Current Issues in the Use of Virtual Simulations for Dismounted Soldier Training

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ABSTRACT

Research on the use of virtual simulation to train Soldiers and leaders in small dismounted units has largely focused on the use of specially developed, relatively high-fidelity PC-based simulators. It has been successful in demonstrating that virtual simulation can adequately support the performance of a variety of Soldier activities, and is perceived to be effective for training both individual and collective Soldier skills. However, as computer graphics technology has advanced, the interface devices (head-mounted or projection displays, position trackers, and instrumented mock weapons) required for immersive virtual simulations have become a relatively larger contributor to the cost of simulators than the simulation engine. This raises the question of whether a high-fidelity interface contributes sufficiently to training effectiveness to justify its cost. In addition, the widespread availability and use of video and computer games has raised the question of whether either commercial games or specially designed games can meet some part of the Army's training needs. This paper describes and discusses these issues in detail, presents supporting research evidence, and describes future research needs.

1.0 INTRODUCTION

The potential benefits of using virtual simulation to train Soldiers and leaders in small dismounted units have been recognized for more than a decade. During that period the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has conducted research to evaluate the capabilities of virtual technology to provide dismounted Soldier and leader training, the effectiveness of that training and instructional techniques to enhance it, and mechanisms for providing performance measurement and feedback. The focus of the research has largely been on the use of specially developed, relatively high-fidelity PC-based virtual simulators. Our approach has included both field assessments of virtual training technologies with Soldiers in realistic training settings and more scientifically rigorous experimentation in a laboratory setting. The research program has been successful in demonstrating that virtual simulation can adequately support the performance of a variety of Soldier activities, and is perceived to be effective for training both individual and collective Soldier skills.

Knerr, B.W. (2006) Current Issues in the Use of Virtual Simulations for Dismounted Soldier Training. In *Virtual Media for Military Applications* (pp. 21-1 – 21-12). Meeting Proceedings RTO-MP-HFM-136, Paper 21. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

During the past few years, however, there have been changes in both the training needs of the Army and the range of potential training solutions available. These changes present both new challenges and new opportunities.

In part because of changes in doctrine describing how we expect to fight in the future, and in part because of the lessons we have learned in current operations in Iraq and Afghanistan, the Army now recognizes a need to train Soldiers and leaders to be adaptable, capable of responding to rapidly changing situations, and attuned to cultural conditions, in addition to being proficient in high-intensity combat operations. With this new context, it is proposed that virtual simulation could be used not only to train for relatively straight-forward combat operations, but also to train the decision making and command and control skills that small unit leaders and Soldiers need in the current operating environment. This change in training needs has implications for simulation requirements.

At the same time, advances in computer graphics technology and processing power have made it possible to generate the graphics and calculate weapons and environmental effects with moderate-cost PCs, at costs approaching 1% of the cost of the graphics generators of a decade ago. However, the costs of the interface devices (head-mounted or projection displays, position trackers, and instrumented mock weapons) have declined only slightly during the same period, making them a much larger contributor to the cost of simulators than the computer itself. Do these high-fidelity interface devices (locomotion devices or immersive displays) contribute enough to training effectiveness to justify their cost?

In addition, the availability and presumed widespread use of video and computer games by Soldiers has created interest in the use of either commercial or specially designed games to meet some part of the Army's training needs. While such games were initially seen as being too constrained and insufficiently realistic to provide training benefits, the potential to take advantage of both the huge commercial investment in video game technology and the experience of Soldiers playing video games has tremendous appeal. Are Soldiers as familiar with these games as we assume, and how well do the games train?

This paper will describe and discuss these issues in more detail, presents supporting research evidence from recent field assessments and experiments, and describe future research needs.

2.0 BACKGROUND RESEARCH

ARI has been interested in the use of virtual simulation to train dismounted Soldiers for more than a decade. Our research began with analyses of the feasibility of using VE technology for dismounted Soldier training and the identification of difficult technical problems and research issues (Levison and Pew, 1993; Jacobs et al., 1994). With these as a basis, we initiated a laboratory research program to investigate critical behavioral science research issues, ranging from the investigation of interface effects on task performance to the effects of geographically distributed team members on training effectiveness. Reviews of the research are contained in Knerr, Lampton, Singer, Witmer, and Goldberg (1998) and Lampton, Knerr, Martin, and Washburn (2002).

In 1997 we began to expand our research program to include field experiments as well as laboratory experimentation. We were able to do this by forming partnerships with other Army research and developments organizations with which we had goals in common. While these field experiments sometimes lacked the control and precision of our laboratory experiments, they compensated by providing an opportunity to obtain data on the use of virtual simulation technology by Soldiers as they performed actual Soldier tasks.

Our involvement with field experiments began with Dismounted Warrior Network (DWN). DWN was a U.S. Army Simulation, Training, and Instrumentation Command (STRICOM)[1] research and development program to develop a virtual simulation capability for dismounted Soldiers. A series of experiments was conducted during 1997 to investigate different simulator interfaces (Lockheed Martin Corporation, 1997; Pleban, Dyer, Salter, and Brown, 1998). A follow-on project entitled DWN Enhancements for Restricted Terrain (DWN ERT) focused on Military Operations in Urban Terrain (MOUT). Simulators were modified and capabilities added based on lessons learned in the DWN experiments. Experiments conducted in 1998 produced the general conclusion that although the simulation capability was still not sufficiently mature to support the training of squad missions in an urban environment, it showed potential (Lockheed Martin Corporation, 1998; Salter, Eakin, and Knerr, 1999).

During the next phase of the research, ARI participated in a multi-organizational program entitled "Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal." This four-year effort focused on overcoming critical technological challenges to high fidelity dismounted Soldier simulation identified during the previous research. These critical challenges included: simulating locomotion; tracking weapons and body positions; creating realistic performance of computer-controlled dismounted friendly and enemy Soldiers; simulation of night equipment and sensor images; making terrain and structures dynamic; developing appropriate training strategies and methods; assessing individual and unit performance; and determining transfer of training from virtual to live environments. At the end of each year of the effort, we conducted a series of exercises with Soldiers to help assess our progress. The overall effort was successful, although some of the individual technologies were identified as requiring further improvement or not yet sufficiently mature for use. One of the recommendations resulting from the effort was the following:

> Given the current state of technology, it appears that VE could be used effectively for some types of training and some stages of training. VE could be used for the walk phase of the training, concentrating on improving the decision making, situation awareness, communication, and coordination skills, while real world training could place greater emphasis on the motor skills. Therefore, although there are still further improvements that can be made in the individual technologies, as identified earlier in this report, the next step should be an advanced development effort, taking a total systems approach, to produce a prototype VE training system for the leaders of small dismounted Infantry units. (Knerr et al, 2003, pp. 47-48).

3.0 THE VIRTUAL INTEGRATED MOUT TRAINING SYSTEM (V-IMTS)

Partly as a result of this recommendation, the U.S. Army Research, Development and Engineering Command Simulation and Training Technology Center (RDECOM STTC) led, and ARI participated in, the fielding and evaluation of a prototype deployable dismounted Solder simulation system, the Virtual Integrated MOUT Training System (V-IMTS). This will be described in detail because in many ways it represents the culmination of more than a decade of effort, and because the results provide the basis for much of the discussion which follows.

A deployable shelter approximately 40 feet square was placed next to the control center of the Cassidy Combined Arms Collective Training Center, Fort Campbell, KY. The center consists of a 28-building complex of one- to four-story buildings representing a small town. The control center is adjacent to but

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[1] As a result of a re-organization on 1 October 2002, the participating element within STRICOM became a part of the Research, Development, and Engineering Command, Simulation and Training Technology Center.

physically separated from the complex. Three Soldier Visualization Station Immersive (SVSI) simulators and six SVS Desktop (SVSD) simulators were installed inside the shelter as shown in Figure 1. The SVSI is an immersive virtual simulator (Figure 2) which uses a rear-screen projection system to present images (800 X 600 resolution) on a screen approximately 10 feet wide by 7.5 feet high. The Soldier's head and weapon are tracked using an acoustic/inertial tracking system. The Soldier navigates through the environment via a thumb switch located on the weapon. The SVSD is functionally similar to the SVSI, but the Soldier sits at a PC and views the simulation on an LCD monitor. A joystick is used to control movement and weapons use. The squad leader and two fire team leaders used the SVSIs. The remaining Soldiers used the SVSDs set on tables located immediately behind their fire team leader. The SVSI and SVSD simulators were included in a network with computer-generated forces, an After Action Review (AAR) system, and simulators used for human opposing forces. All Soldiers on the network could see and interact with each other's avatars. Voice communication among the Soldiers was unaided (i.e., they shouted) except for a handheld radio used by the squad leader to communicate with his platoon leader.

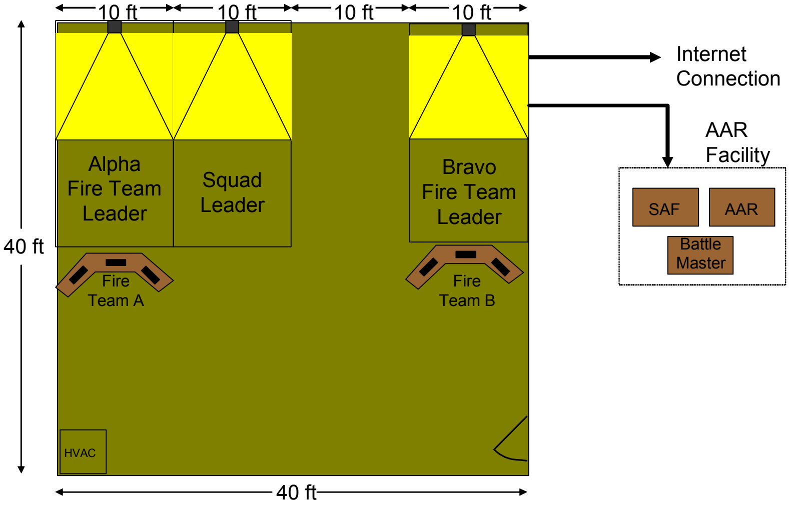

Figure 1: A Diagram of the V-IMTS Deployable Shelter and Simulation Network Components.

Figure 2: A Soldier in the SVSI.

Twenty-seven Soldiers from three existing squads participated in the assessment. While 68% of the Soldiers had served a tour in Iraq or Afghanistan, all three squad leaders, and three of the six team leaders, had served in their current duty position for one month or less. Their unit personnel, assisted by technical personnel, controlled the exercises and conducted the AARs. The scenarios consisted of multiple variants of two missions: Cordon and Search a Building and Attack/Assault a Building. The variants differed in the buildings involved and the positions and actions of the enemy.

It was intended that each squad would conduct two live exercises separated by up to six virtual exercises (depending on time requirements) over a two-day period. However, because of severe weather, only Squad 1 was trained exactly this way. Each squad completed two live exercises separated by two, three, or six virtual exercises. Overall mean duration of the virtual exercises was 16.7 minutes. Squad 1 participated in virtual exercises for 96 minutes, squad 2 participated for 77 minutes, and squad 3 participated for 44 minutes.

At the completion of their training, Soldiers completed a *Simulator Capability Questionnaire,* which asked them to rate how well they could perform each of 54 activities in the simulators, and a *Training Effectiveness Questionnaire*, on which they rated their improvement on each of 11 tasks as a result of their training.

The activities which Soldiers indicated could be performed best included outdoor movement, identification of types of people (civilians, non-combatants within a room, enemy soldiers), identification of tactically significant areas (sectors of observation and responsibility), and individual weapons use (but not grenades). Activities which Soldiers said they could not perform well included maneuver indoors (close to others, past furniture, close to walls, around objects, past other personnel, around corners, through doorways, up and down stairs), and identifying the source and type of fire (enemy or friendly), either by auditory or visual cues. Ratings by the leaders using the SVSI and the Soldiers using the SVSD were similar but not identical. The SVSD was rated slightly but not significantly higher than the SVSI (mean rating of 1.76 vs. 1.66 on a scale of 0 - 3). The SVSI and SVSD ratings were positively correlated ($r = .62$), indicating that in general the same activities tended to be rated similarly on both simulators. However, there were exceptions. The SVSI was rated significantly higher ($p<.05$) than the SVSD on the activities *Fire weapon accurately* and *Aim weapon*, while the opposite was true for *Identify assigned sectors of observation* and *Identify enemy soldiers.*

The training effectiveness ratings are presented in Figure 3. The mean rating was 1.8 on a scale where 1.0 equalled slight improvement and 2.0 equalled moderate improvement. Interestingly, both the leaders and the Soldiers reported about the same amount of overall improvement, although the skills on which they reported improving the most differed. Leaders reported the greatest improvement on *Control of squad/fire team movement during the assault*, *Assess the tactical situation*, *Plan a tactical operation*, and *Coordinate activities with your chain of command*. Soldiers reported the most improvement on *Plan a tactical operation*, *Coordinate activities with your chain of command*, and *Communicate with members of your team or squad*. Perhaps because of the small numbers involved, the differences between leader and Soldier ratings approached significance for only one task, *Control of squad/fire team movement during the assault*.

4.0 THE COSTS OF FULLY IMMERSIVE SIMULATION

An interesting and unexpected aspect of these results is the lack of a significant difference in rated training effectiveness between the Soldiers trained in the SVSD and the leaders trained in the SVSI. Admittedly, they were performing and learning different tasks, but nevertheless it seems to indicate that it might be productive to investigate whether the features of fully immersive simulators produce a training benefit that justifies the cost premium over a simple desktop computer.

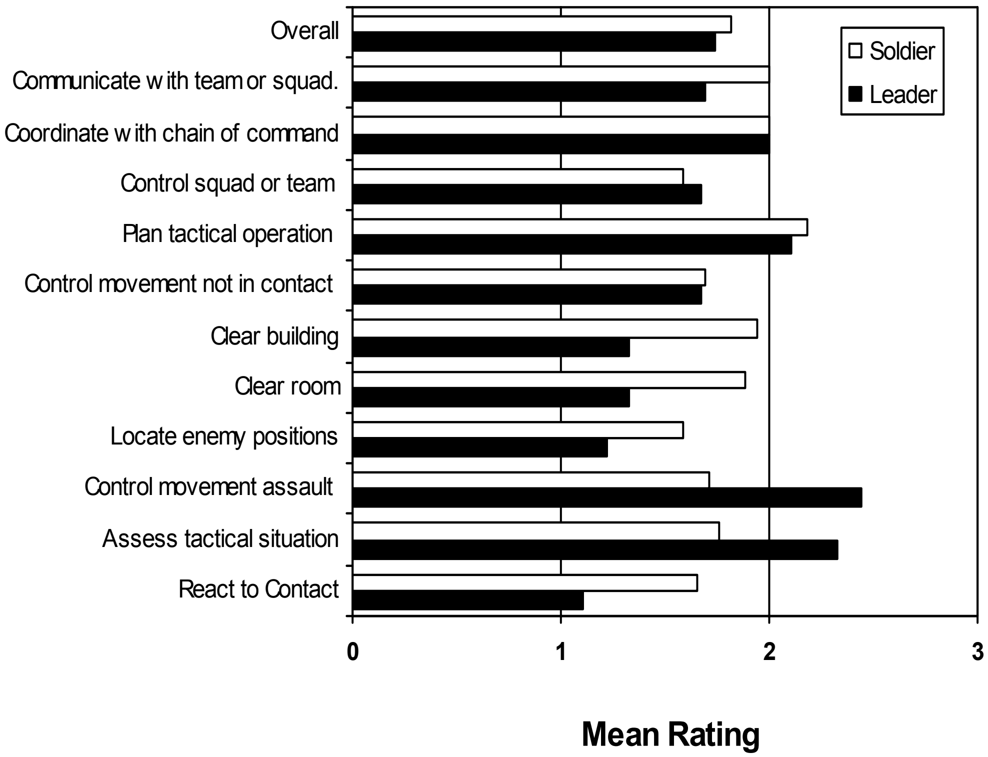

Figure 3: V-IMTS Training Effectiveness Ratings for Leaders and Soldiers.

The cost difference is substantial. Table 1, based on cost data provided by Loftin, Dryer, Belfore, Petty, Phillips, Garcia, Seevi, Lusso, Mastaglio, and Park (2004), shows the estimated cost of the hardware components of an immersive dismounted Soldier simulator built to the specifications of the Army's proposed Soldier CATT Virtual Warrior station. These estimates were made in May 2004. Note that they do not include the computer, simulation software, or a voice communications system. Even using the low cost estimate for each component with an HMD, instead of the more expensive projection display, per-system cost is $81,000. In contrast, the Dell line of gaming PCs begins at $1000, and a very high end Dell gaming PC (XPS 600) with a 24" LCD monitor and joystick costs less than $4200.

Table 1: Immersive Simulator Cost Estimates

Component	Low Estimate	High Estimate
Tracking System	$43,000	$50,000
HMD (1280X1024 resolution))	$26,000	$40,000
Projection Display	$30,000	$350,000
Targeting/Augmented Display	$5,000	$8,000
Binoculars/Nigh Vision Goggles	$4,000	$25,000
Sound System	$3,000	$8,000
Total with Projection Display	$85,000	$441,000
Total with HMD	$81,000	$131,000

5.0 DOES FULL IMMERSION FACILITATE TRAINING AND TRANSFER?

This cost differential makes it prudent to ask whether the training benefit obtained by using a high-fidelity immersive interface provides sufficient training benefit to justify the additional cost. Loftin, Scerbo, McKenzie, Catanzaro, Bailey, Phillips, and Perry (2004) have come closest to addressing this issue directly. They compared a monitor and CAVE for training the conduct of checkpoint operations. Because of radically unequal numbers of participants in the monitor and CAVE groups, they ran no statistical tests, but reported that the trainees in the fully immersive system consistently performed better. However, they concluded that

> Although this difference was found across groups and conditions, the magnitude of the difference was not dramatic. Thus, the ability to port a similar training experience to a less expensive PC platform without major performance differences underscores the potential for providing greater access to this type of VE training in a much more cost effective medium. (p. 12).

Other research addressing the question of interface fidelity on training effectiveness is limited, and has usually involved a comparison of VE systems with and without head-coupled visual displays.

Grant and Magee (1997) used a walking interface in an experiment investigating the acquisition and transfer of spatial knowledge. The participants' task was to learn the location of a number of landmark objects in a science museum. During a transfer test in the actual building, the walking simulator group walked significantly less distance to find all of the landmarks than did the joystick trained group, but they did not find them significantly faster. Grant and Magee claim this as evidence that there is something learned from the walking interface *in addition to* the visual information that can be used for spatial navigation.

Singer, Allen, McDonald, and Gildea (1997) found that training a Hi-VE interface (head-linked stereoscopic HMD and treadmill) produced better configuration knowledge and more rapid response time than a Low-VE interface (non-head-linked stereoscopic HMD and joystick) in a terrain learning task.

Jacquet (2002) found only a minor difference between groups trained to perform a maintenance task in VR vs. a desktop simulator.

In summary, it appears that head-tracked visual displays make a difference in performing spatially-oriented tasks and acquiring spatial knowledge, but this difference, based on a limited number of experiments, does not appear to be large.

6.0 DO SOLDIERS PLAY GAMES?

The use of commercial games connected via local networks or the internet is also being proposed as a training solution. The attractiveness of these games, in addition to presumed training effectiveness (see below), is that Soldiers are assumed to already be familiar with them, and motivated to train with them, even in off-duty hours. Are these assumptions justified?

Roberts, Foehr, and Rideout (2005) conducted an extensive survey of American youth and media in 2004. They found that 8-18 year olds spent an average of 19 minutes per day playing PC games and 49 minutes playing console and handheld games. Fifty-nine percent play some type of interactive games on any given day (68% of males and 51% of females). These results seem to be fairly consistent across race and parent's education and income. However, it cannot be determined from the report what percentage of youth rarely or never play interactive games.

No recent large-scale surveys of Soldier game playing have been conducted. However, Soldiers participating in evaluations of simulations and PC games have been asked about their game-playing experience. Soldiers in the V-IMTS evaluation described earlier reported a mean of 9.5 hours (median 6.5 hours) per week playing computer or video games. A sample of 27 Infantry Soldiers from a separate assessment conducted in FY 2004 (Knerr, Garrity, and Lampton, 2004) reported a mean of 8.5 hours (median 5.0 hours) per week playing computer or video games. However, 7% and 22% of the Soldiers in these samples, respectively, did not play video games. Beal and Christ (2005) found that 30% of their sample of 39 Infantry lieutenants involved in the evaluation of the Rapid Decision Trainer did not play video games, and 51% described themselves as Novice PC game players. Only 13% reported playing more than two hours per week. In their evaluation of the Full Spectrum Command (FSC) game, Beal and Christ (2004) found that 57% of their sample of 54 Infantry lieutenants and captains did not play computer games. Diller, Roberts, Blankenship, and Nielsen (2004), when evaluating the game DARWARS Ambush!, found that 14 of their 18 participants reported playing computer games for at least one hour per week (mean = 12.9 hours per week). Their sample included 2 officers and 16 enlisted personnel, three of whom were women.

The results involving enlisted personnel seem fairly consistent with those of the Roberts, Foehr, and Rideout (2005) survey data reported above. The results involving junior officers seem very different. Whether this is a result of differences in age, education, social factors, or the particular questions asked is not clear. It is safe to assume that a large portion of our potential trainees are familiar with computer or video games. However, we cannot assume that all of them are skilled or enthusiastic game players. This does not mean that games could not provide effective training for them, but it does suggest a need for adequate training in playing the game before training begins in earnest.

A related question is whether Soldiers have access to computers to use for training in their off-duty hours. The ARI Army Personnel Survey Office conducted a survey in the fall of 2002 and found that 99.1% of all Army officers and 87.4% of all enlisted personnel reported having access to the internet, while 98.7% and 84.1%, respectively, reported having access to a PC. The group with the lowest access was junior enlisted personnel, with only 80.4% having access to the internet and 74.8% having access to a PC. These data may have changed, but no recent survey data are available. Moreover, having a computer and internet access in the barracks or residence does not guarantee that those resources can be used by the Soldier for training in off-duty hours.

7.0 CAN GAMES PROVIDE EFFECTIVE TRAINING?

The most important question about games is whether they provide effective training. While most researchers seem to agree that computer games can be effective training tools, there is very little empirical evidence to support that conclusion (Belanich, Mullen, and Dressel, 2004). In a recent comprehensive review of the effectiveness of instructional games, Hayes (2005) concluded that “although research has shown that some games can provide effective learning for a variety of learners for several different tasks (e.g., math, attitudes, electronics, and economics), this does not tell us whether to use a game for our specific instructional task” (p. 6). Likewise, Bonk and Dennen (2005) noted the lack of research on the impact of instructional games on analysis and decision making skills. In particular, there is little research that would particularly apply to training dismounted Soldier unit and Leader skills.

Beal and Christ (2004) conducted an evaluation of FSC, a PC game designed to let prospective Infantry Company Commanders analyze, plan and execute missions. While the students believed that FSC was an effective means of training, this was not supported by other data, quite possibly because the students had limited training time with the game. Beal and Christ (2005) also conducted an evaluation of the Rapid Decision Trainer (RDT), a PC-based simulation developed to prepare Infantry lieutenants to serve as rifle platoon leaders during a live fire exercise. The trainees reported that they believed that the RDT had training value. Diller, Roberts, Blankenship, and Nielsen (2004) reported that their trainees gave the game DARWARS Ambush! (a PC game designed to train convoy operations) high ratings of effectiveness. No performance data were obtained.

Evidence about the effectiveness of PC games for training Soldier skills, therefore, is based on the subjective opinions of trainees, and not on objective measures of training effectiveness.

8.0 DISCUSSION

We would like to be able to make recommendations to the Army about the appropriate roles of immersive simulations, low cost simulations, and PC-based games for training dismounted Infantry Soldiers, leaders, and small units. These approaches have different acquisition, operation, and support costs. There is a lack of sound empirical evidence, based on objective measures of performance, which would lead to recommendations about training and cost effectiveness in which we could have confidence. Researchers and research reviewers seem to agree that each of these approaches can be effective if used appropriately. Research to date has largely addressed the question of whether one of those approaches can be effective, and (with few exceptions) has not generally compared the effectiveness or cost-effectiveness of the different approaches. A likely reason for this is that the addressing this issue experimentally would require a substantial investment in equipment, support personnel, and Soldier trainees. Yet without this evidence, the Army does not have a sound basis for selecting the most cost effective mix of training methods.

In addition to the question of effectiveness, we would also like to know more about the motivation of prospective trainees to use computer or video games and their familiarity and proficiency with them. Data from small samples of Soldiers who participated in evaluations suggest that a fairly large percentage of male enlisted personnel, possibly 75% or higher, play computer or video games weekly or more frequently. Officers appear to play less frequently than enlisted Soldiers. In addition, based on civilian data, we would expect that female Soldiers would play less frequently than male Soldiers. We know little about the types of games that Soldiers play (e.g., first person shooter vs. role player). Since game playing experience has implications for the types of games that could be used for training and the amount and type of prerequisite game playing training required, we would like to have a much better picture of the both current and projected Soldier and leader familiarity and experience with different types of interactive games.

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