Journal of Human Performance in Extreme Environments

Volume 7 | Issue 2 Article 11

Published online: 10-1-2003

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Donald R. Lampton
U.S. Army Research Institute

Bryan R. Clark
U.S. Army Research Institute

Bruce W. Knerr
U.S. Army Research Institute

Recommended Citation

Lampton, Donald R.; Clark, Bryan R.; and Knerr, Bruce W. (2003) "Urban Combat: The Ultimate Extreme Environment," *Journal of Human Performance in Extreme Environments*: Vol. 7 : Iss. 2 , Article 11.
DOI: 10.7771/2327-2937.1036
Available at: http://docs.lib.purdue.edu/jhpee/vol7/iss2/11

Urban Combat: The Ultimate Extreme Environment

Donald R. Lampton, Bryan R. Clark, and **Bruce W. Knerr,** *U.S. Army Research Institute, Simulator Systems Research Unit, Orlando, Florida*

Urban combat is one of the most extreme environments imaginable. Our paper describes training and simulation research to improve the training of small teams that operate on foot in urban combat and stability operations. We present an overview of urban combat as an extreme environment. Next, we trace the history of the training and technology developments that shaped our present research. The focus of our paper is the After Action Review (AAR) process as applied to small team exercises conducted in immersive virtual environments. A PC-based AAR system is described and examples are given of its use for training and training research. The training emphasizes practice of command and control skills, decision making, and situation awareness. Future research goals are outlined. Current live training capabilities are described to provide a context of the overall training environment with which virtual training systems will be integrated.

Introduction

Modern urban combat requires the execution of highly developed cognitive and physical skills in extreme physical and social environments with little margin for error. Overshadowing both the cognitive and physical demands is the nature of combat itself, described by the military historian N. T. Dupuy (1987) as the constant danger of death from lethal weapons employed by opponents with deadly intent.

Urban combat—military terms for urban combat include Military Operations in (or on) Urbanized Terrain (MOUT), and Fighting in Built-Up Areas (FIBUA)—may involve small villages, shanty towns, very old cities, or modern cities and industrial parks. Modern cities present difficult three-dimensional challenges with tunnels, sewers, and high rise buildings, in addition to expansive ground or street levels. In contrast to open terrain, communication and position location equipment may function differently, or not at all, inside urban areas.

The physical extremes of urban combat can include temperature, hot or cold, and altitude stressors interacting with the requirement to engage in strenuous effort while carrying heavy loads and wearing body armor and sometimes chemical protective clothing.

The cognitive demands of urban combat are also extreme: split-second decision making is required integrating general doctrine; highly detailed tactics, techniques, and procedures; and rules of engagement. U.S. Marine Corps General Charles Krulak succinctly described the challenge: "In one moment in time, our service members will be feeding and clothing displaced refugees - providing humanitarian assistance. In the next moment, they will be holding two warring tribes apart - conducting peacekeeping operations. Finally, they will be fighting a highly lethal mid-intensity battle. All on the same day, all within three city blocks. It will be what we call the three block war" (Krulak, 1997).

Human performance in urban combat is a function of many factors including personnel, equipment, organization, doctrine, and training. The focus of our paper is the use of Virtual Environments (VEs) for training small teams in urban combat.

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http://dx.doi.org/10.7771/2327-2937.1036

Background

In the early 1970's, major changes occurred in Army training, with the use of objective standards replacing subjective evaluations ("ARI support", 1995). Laser-based tactical engagement systems provided an objective means of casualty assessment during training exercises. One-sided post-exercise critiques or lectures were replaced by the After Action Review (AAR) process. The AAR process involves active discussion among the exercise controllers and the trainees. AARs provide trainees with a shared understanding of what happened during an exercise and why it happened, so that they can identify ways to improve their performance. Sullivan and Harper (1996) pointed out that the AAR process provides a structured method of facilitating learning from complex experiences that are often very ambiguous. They proposed that the AAR process could be of value for applications in addition to military training. Morrison and Meliza (1999) present an excellent review of both the historical and conceptual foundations of the AAR method.

In the 1980's, a joint DARPA/Army program led to the development of SIMULATION NETWORK (SIMNET), a large scale, local and long haul networking of military weapons simulators (for example, tanks). The virtual battlefields created by SIMNET, and the Close Combat Tactical Trainer which followed, provided a cost-effective, safe, and flexible compliment to traditional field training. As with field training, the AAR system became an integral part of virtual training. Meliza (1998) described the development of AAR systems for armor training in virtual environments.

Gorman (1990) proposed that simulation capabilities be developed specifically to improve the representation of the individual combatant (for example, Foot Soldiers) on the virtual battlefield. Such a simulation capability would not only have training applications, but could also support mission rehearsal, and concept development testing for new organization, doctrine, and equipment.

Immersive Virtual Environment Research For Urban Combat Training

In 1992, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), with the support of the University of Central Florida's Institute for Simulation and Training (IST), established a program of research on the use of immersive virtual environments (VEs) for training dismounted Soldiers, such as Infantry and Special Forces. Initial experiments addressed perception, distance estimation, and acquisition of spatial knowledge in VEs. More recent efforts looked at instructional features and strategies (for example, demonstration, coaching, and AAR) for training immersed teams. The overall program is reviewed, with a focus on the evolution of VE technologies, in Lampton, Knerr, Martin, and Washburn (2002). A common thread for much of this research was the assumption that VE training and simulation applications would involve the use of Head Mounted Displays (HMDs), or similar display devices, for immersing the participants in a VE. Although in general the performance and affordability of HMDs has yet to meet our optimistic expectation of 1992, our previous research designs and materials are now being used in Augmented Reality research.

Beyond our in-house VE research, ARI was involved in a four year joint Science and Technology Objective (STO) entitled "Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal" (Knerr, et al., in press). Participant organizations included: the U.S. Army Research Institute Simulator Systems (ARI-SSRU) and Infantry Forces Research Units (ARI-IFRU), the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), and the U.S. Army Research Laboratory Human Research and Engineering Directorate (ARL-HRED) and Computational and Information Sciences Directorate (ARL-CISD). The four-year effort (1999-2002) focused on overcoming critical technological challenges that currently prevent high fidelity dismounted Soldier simulation. These challenges include: simulating locomotion; creating realistic performance of computer-controlled dismounted friendly and enemy soldiers; changing terrain and structures during an exercise, and developing appropriate training strategies and methods. The effort built upon previous efforts of the participating organizations in the development and use of virtual simulations.

During each year of the STO there were two major types of activities: research and development of the individual technologies, and preparation for and conduct of a Culminating Event (CE). The purpose of the CE was to make sure that the various technologies under development were interoperable, and to obtain Soldier feedback on their use.

For three of the four years, the CEs were conducted at the Dismounted BattleSpace Battle Laboratory at Fort Benning, Georgia. Facilities at that Battle Laboratory include the Squad Synthetic Environment (SSE). (The SSE is a research system. However, we believe the SSE provides a preview of the VE training systems that will be fielded in the near future. Similarly, the squad level exercises conducted with the SSE as part of the research described below represent a way in which the training systems could be used.)

The SSE is an integrated set of dismounted solider simulators which are individually referred to as a Soldier

Figure 1. Soldier Visualization Station (SVS).

Visualization Station (SVS). The SVS (see Figure 1) is an immersive 3D virtual simulator. A PC-based rear-screen projection system presents images in 1024 X 768 resolution on a single screen approximately 10 feet wide by 7.5 feet high. The Soldier can stand, kneel, or lie prone within a ten-foot square enclosure. The immersed Soldier's head and weapon are tracked using an acoustic and inertial tracking system. The Soldier can move within this enclosure, and his movement and posture changes are tracked and reflected in perspective changes in the VE. The Soldier navigates through the environment via a thumb switch, which serves as a mini-joystick, located on the weapon. The headset is a component of a simulated radio network.

Nine of the SVSs can be networked to immerse a full squad of Soldiers. A computer generated forces system and role players are used to represent the enemy, other friendly forces, and civilians. The computer generated forces system is called Dismounted Infantry Semi-Automated Forces (DISAF).

Typical squad-level exercise took place as described below. The platoon leader, portrayed by a role player, issued the initial order describing the mission the squad was to conduct. The Squad Leader then conducted planning and issued an order to his squad. The participants then entered the SVSs and conducted the mission in the VE. Examples of exercise scenarios used during the STO research are: roving patrol, crowd control, hostage rescue, and assault and clear a building. The scenarios were structured to support training effectiveness and performance measurement. Each exercise lasted about thirty minutes. Available VEs included models of the actual Shughart-Gordon and McKenna MOUT live training sites, and a notional area of modern high-rise buildings.

After each exercise an AAR was conducted using the Dismounted Infantry Virtual After Action Review System (DIVAARS). The DIVAARS (see Figure 2) was used to quickly determine and review the critical events that occurred during an exercise. Discussion topics ranged from specific aspects of reporting, and tactics, techniques, and procedures, to more general concepts such as mission tempo and situation awareness. Most of the AARs were completed in less than 20 minutes.

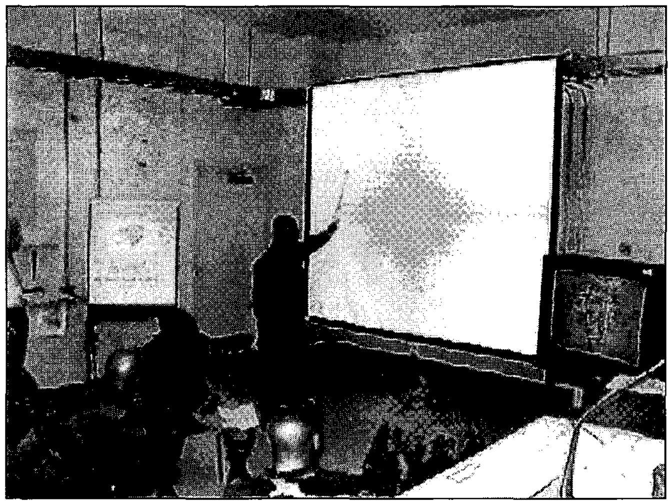

Figure 2. An After Action Review.

One of the main goals throughout the four year STO was to improve the AAR capability for Infantry exercises conducted in VEs. DIVAARS was developed to meet two needs. The first was to provide Soldiers with a common understanding of what happened during an exercise and why it happened, so that they can identify ways to improve their performance. The second was to facilitate data analysis, in order to support both training feedback and research and development. Determining what happened during an exercise is particularly difficult in an urban environment, because buildings and other structures break up the visual field and limit the portion of the battlefield that can be observed by any one person.

The DIVAARS connects to the network used by the soldier simulators and DISAF, and permits observation and recording of the exercise data. DIVAARS offers a flexible replay system with a control panel similar to that of a DVD player. The scenario can be rewound, fast-forwarded, or paused. Important viewpoints or events can be bookmarked or tagged so they may be quickly returned to during an

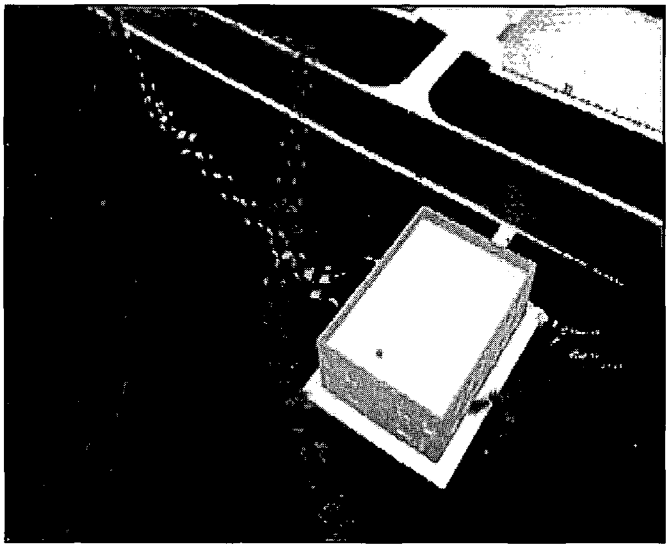

Figure 3. *Movement tracks of Squad members.*

AAR. The entities (avatars of the squad members and enemies) each have markers above their heads for easy identification, as well as multi-colored movement tracks which, like breadcrumbs, show the path they took through the scenario. Figure 3 shows the tracking feature. DIVAARS scenarios may be viewed from many perspectives including top-down views, fly mode, and a first-person perspective from any entity's viewpoint. Furthermore, buildings may be deconstructed to view any floor within the building (see Figure 4).

The system's dynamic terrain features special effects such as bullet holes (dings) on buildings, as well as larger holes from explosive charges (to breach a building). When weapons are used, including rifles, smoke, and grenades, a "bullet line" appears which may be traced back to the firing shooter. This is very useful in determining who successfully shot the enemy or target. Additionally, graphs and tables are available to show the statistics for kills, posture, rounds fired, etc. During playback, DIVAARS features synchronized audio playback from radio communications, as well as sound effects such as weapon firing. Environmental effects, like time of day (daylight versus night scene), and fog level (visibility) may also be altered at any time.

For the traditional AAR goal of determining "what" happened during a mission, the DIVAARS replay recreates exactly what happened during the mission. During the replay, the unit members can observe the location, posture, and actions of all the other members.

Unlike live field training, DIVAARS can replay mission action exactly as viewed by any of the participants. These features not only support the trainees' explanation of why events happened but also help the unit members develop shared mental models of individual and unit tasks. Watching the replay may also strengthen group identification and cohesiveness. Finally, several DIVAARS features enhance memory so those lessons learned are more likely to be employed in subsequent training and missions. Examples are: depicting critical events in slow motion and from multiple perspectives, and "freeze frame" graphics depicting the views of both the shooter and the target at the moment the shot is fired.

The hardware requirements for DIVAARS are a dual processor PC and a good graphics card. The DIVAARS software uses a Linux system and can be provided at no cost to requesting U.S. government agencies. Detailed technical information about DIVAARS is presented by Knerr, Lampton, Martin, Washburn, and Cope (2002).

DIVAARS has received very positive ratings from almost all the Soldiers who participated in AARs conducted with the system. Almost all of the participants "agreed" or 'strongly agreed" that an AAR conducted with DIVAARS made clear: the order in which key events occurred during the mission, what and why things happened the way they did during a mission, and how to do better in accomplishing the mission.

We recognize that these very favorable ratings also reflect the contributions of the AAR facilitator. The AAR facilitator displayed an in-depth understanding of squad-level doctrine, training principles and how to apply them, and the AAR process.

It is unrealistic to expect to always have available an AAR facilitator with that highly developed knowledge and skills. We plan to conduct research on how to expedite

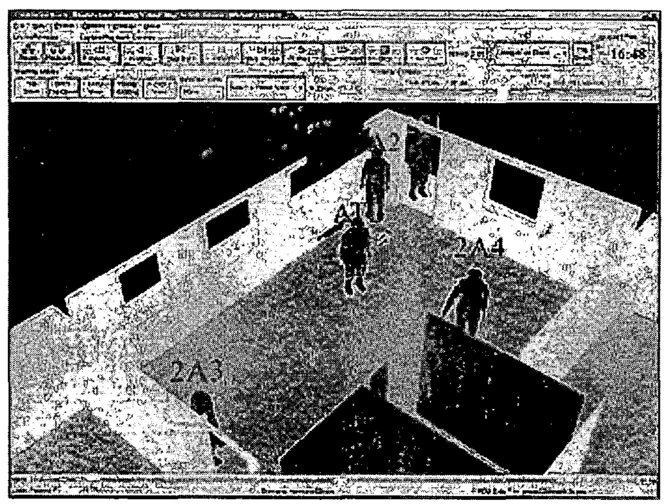

Figure 4. *View of Squad action within a building.*

the development of AAR facilitator skills. In addition, we are involved with two Small Business Innovation Research contracts to develop automated support for the AAR process. One contract addresses measurement of Situation Awareness, the other analysis of communications. Goals for both include having preliminary analyses available in time to provide feedback during the AAR, and then more detailed analyses available later to support research and training management.

Finally, there is a broad research area of AAR capabilities and training effectiveness. Although the AAR method is widely accepted and believed to be effective, there is little empirical data available that indicate what AAR capabilities or features contribute most to training effectiveness, or how they should be used to optimize effectiveness.

Live Training Facilities

In the last ten years there have been extraordinary improvements in live training MOUT facilities equipped with technologies to simulate many environmental factors to make training as realistic as possible (see Figure 5).Video cameras are used extensively inside and outside buildings to support performance evaluation and feedback. Soldiers encounter devastated buildings, fires, smoke screens, and (role-player) crowds of civilians. Simulated sounds include weapon fire, ambient noise such as conversation (in multiple languages), riots, screams, and civilian and military vehicles. Some training facilities even feature realistic smells of war, including smoke, sewage and air pollution.

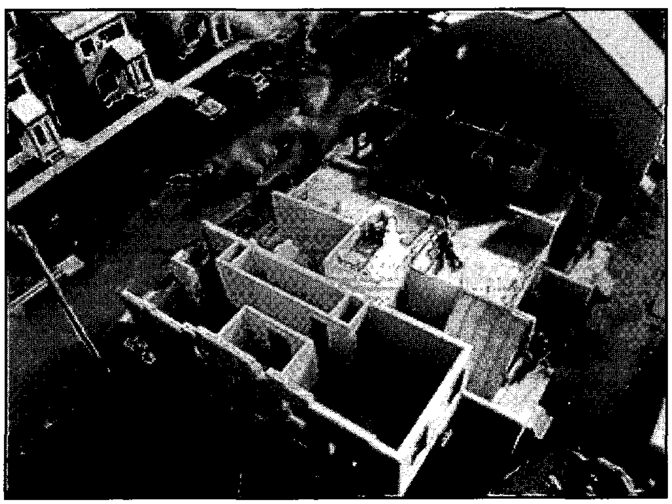

Figure 5. *Modern MOUT training facility.*

(photo credit: http://www.hq.usace.army.mil/cepa/pubs/apr02/story11.htm)

Augmented Reality

Augmented Reality is an alternative simulation and training asset for urban combat training. Augmented Reality combines the real world with the virtual world, viewed through a head-mounted display (HMD). An advantage of Augmented Reality systems is that the training environment is the real-world with an overlay of objects and entities, e.g. enemies. Unlike virtual reality, the environment is already created; the main challenge is programming the location and timing for the appearance of the overlaid virtual objects and entities. Barfield and Caudell (2001) describe two main types of Augmented Reality, based on the way in which the display information is processed. Optical-based systems involve a see-through HMD, which allows the viewer to see the real world with an overlay of the virtual display. Video-based systems involve a live video feed of the real world, and combine it with the virtual world before displaying it for the viewer. A benefit of optical-based systems is that the display is processed in "real-time," while video-based systems process the display information, combining the video feed with the computer-based graphics, prior to making it available to the viewer.

A Look Ahead

Our current vision of near term training developments is of a very close integration of live and virtual training capabilities, integrated to the extent that live and virtual training systems will be co-located. As technologies improve to track the position and activities of Soldiers in the real world, both live and virtual training systems may eventually employ AAR systems similar to DIVAARS. Thus a virtual AAR playback would be available for live training exercises in addition to the camera-supported AAR systems that are available today. The role of Augmented Reality in this mix is not yet clear. The current status of Augmented Reality is in some ways reminiscent of Virtual Reality ten years ago: apparent tremendous potential awaiting solution of several technology challenges.

Acknowledgements

Opinions expressed are those of the authors and do not represent an official position of the U.S. Army or the Army Research Institute.

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