have one appear. They also said that the weapons should physically look different, that "a SAW should look like a SAW and a 203 like a 203." There should be more noise in the VR, and use and sounds of grenades.

The Best Possible VIC

Another question asked the soldiers how they would combine the features of the VICs to produce the best possible VIC. There were many possibilities, but the overall task was to combine positive aspects of VICs, ignoring the aspects they did not like. They suggested aiming from A, with the somewhat realistic virtual iron sight and a weapon where the weight was correct. In A, they felt like they were actually in the simulation (immersed) with equipment on, but although they liked the sensor concept, they did not want the reflectors which kept falling off, nor did they want to share a shirt. One suggested a "real, full-body, VR suit." They liked that A provided the opportunity for all firing positions; the absence of wires (full mobility) was a benefit. Some suggested that combining the wires into a pack for VICs D, E, and G would help.

They wanted the physical aspect of the locomotion from Golf but not the ODT itself unless the treadmill was without the wires, harness and constant jerking motion. Instead of a treadmill, some thought maybe walking within a room-like enclosure might be useful. They liked the surround screen from VIC E because of 360 degree viewing ability, and 180 degrees of peripheral vision. They liked the earphone audio. They thought of VIC D as "little brother to the dome." They also asked for an aiming indicator for when they were on target.

Capability Assessment Questionnaire Results - Engineering Experiments

The Engineering Experiment Capability Questionnaires were scored by assigning values of one through five to the item responses, with a value of one assigned to the least favorable response (e.g., "completely different", "much slower"), and a value of five assigned to the most favorable (e.g., "exactly like", "much quicker"). On the Similarity dimension, higher scores represent greater similarity to the real world. For the other dimensions, a score of 3.00 indicates the VIC is about the same as the real world, with higher scores indicating faster, better, or less difficult performance, and scores below 3.00 representing slower, worse or more difficult performance. Repeated measures ANOVAs were used to compare the ratings for each VIC on each dimension for each task. Mean function scores (the mean of the item scores which compose that function) were also calculated and analyzed in the same way.[1] If the overall F values were significant, pairwise t tests were performed as *post hoc* tests to determine which VICs were rated differently.

Overall Ratings (Similarity, Speed, Performance, and Difficulty)

Mean ratings of each VIC on each dimension are shown in Table 4. The pattern of results presented there was repeated again and again for the individual items. Ratings for VICs A, D, and E were very similar, while VIC G was rated less favorably. On 19 of the 33 tasks, the ratings of the VICs differed significantly on one or more dimensions.

Table 4

Overall Mean Ratings of each VIC on each Dimension (Engineering Experiments)

Dimension	A	D	E	G
Similarity	3.31	3.23	3.25	2.69
Quality	3.00	3.12	2.92	2.39
Difficulty	2.99	3.21	2.97	2.34
Speed	3.19	3.16	3.10	2.48

Ratings on Movement Inside and Outside Buildings, Detect and Engage Targets

Table 5 presents the comparisons of the VICs on each of the four functions. There were significant differences among the VICs on three of the four. Ratings for VICs A, D, and E were at or somewhat above the midpoints of the scales ("about the same as the real world"), with mean ratings ranging from 2.83 to 3.58. Ratings for VICs A, D, and E did not differ significantly (p >.05) on any of the functions for any dimension. Ratings for VIC G were consistently below the midpoints of the scales, with mean ratings between 2.09 and 2.43.

[1] From a statistical standpoint, it would have been preferable to perform a single ANOVA with VIC, dimension, and task as the independent variables, rather than performing separate analyses. However, this requires that each soldier rate each task for each VIC on each dimension. No soldier did that, making that type of analysis impossible.

Ratings for VIC G were also significantly lower than one or more of the other VICs on 10 of the 16 functions.

Table 5

Similarity to the Real World, Quality of Performance, Difficulty of Performance, and Speed of Performance: Mean Ratings, Engineering Experiments

Dimension & Function	F[a]	N	p	VIC A	VIC D	VIC E	VIC G
Engage Targets							
Similarity to the Real World		9	.001	**3.53**	**3.58**	**3.22**	2.29
Quality of Performance		9	.000	**3.07**	**3.40**	**3.23**	2.09
Difficulty of Performance		8	.005	**2.95**	**3.23**	**3.04**	2.20
Speed of Performance		9	.025	3.27	**3.36**	**3.04**	2.38
Detect Targets							
Similarity to the Real World		9	NS	3.15	3.16	3.41	2.66
Quality of Performance		9	.006	3.09	**3.35**	**3.15**	2.34
Difficulty of Performance		8	.000	2.99	**3.18**	2.83	2.39
Speed of Performance		9	.004	3.27	3.09	**2.99**	2.29
Move Inside Buildings							
Similarity to the Real World		7	NS	3.38	3.01	3.06	2.78
Quality of Performance		7	NS	2.90	2.59	2.36	2.33
Difficulty of Performance		7	NS	2.89	2.65	2.60	2.28
Speed of Performance		7	NS	3.05	2.88	2.83	2.58
Move Outside Buildings							
Similarity to the Real World		9	NS	3.25	3.02	3.11	2.63
Quality of Performance		9	.007	**3.15**	**3.18**	**3.06**	2.43
Difficulty of Performance		9	.001	**3.30**	**3.32**	**3.00**	2.26
Speed of Performance		9	.009	**3.43**	3.28	**3.31**	2.37

Notes. Means in bold differ significantly ($p<.05$) from the VIC G mean for the same function.

[a] df = 3,24 for N = 9; df = 3,21 for N = 8; and df = 3,18 for N = 7.

For the engineering test task Engage Targets, VICs A, D, and E did not differ significantly among themselves. VICs D and E were rated more favorably than VIC G on all four dimensions. VIC A was rated more favorably than VIC G on similarity to the real world, quality of performance, and difficulty of performance, but not speed of performance.

There were no significant differences among VICs on the engineering task Move Inside Buildings. On the engineering task Move Outside Buildings. VIC G was rated less favorably than each of the other VICs on the dimensions of qualityof performance and difficulty of performance. It was also rated less favorably than VICs A and E on the dimension of speed of performance.

Other engineering test ratings results are shown in Appendix E. They primarily show the consistency of the relatively low ratings given to VIC G. It is interesting to note that the wider field of view of VIC E did not improve performance relative to VIC D.

Capability Assessment Questionnaire Results - User Experiments

The User Experiment Capability Questionnaires were administered during the second week, after the long weekend, and after the soldiers had performed some collective tasks. The questions were designed to gauge opinions about each of the VICs, and how well performance in the VIC mimicked performance in the real world. Interpreting the results of the user experiment questionnaires is problematic. As the researchers examined the responses, the comments therein were sometimes in conflict with the previously given oral comments. For example, throughout the course of the two-week period they spoke very negatively about VIC G. However, their ratings, although lower than those given to the other VICs, were none the less fairly high. Additionally, some soldiers answered the questions very rapidly. The fatigue or apparent fatigue reported by the soldiers may have caused some to rush through in order to maximize the break time in between VIC exercises.

Overall Ratings (Similarity, Speed, Performance and Difficulty)

As earlier, questionnaires were scored on a five-point scale. On the Similarity dimension, a greater similarity to the real world is represented by higher scores (e.g., a score of 5 indicates the task was rated as "exactly like" the real world, a score of 1 indicates a task was rated as "completely different" from the real world). The other three dimensions of Quickness, Performance, and Difficulty were scored slightly differently, with a score of 3 indicating that a task was rated as "about the same" as real world experience. Scores above 3 indicate that a task was performed more quickly, better, or with less difficulty than in the real world, and scores below 3 indicate that the task was performed more slowly, worse, or with greater difficulty than in the real world. One goal in development of simulator technology is to create a virtual training environment that is as close to real world experience as possible. Therefore, it is no more desirable to be able to perform a task much faster or more easily than in real life, than it is for performance to be much slower or more difficult. Thus a 3 is the optimum score for Quickness, Performance or Difficulty. Table 6 shows the relatively high standing of VIC D.

Table 6

Overall Mean Ratings of each VIC on each Dimension (User Exercises)

Dimension	VIC A	VIC D	VIC E	VIC G
Similarity	2.50	3.30	3.06	2.90
Speed	2.70	2.96	2.76	2.61
Quality	2.60	2.90	2.79	2.66
Difficulty	2.60	2.95	2.85	2.68

<u>Ratings on Tactical Movement, Room Clearing, React to Contact/Engage, Communicate</u>

Participants were asked to rate each VIC as they performed four sets of tasks. These consisted of Tactical Movement, Room Clearing, React to Contact/ Engage, and Communicate. Each of these task sets included from seven to eleven specific functions that respondents performed in the VIC and then rated on the questionnaire. Table 7 shows the mean ratings of each of these dimensions for the eight soldiers. Further data are presented in Appendix E. Overall, one of the biggest problems for all VICs was realism. Too often the test soldiers became distracted by technical difficulties and instances where the performance of their VICs or the appearance of the avatars was totally inconsistent with the real world. Although no VIC was without fault, some were clearly better able to pass the reasonable performance test.

Tactical Movement included subtasks designed to assess VIC capability outside buildings (maintain formation, move past windows, cross open areas), and inside buildings (enter building through doorway, negotiate stairs, move around corners). Respondents generally rated these tasks as being most similar to real world performance in VIC D, with VIC A rated as least similar to the real world. VIC E was rated as the least difficult to use on this task. Overall, respondents rated VIC D and VIC E substantially higher on Tactical Movement than VIC A or VIC G. These ratings, however, were not statistically significant.

Table 7

Similarity to the Real World, Quality of Performance, Difficulty of Performance, and Speed of Performance: Mean Ratings, User Exercises

Dimension & Function	N	P	VIC			
			A	D	E	G
Tactical Movement						
Similarity to real world	8	NS	2.28	3.21	3.09	2.70
Speed of Performance	8	NS	2.60	3.05	2.90	2.34
Quality of Performance	8	NS	2.33	3.05	2.92	2.48
Difficulty of Performance	8	NS	2.40	2.95	3.12	2.46
Room Clearing						
Similarity to real world	8	**.006**	2.15	3.46	3.00	2.54
Speed of Performance	8	NS	2.46	2.94	2.79	2.53
Quality of Performance	8	NS	2.22	2.86	2.76	2.35
Difficulty of Performance	8	NS	2.35	2.90	2.59	2.43
React to Contact/Engage						
Similarity to real world	8	NS	2.64	3.20	3.08	3.13
Speed of Performance	8	NS	2.74	2.88	2.50	2.63
Quality of Performance	8	NS	2.74	2.75	2.50	2.78
Difficulty of Performance	8	NS	2.72	2.92	2.72	2.88
Communicate						
Similarity to real world	8	NS	2.96	3.35	3.10	3.26
Speed of Performance	8	NS	3.03	2.99	2.88	2.97
Quality of Performance	8	NS	3.13	2.95	3.00	2.98
Difficulty of Performance	8	NS	2.95	3.05	3.00	2.99

Room Clearing consisted of nine subtasks. These included such tasks as take position within a room, stack, move past other personnel in room, and clear a hallway or room. VIC D was the most highly rated on the Room Clearing task set, particularly along the dimension of Similarity [$F(5.141,3)=.05$, $p=.006$], while VIC A was rated least favorably along all four dimensions for this task. (Tukey's HSD post hoc analysis was conducted and statistically significant mean differences between VIC Alpha and VIC Delta were confirmed (-1.31, $p=.005$) for Room Clearing similarity.) With the exception of similarity, ratings on the remaining three dimensions were not statistically significant.

The task set React to Contact/Engage contained seven subtasks which included such items as determine origin of enemy fire, target acquisition, fire at enemy personnel, and reload weapon. The differences between ratings were not significant, but the trend of VIC D with slightly higher ratings continued.

The Communicate task included nine subtasks such as identify and locate team members, communicate with own and other fire team, report to squad leader, and consolidate and reorganize. Ratings of VICs on this task set were comparable, and non-significant across all dimensions, with each rated as nearly the same as real world experience in Quickness, Quality of performance, and Difficulty. VIC D and VIC G were rated most Similar to real world experience. VIC A was rated highest in Quality of performance and Quickness. VIC E was rated slightly lower on this subtask.

Additional Interview Comments

This section incorporates information from the remainder of the structured interview comments. It covers impressions about the simulation in general rather than about the specific VICs, and overall soldier comments about their experiences.

MOUT Training

One area of concern to the soldiers was the difference in performance at the McKenna and VIC MOUT sites. All observers noted that movement was much better at McKenna (real world) than in the simulation. The soldiers could move close to walls or in other tight spaces like doorways and halls with no difficulty, unlike in the VIC rooms where they bumped each other. At McKenna they cleared hallways and stairwells together as a team, making the assault more nearly realistic. In the VICs, rooms seemed "very small and not the real size" and "everything was cluttered up; we were stumbling and falling over each other. Half the time I did not know the location of my fire team members. " In the VICs they could not stack (stand close together) properly inside the building, or use grenades or hand and arm signals. Both the special effects and the communication signals are critical parts of Infantry room clearing behavior.

Normal soldier to soldier communications were not replicated in the VICs, and command and control in rooms was unrealistic. VIC commo was too good, as the setting was unrealistically quiet. Additionally, one said commo "wasn't the same. You lose face and body language. For instance, I can tell what my sergeant wants just by the way he moves even if he is saying something else." One suggested that "poor communication may have lead to some of us getting shot by our own guys during some of the missions in the VICs." At McKenna, but not in the VICs, they got out of breath and tripped over things. In the VICs they could only see, never hear the OPFOR. One said, "We had better situational awareness at the MOUT site; I knew where everyone was at in relation to my location inside the building."

VIC Weapon Systems

The best-liked feature of the VICs was the Land Warrior IHAS, available in a VIC but not yet in the real world. The soldiers saw the potential benefits of extending the weapon, and looking around corners, despite the fact that in some instances the IHAS did not work very well. They could easily see the future utility of this weapon system, but its benefit was independent of VIC performance.

They wanted a wireless (untethered) weapon, with true weight, and more realistic reload. The magazine change procedure in the VICs was unconvincing, as was the alternative, unlimited ammunition. One suggested physically dropping the empty magazine and taking another from the ammo pouch to reload. They asked for an expanded weapon list with hand grenades and the "shape, features and sound of weapons and military uniforms from countries [they] might have to fight in the future."

Aiming was always a problem. Soldiers could not use "Kentucky windage" to adjust aim. If a VIC round went over the target, there was no ground burst. They had to fire short and "walk it in". It was worse with the IHAS where the apparent round burst (visual) did not correspond to the apparent fall of the round. The burst appeared toward the actual front of the weapon, whereas the round corresponded to the center of the crosshairs. This anomaly was very disconcerting. One soldier expressed his frustration: "The ideal VIC would have a more accurate weapon sighting system that would allow me to line-up targets without having to turn my weapon sideways or upside down." Additionally, all VICs had a slight, disturbing delay in the shot after trigger pull.

VIC Movement

The soldiers continuously reiterated VIC movement difficulties, and with all VICs, especially G, the tendency to focus more on movement than on the mission. Besides their individual locomotion problems, they could not stack or move well as an element. Bumping into a door, getting stuck, or walking through walls was frustrating, and was compounded by their inability to see their own avatars. Technical glitches also caused difficulties. It was distracting to see team members jumping around or moving out while still apparently in a prone or kneeling position. They also said that the thumb joysticks were different from each other and hard to control.

VIC Simulation in General

The soldiers were encouraged to think about ways to use VICs and the VR simulation. Despite overall dissatisfaction with aspects of the VICs, the soldiers had some good suggestions. Most agreed that with communication problems fixed, the VICs could be used to build cohesive teams, and provide practice in leadership skills for both team and squad leaders. Simulation was also seen as a way to integrate new soldiers into a unit. In a simulation, with less chance of injury or fratricide, a unit can repeat a scenario over and over, no matter how long it takes. A dropped magazine is not lost forever and ammunition can be reconstituted at will. VICs could be used for planning: "If you have really good intel and you could set up a room in the virtual world - you could have the layout of the place - you could be there without being there." Again, problems identified in the prototype VICs would have to be remedied first.

Negatively, some felt simulators like VICs should be used only for rehearsal and practice, not for actual training. They said they need to know the basics first, since it is easily possible to develop bad habits in a VIC. A frequent example was failure to put weapons on safe. Leaders, separated from their soldiers, could not see this behavior, and could therefore not correct it.

Several suggested that simulations should in some way incorporate bloodshed and casualty evacuation. "If you really intend to go to war, you need to be desensitized to that. Also the enemy shouldn't die right away. He could maybe go down screaming but still be shooting at you...You could have to drag injured people out, because in the real world when someone gets injured you have to get them out." This suggestion was less one for realism than for the full range of soldier behaviors.

Simulator Sickness Questionnaires

A slightly modified version of the Simulator Sickness Questionnaire (SSQ) (Appendix A) was administered to all soldiers at the beginning of each day and at the completion of each session on the VICs. Symptom frequency for the first seven days of the experiments is shown in Table 8. After the first week of experimentation some changes occurred that impacted on further data collection in this area. The test soldiers participated in an unrelated weekend-long field exercise with their unit. Normal sleep patterns were disrupted and many soldiers reported to the LWTB in various states of fatigue on the first morning of the USEX. Their symptoms as reported on the morning comfort questionnaire and at the end of the day were atypical, and in all likelihood, unrelated to the VICs. For that reason, while some of that data will be presented later for comparison purposes, it has been excluded from the following analysis.

Table 8

Symptom Frequency (Percentages) Before and After VIC Use, First Week Only

Symptom	Participants Reporting Symptom (%)	
	Pre	Post
Eyestrain	1.6	28.0
Difficulty focusing	1.6	25.5
General discomfort	1.6	18.5
Headache	3.2	17.8
Blurred vision	0.0	16.6
Fatigue	14.5	9.6
Nausea	1.6	8.9
Dizzy with eyes open	0.0	8.9
Stomach awareness	1.6	7.6
Fullness of the head	0.0	7.0
Dizzy with eyes closed	0.0	3.8
Burping	1.6	3.8
Vertigo	0.0	3.2
Salivation increased	0.0	3.2
Difficulty concentrating	1.6	2.5
Cold sweating	0.0	0.0
Number of reports	62	157

Except for fatigue, which was reported on 14.5% of the pre-session questionnaires, the soldiers generally began the day free of symptoms. Seven different symptoms were reported on one questionnaire each, and one (headache) was reported on two. In contrast, five symptoms, not including fatigue, were reported on more than 15% of the post-session questionnaires. Four of the five most frequently reported symptoms involved the human visual system - eyestrain, difficulty focusing, blurred vision, and headache. Figure 1 shows the effects of exposure to the VICs.

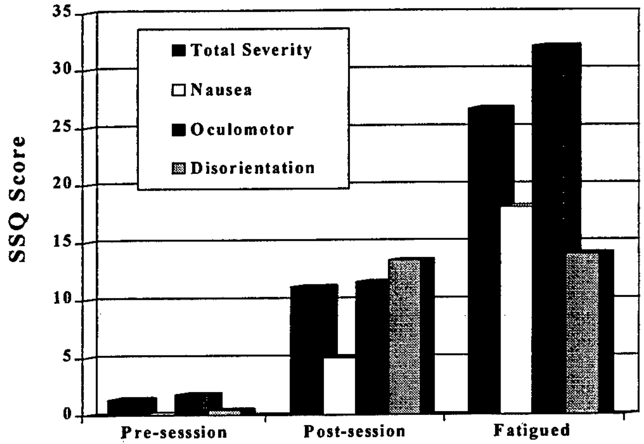

Figure 1. Mean SSQ scores prior to and after VIC use.

The pre-post change in symptoms was also apparent when the questionnaires were scored using the standard scoring procedures found in Kennedy, Lane, Berbaum, and Lilienthal, 1993. These procedures generate an overall Total Severity Score and subscale scores on three dimensions - Nausea, Oculomotor, and Disorientation. As shown in Figure 1, the exposure to the VICs produced a substantial increase on each of those measures. A series of ANOVAs and Duncan multiple range tests were conducted to determine if the Post-exposure symptoms were affected by the particular VIC used.

The results confirm the initial impression conveyed by Figure 2. Use of the different VICs resulted in significantly different Total Severity ($F_{(3,153)} = 6.13$, $p = .001$), Disorientation ($F_{(3,153)} = 5.80$, $p = .001$), Oculomotor ($F_{(3,153)} = 4.95$, $p = .003$), and Nausea ($F_{(3,153)} = 5.93$, $p = .001$) scores. Duncan's multiple range test (aplha = .05), showed VIC G symptoms to be more severe than each of the other three VICs on each measure. The symptoms produced by VICs A, D, and E did not differ significantly.

Over the weekend between the engineering experiments and the user exercises, the soldiers participated with their unit in a field exercise. They were out of doors from early Saturday morning to early Monday morning, and reported that they received little or no sleep Sunday night (mean = 1.9 hours). Their Monday morning pre-training scores are shown in Figure 1 as "fatigued."

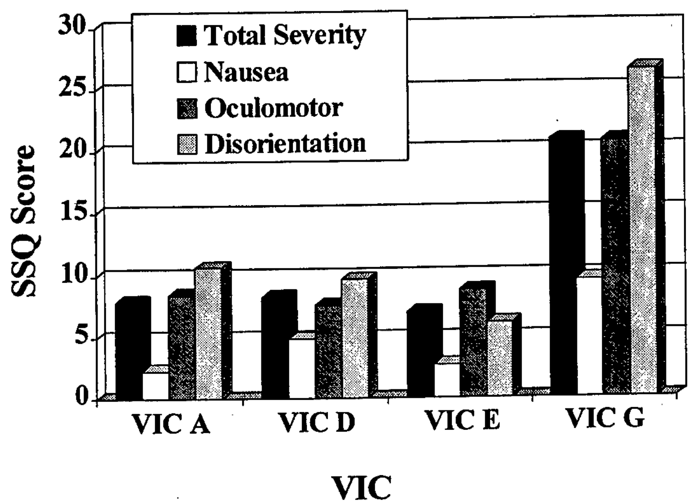

Figure 2. Mean SSQ scores by VIC

There was no significant variation in post-session SSQ scores over the two days of preparation and the five days of the engineering experiments. While other items may have contributed slightly to the differences in the symptoms reported for each VIC, the symptoms reported during the engineering week seem to stem primarily from significant differences among the VICs on five of the items: eyestrain, difficulty focusing, general discomfort, blurred vision, and increased salivation. Means, F-values, and significance levels from engineering week data are shown in Table 9. Mean symptom score is calculated by multiplying the number of None, Slight, Moderate, and Severe responses by 0, 1, 2, and 3, respectively, and dividing by the number of responses. Mean symptom score can range from 0 (all responses None) to 3 (all responses Severe). VIC G appeared to account for most problems. Duncan's multiple range tests indicated that the symptom scores produced by VIC G were higher than those produced by the other VICs (alpha = .05).

Table 9

Significant Differences Among the VICs on Individual SSQ Items

Symptom			Mean Symptom Score			
	F^a	p	VIC A	VIC D	VIC E	VIC G
Eyestrain	4.13	.008	.21	.23	.36	.66
Difficulty focusing	6.01	.001	.37	.18	.18	.76
General discomfort	3.45	.018	.16	.16	.13	.43
Blurred vision	3.84	.011	.18	.15	.08	.46
Salivation increased	5.23	.002	.00	.00	.00	.12

[a] df = 3, 153

Discussion

Simulator Sickness

The general level of simulator sickness levels reported is consistent with those found in other VE research. Total Severity scores reported for a series of experiments in ARI's Virtual Environment Research Laboratory (Knerr et al., 1998a) have varied from 13 to 38. In comparison, the means of 7-8 for VICs A, D, and E, and 20.8 for VIC G are low. This may be due to the generally short individual sessions during the Engineering Experiments. It may also be due to the differences between college students and Infantry soldiers. Soldiers may have experiences with make them less susceptible to simulator sickness, or may simply have developed greater tolerance for discomfort.

It is clear that the combination of the HMD and ODT used in VIC G performed least well in terms of both rated task performance and comfort. It was rated significantly lower than the other VICs were on every function except movement inside buildings. It also produced an overall level of symptom frequency more than twice that of the other VICs. It cannot be determined from these experiments whether these difficulties would have resulted from any combination of HMD and walking platform, or whether they resulted from the characteristics of the particular devices used or their combination. Walking, or even standing still, on a moving surface with one's view of the real world completely or partially obscured and without being able to maintain contact with any fixed surfaces is a difficult task. The absence of a real worldview in combination with the moving surface may also contribute to simulator sickness. On the other hand, the higher frequency of symptoms related to the visual system (eyestrain, difficulty focusing, and blurred vision) suggests that the HMD used was not or could not be adjusted properly.

The weekend field exercise provided an interesting benchmark for evaluating the simulator sickness symptoms. Clearly, the soldiers "felt worse" after the field exercise (an extended period of exercise and sleep loss in a hot and humid Georgia summer) than after a typical VIC session, and even after a VIC G session (short periods of activity in an air-conditioned facility). There was no evidence that repeated use of the VICs had a cumulative effect on simulator sickness symptoms. On the other hand, there was no evidence of adaptation. It is not known what level of symptoms an extended period of VIC use would produce.

Major Technological Challenges

With respect to the entire VIC experience, the most telling comment was one made by a soldier when asked about how hard it was to distinguish his fire team from the DI SAF fire team: "We were disorganized; they had a destination." In other words, it was easy to tell by the performance. Additionally, the simulation as a whole was so unrealistic that the test soldiers had difficulty maintaining focus.

Irrespective of the strengths and weaknesses of the individual VICs, these engineering and user experiments identified a number of problems, common to all of the VICs, which need to be overcome before virtual environment technology will be applicable to the training of a wide variety of Dismounted Infantry collective tasks. The most crucial tasks to consider as possible candidates for simulation are those most often performed by the Dismounted Infantryman, to include shooting and maneuvering on foot. If the basic tasks of move, shoot and communicate are not accurately reproduced in the VE, then many of the finer points in the simulation are of minimal consequence. Soldiers are expected to behave in a manner consistent with real world tactical procedures while participating in virtual world exercises. If these exercises involve use of an unrealistic weapon, and unrealistically behaving avatars to represent other fire team members, the participants will have difficulty taking any part of the exercise seriously. The problems identified are described below in rough order of importance. None of them appear to be easy to solve.

Weapon Aiming and Position Tracking.

Weapons and position tracking were sufficiently error prone to make individual weapon fire unrealistically inaccurate, and to introduce errors in posture. In the DWN ERT series, weapon aiming and subsequent target engagement was unsatisfactory. The VIC inability to support realistic aiming behavior impacted on every trial. Comments about the way they had to hold the weapon to hit the target indicate just how unsuccessful this was. They could not use normal adjustment techniques. Errors were inconsistent, and the soldiers never felt certain that their engagement techniques would be successful. The inability to walk the round to the target was frustrating, and unlike their real world experiences and training. The IHAS was a mixed blessing. Although preferred to the iron sights in VICs D and E, it was totally unacceptable in VIC G. Aiming and weapon performance is so basic to an Infantryman that any deviation from reality is a major distraction. While it is probably not necessary for many training applications that weapon tracking must be accurate enough to mirror soldiers' performance with the real weapon, target hit probabilities which differ noticeably from real world values are likely to be detracting and create problems of credibility of the simulation.

Simulating Locomotion (Low Cognitive Demand).

Movement, not unlike aiming, is a basic Infantry skill. Walking and running in the real world are well-practiced skills, and are performed without much conscious attention. Ideally, for training applications, the method of locomotion should be easy to learn and simple and "natural" enough that the trainees can attend to the training, rather than the mechanics of locomotion. Walking and running in the virtual world are new skills, and the soldiers in these experiments were unable to master them in the time allotted. They were unable to navigate the route through the building as rapidly as in the real world, and they made frequent collisions with the walls while doing so.

In fairness, this cannot be attributed solely to the method of locomotion itself. The visual display systems appear also to be a part of the problem. VICs A and G provided a narrow field of view, which made orientation difficult. VICs D and E caused objects to blur when they were located between the display screen and the soldier's viewpoint. The interior building walls shared a common texture, with no shadows, so it was frequently difficult to detect angles or openings in the interior walls, or to judge distance from them. Besides the obvious problems with the ODT, the movement circle of VIC A, the thumb switches, and the posture changing difficulties of D and E created difficulties. To avoid negative training, the soldier must be able to adopt any natural position to do his job. While point to point locomotion could be omitted from the simulation task list, within building movement is critical for MOUT scenarios. Any VIC will have to be able to appear on the database in the same postural (prone, kneeling, stacked, etc.) configurations as in the real world. Avatars must be able to move in pairs or in formation, without the technical problems evidenced here. Even one avatar stuck in a wall or standing on another's shoulders destroys the mood or the credibility of the scenario.

Communicating

There is a frequently reiterated need for gestures and other non-verbal communication like hand and arm signals. Much Infantry communication is based on these behaviors, and relying on radios or other audible signals may provide negative training. Simulated grenades and smoke are also forms of communication as they serve as signals. The current communication system (fully audible) was unrealistic, and in many cases, too good. Messages were too clear, and the scenario was too quiet between messages.

Soldiers noted the importance of non-verbal communication in MOUT actions, particularly gestures and facial expressions. The incorporation of gestures requires two things: a position tracking system that can track limbs (arms, hands, and perhaps fingers) with the degree of accuracy necessary to recognize the gesture; and an avatar which can produce or display the gesture for the other participants at a sufficient level of detail. VIC A has the capability to do both of these things with some level of detail, although not down to the finger level of detail. The other VICs had neither capability, although it is possible that, with additional trackers, gross gestures could be captured. DI Guy appears to be capable of producing gestures if they were added to his movement library. Recognition of small (finger) gestures and facial expressions does not appear to be possible at this time.

Soldiers also commented that audio communication was too good. This was in part the case because the audio system was physically independent of the virtual simulation. An easy but crude "improvement" would be the introduction of random noise into the audio system to interfere with voice communications. A more realistic solution would involve acoustical modeling that takes into account distance, intervening obstacles, and speaker and listener orientation and modifies the sound accordingly.

Wide FOV Displays

In addition to facilitating locomotion, visual displays with wider fields of view would help soldiers search for targets and maintain position relative to other team members. Lightweight, low-cost HMDs are simply not available. Manufacturers have been increasing resolution, while maintaining or even decreasing the FOV. It is not clear whether this is because of perceived market interest or engineering problems involved in creating wide-FOV HMDs. In addition, for wireless HMD systems like VIC A, increased FOV would also increase transmission bandwidth.

Minor Problem Areas

Certain difficulties or areas observed in both the DWN and the DWN ERT experiments should be able to be overcome with a minimum of effort. Included in the list of resolvable problems are some which are needed to improve the perception of realism in simulated fire team missions.

Additional Individual Weapons

Modeling additional individual weapons (SAW, grenade launcher) will require effort but can be done with additional software tools. Relatively straightforward fixes could include issuing a SAW to the SAW gunner, or updating weapons as new ones are added to the inventory. Grenades pose the greatest problem, but in terms of soldier satisfaction would be a definite asset given their prevalent use in MOUT scenarios. Effects modeling should not be too difficult, but realistic delivery requires accurate, rapid arm and hand tracking and has substantial potential for damage to equipment and injury to other participants. A work-around solution, which does not actually involve throwing an object, may be required.

Database Enhancements

Another area, which should be able to be improved with minor difficulty, relates to the visual database. Repeated comments about inability to discriminate rooms from each other, or about "uniform gray cinderblock walls" show that the soldiers were at least somewhat distracted by these database deficiencies. Their continued commentary about furniture and places for snipers to hide indicates, too, that they were focusing on the absence of these features. While perhaps not important, they were distracting to soldier performance.

Errors in Database (VIC A)

It may be time-consuming to check the database thoroughly and identify and correct the anomalies that caused soldiers to bounce to the roof, but not technically difficult.

Weak and Dead Batteries (VIC A)

Once a regular pattern of use has been established, the need for rechargeable batteries and battery charges can be accurately determined. For future experiments, it is probably better to overestimate requirements than to underestimate them.

HMD Adjustments (VIC G)

The VIC G HMD could be adjusted so that the eyepieces were located in front of the soldier's eyes. The relatively high level of oculomotor discomfort reported after VIC G use suggests that this adjustment was not being or could not be performed correctly. Standard procedures need to be developed and used to minimize this problem.

Clean Clothing (VIC A)

A better method of attaching the reflective markers to the soldiers than having them share shirts and boots needs to be developed.

Directional Audio

With the current configurations, the test soldiers were generally unable to tell where fire was coming from – inside or outside, in the same room or upstairs. This was especially bad for the team leader. Some improvement in this area would be beneficial.

Individual Weapons Characteristics

Soldiers complained when the simulated M-16 did not have the feel or other characteristics (such as ammunition limit or requirement to physically insert a new clip) of the actual weapon. While some of these aspects are not trivial (e.g., ejecting an empty clip) they should not be difficult to implement, and the weapons simulations that result should be useable across a variety of potential VIC configurations. Regardless of whether realism is needed for the actual conduct of the experimental design or a mission based scenario, realism is needed for the soldier to behave with the weapon in a manner that is consistent with the way he treats his real weapon. Continued comments about the "feel" of the weapon, or its weight, indicate that it must look and perform in a manner very similar to his own. Similarly, the disparaging comments about unlimited ammunition or unrealistic reloading procedures indicate that behaviors used in operating the simulation's weapon need to be consistent with behaviors used in the real world. These issues should be resolvable. A rifle more nearly of the weight of the M16, one which required the removal of an empty magazine and replacement with a fresh one would lend much needed realism and reduce a major distracter.

Posture Indicator (VIC G)

Since soldiers using VIC G were always standing in the real world, they often could not tell whether they were in a standing, kneeling, or prone position in the virtual world. A visible indicator, as simple as a small indicator that would appear on one side of the visual display, would provide much-needed information.

Recommended Training Applications

A central issue, which must remain at the forefront of any evaluation, is the ultimate purpose for which these simulator systems are designed. As several soldiers suggested, planning and preparation for specific missions is probably the most practical use for distributed simulator technology at its present functional capability. Improvement of team cohesion, leadership practices, and broad-spectrum scenario rehearsals are other potentially feasible uses for the VIC systems. For these types of exercises it is less important that realistic physical movement be performed by soldiers in the VIC, than that the avatar move smoothly through the virtual environment.

Mission planning, in advance of real world or simulator world rehearsal could also be effected in a VIC by walk throughs with alternative choices or options, not unlike the process used in course of action development. Several alternatives to any operation could be attempted in advance of a final plan. The use of simulations for mission rehearsal (in lieu of a training function) aligns with soldier comments that untrained soldiers would be likely to learn bad habits in the simulation. When soldiers are in a training mode (crawl, not walk or run) the leader needs to be able to watch the trainee from close by and apply on the spot correction. The physical separation forced by the simulators precludes one to one monitoring.

The simulators could be used to train small unit leaders to control DI SAF soldiers (simulated fire teams). The VIC soldiers could guide or instruct their simulated teams and real soldiers in VICs. Additionally, integration of new soldiers into a squad or into a team could be made easier through the use of simulation to train new soldiers in SOPs. Coordination for dangerous procedures can also be practiced in the simulation to ensure maximum safety. MOUT scenarios, with depiction of real buildings, could be very useful for training. In addition to correction of previously identified deficiencies, a more nearly 360-degree view with peripheral vision and the ability to walk, turn, run and low-crawl would be advantageous. The soldiers also commented on potential benefit of seeing their own bodies (avatars), and own posture changes.

Lessons Learned

Based on the results of both the DWN and the DWN ERT experiments, there are recurrent lessons to be learned. The foremost is, as previously noted, that if a soldier in a simulator is expected to be an active DI participant in collective fire team missions, then the problems associated with locomotion and maneuverability must be resolved so he can operate in concert with the rest of his squad.

Similarly, even if the simulation will not be used for marksmanship, the virtual weapon must act in a manner consistent with reality, and with his primary weapon. The weapon must look and feel like a real weapon, and must perform within certain parameters. Otherwise, the distracters will be so great as to outweigh the benefits. If communication or command and control is an area on which performance will be evaluated, communications must more nearly approach realism.

Data collection is still a problem. The automatic computer generated data serves one purpose. The data gathered from the soldiers themselves, whether by observations or through questionnaires and interviews, serves another. There were here and are always, certain questions about reliability of written responses. How best to collect this data on a non-interference basis is still to be determined. If an exercise is interrupted in the middle to ask the soldier questions, it changes the exercise. Non-interference observations run the risk of missing something. Good performance measures may have to be developed based on small vignettes, easily measured.

Despite the small number of soldiers participating in the DWN ERT and the earlier DWN experiments, it is essential, however, that soldier contributions and suggestions not be taken lightly. All Infantry soldiers learn the same basic skills, and operate under the same tactical guidelines, regardless of individual differences. Therefore, the DWN ERT results, offered with both candor and enthusiasm, can probably be generalized to a wider dismounted Infantry population.

Summary

Briefly focusing again on the specific VICs, although there sometimes appeared to be more positive aspects to VICs A, G and E than to VIC D, this VIC had far fewer negative aspects than the others did. VIC G was generally the most unacceptable, and there were many undesirable aspects of VIC A. VIC E, although very similar to VIC D, appeared to provide little value added. Thus VIC D was the default choice: they did not really like VIC D very well, but they disliked it less than they disliked the other VICs.

Additionally, the present prototype VICs are so far from reality that they encourage or at least invite negative training, as was demonstrated in soldier failure to low-crawl beneath windows, and the repeated silhouetting in doorways. They could perform the tasks, but they were not really relating them to, or comparing them to real world missions. Whether as a consequence of the experimental situation per se (technical problems or a non-training event), or of the inherent failings of the VICs, the experience did not immerse the test soldiers to a point where they felt truly involved as individuals or as fire team members. The DWN ERT systems, like the DWN systems before them, were likened to video games, but unfortunately, video games they would not choose to play. They did not take any of them very seriously. As noted earlier, full immersion active participation needs closer fidelity than shown in the VICs.

Conclusions and Recommendations

As previously stated, all of the VICs are in the early stages of prototype evaluation, and improvements are a continuous and iterative process. The results of this and past investigations (DWN ERT and DWN) should be sufficient to give direction to future development. However, the ultimate purpose and practical usefulness of simulator technologies must be considered when design modifications are implemented. While virtual systems may be useful for performance of some individual and collective tasks, the DWN ERT provided little discrimination. Some tasks are clearly within the capabilities of current technology, but some are still too hard to do, or too unrealistic. Matching VIC capabilities and appropriate tasks is difficult. The value of simulating some tasks is still in question. Just because one can simulate them, does it make sense to? Is the ultimate benefit worth the cost involved? Movement from one point to another is not difficult to simulate, even in a prototype VIC. However, many would question committing resources to locomotion practice.

Another set of questions needs to be answered. How important is it to be able to physically move in a realistic way in the simulation, if it is difficult to control this movement? Is it necessary to replicate the movement function? Perhaps a joystick could be substituted to get the soldier from point A to point B, with the real "training" coming from what happens once the avatar gets to the action. If the task is building clearing, a better focus for the simulation might be on taking positions within a room, avoiding windows, and practicing aiming points, rather than on the movement into the room per se. Similarly, how important is total perceptual immersion at the expense of weapon accuracy and realism? When marksmanship is not being measured, a video game-like pointing device may be sufficient. Unless accuracy is the focus, "good enough" may be good enough.

Great improvements have been made in making the virtual world accessible to Infantry training; the DWN ERT exercises represent one more necessary phase. As virtual simulations such as the CCTT come increasingly close to full fielding, representation of the dismounted infantryman becomes even more critical. Continuing improvements to the virtual individual combatants and their accompanying databases will provide potential answers to the existing challenges and fields for further research.

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List of Acronyms

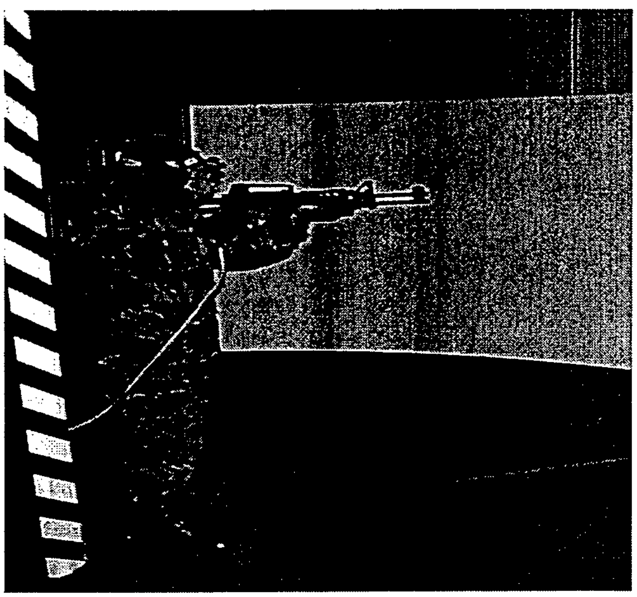
AAR	After Action Review
ACTD	Advanced Concepts Technology Demonstration
ADST	Advanced Distributed Simulation Technology
ARL	Army Research Laboratory
BFV	Bradley Fighting Vehicle
BLUFOR	Blue Force (Friendly Forces)
CCTT	Close Combat Tactical Trainer
DBBL	Dismounted Battlespace Battle Lab
DI	Dismounted Infantry
DIS	Distributed Interactive Simulation
DI SAF	Dismounted Infantry Semi-Automated Forces
DSS	Dismounted Soldier System
DWN	Dismounted Warrior Network
DWN ERT	Dismounted Warrior Network Enhancements for Restricted Terrain
FOV	Field of View
HMD	Head Mounted Display
IHAS	Integrated Helmet Assembly System
LW	Land Warrior
LWTB	Land Warrior Test Bed

MOUT	Military Operations in Urban Terrain
ODT	Omni-Directional Treadmill
OPFOR	Opposing Forces
RBD	Reality by Design
SAF	Semi-Automated Forces
SAW	Squad Automatic Weapon
SIMNET	Simulation Networking
STP21	Small Team Portal into the 21st Century
STRICOM	Simulation, Training, and Instrumentation Command
SVS	Soldier Visualization Station
USEX	User Exercises
VE	Virtual Environment
VIC	Virtual Individual Combatant
VR	Virtual Reality
WISE	Walk-In Synthetic Environment

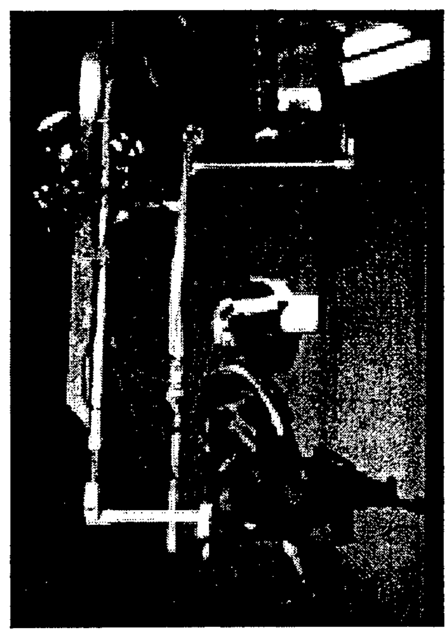
APPENDIX A – Photographs of each Virtual Individual Combatant.

VIC ALPHA

VIC DELTA



VIC ECHO



VIC GOLF

Appendix B Forms, Questionnaires and Other Measures of Performance

Appendix B -.1 Dismounted Warrior Network
Biographical Information Questionnaire

Name__________________________ Unit (include plt) ______

Please fill in the blank or mark or circle the appropriate response.

1. What is your age? _____ Years

2. MOS _________

3. Rank ________

4. Time in service: Years _____ Months _____

5. What is your current duty position? ____________ How long in this position ? _______

6. What Army training courses have you completed? Check all that apply.

___ OSUT/AIT _____ PLDC _____BNCOC _____BFV Leader Course
___ Airborne _____ Ranger ____ Air Assault
___ Other (please specify)

7. How often have you trained at the McKenna MOUT site since basic training?
___ this week only ___ just demos ___ demos and other training

8. Have you ever participated in close quarter combat (room clearing) training EXCEPT for a demo? yes no

9. How susceptible to motion or car sickness do you feel you are?

0	1	2	3	4	5	6	7
not susceptible	very mildly			average			very highly

10. Do you have a history of epilepsy or seizures? yes no

11. Do you have normal or corrected to normal 20/20 vision? yes no

Appendix B.1 (continued)

12. Are you color blind? yes no

13. Are you ___ right handed? ___ left handed?

14. How many hours per week do you use computers? _____ hours per week

15. How many hours per week do you play video games? _____ hours per week

16. How many times in the last year have you experienced a virtual reality game or entertainment?

0 1 2 3 4 5 6 7 8 9 10 11 12+

17. My level of confidence in using computers is

1	2	3	4	5
low		average		high

18. I enjoy playing video games (home or arcade).

1	2	3	4	5
disagree		unsure		agree

19. I am _____ at playing video games.

1	2	3	4	5
bad		average		good

20. Have you ever been in a Virtual Individual Combatant (VIC) simulator at the Land Warrior Test Bed before? Yes No

    If YES, which one(s)? (Describe if you cannot remember the name)

21. Have you had any <u>other</u> experience with military computer simulations? Yes No
    If yes, please describe briefly or give the names of the simulators.

Appendix B.2
No.__________
Time_____________
Date_____________
VIC_____________
Session No.________

Participant____________

Dismounted Warrior Network
Engineering Experiments
Symptom Checklist

Instructions: Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

1. General Discomfort	None Slight Moderate Severe
2. Fatigue	None Slight Moderate Severe
3. Headache	None Slight Moderate Severe
4. Eye Strain	None Slight Moderate Severe
5. Difficulty focusing	None Slight Moderate Severe
6. Salivation increased	None Slight Moderate Severe
7. a. Warm Sweating (from temperature or exertion)	None Slight Moderate Severe
b. Cold Sweating (from discomfort or nervousness)	None Slight Moderate Severe
8. Nausea	None Slight Moderate Severe
9. Difficulty concentrating	None Slight Moderate Severe
10. "Fullness of the Head"	None Slight Moderate Severe
11. Blurred Vision	None Slight Moderate Severe
12. a. Dizziness with eyes open	None Slight Moderate Severe
b. Dizziness with eyes closed	None Slight Moderate Severe

13. Vertigo	None Slight Moderate Severe
14. *Stomach awareness	None Slight Moderate Severe
15. Burping	None Slight Moderate Severe

16. Other (describe):

____

____

* Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Appendix B.3

Date______________
Participant No.______

Dismounted Warrior Network
Comfort Questionnaire

1. Are you in your usual state of fitness: YES NO

If not, what is the nature of your illness (flu, cold, etc.).

2. Please indicate all medication you have used in the past 24 hours:

(a) NONE

(b) Sedatives or tranquilizers

(c) Aspirin, Tylenol, other analgesics

(d) Anti-histamines

(e) Decongestants

(f) other (specify):

3. How many hours sleep did you get last night? ___ (Hours)

Was this amount sufficient? YES NO

4. Did you notice any delayed or after effects after your last DWN session? YES NO

If so, please describe them.

VIC CAPABILITY ASSESSMENT QUESTIONNAIRE USER EXERCISES NAME:________ DATE:______TIME:______ **Please answer these questions about VIC ___. Check the box that most closely corresponds to your experiences in the VIC.**	**How *similar* was the way you performed each task in the VIC compared to the way you perform it in the real world?**					**How *quickly* could you perform each task in the VIC compared to how quickly you can perform it in the real world?**					**How *well* could you perform each task in the VIC compared to how well you can perform it in the real world?**					**How *difficult* was it for you to perform each task in the VIC compared to how difficult it is in the real world?**				
	Exactly Like	Very Similar	Somewhat Similar	Very Different	Completely Different	Much Quicker	Somewhat Quicker	About the Same	Somewhat Slower	Much Slower	Much Better	Somewhat Better	About the Same	Somewhat Worse	Much Worse	Much Less Difficult	Somewhat Less Difficult	About the Same	Somewhat More Difficult	Much More Difficult
TACTICAL MOVEMENT																				
Outside Buildings																				
Maintain formation																				
Move close to/hug building																				
Move past windows																				
Cross open areas																				
Breach door using SAW																				
Inside Buildings																				
Enter building through mousehole																				
Enter building through doorway																				
Move around a corner																				
Move/climb up the stairs																				
Move/climb down the stairs																				
Exit from a building																				

VIC CAPABILITY ASSESSMENT QUESTIONNAIRE USER EXERCISES NAME:________ DATE:______TIME:______ Please answer these questions about VIC ___. Check the box that most closely corresponds to your experiences in the VIC.	How *similar* was the way you performed each task in the VIC compared to the way you perform it in the real world?					How *quickly* could you perform each task in the VIC compared to how quickly you can perform it in the real world?					How *well* could you perform each task in the VIC compared to how well you can perform it in the real world?					How *difficult* was it for you to perform each task in the VIC compared to how difficult it is in the real world?				
	Exactly Like	Very Similar	Somewhat Similar	Very Different	Completely Different	Much Quicker	Somewhat Quicker	About the Same	Somewhat Slower	Much Slower	Much Better	Somewhat Better	About the Same	Somewhat Worse	Much Worse	Much Less Difficult	Somewhat Less Difficult	About the Same	Somewhat More Difficult	Much More Difficult
PERFORM ROOM CLEARING																				
Clear a hallway																				
Stack																				
Enter a room																				
Secure entry point																				
Take position within a room																				
Move past other personnel in room																				
Clear a room																				
Determine room is cleared																				
Establish security																				

VIC CAPABILITY ASSESSMENT QUESTIONNAIRE USER EXERCISES NAME:____________ DATE:________TIME:________ **Please answer these questions about VIC ___. Check the box that most closely corresponds to your experiences in the VIC.**	**How *similar* was the way you performed each task in the VIC compared to the way you perform it in the real world?**					**How *quickly* could you perform each task in the VIC compared to how quickly you can perform it in the real world?**					**How *well* could you perform each task in the VIC compared to how well you can perform it in the real world?**					**How *difficult* was it for you to perform each task in the VIC compared to how difficult it is in the real world?**				
	Exactly Like	Very Similar	Somewhat Similar	Very Different	Completely Different	Much Quicker	Somewhat Quicker	About the Same	Somewhat Slower	Much Slower	Much Better	Somewhat Better	About the Same	Somewhat Worse	Much Worse	Much Less Difficult	Somewhat Less Difficult	About the Same	Somewhat More Difficult	Much More Difficult
REACT TO CONTACT/ ENGAGE																				
Determine origin of enemy fire																				
Acquire target at higher elevation																				
Acquire target at lower elevation																				
Fire at enemy personnel																				
Switch firing hands																				
Fire in short bursts																				
Reload weapon																				

VIC CAPABILITY ASSESSMENT QUESTIONNAIRE **USER EXERCISES** NAME:____________ DATE:________TIME:_______ **Please answer these questions about VIC ___. Check the box that most closely corresponds to your experiences in the VIC.**	**How *similar* was the way you performed each task in the VIC compared to the way you perform it in the real world?**					**How *quickly* could you perform each task in the VIC compared to how quickly you can perform it in the real world?**					**How *well* could you perform each task in the VIC compared to how well you can perform it in the real world?**					**How *difficult* was it for you to perform each task in the VIC compared to how difficult it is in the real world?**				
	Exactly Like	**Very Similar**	**Somewhat Similar**	**Very Different**	**Completely Different**	**Much Quicker**	**Somewhat Quicker**	**About the Same**	**Somewhat Slower**	**Much Slower**	**Much Better**	**Somewhat Better**	**About the Same**	**Somewhat Worse**	**Much Worse**	**Much Less Difficult**	**Somewhat Less Difficult**	**About the Same**	**Somewhat More Difficult**	**Much More Difficult**
COMMUNICATE																				
Employ virtual radio																				
Identify own fire team members																				
Know location of team members																				
Communicate with *own* fire team																				
Communicate with *other* fire team																				
Report to higher (to squad leader)																				
Indicate exit from room																				
Indicate room is clear																				
Consolidate & reorganize																				

VIC CAPABILITY ASSESSMENT QUESTIONNAIRE

ENGINEERING EXPERIMENTS

ID:_______________

Date:________ Time:____

Please answer these questions about VIC ___. Check the box that most closely corresponds to your experiences in the VIC.

	How *similar* was the way you performed each task in the VIC compared to the way you perform it in the real world?					How *quickly* could you perform each task in the VIC compared to how quickly you can perform it in the real world?					How *well* could you perform each task in the VIC compared to how well you can perform it in the real world?					How *difficult* was it for you to perform each task in the VIC compared to how difficult it is in the real world?				
	Exactly Like	Very Similar	Somewhat Similar	Very Different	Completely Different	Much Quicker	Somewhat Quicker	About the Same	Somwhat Slower	Much Slower	Much Better	Somewhat Better	About the Same	Somewhat Worse	Much Worse	Much Less Difficult	Somewhat Less Difficult	About the Same	Somewhat More Difficult	Much More Difficult
MOVEMENT																				
Outside Buildings																				
Move close to/hug building																				
Move past windows																				
Cross open areas																				
Cross obstacles																				
Maintain orientation																				
Avoid collisions																				
Change direction while moving																				
Maintain balance while moving																				
Inside Buildings																				
Enter a building																				
Move through doorways																				
Move around corners																				
Move through hallways																				
Enter a room																				
Take positions within a room																				
Move past other personnel																				
Move/climb up the stairs.																				
Move/climb down the stairs																				

VIC CAPABILITY ASSESSMENT QUESTIONNAIRE ENGINEERING EXPERIMENTS ID:_______________ **Please answer these questions about VIC ___. Check the box that most closely corresponds to your experiences in the VIC.**	**How *similar* was the way you performed each task in the VIC compared to the way you perform it in the real world?**					**How *quickly* could you perform each task in the VIC compared to how quickly you can perform it in the real world?**					**How *well* could you perform each task in the VIC compared to how well you can perform it in the real world?**					**How *difficult* was it for you to perform each task in the VIC compared to how difficult it is in the real world?**				
	Exactly Like	**Very Similar**	**Somewhat Similar**	**Very Different**	**Completely Different**	**Much Quicker**	**Somewhat Quicker**	**About the Same**	**Somwhat Slower**	**Much Slower**	**Much Better**	**Somewhat Better**	**About the Same**	**Somewhat Worse**	**Much Worse**	**Much Less Difficult**	**Somewhat Less Difficult**	**About the Same**	**Somewhat More Difficult**	**Much More Difficult**
Exit from a building																				
Avoid collisions																				
Change direction while moving																				
Maintain balance while moving																				
Maintain orientation																				
DETECT TARGETS																				
Search for targets																				
Detect targets while stationary																				
Detect targets while moving																				
Determine origin/direction of enemy fire																				
Detect targets at higher elevations																				
Detect targets at lower elevations.																				
ENGAGE TARGETS																				
Aim weapon																				
Fire weapon																				
Engage targets from prone position																				
Engage targets from kneeling position																				
Engage targets from standing position																				

Appendix B.6

STRUCTURED INTERVIEW
VIC

Name:	Date:	Interviewer:

1. What were the best features of each VIC?

VIC Alpha:	VIC Delta:	VIC Echo:	VIC Golf:

2. What were the least desirable features for each VIC? What features would you change?

VIC Alpha:	VIC Delta:	VIC Echo:	VIC Golf:

3.a) In which VIC was the visual display most like the real world?

b) In which VIC was the visual display least like the real world?

4.a) In which VIC was movement most like the real world?

b) In which VIC was movement least like the real world?

5.a) In which VIC was shooting most like the real world?

b) In which VIC was shooting least like the real world?

6. Were you able to tell where the enemy fire was coming from? Were there any differences in this between the VICs?

7. a) How difficult was it to differentiate your fire team from the enemy soldiers?

b) How difficult was it to differentiate your fire team from the other fire team?

8. What changes need to be made to the MOUT database? How does it need to be different?

9. Which pieces from the different VICs would you put together to form a new and better VIC?

10) What else did I forget to ask you?

Appendix C

McKenna MOUT Site, Fort Benning, GA

Mission Scenario: Enter Building & Clear Designated Rooms
Behavioral Observation Checklist (from FM 90-10-1)

Soldiers:
#1 (Squad Leader)
#2 (Fire Team Leader/Rifleman)
#3 (Rifleman/203)
#4 (Rifleman/203)
#5 (Fire Team Leader/Rifleman)
#6 (Rifleman)
#7 (SAW Gunner)
#8 (SAW Gunner)
9 (Rifleman)

PART A

1. Accidental discharge of weapon. One accidental discharge occurred. #7 discharged his weapon in the vicinity of #5. As the fire team (FT) was moving out of room 1 into room 2, #7's weapon accidentally discharged.

2. Difficulty firing weapon. Other than the accidental discharge by #7, every soldier handled his weapon appropriately during both the initial assault and subsequent room clearing exercise.

3. Fire control and discipline. Every soldier utilized excellent fire control during and throughout the assault. Soldiers discharged their weapons in burst of 3 rounds or less. No one fired recklessly. The only exception was the accidental discharge by #7.

4. Tactical positions used. Soldiers were not consistent or systematic in their use of various tactical positions. Soldiers were observed standing when they should have been kneeling or squatting. Specifically, #4, #3 and #8 repeatedly exposed themselves by not taking appropriate cover. No one used the prone position during the assault.

5. Problems acquiring, identifying and engaging targets. There were no opposition forces occupying the building during the assault. The "lone sniper" occupying one room on the first floor was quickly identified and quickly neutralized.

6. Soldier fully integrated, functional, in sync with members of FT and cognizant of his location and the location of other soldiers in his FT/squad. All soldiers worked together in concert and backed each other up. FT Leaders were continuously aware of the location of each member of their team. Movement to and through the objective was smooth and well orchestrated.

7. Locomotion problems, e.g., rate of speed, direction, stopping. Movement to the building was well coordinated and tactically smooth. Even though entry into the building was through a narrow window on the side of the building, and not a blast hole as previously rehearsed, there were no glitches and everyone performed their assigned task as planned. Entry into the building through the narrow side window was performed in under 1 minute. Once in the building, no movement/locomotion problems were observed. Again, everyone knew and performed their assigned task well.

8. Soldier frustrated, disoriented, confused, baffled, overwhelmed or distracted. No. All soldiers displayed a high state of readiness and demonstrated great enthusiasm and realism. They approached the mission like it was "the real thing." The soldiers were able to maintain the same high degree of intensity from start to finish.

PART B

9. Lies prone to look around corners. No one took the time to perform this tactical movement skill. Instead, soldiers looked around corners in a somewhat kneeling/ squatting type position.

10. Extend weapon beyond corner or object. Several soldiers (#4, #3, #9, #7) gave their position away by extending their weapon beyond the corner where they were positioned.

11. Keeps head below windows and hugs wall when moving past windows. All soldiers hugged the wall while moving through the first floor hallway. The same tactical awareness did not hold true for moving past windows. No one took the time to stoop down or low crawl past windows.

12. Stays close to wall and steps or jumps over the window when moving past basement window. The scenario did not afford soldiers the opportunity to practice this tactical movement skill.

13. Moves across open areas in group with other members of his FT. Soldiers assaulted the building by moving across 100 feet of open terrain as a unified attack element. Once at the window, they reconstituted and moved through the window according to a pre-planned order of entry.

14. When moving to an adjacent building across an open area, maintains a distance of 3 to 5 meters in relation to other soldiers in his FT, moves quickly and makes abrupt flanking movements (on line). The scenario did not afford soldiers the opportunity to practice this tactical movement skill.

15. When firing from a covered position, soldier fires around the side of his cover, not over the top. After entering the building and clearing the first room, #7 and #8 took cover behind a refrigerator and desk situated in the hallway adjacent to the room they

had just cleared. While in kneeling/squatting position, #7 and #8 fired their weapons around the side of their cover, not over the top.

16. Soldier fires from his left shoulder when firing from the left corner of a building and from his right shoulder when firing from the right corner of a building. The scenario did not afford soldiers the opportunity to practice this firing technique. However, once inside the building, all soldiers did utilize this firing technique when approaching and assaulting rooms situated on either the left or right side of the hallway.

17. Order issued to lift or shift fire support. Prior to the start of the assault, order issued by the Platoon Leader to shift fire so assault team could enter building at the designated point of entry.

18. Platoon Leader orders squad to assault building. Yes.

19. Soldier and FT employ crawl/crouch-walk mode when "stacking." Prior to entering the building via a first floor window, soldiers perform "stacking" procedure utilizing crouch-walk posture. Once stacked, soldiers entered the window as pre-planned.

20. FT weapons are "oriented" (weapons pointed up, rear, forward and outward) prior to assault. While stacked and waiting outside the window to enter the building, soldiers provide fire-team security by aiming weapons outward, upward, forward and to the rear. SAW Gunner was oriented to the rear and was the last to enter the building.

21. Soldier avoids silhouetting himself in doorways and windows. After clearing rooms one and two, soldiers occupying those rooms (#3, #4, #7 and #8) repeatedly walked past and stood in front of windows located at the rear of the building.

22. When moving in hallways, soldier stays low against the wall. All soldiers assigned to clear rooms three, four and five stayed low and hugged the wall prior to their assaults.

23. When entering a room, soldier avoids using the door handle. Instead, he fires a short burst of automatic fire through the door before attempting to "bust" through the door. The scenario did not afford soldiers the opportunity to practice this room clearing technique. However, after using hand-grenades to perform initial room clearance, soldiers "sprayed" each room with a short burst of fire before entering the room.

24. Before entering a room, lead soldier "cooks" off concussion grenade, throws it into room and shouts "frag out". #2 and #5 cooked off a "concussion grenade" and yelled "frag out" before throwing the hand grenade into the room they were assigned to clear.

25. First soldier enters the room, positions himself to the left or right (against the wall), scans the room and engages targets with short burst of automatic fire. Yes.

26. First soldier in the room shouts the command "next man in, left (or right)." Yes.

27. Second soldier entering the room shouts “coming in, left (or right), “ and positions himself to the left or right of the entrance, up against the wall. Yes.

28. Once in position, second soldier shouts “next man in (right or left)” This procedure was repeated until every soldier assigned to a particular room occupied that room. Soldiers not assigned to a room stood in the hallway and provided security.

29. Once room is clear, FT leader shouts “clear” and designates the room as such per SOP. Yes.

30. Fire Team Leaders demonstrate proper voice and radio communication skills and techniques. Correct voice commands were used by both FT Leaders and fire team members. This mission did not use radios for communication.

31. FT members follow voice commands. Yes.

32. Security team posted. Yes.

33. FT consolidates and reorganizes as necessary. Yes.

Part C

McKenna exercises: Routes A and B (non-tactical and tactical runs).

#1 Soldier performed non-tactical route exactly as rehearsed. During tactical route, soldier encountered no problems and used correct tactical search and movement skills.

#2 Soldier performed non-tactical route exactly as rehearsed. During tactical route, soldier encountered no problems and used correct tactical search and movement skills.

#3 During non-tactical route, soldier was in a hurry to complete the exercise and got lost on the second floor. Following re-direction, soldier was able to re-orient himself and complete the route with no additional problems. During tactical route, soldier used correct tactical search and movement skills.

#4 Soldier performed non-tactical route exactly as rehearsed. During tactical route, soldier encountered no problems and used correct tactical search and movement skills.

#5 During non-tactical route, soldier became disoriented on the second floor and got lost. Following re-direction, soldier was able to re-orient himself and complete the route with no additional problems. During tactical route, soldier did not employ good tactical search and movement skills. More than once, the soldier silhouetted himself in doorways and windows and did not hug walls and stay low when moving through hallways.

#6 Soldier performed non-tactical route exactly as rehearsed. During tactical route, soldier encountered no problems and used correct tactical search and movement skills.

#7 During non-tactical route, soldier became disoriented on the second floor, entered rooms out of sequence, and got lost. Following re-direction, soldier was able to re-orient himself and complete the route with no additional problems. During tactical route, soldier did not employ good tactical search and movement skills. Soldier repeatedly silhouetted himself in doorways and windows, did not hug walls and stay low in hallways, and extended his weapon beyond corners.

#8 Soldier performed non-tactical route exactly as rehearsed. Although the soldier encountered no problems following his tactical route, he failed to use correct tactical search and movement skills. Soldier extended his weapon beyond corners and did not kneel, squat or lay prone to look around corners.

#9 During non-tactical route, soldier entered rooms on the first floor out of sequence. Following re-direction, soldier corrected his mistake and experienced no additional problems following either the non-tactical or tactical route. Soldier's use of tactical search and movement skills very inconsistent and sporadic. On the first floor, the soldier hugged walls. On the second floor, however, he did not hug walls and walked in the middle of the hallway as he made his way to the rear stairwell.

Appendix D

Structured Interviews - Summary of Key Comments

[Comments from various soldiers have been consolidated and slightly edited, and identifying information has been deleted. If several soldiers made the same comment, it was not repeated.]

<u>What were the best features of each VIC?</u>

<u>ALPHA</u>:

Aiming realistic. Liked being able to turn around and have own movement changing the view. It provided good peripheral vision. The front sight aperture made the weapon feel real. Actual weight of the weapon made it feel very real. Freedom of motion, ability to rotate 360 degrees. This rifle felt more realistic than the others because of weight and the front sight. Like being able to look around corners and to the left and right.

<u>DELTA</u>:

This VIC was easiest to operate. IHAS allowed me to look around corners and engage targets. It forced me to kneel and lay prone. The joystick allowed me to move faster than any of the other VICs. Good FOV. Just point & shoot. Look up & down and body mimics real world even though not connected.

<u>ECHO</u>:

Liked the wide FOV and display was the clearest. Like D easy to move in it and liked the IHAS. Liked 80 degrees of vision. Provided good peripheral vision when it came to identifying targets and seeing objects. Movement in E felt more realistic than on D. You're in there surrounded by screens – audio is awesome, maybe because it is in the corner? You can pie around a corner, can move good, get into it; surrounding. It made me dizzy sometimes and also the walls seemed close. It was hard to move inside the building. With big screens it was easier to go through doors. IHAS was great for sighting and firing.

<u>GOLF</u>:

Being able to run and walk gave sense of movement which made the mission seem more real. Gave the physical aspect of moving through the building. This added a small degree of realism to the mission. It made me feel as though I was actually walking and running. A sense of actually engaging in physical movement. It made the feel of walking through the mission real. The treadmill was fun, but that's not applicable to the project. I just liked it. Sometimes moving on the treadmill actually got me hyped up.

What were the least desirable features for each VIC? What would you change?

ALPHA:

Visual display got fuzzy, especially when you turned your head. Batteries went dead too often making the system go down. Had to stay close to the center of the area or you had to stop everything and recalibrate. There was a delay in the visual display when you moved your head. Helmet display was difficult to get right over glasses. Should put a new battery in. Need to have two BDUs. Should put on top of own shirt not T-shirt. Having to put on all the equipment was a hassle. BDU top got sweaty and smelled bad after the second day. It was a real hygiene issue. Even when it was working good display would keep blinking off. Inability to physically move around was a big problem. Getting stuck in the wall made it hard to stay focused on the mission.

DELTA:

Several times I had to pull the trigger more than once to get the weapon to fire. Changing magazines was not realistic. Sometimes the screen got blurry and I had to be careful not to move or drift to close to the screen. IHAS was hard to look through and it was hard to see and judge the distance of far off targets. I pretty much had to look straight ahead. Constantly having to move back and forth to clear my vision. Too much distraction from the computer people sitting and standing behind me. This made it hard to hear and concentrate. The rifle was too light and did not feel like a real one. In prone, I had to push myself up very high on my elbows to see targets. The thumb joystick is hard to control and the iron sight is too. You had to crouch down to look up on top of buildings.

ECHO:

The joystick was a problem to control. It could be like Alpha and just turn on you. Joystick was less of a problem because you had a wider view. W/o IHAS can't hit anything on L and R screen. Can't adjust fire on the sides. Like D, you had to crouch to look up. Should have a button that brings the IHAS up when you need it. When I tried to move fast from left to right, I always got dizzy. The dome effect is good because it allowed move to see everything. Field of view was very wide. The selector switch is not the right size. This required me to look down when changing it. Should be able to change it by touch, not vision. Had to keep flipping IHAS up and down to move and see targets. The screen kept changing colors and this made it hard for me to stay focused. This hurt my concentration.

GOLF:

Very hard to walk with the IHAS down. Had to keep looking down at my feet to keep balanced. The treadmill was very jerky and did not feel natural. I got a headache from all the jerking. It was hard to turn my body to see what was going on. Need to have less wires hooked up to the soldier. Always had the feeling I was going to fall. Focused more on keeping my balance and not the mission. Easy to get disoriented on treadmill. Easy to get tangled in the wires. Peripheral view was very limited - could pretty much only look straight ahead.

Being in a harness was unrealistic. Treadmill was very sensitive to movement. It was hard to keep up with the others. It was very hard to approach and turn corners. Need the side piece- like the kind you get at the eye doctor when your eyes have been dilated so the sides don't bother you. Couldn't do a 360 without getting tangled. Aiming the floating weapon was bad. Didn't like using a button to change posture and many times didn't know what posture they were in.

In which VIC was the visual display most like the real world? E because the view was wide and clear. D flat screen as changed on Friday. E&D sense of outside. A but the shape of the weapon needs to look more realistic. It's on eyes and you feel like you are there. The gray walls inside the buildings made it hard to determine distance and depth. The figures need to look more realistic.

In which VIC was the visual display least like the real world? D because of only one screen view. A because the view is distorted. Blockier faces. None (2). If visuals were all working they were all the same. G- when running, the screen would slightly bounce up and down; color was too bright. The building [LWTB] should have been dimmer.

In which VIC was movement most like the real world? G - if you could keep it up and get good at it; get the bugs out. The piece in the back helped so you didn't go around; felt it and went the other way. If it worked it would be awesome. It was hard to keep up. If you could take all positions (postures) like in A, it would be most like the real world. D - it's faster.

In which VIC was movement least like the real world? A going L to R. D and E. The joy stick made it feel like I was at an arcade at the mall. I was pretty much stationary. It was impossible to stack. Moving forward and lateral was hard.

In which VIC was shooting most like the real world? A - front sight post gave me the feel of actually pointing my weapon at targets. Hard to line-up targets on the other VICs. Look through front and rear sight post w eye piece. Weapon didn't have wires tied to it. D and E with IHAS. You have iron sight like the real world. Need to change the weapon to make it more to scale though. D is good and E could be. If it were aligned right with the iron sight, they would be the same.

In which VIC was shooting least like the real world? G - "I hit one target the whole time I was on it." Weapon flying in the air. Hard to line-up the IHAS and sight the weapon. Involuntary movement of treadmill made it hard to aim my weapon and keep my balance at the same time. E - IHAS made it hard to point and fire weapon. IHAS and weapon not synchronized. D - IHAS was not zeroed properly. It was hard to line it up with the weapon. Sometimes I had to point my weapon in the opposite direction I was looking just to get the target in my sights.

<u>How difficult was it to differentiate your fire team from the OPFOR?</u> OPFOR were easy to ID. Our fire team was easy because of the numbers, easier than the real world. At first it was hard - not know what to look for, what outfits, nothing on them to tell – dark suits, maybe a symbol? Everybody had green and it was hard to separate the good guys from the bad guys. I got confused because our uniforms looked so much alike. When they changed to the black uniforms it was easy. Couldn't tell if the person I was looking at was the enemy or someone in my fire team. In the real world, I would have been shot while waiting. Enemy looked like us physically. Their weapons also looked similar to our rifles.

<u>What changes need to be made in the MOUT database?</u> Put things in the rooms. It would give the OPFOR something to hide behind and add realism. In combat rooms full of stuff – in real life couldn't run through it. Contrast between doorways and openings and the wall. Everything looks flat when in or by a doorway. Everything is the same color—there is nothing for depth perception. Different fixtures in rooms, it shouldn't be the same all the time. Furniture needs to be added inside the building. Gray should not be used because it created depth perception problems. Should not be able to walk through walls into other rooms. Should be noise in the building and grenades. Be able to be wounded and have the option to call for a medic and have one appear. The weapons should physically look different. Put civilians in the building.

<u>Which pieces from the different VICs would you put together to form a new VIC?</u>

Aiming from A, movement from G, surround screen like E. Sensors track all you do and could tell where you are injured. E gets you free to move. Good audio. Not the treadmill. Combine A and E and put face in it. G makes you mobile; in A you are in it with equipment on; in E with 360 view. Need earphones to talk and hear. Positions (postures) from A. Keep IHAS and combine it with the virtual iron sight from A. Add a dot to say when you were on target and get rid of all the wires. Instead of treadmill, put someone in a big room and actually walk. Don't know how you'd do that though, it'd be expensive. Weapon from D, screen from E. Get rid of suit from A, cause reflectors keep coming off, but keep the rest, because wiring is in the way on others. If they could put all the stuff in a pack instead of being wired that would be good. Like being able to turn all the way around and just use joystick to move forward and backward on A. A weight of the weapon felt correct and the sighting was somewhat realistic. The treadmill minus the wires, harness and constant jerking motion.

<u>What could you do tactically at McKenna MOUT site but not in the VIC?</u> Move close to walls. Grenades, smoke. Movement in tight spaces like doorways and halls. Hand and arm signals. Overall commo was not replicated. Lose your breath, tripping, physical, hear enemy coming. Command and control in rooms. <u>In the VIC but not McKenna</u>? Walls – move through; not hear, see only. Commo was too good; noisy at site. IHAS is awesome if you had a few in MOUT.

Couldn't have physical contact with my people. Couldn't climb ladders to the roof, couldn't do combat rolls, couldn't talk to people face-to-face. Even though we had the commo, it wasn't the same. You lose face and body language. Couldn't see myself and my surroundings. Movement was better at McKenna. In the VICs, we could not stack properly inside the building. Better situational awareness at the MOUT site; I knew where everyone was at in relation to my location inside the building. At the MOUT site, we could clear hallways and stairwells together as a team. This made the assault much more realistic. In the VICs, everything was cluttered up; we were stumbling and falling over each other. Half the time I did not know the location of my fire team members. There was too much confusion because everyone got jammed up in the rooms, hallways and on the stairwells. Communication in the VICs was a real problem.

What would the ideal VIC have to do to be good for MOUT training? 360 view. Wireless weapon. Walking, turning, and your own posture changes. Grenades. Hand and arm signals. Real weapon with weight. Different weapons. Weapon reload. Physical, good commo; dismounted training, strong cohesion and team work. Physical contact is important, to touch things. Would need a screen that worked for me as an individual. People see differently, it would have to be attuned to me. Be able to look and see targets at higher elevations easier and the aim would have to be dead-on. Not computer aiming but what I see through the iron sight. Control movement better. If you could see yourself you could see your position better. More accurate weapon sighting system that would line-up targets without having to turn my weapon sideways or upside down. Safely walk, run and low-crawl, use hand-grenades and other weapons. VIC G is too dangerous because of the fall risk it presents. Should be able to look 360 at all times. At the MOUT site, could do this with no problem.

What do you see new, improved VICs being used for? Make you more aware of OPFOR. See what a larger element might do even though you are training with a fire team or squad element. Build teams. Practice, leadership skills, TLs and SLs. Integrate new soldiers. Train faster; nobody gets hurt, tired and hot. Bad habits here. Planning out missions. If you have really good intel and could set up a room in the virtual world, have the layout of the place - could be there without being there. Have realistic bloodshed. If you really go to war, you need to be desensitized. Enemy shouldn't die right away, could go down screaming but shooting. Drag injured people out. Simulate missions for new soldiers.

What else would you like to say? Could not stack or move well as an element. Distance estimation was bad even for close things so you might bump into the door or wall. Getting stuck in walls or walking through them was frustrating. It was a distraction seeing your team members jumping around or moving out while still in a prone or kneeling position. Liked being out of the elements and still doing something related to their job. All systems slight delay after pulling the trigger. Going room to room was ok but shooting was better. G is the only one where you have to hustle. G needs everything like D and E. Can't move and shoot at the same time. Lean too far forward and start to move. Look around corner with IHAS good. AAR you could see exactly what happened. Good for training crews. Use for trench lines, grenades, clear, stack, and pie corners. Reduce injury; keep going over and over. If you drop a magazine you don't lose it; no fratricide or trip and fall and fire. Go in a file to the hole and walk/go in a line – would go in fire team/buddy teams move over together but G too slow. Point into the building and you go there with D and E. Go down the streets fast with joystick. With G have to move your head up and down to be realistic. W/O IHAS use Kentucky windage. Over head, no burst on ground. Fire short - walk it in. The screen was way off. Helmet too sensitive; screen flickers, moves too easily. Can't tell where the fire is coming from - no idea where fires are. All VIC thumb joysticks hard to control. Different joysticks on different VICs are hard to get used to. Need peripheral vision to help move. If you could see your own body that would be good. I could better tell where I was standing, like was I right next to the wall when I was supposed to be stacking. It would be nice if it had grenades that you could use without killing yourself. VICs should be used strictly for rehearsal and practice, not actual training. Soldiers should know the basics before training on the VICs. It is real easy to pick-up bad habits on the VICs if you do not know right from wrong. Once you know how to properly clear a building, then you can train on the VICs. It is real easy to forget how to do something the right way when you are on the VICs. For this reason, I feel the VICs should be used only after the soldier has been properly trained at the MOUT site.

Appendix E: VIC Capability Assessment Questionnaires

User Exercises (N=8 for all cells).

A. Tactical Movement:

Tactical Movement - Similarity

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.27	3.20	3.09	2.70
Std. Deviation	1.18	1.19	.92	.88

Tactical Movement - Quickness

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.60	3.04	2.90	2.34
Std. Deviation	1.13	1.06	.69	.86

Tactical Movement - Performance

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.32	3.05	2.92	2.48
Std. Deviation	1.08	1.07	.94	.65

Tactical Movement - Difficulty

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.39	2.95	3.12	2.46
Std. Deviation	1.08	1.06	.77	.88

Tactical Movement - Overall Mean Ratings

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.40	3.06	3.01	2.49
Std. Deviation	1.08	1.04	.76	.78

B. Room Clearing

Room Clearing - Similarity

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.15	3.46	3.00	2.54
Std. Deviation	1.01	.70	.53	.44

Room Clearing - Quickness

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.46	2.94	2.79	2.53
Std. Deviation	.96	.94	.69	.55

Room Clearing - Performance

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.22	2.86	2.76	2.35
Std. Deviation	1.11	.96	.84	.55

Room Clearing - Difficulty

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.35	2.90	2.60	2.43
Std. Deviation	1.04	.99	.90	.62

Room Clearing - Overall Mean Ratings

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.30	3.04	2.79	2.46
Std. Deviation	.99	.87	.70	.47

C. React to Contact/Engage:

React to Contact/Engage - Similarity

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.64	3.20	3.08	3.13
Std. Deviation	1.08	.99	.64	.89

React to Contact/Engage - Quickness

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.74	2.88	2.50	2.63
Std. Deviation	1.04	.86	.50	.97

React to Contact/Engage - Performance

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.74	2.75	2.50	2.78
Std. Deviation	1.03	.59	.73	.90

React to Contact/Engage - Difficulty

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.72	2.92	2.72	2.88
Std. Deviation	1.02	.76	.65	.87

React to Contact/Engage - Overall Mean Ratings

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.71	2.94	2.70	2.85
Std. Deviation	1.03	.72	.52	.88

D. Communicate:

Communicate - Similarity

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.96	3.35	3.10	3.26
Std. Deviation	1.19	.98	1.08	.80

Communicate - Quickness

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	3.03	2.99	2.87	2.97
Std. Deviation	.94	.81	1.09	.66

Communicate - Performance

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	3.13	2.95	3.01	2.98
Std. Deviation	1.02	.90	.89	.78

Communicate - Difficulty

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	2.95	3.05	3.00	2.99
Std. Deviation	.85	.92	.90	.75

Communicate - Overall Mean Ratings

	VIC Subject 1-8			
	VIC ALPHA	VIC DELTA	VIC ECHO	VIC GOLF
Mean	3.02	3.09	3.00	3.05
Std. Deviation	.95	.86	.96	.72

Engineering Experiments

The means of the individual items that differed significantly in one or more dimensions are shown below.

Dimension/Task	N	P	VIC A	VIC D	VIC E	VIC G
Move past windows						
Difficulty of Performance	9	.008	3.44	3.33	3.33	2.44
Quality of Performance	9	.023	3.33	3.00	3.33	2.44
Similarity to the Real World	9	.010	3.12	3.12	3.88	2.25
Cross open areas						
Speed of Performance	9	.011	3.89	3.78	4.11	2.67
Cross obstacles						
Difficulty of Performance	9	.028	3.22	3.44	3.22	2.44
Similarity to the Real World	9	.021	3.56	3.00	2.56	2.44
Maintain orientation (outside)						
Speed of Performance	9	.041	3.56	3.11	3.56	2.56
Avoid collisions (outside)						
Quality of Performance	8	.027	2.75	3.25	2.62	2.00
Change direction while moving (outside)						
Difficulty of Performance	9	.012	3.33	3.33	3.00	2.11
Maintain balance while moving (outside)						
Difficulty of Performance	9	.003	3.89	3.67	3.11	2.00
Quality of Performance	9	.001	3.88	3.56	3.67	2.22
Speed of Performance	9	.005	3.67	3.33	3.44	1.56
Take positions within a room						
Quality of Performance	5	.027	2.20	2.80	1.80	2.40
Speed of Performance	5	.031	2.60	2.40	1.60	2.20
Search for targets						
Difficulty of Performance	8	.033	3.12	3.25	3.25	2.25
Quality of Performance	9	.019	2.89	3.67	3.56	2.44
Detect targets while stationary						
Quality of Performance	9	.010	3.56	3.44	3.33	2.22
Speed of Performance	9	.019	3.56	2.89	3.33	2.11
Detect targets while moving						
Speed of Performance	8	.011	3.75	2.75	3.00	2.00
Determine origin/direction of enemy fire						
Speed of Performance	7	.038	2.86	3.29	2.57	1.71
Detect targets at lower elevations						
Quality of Performance	9	.004	3.22	3.56	3.33	2.33
Speed of Performance	9	.025	3.56	3.11	3.00	2.44
Similarity to the Real World	9	.005		3.78	3.56	2.33

Dimension/Task	N	P	VIC A	VIC D	VIC E	VIC G
Aim weapon						
Difficulty of Performance	7	.001	3.29	3.29	2.43	1.71
Quality of Performance	8	.000	3.62	3.38	2.88	1.88
Speed of Performance	9	.001	3.44	3.22	2.67	2.00
Similarity to the Real World	9	.001	3.78	3.00	3.00	1.56
Fire weapon						
Quality of Performance	9	.022	3.22	3.78	3.89	2.89
Speed of Performance	9	.042	3.22	3.67	3.89	2.78
Engage targets from prone position						
Similarity to the Real World	9	.001	3.78	3.00	3.00	1.56
Engage targets from kneeling position						
Difficulty of Performance	8	.008	3.25	3.38	3.25	2.12
Similarity to the Real World	9	.019	3.33	3.89	3.33	2.44
Engage targets from standing position						
Difficulty of Performance	8	.015	2.88	3.38	3.12	1.87
Quality of Performance	9	.001	3.11	3.56	3.33	1.78