Technical Report 1110

Instructional Strategies for Training Teams in Virtual Environments

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14. ABSTRACT *(Maximum 200 words)*:

This report describes the design and implementation of the Fully Immersive Team Training (FITT) research system, and the first experiment conducted with that system. FITT was developed to support research on the use of distributed Virtual Environments (VEs) for training dismounted infantry. The hardware and software functional requirements included: locomotion, object manipulation and aiming, communication among participants, design of avatars for participants and computer generated forces, data capture and playback, as well as a host of networking issues. The first experiment examined instructional strategies involving how and when to give guidance during team training with VEs. Ninety-four college students participated in the experiment. Two-person teams engaged in search missions in VEs depicting building interiors. Teams were given guidance either before (demonstration), during (coaching), or after (replay) the first practice mission, or not given any guidance at all (control group). Performance measures included: speed and accuracy of search, communications, and security procedures. Results indicated that the FITT interface worked well in enabling the participants to move in and interact with the VEs, and to act as a team. The feasibility of implementing and administrating each of the instructional strategies in a VE training context was demonstrated.

15. SUBJECT TERMS

Virtual Environments, Virtual Reality, Dismounted Infantry, Team Training, Presence, Simulator Sickness, Training Transfer

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FOREWORD

The U.S. Army has made a substantial commitment to the use of simulation for training, readiness, concept development, and test and evaluation. Virtual Environment (VE) technology, which uses position tracking and real-time update of visual, auditory, and other displays (e.g., tactile) has the potential to provide simulation-based training for dismounted soldiers. Since VE technologies are relatively new, there is little information to indicate where and how they are best used for dismounted soldier training. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has established a research program to determine the characteristics of the VE technologies needed to allow dismounted soldiers to fight on virtual battlefields. In addition to research needed to determine appropriate VE user interfaces, research is needed to determine appropriate instructional strategies for VE training applications. This research should identify ways of taking advantage of the unique advantages of VEs for training, and for working around the temporary shortfalls in VE technologies.

This report describes research conducted to support the development of VE systems for dismounted soldier training. The results of the research provide information about the characteristics needed for effective immersion, learning, and performance in VEs. The results of this research were briefed to the Office of the Secretary of the Army for Acquisition, Research, and Technology (March, 2000), Headquarters, U.S. Army Training and Doctrine Command (July, 1999), and the Dismounted BattleSpace BattleLab (November, 1999). Information about a portion of this research has also been included in the proceedings of the 1998 IMAGE Society Conference, the 1998 and 1999 Interservice/Industry Training, Simulation, and Education Systems Conference, and the 2000 Human Factors and Ergonomics Society Conference. An article based on this report is in press in the journal *Presence*.

The ARI Simulator Systems Research Unit conducts research to improve the effectiveness of training simulators and simulations. The work described is a part of ARI Work Package 202a, VERITAS (Virtual Environment Research for Infantry Training and Simulation). VERITAS is the ARI portion of a Science and Technology Objective, Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal, which is being carried out in conjunction with the U.S. Army Simulation, Training, and Instrumentation Command and the U.S. Army Research Laboratory.

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Technical Director

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INSTRUCTIONAL STRATEGIES FOR TRAINING TEAMS IN VIRTUAL ENVIRONMENTS

EXECUTIVE SUMMARY

Research Requirement:

The U.S. Army has made a substantial commitment to the use of virtual environment (VE) technology to create virtual battlefields for combat training and mission rehearsal, development of military doctrine, and evaluation of weapon system concepts prior to acquisition decisions. All of these functions would be improved by a better representation of dismounted soldiers on the virtual battlefield. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has established a research program to determine the characteristics of the VE technologies needed to allow dismounted soldiers to fight on virtual battlefields. In addition to research needed to support appropriate VE user interfaces, research is needed to determine appropriate instructional strategies for tapping the unique advantages of VEs for training, and for mitigating the temporary shortfalls in VE technologies.

Procedure:

Functional requirements were generated for mission tasks and environments that would support VE team training research. The missions combined task elements of urban search and rescue, Special Weapons and Tactics Teams (SWAT), and infantry operations inside buildings. These requirements were used to design and implement the Fully Immersive Team Training (FITT) research system. The FITT was used in an experiment to examine instructional strategies for team training in VEs. In that experiment, 94 participants recruited from local colleges served as two-person teams in conducting search missions. After reading the mission training manual, teams received guidance on performing the missions either before (Demonstration), during (Coaching), or after (after-action Replay with critique) practicing the mission tasks, or not at all (Control group). After practice, each team completed a test mission without guidance.

Findings:

Results indicated that the FITT adequately creates immersive environments such that participants can function as teams in learning and performing search, communication, and security procedures for training research purposes. In particular, the FITT interface for walking through the simulated environments was learned quickly by the participants. Each of the instructional strategies could be implemented with the FITT. Both the Control and the Instructional Strategy groups (Demonstration, Coaching, and Replay) improved with practice on some performance measures. For the test mission performance measures, differences between the Control group and the Instructional Strategy groups were not statistically significant, nor were the differences among the Instructional Strategy groups. Despite the brevity of the VE immersions, about eight minutes per mission followed by a rest break, simulator sickness was a problem in that about nine percent of the participants withdrew before completion of the experiment.

Utilization of Findings:

Technical lessons learned from this experiment were used in the development of a follow-on system that will be used in research to examine distributed team training in which the participants are at remote sites. Lessons learned concerning the instructional strategies will be incorporated in a follow-on effort to develop tactical training for small unit infantry leaders.

The FITT interface for locomotion (walking) through VE should be of value in many VE applications, including training, architectural design, education, and recreation.

INSTRUCTIONAL STRATEGIES FOR TRAINING TEAMS IN VIRTUAL ENVIRONMENTS

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INSTRUCTIONAL STRATEGIES FOR TRAINING TEAMS IN VIRTUAL ENVIRONMENTS

This report describes the design and implementation of the Fully Immersive Team Training (FITT) research system, and the first experiment conducted with the system. FITT was developed to support research on the use of distributed Virtual Environments (VEs) for training dismounted infantry. The research is focused on VE training applications for small units and unit leaders.

The report is organized as follows: the background section briefly describes the military training requirement that this research addresses, and outlines our previous research in this area. Next, an in-depth description of the design and implementation of the FITT research system is presented. The final major section of the report describes the design, procedure, results and discussion of the first experiment conducted with the FITT, and implications for future research.

Background

The U.S. Army has made a substantial investment in the use of VEs for training. The SIMNET program (Alluisi, 1991) and initial efforts with the Close Combat Tactical Trainer focused primarily on collective training involving combat vehicles such as tanks and infantry fighting vehicles. There is now a growing effort to develop methods to use immersive VEs to train soldiers who fight on foot, such as infantry and special operations forces. The expanding interest in inserting the individual combatant into the virtual battlefield is driven by a number of factors, including the recognition that members of small dismounted units will face greater responsibilities and challenges in both combined arms combat and in contingency operations. In addition to supporting Army training requirements, individual virtual simulation could support mission planning and rehearsal. The capability to insert the individual combatant into a virtual combined arms battlefield could also be used in the conceptualization, design, and testing of new equipment, doctrine, and organization.

VE Training Considerations

The National Research Council's Committee on Virtual Reality Research and Development has identified numerous ways in which VE has tremendous potential as a training medium (Durlach & Mavor, 1995). For example, it can be expected that VE-based training will eventually offer the benefits of traditional simulator-based training such as safety, flexibility, repeatability, and cost effectiveness. In addition, for some situations VE training may prove more effective than conventional training in the physical world. VEs offer rich learning possibilities such as providing multiple viewpoints and various levels of abstraction that cannot be created with conventional training. However, the Council pointed out that current (as of 1995) VE work in training was at the research and development stage. Challenges to the use of VE for training include not only inadequacies of the currently available VE technologies but also a lack of knowledge concerning basic psychological issues related to training and training transfer. Thus, maximizing positive transfer from VE training to real-world performance, and avoiding negative transfer, requires not only improvements in VE technology but also in our knowledge of how to design and use VE training systems. Johnson, Rickel, Stiles, and Munro (1998) also present compelling arguments that the development of effective VE training systems must involve more than considerations of the fidelity of the renderings and accuracy of simulated behaviors.

ARI/IST VE Training Research

Since 1992, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), in conjunction with the University of Central Florida's Institute for Simulation and Training (IST), has undertaken a program of behavioral science research to investigate the use of VE technologies to support training of dismounted soldier tasks. The research has been concerned primarily with three issues: (1) how the characteristics of the individual's interface with the VE affect task performance and the acquisition of new skills, (2) how skills can best be trained in VEs and how well they transfer to the real world, and (3) the incidence and severity of the side effects that can result from immersion in VEs. To date research in this program has examined VE display and input device requirements for training tasks such as visual tracking, object manipulation, locomotion, distance estimation, route learning in buildings, building search, and land navigation. Variables investigated included the type of control device, amount of practice on the tasks, stereoscopic vs. monoscopic head-mounted displays (HMDs), and type of display device (monitor, Binocular Omni-Orientation Monitor, or HMD). Under this program, thirteen experiments involving over 500 human participants have been conducted. This research is summarized in Knerr et al. (1998).

Development of the FITT Functional Requirements

Previous ARI VE training research involved immersing individuals one at a time. Developing a system for teams, the FITT system, presented a number of challenges. We required a system in which two individuals (with potential for expansion to larger teams) could be immersed simultaneously and engage in meaningful team activities. In addition, we required a system that could support instructional features and interventions beyond the simulation of real-world conditions.

For our initial research in using VEs to train teams, we wanted tasks that would require rapid decision making in complex, dynamic environments; situation awareness; and teamwork. A challenge was to develop tasks that could be implemented with current VE technology and represented the critical elements of military tasks, yet were not beyond the grasp of participants with no previous military training. (For initial experiments with new systems, we recruit our research participants from local colleges.).

To develop the tasks we reviewed field manuals for infantry combat in built-up areas, urban search and rescue procedures, and training videotapes for Special Weapons and Tactics Team procedures. From these, we developed procedures that are generalized versions of tasks and activities that would be performed during emergencies such as urban search and rescue missions, hostage rescue, or disasters involving hazardous materials (HAZMAT).

The tasks are organized as a mission in which a two-person team searches the rooms of a building for canisters containing hazardous gas. The team carries equipment to determine if a canister contains gas and to deactivate the canisters if necessary. Each team member is represented in the VE by an avatar. The avatars wear protective clothing and a breathing apparatus, and carry a tranquilizer dart gun that can temporarily incapacitate the enemy. The search is complicated by the threat of interference by enemy forces.

Team member #1 is the designated Team Leader. The Team Leader directs team movement to provide an efficient search while maintaining team security. The leader radios reports of canister deactivations and encounters with the enemy to an off-site mission commander. In addition to a tranquilizer dart gun, the Team Leader carries a paint marker used to mark the doorways of rooms that have been searched. Team member #2, the HAZMAT Equipment Specialist, carries a dart gun and a device to detect and deactivate active canisters. The tools reflect the roles of the team members: a successful mission requires that team members cooperate with each other.

The missions are situated in a ten-room building. Computer-generated enemy and innocent bystanders move through hallways and rooms. The presence of both enemy and neutral forces require rapid shoot/don't shoot decisions. Enemies can be either lightly armed looters or heavily armed terrorists, requiring the trainee teams to prioritize targets.

Mission instructions specify the amount of air available for each mission. Team members must remember to periodically check their remaining air supply indicators, and must decide when to begin exiting the building. This is not an easy decision in that leaving too soon wastes search time, but underestimating the time needed to exit the building results in mission failure.

Procedures include rules for: the order in which rooms are searched, team formation for room entry, actions on contact with enemy and innocent bystanders, assigned areas of responsibility within a room, and how and what to report on the radio network. Successful performance of some of the procedures requires the team members to coordinate their movements and actions to within a second of each other.

A training manual was developed to introduce naive participants to the mission procedures. The 2,300 word, thirteen-page training manual includes a mission overview, learning objectives, task descriptions with graphics, and ends with a mnemonic to help the participant/trainee remember the procedures. The manual does not assume that the reader has any previous training or experience directly relevant to the mission tasks. The Flesch-Kincaid readability score of 7.4 for the manual falls within the range recommended for manuals for the armed services (MIL-M-38784B, 1983). The training manual for the Team Leader is at Appendix B. (The actual manuals presented to the participants were printed in color.) A paper and pencil knowledge test was developed to measure each participant's mastery of the manual.

The two-person FITT team meets the defining characteristics of teams listed by Salas, Dickinson, Converse, and Tannenbaum (1992) in their review of team training research: there is some organizational structure of the team members; each individual team member has specific tasks or functions; and there is a common goal, mission, or objective.

FITT Design

FITT incorporates a number of modular components to provide a flexible framework for developing networked team training applications. The primary components of this system are the individual combatant simulator (ICS), a computer-generated entity server (CGES), a mission controller/experimenter station, an audio system to simulate radio communication between the participants, and a system for data collection and mission playback.

Hardware Configuration

FITT consists of the following hardware components:

ICS #1:

- 8 Processor / 3 Pipe Silicon Graphics Onyx™ RE2 (Team Leader and CGES)
- 6 Tracker Ascension MotionStar™
- Virtual Research VR4™ Head Mounted Display

ICS #2:

- 4 Processor / 1 Pipe Silicon Graphics Onyx™ RE2 (Specialist)
- 6 Tracker Ascension Flock of Birds™
- Virtual Research VR4 Head™ Mounted Display

Silicon Graphics Indigo2™ High Impact (Stealth)
Silicon Graphics Indy™ (Data Collection)
Dell Pentium 90 (Audio Capture)
Dell 486 (Startup Browser)
Misc. handheld input devices
Misc. video equipment for observing player views and videotaping after action critiques.

This hardware list is used for the current two player configuration of FITT. The configuration is easily scalable, and extra ICSs could be added, as necessary, to support more players in the VE. Note that the extra processing power of the 8 processor Onyx allows it to run the CGES component, in addition to its duties as an ICS.

Individual Combatant Simulator

The ICS provides a link between the participant and the networked VE. This simulator provides a view into the shared virtual world via an image generator and a viewpoint-tracked display device. The ICS also provides a means for interacting directly with the virtual world through a variety of Input/Output devices that can be selected according to their applicability to the mission scenario. Finally, it is the role of the ICS to translate the real-world gestures and movements of the participant into appropriate avatar responses.

Sensor Configuration

Each team member is suited with six position sensors (Figure 1) used to determine body position, view, and locomotion. As can been seen in Figure 2, the FITT system can accommodate a wide range in participant height and morphology. The sensor mounted on the HMD determines gaze direction. Body direction is measured by the position of a sensor mounted on a lightweight wooden backpack worn by each participant. This sensor determines which direction the participant's torso is facing, and which direction he or she will walk when moving forward. The back pack also acts as a cable guide for the wires that run to the sensors.

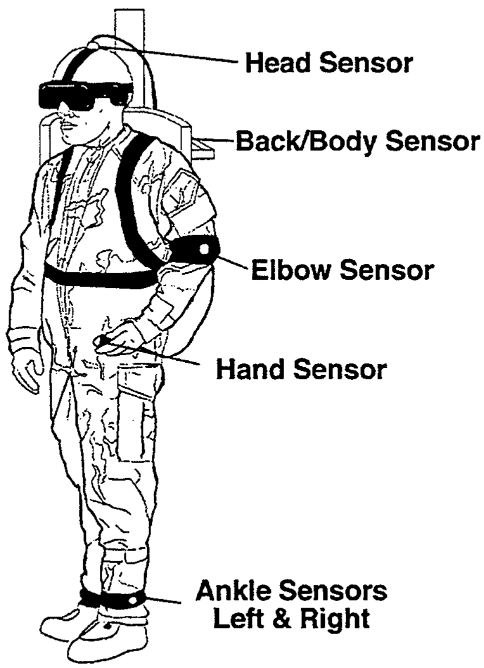


Figure 1. Sensor configuration.

Locomotion method. The ankle trackers are used for locomotion through the VE. Stride length is determined by the amount of time the angle sensor is held above a defined height. Slowly marching in place, raising and lowering the feet, provides a smooth gait through the VE. The software object responsible for ambulating the participant watches the step height by comparing the height of the ankle trackers relative to the base of the ICS. When the tracker crosses a software-defined threshold, a step is initiated and the height of the step is translated into pitch rotations for the hip and knee joints, allowing the avatar to raise and lower its legs as the player walks. The locomotion model also allows discrete backward steps.

Arm articulation. The right arm of each player is tracked in order to articulate the arm of the virtual avatar. This requires two sensors working in conjunction with the back sensor. The position of the player's shoulder joint is determined by offset from the back tracker. This phantom shoulder position is used with a sensor strapped to the elbow to derive a vector for the upper arm. An additional sensor mounted on the input device and held within the hand of the player provides a way of deriving the vector for the lower arm position.

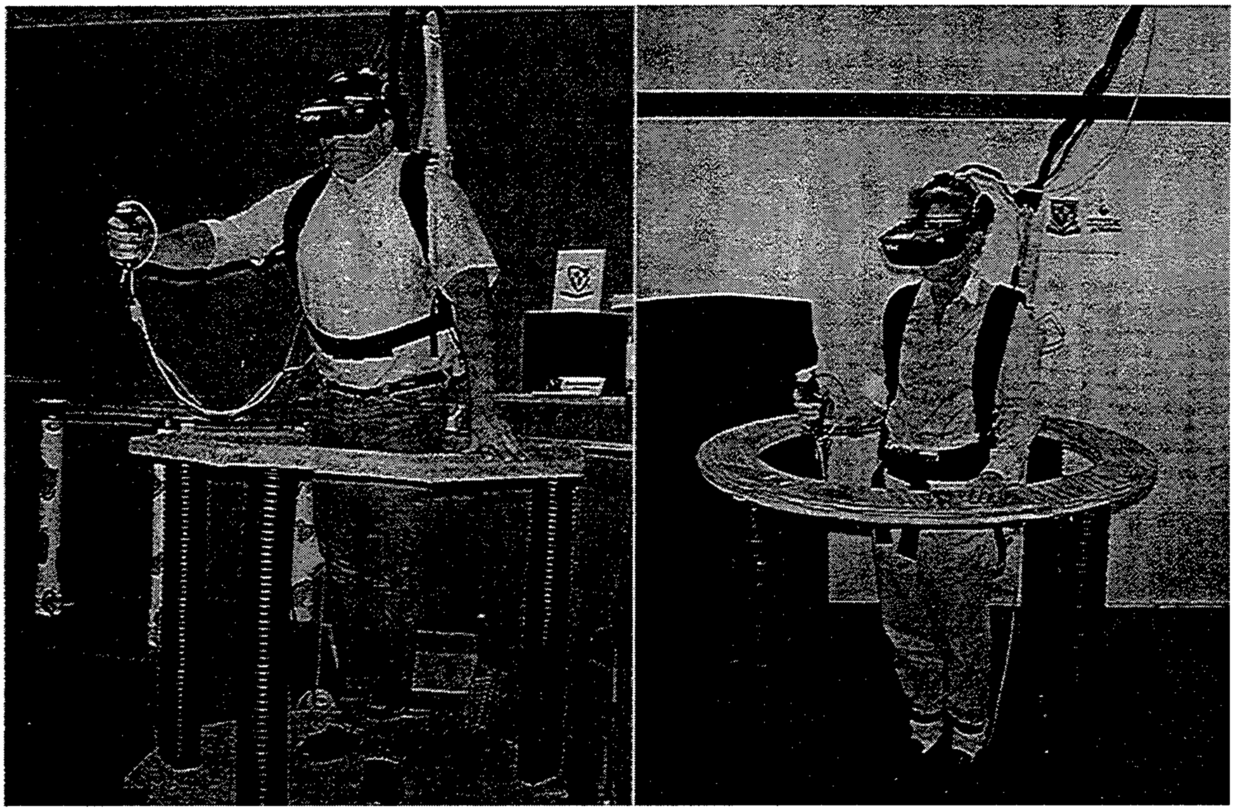


Figure 2. Individual combatant simulators.

Despite the existence of methods for animating avatar arm movement using only a back sensor and a hand (Tolani, Deepak, & Badler, 1996), the FITT development team chose the expense of an extra sensor for the finer model granularity offered. In addition, a fully rotational model of the upper and lower arm provides a mechanism to implement complex hand and arm signals.

Manual control device. The initial objective of the design team was to provide a manual controller device that approximated the mass and size or "heft" of an actual pistol or comparable item of equipment. Informal pilot testing quickly revealed that after only a few minutes into a mission, the weight of the controller became distracting. A very light controller was eventually settled upon: the palm grip of a Gravis Blackhawk joystick (Figures 3 & 4). The controller thumb switch advances/cycles through an array of configurable hand held items, beginning with an empty hand, then the sidearm, and then through the tools available to the team member. (Team Leaders were equipped with paint markers, and Equipment Specialists were outfitted with gas canister detector/deactivators.) The index finger is held over the 'trigger'.

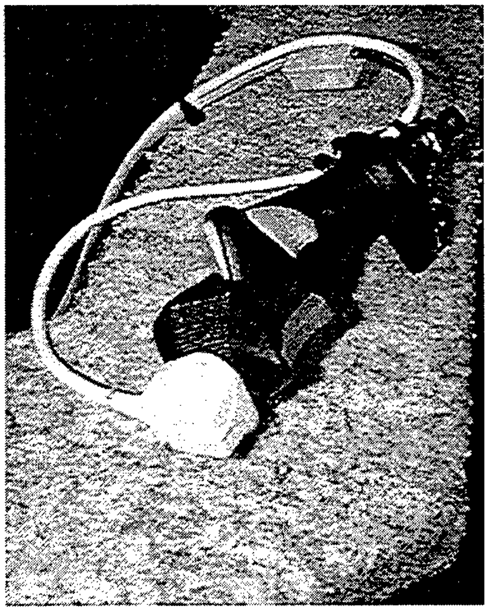


Figure 3. Hand controller input device.

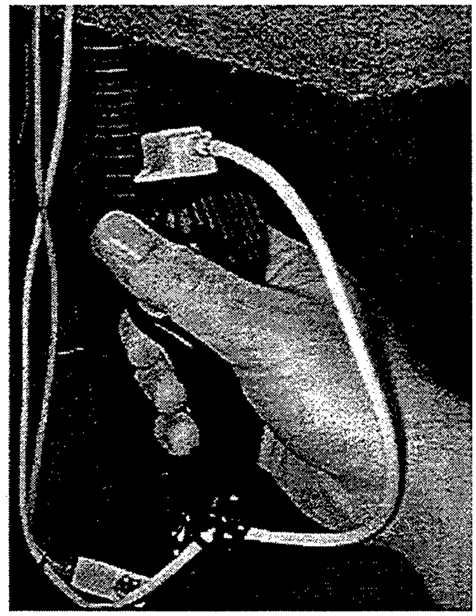


Figure 4. Controller in use.

Computer-generated Entity Server

The CGES provides support for all of the simulated entities in the VE. Environmental attributes that can be expressed as a Boolean state variable (such as doors left open or closed, or lights turned on or off) can be rapidly configured and implemented in FITT. For example, gas canisters encountered in the VE can be found in one of two states: active or "dud". In addition to serving simple two-state environmental elements, CGES can also be used to serve more sophisticated entities such as computer-generated enemies, referred to as Opposing Forces (OPFOR). Although configuration of these types of dynamic elements is not as quickly implemented as Boolean elements, (they generally require the development of custom behavior code) allowances have been made for a broad range of expression on the part of the mission designer. The OPFOR can be programmed with various levels of hostility and ability. Configurable parameters for OPFOR include span of peripheral vision, response time for orienting toward and firing at a participant after sighting a mission participant, sentry path, and accuracy with a weapon. For example, OPFOR can vary from an armed terrorist with pinpoint firing accuracy and a high degree of visual acuity, to a lightly armed looter, to an unarmed innocent bystander who should not be fired at when sighted. The OPFOR can also be set to stand in place and guard an area, or can be given a sentry path to follow and search for intruders (that is, the participants/trainees). Each OPFOR reacts to being shot by the players' tranquilizer pistols by slumping to the ground, and not moving for the remainder of the simulation.

Mission Commander/Experimenter Station

The FITT system mission commander\experimenter station was developed with features to allow a single individual to serve as the mission commander and as an experimenter. As commander, appropriate communications are exchanged with the participant team members over the simulated radio network. The station also supports experimenter tasks such as scoring team performance and instructional interventions such as coaching. A single keystroke toggles the display between a top-down view of the entire building that the team is searching and a zoomed-in close-up view centered over the team leader. To allow the commander to discern more easily which equipment is in use at a given time, the equipment in use by each team member is visually represented much larger than scale relative to the HAZMAT-suited avatars. Along with the graphical display of the players' positions in the VE, statistics are displayed which quantify the actions of the participants and assist the experimenter in determining the efficiency of the team as they move through their required tasks. For example, the display includes the number of times each participant: has been engaged by enemy fire during a mission, has changed equipment, and has collided with something in the VE.

Audio system

Audio communication is an essential ingredient of FITT. The audio for each player integrates environmental sounds such as gun shots, door openings and closings, and collision sounds, as well as communication with the other two members of the team. Because the ICSs are in separate rooms, the participants can speak to each other during the mission only over a simulated radio net. This avoids the problem that if the ICSs were in the same room the direction of voice would not change appropriately as the participants' avatars changed their relative positions to each other. Microphones attached to the HMDs at the Leader and Specialist positions feed their signals to the master mixing console, where the Commander's microphone signal is included in the mix. The Commander can talk with each of the other team members separately if the need arises. The signal from the master mixer is then sent back to each player where a small mixer integrates it with environmental sounds generated from audio files on the ICS machines. These final signal mixes are then delivered to the headsets of the HMDs.

Audio Capture and playback is performed by a separate machine, a Dell Optiplex 560 PC running Windows 95. The PC's sound hardware (a Sound Blaster™ AWE64) is connected to an intercom system that allows both players and the experimenter to talk to each other as if communicating via radio. The PC is also attached via serial cable to both the SGI Onyx running the playback system, and the SGI Indy running the data capture program. During data capture, the PC receives its recording commands from the Indy. The Indy first instructs the PC to ready itself for audio capture and informs it of the current trial's unique ID number. Next, it instructs the PC to begin audio capture. At this point the PC begins "listening" on its audio input port for audio communication. When the audio level rises above a preset threshold, the PC saves the current time (from its internal multimedia timer) and begins recording audio into a .wav file. The threshold code acts as a software voice activated circuit, and reduces the size of the .wav files when no communication is occurring. After the audio level falls below the threshold for a fixed amount of time, recording stops. The PC calculates the length of the audio clip and saves the ending time of the clip. It then returns to "listening" mode. Finally, the SGI Indy informs the PC when to stop recording audio. All audio clips with their associated time stamps are then saved into a file in the same directory as the .wav files. This allows them to be recalled later by the playback system.

Data Capture and Playback System

During any mission, the data collection system records all of the network traffic. This recording can be used to replay events as they unfolded during a particular mission, or it may be analyzed to produce a numerical summary for performance evaluation. Along with recording the network traffic, the data collection system also records all of the voice communications among the participants in the exercise. When the data stream is played back, the audio of those communications is also played to provide synchronized audio and visual replay of the mission.

Data recording is accomplished by capturing the Protocol Data Unit (PDU) traffic from all participating machines (both player machines and the CGES server) into a terse binary file. The data capture program runs on an SGI Indy workstation attached to the network. The start of data recording is signaled by a Start/Resume PDU, and the end is signaled by a Stop/Freeze PDU. These are sent by the experimenter via the Stealth machine's keyboard, to all machines at the beginning of the experimental trial. All PDUs are time stamped by the sending machine and all machines are time slaved to one designated master time server during each experimental run. This assures that all data can be reconstructed in the proper sequence during playback.

The Playback system is designed to allow experimenters and participants to view a complete audio/visual computer-generated reenactment of an experimental trial (mission). Features of this system include:

- The ability to view any instant of the experiment from any viewpoint
- The ability to advance or rewind the reenactment at any desired rate of speed
- The accurate representation of environment changes (such as doors opening and paint marks on walls) both during normal playback and fast/slow motion
- The recreation of audio cues (door sounds for example) and player audio communications synchronized to the visual playback

The Playback system runs on either of the SGI Onyx RealityEngine2 machines used as ICS stations during the mission. The software is built from the same libraries used to develop the experiment. In effect, it acts as a stealth station with a variable viewpoint, but reads PDUs out of a data capture file rather than fresh off the network. In addition, the same PC used to record the participants' audio communication is used to play back this audio, allowing the experimenters and participants to both hear, as well as see, how the mission progressed. The control panel for the viewer has familiar VCR-style controls allowing play, stop, rewind, and fast-forward at the click of a mouse. There is also a shuttle dial that allows for variable speed playback, both slower and faster than normal. The panel provides a real-time clock and a PDU counter to indicate where in the recorded mission the playback system is currently pointing.

The playback system begins by first reading in the requested PDU file, sorting the PDUs chronologically (by their saved time stamp), and pre-loading the appropriate body and environment models. It then establishes communications with the audio playback PC, instructing it to prepare to play the appropriate trial's audio data. When the play button is pressed on the Playback control panel, the PC is sent a "play" command with the current time index (in milliseconds). The PC then computes which .wav file to play based on this time index. If the time happens to fall in between two .wav files in its list, it waits until the correct time to play. If the time is somewhere within a .wav file, it begins playback from an appropriate offset into the file. Audio is only played while the system is in real-time playback mode; therefore, if any control other than "play" is selected on the control panel, the audio PC is instructed by the SGI to stop playback.

The simulation time is computed by the SGI running the visual portion of the playback system. If the playback system is in "play" mode, the system's real-time clock is used to update the simulation time each frame. This provides an accurate representation of the passage of time. If it is in a fast-wind or slow-motion mode, the time is arbitrarily incremented or decremented. Each frame, the SGI reads all PDUs from the file that happened prior to (or if rewinding, subsequent to) the current simulation time. As each PDU is read, the appropriate entities are updated, the appropriate weapons fired, and the appropriate doors opened or closed. After all necessary PDUs are processed, the next frame is drawn and the cycle repeated. Originally, a method was to be implemented that would continuously synchronize the graphics data to the audio, because the audio capture PC is not time slaved to the primary simulation machines. Preliminary testing demonstrated that this was not necessary, however, as both the PC's and the SGI's internal clocks were independently accurate enough to control the timing of their respective playbacks. That is, no discrepancy in the audio and visual data was perceived over the length of any trial's playback.

Avatars

FITT provides a means for representing participants within the shared virtual world as avatars. As shown in Figure 5, the avatar of each team member depicts a person in HAZMAT gear: a bulky chemical protective suit with a helmet containing breathing apparatus. Thus, the limitations of the FITT to represent locomotion, vision, audition, and haptic factors enhance, rather than detract from, the sense of presence. For example, the participants are told that the HAZMAT suit and body armor provide protection but limit speed of movement to walking and prevent running, crawling, or jumping.

Loftin (1998) described a team training VE for which high fidelity human models were developed to serve as avatars for each of the actual participants in VE training. Because our research involves hundreds of different participants it is not practical to develop a model for each individual participant. Therefore, an additional advantage to using the HAZMAT suited avatars is that they do not depict body morphology, gender, or ethnicity.

The 3D-avatar model incorporates 45 degree of freedom beads allowing for realistic deflection of limbs and torso. Setting the proper rotation angles for these degree of freedom beads is the responsibility of the ICS.

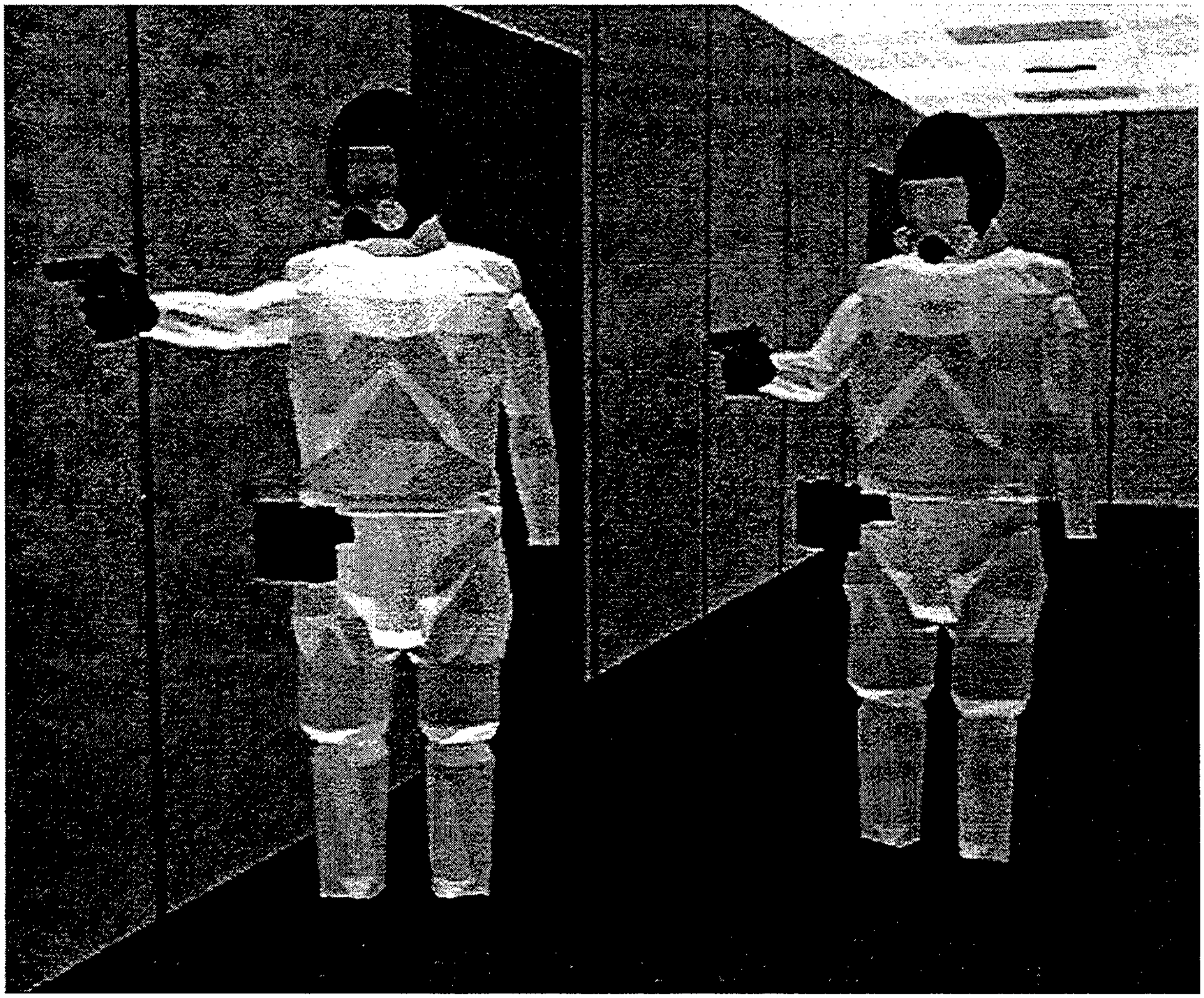


Figure 5. Avatars in HAZMAT suits.

<u>Virtual Environments</u>

The basic floor plan for the search mission consists of 10 rooms positioned along a hallway containing one ninety degree turn. Six of these floor plans were developed. Each contains the same square footage to be searched but they differ in the directions in which hallways branch and the locations of the rooms. Thus, across different missions the search task is of equivalent difficulty but the layout of the building can not be memorized. A seventh floor plan has also been created which involves a multistory structure and presents a much more challenging search task.

Two separate VEs were designed to provide practice in walking in a VE and to practice using the manual control device to select and use equipment. The first consists of a large room and a connecting series of corridors. The large room contains a pattern at eye-height on which the participant can focus as a reference while adjusting the HMD. The corridors, designed after the Virtual Environment Performance Assessment Battery (VEPAB) hallways task (Lampton, et al. 1994), provide practice walking under more demanding conditions and allow speed and accuracy (collisions) measures for each participant. The second VE contains examples of the various types of equipment and friendlies, enemies, and neutrals that can be encountered during the missions. In this VE the participants separately practice using the pistol and the equipment unique to their role in the team.

Networking Issues

The FITT is a networked simulation environment that uses the Distributed Interactive Simulation (DIS) protocol to pass messages back and forth. A subset of DIS protocol version 2.0.4 has been implemented for this project. Fully articulated human figures are not explicitly supported by the DIS protocol. For FITT, body and limb position are transmitted via articulated parts structures attached to the Entity State PDU. The following DIS PDUs are used during the application:

Entity State PDU This is the primary PDU used for the player avatars and the computer-generated opposition forces. The articulated parts array is used to broadcast the position and posture of the avatar. A total of 47 articulated part parameters are available for modification during the simulation.

Fire PDU – Detonate PDU These two PDUs are used for the paint marker tool and the Gas Cylinder de-activator tool, as well as for the tranquilizer dart pistols available to team members.

Action Request PDU Door opening and closing events are broadcast using these PDUs.

Start PDU – Stop PDU Used by the menu software for starting and stopping the simulation.

Collision PDU Used by the Data capture hardware to log collisions for playback.

One important aspect of the FITT software is that the DIS PDU traffic is handled by an Entity Services application that runs as its own process on each network machine. All message queuing and dead reckoning for all PDUs are encapsulated within this Entity Service running on the host machine. Applications wishing to use the Entity Service log on as a client.

A final word about our choice of the Entity State PDU as the primary avatar state vehicle: at the start of this experiment, an evaluation of the human figure problem was made. The graphical representation of the human figure, in contrast to a vehicle, requires a relatively large number of articulated parts. For example, the current system supports fourteen different joints of the human body each with three rotations. In general, there are two methods that can be used for transmitting human figures within DIS. An Entity State PDU with all the articulated parts can be sent, or a Data PDU can be used to transmit the human articulated parts. Technically, the DIS standard does not support articulated parts of human figure in its articulated parts enumeration (the enumeration focuses more on the parts of vehicles such as a turret). However, we chose to use Entity State PDUs because it was felt that articulated part information really should go along with all the other entity information even if the DIS standard did not include human figures in its enumerations (some arbitrary articulated part types were used).

Simulation Startup from Browser

FITT uses six computers, all of which have their own unique startup sequences depending on which options the user wishes to run. To deal with experiment startup complications, we developed a multi-layered menu program in Java to select the various options available and launch the simulation from one terminal.

The menu allows the user to control any part of the simulation from one terminal. The menu has options to place the machines into or take them out of Multi Channel Option (MCO) mode (allows for stereo view). It can be used to set up information for data capture, start/stop a simulation, process captured data, play back a previously run simulation, and email the collected data. It can also bring the systems off the network as a restricted subnet for maintaining a distinct and stable experimental environment.

The menu program is a client/server combination. The server is a Java application that can be run on any one of the computers used for the simulation. The server receives commands and options from the client interface. Then, depending on the options, the server uses the Java System.exec() method to remotely start up the parameters of the simulation needed on the various machines. After executing the commands, the server updates the state information of the client.

Originally, the client interface was designed as an applet that would run through an internet browser. It was changed to an application to get around the security restrictions imposed by applets and browsers. Specifically, the browser would not allow an applet to communicate with an application unless the application was running on the same host from which the applet was loaded. Thus, our options were to either set up the machine running the application as a web server, or to write the client as an application as well.

Due to the reboot process incurred while taking the machines on and off the lab's general development network, the menu needed to be robust. The client and server are both able to survive if the other is killed. If the client is killed, the server simply waits for a new client to connect and then updates the new client with the current state of the simulation. If the server is killed (due to system reboot while taking the simulation off the network), the client will display a "Waiting for server message" and attempt to reconnect to the server. Once the server is running again, it will connect to the machines involved, determine the current state of the simulation, and then wait for the client to reconnect.

Summary of FITT development and Implementation

In implementing FITT, IST built upon its previous VE development efforts by incorporating a networked virtual environment system, a sophisticated action-after critique system, and a new Java-based menu system. The networked system built upon previous work by IST (for the U.S. Army Simulation, Training and Instrumentation Command (STRICOM) under the Dynamic Terrain project) by modifying existing DIS protocols to support human avatars and environment elements (for example, operable doors and leaking canisters). The action-after critique system captures all environment network traffic and audio communication, and provides a playback mechanism, which can be used for reviewing the mission with the participants. The new Java-based menu system replaced the old text-based menu system used by previous experiments and provided necessary enhancement due to the quantity of machines necessary to support the experiment during run-time. Overall, the FITT system provides a robust and flexible networked virtual environment system using an object-oriented design running on multiple workstations.

Instructional Strategies for Team Training in Virtual Environments Experiment

For our first experiment looking at team training in VE we sought to implement straightforward (simple) implementations of tradition instructional strategies involving when to give guidance to the trainees. These were: guidance given either before (demonstration), during (coaching), or after (replay) the first practice mission, or not at all (control group). Thus, the instructional strategies differ in when guidance is given. We did not expect that any particular strategy would be significantly superior to the others, but rather wished to conduct an exploratory comparison of their effectiveness.

Instructional Strategies

Demonstration

Demonstrations provide an observer with information about the required behaviors, actions, or strategies associated with a task. We believe that the unique capabilities of VE can enhance what has already proven to be an effective instructional strategy.

In the demonstration group, the team members watched a replay of a mission conducted by an "expert" team highly practiced with the tasks. The replay is of the movement of the avatars, viewed from above and centered on the team leader, as they correctly perform the mission tasks. Thus, the trainees see the avatars in proper formation, and hear examples of appropriate radio communications, before they attempt the practice and test missions. The demonstration provides an example of good team coordination and a feel for the tempo appropriate for the individual tasks and the overall mission.

The demonstration mission was produced by having an experienced team perform a mission, and videotaping a playback of that mission. (Prior experience was based on performing missions to help test the system and several missions conducted specifically to rehearse for the demonstration mission.) During the playback, the view was zoomed in and out. For example, when the team assumed the "stack" formation the view was zoomed in to give a better view of the proper formation. During engagements with the enemy, the view was zoomed in and out so that both the team and Opposing Forces were shown. The demonstration team featured three easily distinguished voices: mature man (Team Leader) youthful man (Equipment Specialist), mature woman (Mission Commander). There was no narration additional to communication that occurred as part of the mission.

Coaching

Coaching involves knowing what to say, and when to say it, to the trainees. In the coaching condition, the participants received guidance from the mission commander while they attempted the missions. Coaching provided immediate feedback and prevented the participants from practicing procedures incorrectly. The frequency of coaching was expected to naturally "fade" as the participants required less guidance as they gained experience. A potential problem with coaching is that it may rapidly bring a team to a high level of performance, but may also lead to problems when the coaching "crutch" is not available during the test mission.

Replay (with critique)

After performing a mission, the participants watched a replay of that mission. During the replay, the mission commander pointed out the strengths and weaknesses of the mission. This approach is similar to the after-action review (AAR). The AAR is the Army's approved method for providing feedback to trainees as part of their performance oriented training (Meliza, 1996). The AAR is a professional discussion conducted after training exercises to maximize and reinforce learning by involving the participants in the training diagnostic process. An effective AAR is one in which performance problems are identified, defined, and solved in such a manner that allows the trainees to learn from their performance. The main goal is to identify strengths and weaknesses while focusing on problem solving to allow trainees to determine their level of skill and decide what they need to do to improve their performance. Through participation in an AAR, trainees get to identify the tasks accomplished and the tasks requiring improvement.

Among the ways that our after-action critique conducted in this experiment differed from a standard Army AAR was that the replay was not paused for comments. In addition, discussion by the participants was greatly limited.

In both the coaching and replay conditions, the experimenter had a checklist to aid in scoring team performance and providing consistent feedback. The checklist items were those included in the mission scoring criteria (Table 2).

No external feedback (control group)

This group received no feedback other than that intrinsic to performing the missions, and provided a baseline with which to compare the performance of the instructional strategy groups. In some experiments the control group represents a "no training" condition to determine chance performance. This is not the case in our design. The control group teams studied the team mission training manual as did the instructional strategy groups, and completed two practice missions before conducting a third test mission.

Note that total training time was held constant across groups. The control group teams, therefore, performed one more practice mission than the demonstration and replay teams. The demonstration and replay teams watched a mission replay in place of a second practice mission.

Experimental Procedure and Design

Ninety-four participants were recruited from local colleges and scheduled two at a time. Participants had the option of receiving extra credit points from their instructors or seven dollars for each hour of participation. If one of the scheduled two participants did not show up, then an experimenter's confederate served as the second team member. Participants read and signed a consent form, then completed background information and baseline (pre-immersion) Simulator Sickness Questionnaires (SSQ). (See Kennedy, Lane, Lilienthal, Berbaum, and Hettinger (1992) for a comprehensive description of the SSQ.) Next, they watched a videotape showing how to walk and use equipment in the VE. A coin flip determined who would be the Team Leader. (For teams with an experimental confederate, the participant was always designated the Team Leader. A list of rules defined the limits on the ways the confederate could help the leader. Basically, the confederate performed the Equipment Specialist duties very efficiently, but was instructed not to help the leader with navigating the building, performing leader procedures, or monitoring or dealing with the time limit.)

Two different VEs provided familiarization with using the FITT system. The first VE provided practice walking in VEs. After a break, a second VE allowed the participant to practice using equipment, more demanding walking tasks, and to recognize a team mate, types of enemy, and innocent bystanders. Thus, before participants conducted a mission as a team, they had each practiced individually in moving through VEs, aiming and firing the pistol, and operating the equipment unique to their assigned role.

Next, the participants read the mission training manual. A paper and pencil knowledge test based on the mission procedures was then administered. The participants were told which, if any, items they missed and the correct responses.

Up to this point, all participants received the same treatment. They were then assigned to one of the four conditions shown in Table 1.

For purposes of illustration of the training phase we consider the control group first. The teams in this group conducted three missions, with a rest break between missions. Each of these missions was different but of equivalent difficulty as defined by the number of canisters and OPFOR to be dealt with. The mission scores for the control group allow us to plot change in performance as a function of practice without external feedback or guidance. Performance on the third mission can be compared with the test mission of the other instructional strategy groups.

The demonstration group watched a replay of a mission performed by a team highly familiar and practiced with the mission tasks. The demonstration was given in place of one practice mission. After watching the demonstration, the team then had a practice mission session, and then the test mission session. In a similar manner, in place of a second practice mission session, the replay group teams watched a replay of their own performance of the first practice mission. In the coaching condition, the commander/experimenter provided prompts or suggestions as the team conducted the mission.

Table 1.

Research Design

Group	Training Phase		Test
	(Mission # 1)	(Mission # 2)	(Mission # 3)
Demonstration	Watch Demonstration	Practice	Test
Coaching	Practice with Coaching	Practice with Coaching	Test
Replay	Practice	Critique During Replay	Test
Control	Practice	Practice	Test

The demonstration and each mission exercise, replay, and test were eight minutes in duration. This time limit made sure that all groups had the same total training time. Two different scenarios were counterbalanced across the first and third missions.The scenarios differed in the layout of the rooms within the building and the placement of canisters and OPFOR.

After each mission, the participants completed another SSQ. After the last mission, participants were told the purpose of the experiment and given the opportunity to ask questions. Total time was two hours.

Performance Measures

The criteria for measuring team performance of the mission procedures are presented in Table 2. Data streams from each mission were replayed and recorded on videotape. Raters used checklists to score each of the procedures, pausing or replaying mission segments when necessary to aid scoring.

Table 2

Description of Mission Procedures and Scoring Criteria

Procedure	Description (scoring criteria)
Room search order	Is the right turn rule observed by both team members in the search of building's rooms?
Proper entry formation and coordination	Do team members align themselves properly with the doorway, and recite "stack/ready/go" protocol correctly?
Room entry	Does the team leader move far enough into the room to allow equipment specialist to pass through the doorway?
Effectiveness of search	Does team penetrate the room adequately to see around all obscuring furniture, etc; were any canisters missed?
Room exit	Does team exit the room together, with team leader in front?
Room marking	Does team leader use paint gun to mark the outside of the room (above the doorway)that was just searched?
Pistol in hand	Does the equipment specialist have pistol selected when leaving room?
"Contact" announced	Do team members clearly announce "contact" upon encountering enemy?
Appropriate target, number of shots, and clear line of fire	Do team members incapacitate enemy (and not innocent bystanders; do they fire a minimum of tranquilizer darts, and; do they move around each other (and other obstructions) to obtain a clear line of fire?
Reports contact	Does team leader report to the commander that contact with enemy has occurred?
Correct call sign; proper format	In reporting the above information, does the team leader initiate and carry out commo in accordance with protocols in the training manual?
Correct enemy type and number	In reporting to the commander, does the team leader properly identify the enemy type (looter or terrorist) and number?
Hazardous gas canisters	Does the equipment specialist check canister(s), if present; does the equipment specialist then inform the team leader of the canister's original and current status (e.g., "active and now deactivated;" or "dud")?
Reporting of hazardous gas canisters	Does the team leader properly describe to the commander both the number and status of the canisters encountered, and follow correct call sign and format protocols?

Results

This section begins with background information on the research participants. Next, performance measures are presented. There are two categories of performance measures. The first consists of those measures recorded once per mission. (For example, did the team exit the building within the time limit?) The second category consists of measures taken several times per mission, such as proper formation for entering a room and actions on encountering enemy. Following the logic of the experimental design, performance on the last mission is the primary focus of the summaries of both categories of performance measures. Performance on the practice missions is also described. Performance by teams with two participants is compared with that of teams with a confederate. Frequency and severity of the occurrence of simulator sickness are discussed briefly. Participants' ratings of several characteristics and dimensions of teamwork are presented and ratings of aspects of presence, the sense of being immersed in the VE, are summarized.

Participant background information

Ninety-four participants were involved in this experiment. Fifty-two (55%) were women and 42 (45%) were men. Their age ranged from 17 to 54 with an average of 21. Nine of them withdrew because of simulator sickness. Three teammates of those simulator sickness withdrawals could not be accommodated with teammates and are not included in the participant count for determining the number and percentage of participants who withdrew because of simulator sickness. Although they did not withdraw, they also, through no fault of their own, did not complete the experiment. Obviously, performance data are not available for those teams that did not complete the experiment. In addition, for some of the teams (involving ten participants) that did complete the experiment, data capture and storage problems resulted in loss of some performance data. Therefore, the number of participants varies, as indicated, across the various analyses.

The remaining 81 participants formed 49 teams, 26 "real" teams in which both members were experimental subjects and 23 confederate teams in which the confederate performed the role of Equipment Specialist. The percentage of real teams in the Control, Demonstration, Coaching, and Replay groups were 55%, 50%, 67% and 43%, respectively.

Performance data

Exiting the building within the time limit. Figure 6 presents the percentage of teams per group that exited within the time limit or at least attempted to exit. The number of teams with usable data per condition were: control = 11, demonstration = 12, coaching = 12, and replay = 14. Equivalent procedures were used for the first mission for the replay and control groups, therefore data for those groups were combined as "baseline". Baseline represents the performance on the first mission without a prior demonstration or coaching during the mission.

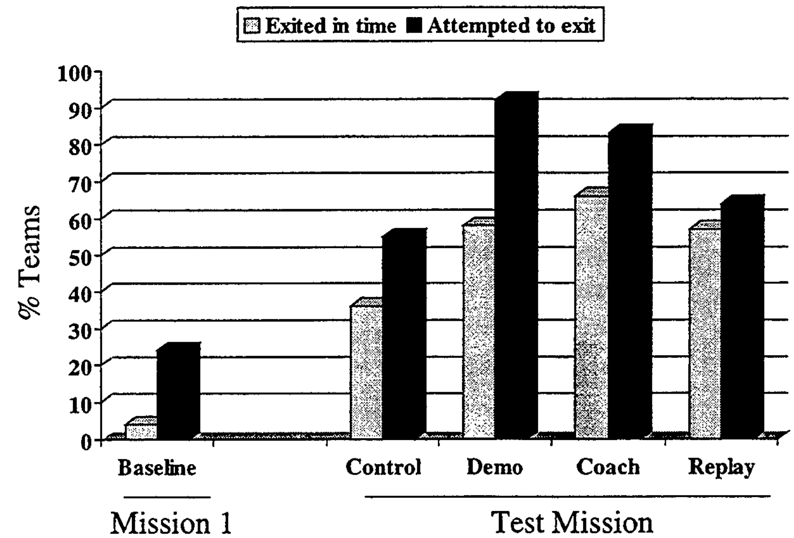


Figure 6. Percentage of teams per group that exited within the time limit or at least attempted to exit. Baseline represents the first mission for the control group and replay group combined.

Because of the small number of teams, we used the odds ratio approach for comparing group performance. The ratio, calculated by dividing the odds of one event by another, provides results in the form of a direct comparison between variables (e.g., "a team in the demonstration group is x times as likely to successfully exit as is a team in the control group"). Advantages of the odds ratio include its being unaffected by sample size or by unequal row or column totals (Howell, 1997). Stated in terms of an odds ratio, teams from all groups combined were about 13.8 times more likely to exit in time during the test mission than the baseline teams were in the first practice mission (chi-square $(1, \underline{N} = 74) = 16.27$, $\underline{p} < .001$). Thus the training sessions improved performance on this performance measure.

The question of whether teams improve with practice alone was addressed by comparing the number of control group teams that successfully exited during the first mission with the number that exited during the test mission. Following the analysis described by Siegel (1956) for related samples (control team is used as its own control) and a small (less than 5) frequency for one cell of the contingency table, a binomial test yielded $\underline{p} = .016$.

Thus the performance of both control and instructional strategy teams improved from the first to the third mission. An instructional strategy team was about 2.7 times more likely to exit in time than was a control-group team. However, following the analysis described by Siegel (1956) for independent samples and a small frequency for one cell of the contingency table, a Fisher exact probability test yielded $\underline{p} = .14$ for the same or a stronger association. Thus the apparently superior performance of the instructional strategy teams relative to control group teams was not statistically significant.

During data collection, we noticed that some teams that failed to exit in time attempted to exit but failed, whereas others did not even try to exit. Teams could be so caught up in the mission, particularly during encounters with enemy, that they forgot to monitor their air gauges. For teams that attempted to exit but failed; some waited until too late to start back, some started back with enough time but then decided "Maybe we have time to search one more room." Teams could also become lost in attempting to retrace their paths. It was generally very clear when a team decided to exit in that usually the Team Leader, but occasionally the Equipment Specialist, would express something to the effect that "We need to leave now."

Figure 6 presents the percentages of teams who at least attempted to exit. All teams combined on the third mission were 3.06 times more likely to attempt to exit than were baseline teams (chi-square $(1, \underline{N}=74) = 14.55$, $\underline{p} < .001$. Looking at the effect of practice alone, the control group teams were about 3.8 times as likely to attempt to exit during the test mission than the baseline teams during their first mission. A binomial test comparing the number of control group teams that attempted to exit during the first mission with the number that attempted to exit during the test mission yielded a significant $\underline{p} = .016$.

For the test mission, an instructional strategy group team was 3.12 times more likely to attempt to exit than a control group team. However, this difference was not statistically significant (chi-square $(1, \underline{N} = 49) = 1.5$, $\underline{p} = .22$).

Procedural tasks

A single composite score was generated for each mission indicating the percentage of correctly executed tasks based on the total number of appropriate opportunities to perform the tasks. Percentage of procedures performed correctly, and the number of rooms entered, out of total possible for the first and test missions are shown in Figure 7. (For the percentage of procedures performed correctly, the number of teams with usable data per condition were: control = 7, demonstration = 9, coaching = 11, and replay = 14.) In a general sense, the percentage score represents the accuracy with which the teams perform in contrast to the number of rooms searched which represents the speed of the building search. For both of these measures Analyses of Variance for a practice effect (control group mission 1 versus mission 3) and instructional strategy effect (test mission, the 3 strategies versus control) were not statistically significant.

Examination of the scores of individual teams indicated a wide range in performance. The highest percentage of procedures score for the last mission was 97. That indicates for practically every room entered and searched, and every encounter with OPFOR and canisters, that team correctly performed all of the tasks listed in Table 2. That team completed searching seven rooms and returned to the designated area with 13 seconds left on the countdown timer. The lowest score was 34. That team entered 8 rooms, correctly executed only 34 percent of the tasks, and did not attempt to exit within the time limit.

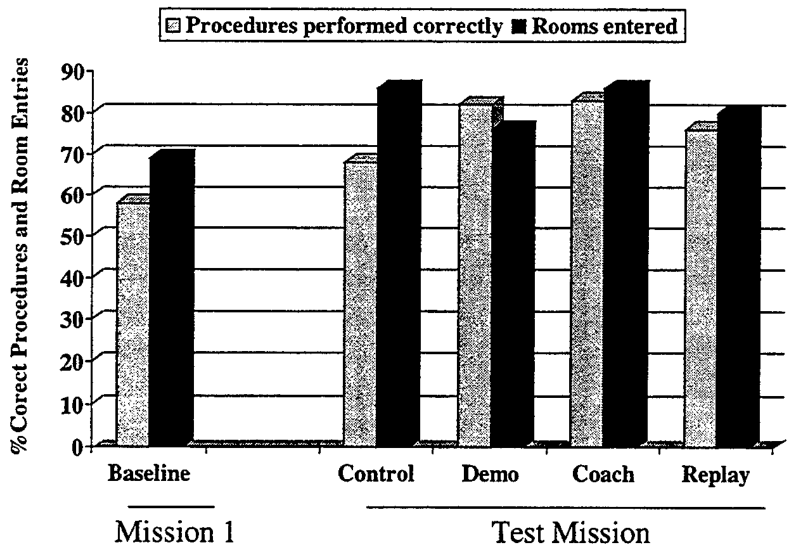


Figure 7. Percentage of procedures performed correctly and number of rooms entered out of' total possible for the first and test missions. Baseline represents the first mission for the control group and replay group combined.

Performance as a function of team composition

Table 3 presents a comparison of performance of teams made up of two recruited participants with that of teams composed of a participant serving as the team leader and an experimenter's confederate as the equipment specialist. For number of rooms searched and percent of correct procedures, t-tests for independent samples did not approach statistical significance.

Table 3

Test Mission Performance as a Function of Team Composition: Two Participants versus a Participant and an Experimenter's Confederate

Performance Measure	Equipment Specialist	
	Participant	Confederate
% exited in time	58 (26)	52 (23)
% attempted to exit	69 (26)	78 (23)
Mean number of rooms searched	8.3 (26)	8.2 (23)
Mean percent correct procedures	78 (20)	78 (21)

Note: The total number of teams is shown in parentheses.

Videotapes of 23 test missions conducted by teams including a confederate were reviewed to determine if the confederate followed the directions for role playing. The confederate was instructed to serve efficiently as the Equipment Specialist but to provide no information, beyond what was called for in the training manual, to influence the performance of the Team Leader. In four of the 23 missions the confederate was judged to be "too helpful".

Simulator Sickness

About 9% of the participants withdrew from the experiment because of simulator sickness. All of the participants who withdrew because of simulator sickness were women. Reason and Brand (1975) suggest that women tend to be more susceptible to motion sickness than men. Given that each mission was relatively brief, only about eight minutes in the HMD at a time, and rest breaks were given between missions, the attrition rate indicates that simulator sickness is still a challenge that must be considered in developing practical training applications using immersive VEs.

Fatigue was the most frequently reported symptom on the pre-immersion SSQ. For all five post-immersion SSQs, eyestrain was the most frequently reported symptom. Only on the SSQ administered after the last mission were any symptoms rated as severe: dizzy eyes open and stomach awareness. The last mission also had the greatest variety of symptoms reported with each of the 16 symptoms reported by at least two participants.

For those participants who completed the experiment, the mean Total Severity score for the SSQ administered after the test mission was 9 and the standard deviation was 17. For those who withdrew, the mean was 38 and the standard deviation was 20 for the SSQ administered after the last mission they attempted. Addition information on simulator sickness data from this experiment is presented in Lampton, Rodriguez, and Cotton (2000).

Participant Ratings of Team Processes

Because there was not enough time to administer lengthy questionnaires during the experimental session, we asked participants to take home the questionnaires and return them within one week. The questionnaires addressed team processes and "presence" the extent to which participants feel immersed in the VE. This take home approach was only attempted for about the last third of the data collection effort. Forty-two of the participants were given a set of questionnaires to take with them and return them within one week. Forty did so.

Two instruments were used to measure participants' ratings of team processes and satisfaction. The first questionnaire, adapted from Harvey and Drolet, (1994), consisted of a list of 14 team characteristics: cooperation, communication, mutual support, mutual respect, atmosphere, cohesion, pride, trust, leadership, participation, decision making, goals and roles, problem solving, and climate. Participants rated each characteristic with a scale ranging from "none" to "excellent". Table 4 presents the mean value and rating frequencies for each item. The table lists the items in descending order of the mean values. Note that most of the ratings are favorable. Two participants indicated that the process of "pride" was not applicable to their team membership.

Table 4

Mean Values and Rating Frequencies for Team Process Items

Item (mean)	Mean	Excellent	Good	Fair	Poor	None
Participation	3.49	56.4	38.5	2.6	2.6	
Mutual Respect*	3.47	55.3	36.8	7.9		
Trust (3.41)	3.41	46.2	48.7	5.1		
Mutual Support	3.26	41	43.6	15.4		
Goals and Roles	3.23	41	41	17.9		
Climate)	3.18	33.3	51.3	15.4		
Cohesion	3.15	33.3	48.7	17.9		
Cooperation	3.15	33.3	48.7	17.9		
Pride**	3.14	32.4	48.6	18.9		
Problem Solving*	3.13	36.8	39.5	23.7		
Atmosphere	3.13	35.9	42	23.1		
Decision Making	3.08	38.5	30.8	30.8		
Leadership	2.95	28.2	41	28.2	2.6	
Communication	2.95	30.8	41	20.5	7.7	

Note: Means based on Excellent = 4, Good = 3, Fair = 2, Poor = 1, None= 0
Percentages based on N = 39
* n =38
**n = 37

The second questionnaire, adapted from Eitington (1996), consisted of eight statements about the quality of the team experience (roles are clear, roles are balanced, decision making is effective, team members work well together, I need to work with the other member to get my job done, I'm satisfied with my level of participation in this team, conflict is handled appropriately and effectively). Rating choices could vary from "strongly disagree" to "strongly agree". Table 5 presents the mean rating value and rating percentages for each item. The table lists the items in descending order of the mean values. Again, in general the participants reported a high level of satisfaction with their membership on the team. The dimension with the highest mean score was 'roles are clear' with a 3.38. The lowest scoring characteristic was 'roles are balanced' with a mean of 2.85. Clearly, the roles were not and were not intended to be balanced in that the Team Leader was expected to lead the mission.

Table 5

Mean Values and Percentages for Team Process Ratings.

Item	Mean	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Roles are clear.	3.38	46.2%	46.2	7.7		
Team members work well together.	3.36	41	53.8	5.1		
I'm satisfied with my membership in this team.	3.33	43.6	48.7	5.1	2.6	
I need to work with the other member to get my job done.	3.28	64.1	17.9	7.7	2.6	7.7
Conflict is handled appropriately and effectively.	3.23	35.9	53.8	7.7	2.6	
I'm satisfied with my level of participation in this team.	3.18	35.9	51.3	7.7	5.1	
Decision making is effective.	3.08	28.2	51.3	20.5		
Roles are balanced.	2.85	28.2	43.6	12.8	15.4	

Note: Means based on Strongly Agree = 4, Agree = 3, Neutral = 2, Disagree = 1, Strongly Disagree = 0

Percentages based on N = 39

Presence

Previous ARI VE research has employed the Presence Questionnaire (PQ) and Immersive Tendencies Questionnaire (ITQ) developed by Witmer and Singer (1994). The PQ was designed to measure the extent to which the VE participant is immersed and involved with the VE. They define presence as the subjective experience of being in one place or environment (the VE) when one is physically situated in another (the real-world VE system). The ITQ was developed to measure the tendency to become involved or immersed. Both questionnaires use participant self-report.

Forty participants completed the questionnaires. We had expected that the mean for the PQ Total Score would be higher than previous ARI VE experiments. This expectation was based upon the use in this experiment of VEs and tasks that are more complex, the presence of a teammate, and the use of sound effects. However, the PQ Total Score mean and standard deviation for this experiment ($M = 98.54$, $SD = 13.48$) were similar to averaged values for previous experiments ($M = 98.11$, $SD = 15.78$) reported in Witmer and Singer (1994). Also contrary to our expectations, the correlation between PQ Total and ITQ Total ($r = .164$, $p = .340$) was not significant.

Discussion

The FITT System

This was the first experiment we conducted with FITT. In addition to examining the use of instructional strategies in distributed immersive VEs, this research also served as a demonstration of new immersive VE technologies and as a usability test of new approaches to moving in, and interacting with, immersive VEs.

In general, the FITT seems to function well as a system for conducting research on team training using immersive VEs. The mission tasks combined many generalizable task components across related but separate domains, such as infantry tactics, SWAT tactics and HAZMAT operations. The HAZMAT equipment and environment that support the mission provided a concise and logical storyline. In addition, the avatars' HAZMAT gear lead to user acceptance of system limitations.

The cognitive aspects of the mission, and not the mechanics of using the VE interface, were the greatest challenge for most participants. Most participants reported that they enjoyed the experience, and seemed highly motivated to perform well on the missions.

A few individuals seemed overwhelmed by the experience, perhaps by the immersive VE and/or the stress of leading a team, and did not function effectively as team leaders even after three practice missions. From a training research perspective this is not necessarily a bad thing, in that some individuals would struggle if placed in a leadership position in comparable real-world tasks.

The FITT system for walking in the VE worked very well. The locomotion system has two strong points: the participant's vestibular and ocular systems are always in accord, and the system requires little train-up time for a novice.

The structured approach to train-up on the FITT system was effective and should be considered for other VE training applications. The narrated videotape provided the participants with a good overview of the system before they were immersed. Simplified VEs and tasks designed specifically to familiarize the participants with the FITT system avoided inconsistencies that can result from a "free play " familiarization session.

In general, the FITT system operated reliably over a data collection period spanning several months. The few significant problems, described below, have been flagged for correction in subsequent versions of the FITT system.

In our experimental design, an important measure of performance was to be the number of times the OPFOR shot members of a team per encounter. A team that followed procedures should be hit fewer times than a team that did not follow procedures. For example, following appropriate procedures, a good team would enter the room quickly with the Team Leader moving far enough into the room to allow the Equipment Specialist to enter. The Team Leader would cover the left side of the room, the Equipment Specialist the right side. Both team members would announce contact, specifying the location and number of OPFOR sighted, and rapidly engage the enemy. The team would sustain few hits even if caught in a crossfire. In contrast, if a Team Leader froze in the doorway or either member failed to cover their assigned sector, that team would sustain many hits. For various reasons related to network speed and object modeling, correctly aimed shots by team members did not always result in timely incapacitation of the OPFOR. This resulted in several instances in which teams quickly and accurately performed action on contact procedures, but still were hit many times by the OPFOR. This unwanted delay varied considerably across missions and therefore the number of hits received was not a usable measure of team performance. As might be expected, a related problem was that participants would continue to fire at OPFOR until the OPFOR would fall. Therefore, the shots fired per encounter measure was more a function of system delay than of aiming accuracy and therefore was also unusable.

For a few data collection sessions, data capture and storage were corrupted to the extent that data from those sessions were unusable. For some other sessions, problems with audio data capture prevented analysis of the communication procedures. In addition to correcting data capture reliability, the system should provide some indication to the experimenter that data capture is, or is not, occurring.

A major problem we encountered in this research was unrelated to the FITT system itself. In designing and conducting research on training applications of VE there are challenges associated with the new and very rapidly changing software and hardware technologies necessary for the creation of immersive, interactive VEs. However, in conducting this experiment, the greatest challenge by far was the recruitment of participants. There were two aspects to this; participant "no-shows", and the great variation across participants along characteristics that we might expect to influence mission performance.

Our design called for two participants at a time. In over seven years of VE research conducted in the ARI/IST laboratory, we have experienced systematic problems with "no shows", that is, students who agree to participate but fail to report at the agreed upon time. For this, our first team training experiment, no-shows were especially problematic in that our design called for two participants at a time. As explained in detail in the procedure section, when only one of the two participants scheduled reported for the experiment, we employed an experimenter's confederate to serve as the second team member. The use of a confederate, holding constant the capabilities and motivation of the second team member, could be a useful approach to team training research and perhaps even team training for that matter. In addition, confederates could be useful in developing and testing role-playing rules to be implemented in computer-generated friendly forces. However, in this situation the use of a confederate was by necessity, not by choice, and added the complication of trying to balance across the four instructional strategy groups the number of teams composed of two recruited participants versus one recruited participant and a confederate.

A second problem was that participants varied greatly in characteristics that we might expect to influence performance on mission procedures. Some of our participants had prior experience that probably helped them during the missions. For example, our participants included a veteran SWAT team leader, Reserve Officer Training Corps (ROTC) cadets, and avid computer gamers. Other participants had almost no experience with computers, and for some English was not their native language.

Both of these problems could be mitigated by a formal arrangement for research participation by ROTC cadets, law enforcement officers, or military personnel.

Instructional Strategies

Before data collection began, we assumed that a unique advantage of the demonstration was that it clearly conveyed an appropriate mission tempo, that is the appropriate speed to perform the procedures. The performance measure of number of rooms searched, and our subjective evaluations of team performance, indicated that on average, teams not in the demonstration group actually assumed a faster tempo than the demonstration group. The steady tempo conveyed in the demonstration apparently emphasized accuracy over speed. It is also possible that the demonstration teams performed more slowly because the had less practice on the task than did the coaching and control groups. Nevertheless, for situations in which a faster tempo is desired, a demonstration could start off at a slower pace, so that the procedures are easy to observe by the trainee, and then the tempo is increased.

We also observed that team members in the demonstration group not only remembered the mission procedures from the demonstration, but also closely modeled specific aspects of the voice communications. For example, when announcing it was time to exit the building, several of the Team Leaders used phrasing (not specified in the training manual) very similar to what they had heard in the demonstration. Although more than 90% of the demonstration teams attempted to exit the building, only about 58 exited in time. Thus, the demonstration clearly presented a highly memorable example of announcing it was time to exit, but did not convey with equivalent effectiveness the higher level skills, such as monitoring time and avoiding distractions, needed to successfully exit within the time limit.

An implication of the observation that the participants imitated closely the tempo and voice communications is that a demonstration should not include any aspect of behavior that you do not want the trainees to copy.

The demonstration intervention is by far the easiest to administer. After the initial effort to produce and record the demonstration mission, it is easy to administer and makes sure that each team receives the same information before their first practice mission.

Coaching was the most difficult intervention to administer. In some situations it was very valuable to be able to correct a mistake the first time it happened rather than watch a procedure being practiced incorrectly throughout a mission as could occur in the other groups. However, there was a tendency to provide too much feedback too soon. In addition, because performance at the beginning of the first practice mission tended to include many errors, coaching was vulnerable to being too negative.

The design of our VEs, in contrast to open terrain or larger building models, took away one potential advantage of coaching. The teams could not get lost or stray outside their assigned sector because the doorway leading beyond their sector was locked. An attempt to go through that doorway was scored as an error but they could not waste a significant amount of the mission time becoming lost, realizing they are lost, and working their way back to where they should be. Coaching would allow intervention at some point during this "lost patrol" situation, reducing the amount of misspent training time.

In contrast to the coaching group in which the experimenter had to provide feedback immediately, the critique given during the replay benefited from the context of having seen the entire mission beforehand. An approach that seemed to work well was to make only one or two points per room. In that way, by the end of the replay most problems could be addressed and examples of good performance could also be noted.

Here are some examples of mistakes which were frequently pointed out during both coaching missions and mission replays. The Team Leader would often start the stack standing too far away from the door about to be entered. This does not allow the Equipment Specialist enough room to stack behind the Team Leader. For either coaching or replay, the experimenter would point out this error. Another frequent mistake involved initial contact with OPFOR when entering a room. Some Team Leaders would freeze in the doorway, preventing the Equipment Specialist from entering the room. Other frequent mistakes involved forgetting to use the radio call signs and forgetting to switch to the pistol after using the paint marker. "Keep track of the elapsed time" was a frequent admonition.

That at least some of the control group teams did well indicated that the mission manual contained adequate information and that practice without any external guidance could lead to improved performance. For other control group teams, performance actually deteriorated as they forgot procedures or developed nonproductive or counterproductive variations of the procedures.

These instruction strategies are not mutually exclusive. We expect that an effective VE training system would use aspects of all of these strategies.

There are a number of factors which may have contributed to the failure to find statistically significant differences in performance scores between the control group and the three instructional strategy conditions. The first was the high variability in performance among teams even in the same treatment condition. The participant population was highly heterogeneous, including introductory psychology students and advanced ROTC students, a wide range of ages, and teams composed of members who were sometimes close friends, sometimes complete strangers, and sometimes even parent and adult child. Whereas some teams were truly naive teams, others included a confederate.

The second factor was the multidimensional nature of the task, which allowed teams the flexibility to give greater emphasis to different aspects of the task, such as speed of search or accuracy.

The third factor was the effectiveness of the control group training. Control group performance improved over the three missions, despite the fact that those teams were given no feedback other than that intrinsic to the task. This intrinsic feedback, combined with the fact that the control group received more task practice than all but the coaching group teams, was apparently enough to boost their performance to the level of the instructional strategy groups. The results might have been very different if the groups had been equated on mission time, rather than total training time.

Finally, it should be noted that the teams actually had very little exposure to the instructional strategies. The demonstration and replay sessions lasted eight minutes each. Coaching was provided during two eight-minute missions, while the team was actually engaged in performing the mission.

Presence

We had expected, but did not find, that the Presence questionnaire scores would be higher than previous ARI VE experiments. This expectation was based upon the use in this experiment of VEs and tasks that are more complex, the presence of a teammate, and the use of sound effects. In addition, several of the participants reported that they felt highly involved in the missions to that extent that they became nervous. It may be that the high complexity of the experimental task so engrossed the participants in trying to recall the correct procedures that they did not attend to the other aspects of the VE. For VE training research, significant challenges remain as to how to define and measure the sense of presence.

Future Research

Technical lessons learned from this experiment were used in the development of a follow-on system that will be used in research to examine distributed team training in which the participants are at remote sites. Lessons learned concerning the instructional strategies will be incorporated in a Science and Technology Objective (STO) involving Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal.

References

Alluisi, Earl. A. (1991). The development of technology for collective training: SIMNET, a case history. *Human Factors*, 33(3), pp. 343-362.

Durlach, N. I., & Mavor, A. S. (Eds.) (1995). *Virtual Reality: Scientific and technological challenges*. National Research Council, National Academy Press, USA.

Eitington, J. L. (1996). *The winning trainer*. Gulf Publishing Company, Houston, Texas.

Harvey, T. R., and Drolet, B. (1994). *Building teams, building people: Expanding the fifth resource*. Technomic Publishing Co., Lancaster.

Howell, D. C. (1997). *Statistical Methods for Psychology*. Duxbury Press. Belmont, CA.

Johnson, W. L, Rickel, J., Stiles. R., & Munro, A. (1998). Integrating pedagogical agents into Virtual Environments. *Presence: Teleoperators and Virtual Environments*, Vol. 7, No. 6, 523-546.

Knerr B. W., Lampton, D. R., Singer, M. J., Witmer, B.G., Goldberg, S. L., Parsons, K.A., & Parsons, J. (1998). *Virtual Environments for dismounted soldier training and performance: Results, recommendations, and issues*. (Technical Report 1089). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Lampton, D. R., Knerr, B. W., Goldberg, S. L., Bliss, J. P., Moshell, J. M., & Blau, B. S. (1994). The Virtual Environment Performance Assessment Battery (VEPAB): Development and evaluation. *Presence: Teleoperators and Virtual Environments*, 3(2), 145-157.

Lampton, D. R., Rodriguez, M. E., & Cotton, J. E. (2000). Simulator sickness symptoms during team training in immersive virtual environments. *Proceedings of the 44th Annual Meeting of the Human Factors and Ergonomics Society*. San Diego, CA.

Loftin, R. B. (1998). Distributed Virtual Environments for collective training. *Proceedings of the 1998 IMAGE Conference*. Scottsdale, AZ. August.

Meliza, L. (1996). *Standardizing Army after-action review systems*. (ARI Research Report 1702). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences. (AD-A32-2044)

MIL-M-38784B. (1983). *Military Specification Manuals, Technical: General Style and Format Requirements*. Washington, DC: Department of Defense

Parsons, J., Lampton, D. R., Parsons, K. A., Knerr, B. W., Russell, D., Martin, G., Daly, J., Kline, B., Weaver, M. (1998). Fully immersive team training: A networked testbed for ground-based training missions. *Proceedings of the Interservice/Industry Training Systems and Education Conference*. Orlando, FL.

Reason, J. T. and Brand, J. J. (1975). *Motion sickness*. London: Academic Press.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. I. (1992). Toward an understanding of team performance and training. In R. W. Swezey & E. Salas (Eds.). *Teams: Their training and performance* (pp. 3-29). Norwood, NJ: Ablex Publishing Corp.

Siegel S. (1956). Nonparametric statistics. New York: McGraw-Hill:

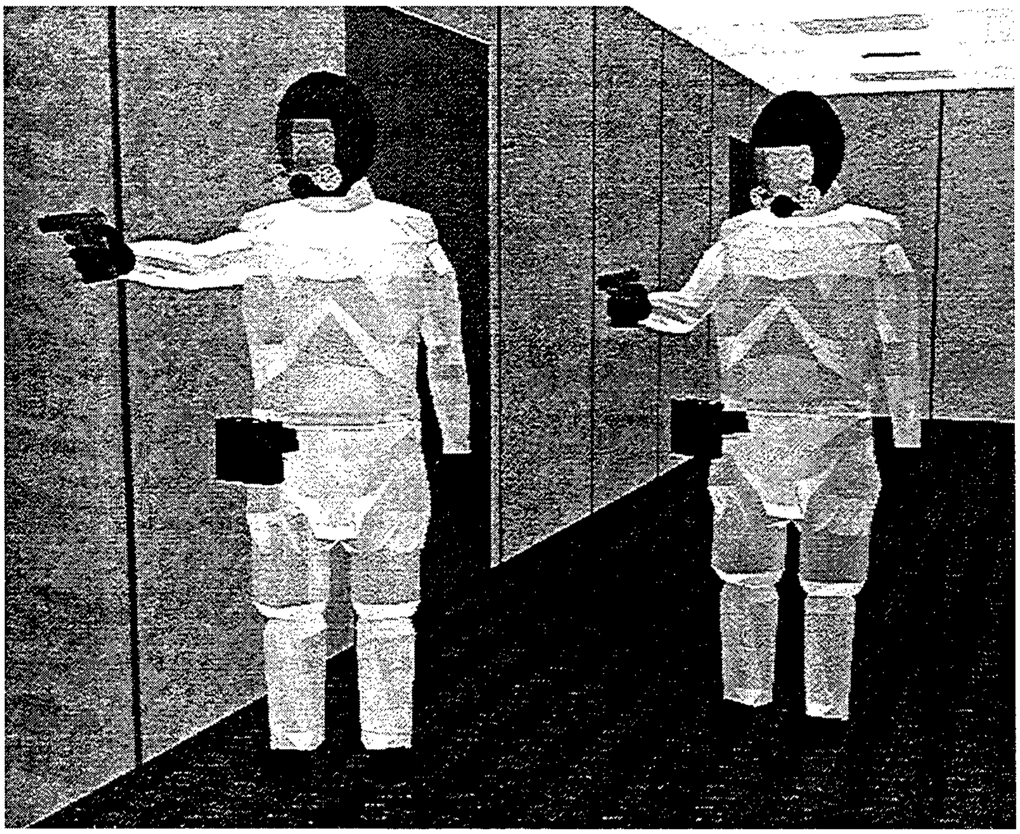
Tolani, Deepak & Badler, Norman I. (1996). Real-Time Inverse Kinematics of the Human Arm. *Presence: Teleoperators and Virtual Environments*, 5(4), 393-401.

Appendix A. Acronyms

AAR	After Action Review
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
CGES	Computer Generated Entity Server
DIS	Distributed Interactive Simulation
FITT	Fully Immersive Team Training
HAZMAT	Hazardous Materials
HMD	Head Mounted Display
ICS	Individual Combatant Simulator
ITQ	Immersive Tendencies Questionnaire
MCO	Multi Channel Option
OPFOR	Opposing Forces
PC	Personal Computer
PDU	Protocol Data Unit
PQ	Presence Questionnaire
RE2	Reality Engine 2
ROTC	Reserve Officer Training Corps
SGI	Silicon Graphics, Inc
SSQ	Simulator Sickness Questionnaire
STO	Science and Technology Objective
STRICOM	Simulation, Training and Instrumentation Command
SWAT	Special Weapons and Tactics Teams
VCR	Video Cassette Recorder
VE	Virtual Environment
VEPAB	Virtual Environment Performance Assessment Battery

Appendix B

Hazardous Materials (HAZMAT) Team Training Manual



Duty Position: Team Leader

Team Leader Trainee ____________________
(name)

____
(date)

Team Task Overview

A two-person team searches rooms of a building for canisters containing hazardous gas. The team carries equipment to determine if a canister contains gas and to deactivate the canisters. The search is complicated by the threat of interference by looters and terrorists. Each team member carries a tranquilizer dart gun (Pistol) which can temporarily incapacitate the enemy. Air tank capacity limits the search time to a maximum of 8 minutes per mission. Simulated speed of movement is at most a fast walk.

Team member #1 is the designated Team Leader. The Team Leader directs team movement to provide an efficient search while maintaining team security. The leader radios reports of deactivations and encounters with the enemy to an off-site Mission Commander. In addition to a Pistol, the Team Leader carries a Paint Marker used to mark rooms that have been searched.

Team member #2 is the HAZMAT (hazardous materials) Equipment Specialist. In addition to a Pistol, the Equipment Specialist carries a device to detect if a canister is active and to deactivate the canister.

You will have several opportunities to practice the procedures described in this manual. The other members of your team will count on you to follow these procedures.

The overall team performance measure is the number of canisters deactivated and reported. Failure to exit the building before air supplies expire or major breakdowns in team security procedures will be scored as failed missions.

Learning Objectives

In this manual you will learn:

The rule for the order in which to search rooms and how to keep track of which rooms you have already searched.

How your team should move through hallways and enter rooms.

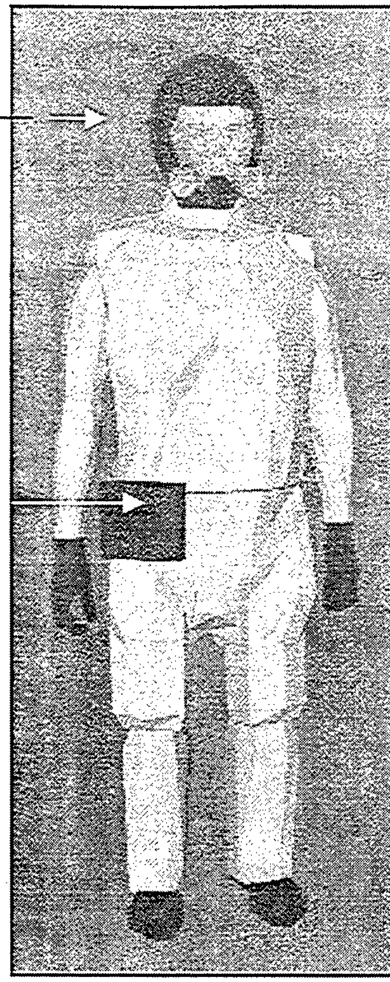
When and how to communicate using appropriate radio call signs.

What to do when you encounter ENEMY.

A general idea of the responsibilities of your other team member.

HAZMAT Team Member

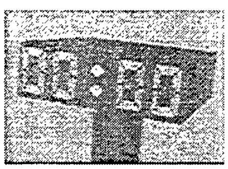
Helmet provides protection but restricts field of view.



Suit and body armor provide protection but limit speed of movement to walking only.
No running, crawling, or jumping!

Count-down timer indicates remaining air supply.

Your view of timer:



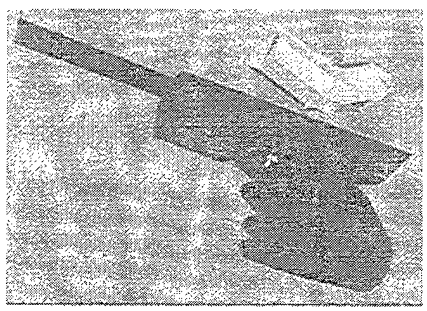
Team Leader Duties Overview

The primary duties of the Team Leader involve search, communications, and security procedures.

Search:

1) use the right-turn rule (explained later) for efficient search of an assigned section of the building

2) use the Paint Marker to mark a room after your team searches it



Paint Marker

Communication:

1) inform the off-site Commander of your mission progress

2) coordinate search and security with your team member

Security:

1) move through hallways and doorways in proper team formation

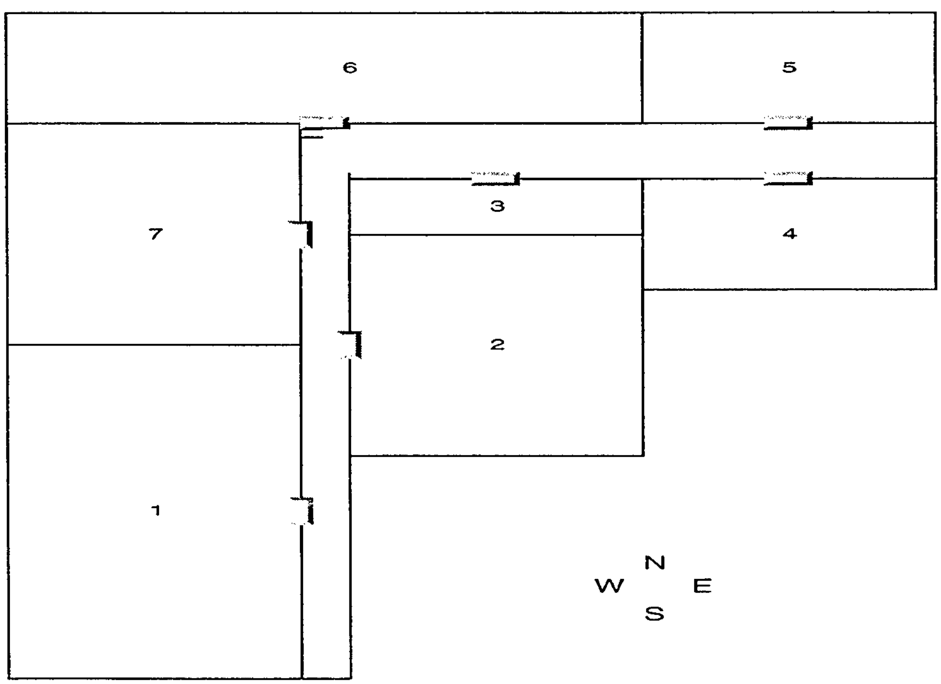
2) use your Tranquilizer Pistol to engage enemy quickly and decisively

Tranquilizer Pistol

The Right-Turn Search Rule

The right turn rule is a rule of thumb to help you organize your search pattern. At any point in the building where you have a choice of directions, turn right if possible. Look at Figure 1. For this example assume that you start your mission in room #1. After searching that room you would exit through the doorway on the east wall. Use the paint marker to put an "X" above the doorway, indicating that you have searched that room. Exercising the right turn rule, you would turn right (south) and proceed to the end of the hallway. The hallway is a dead end, so you would turn around and proceed north. You will pass the room you just searched and come to a doorway on the right side of the hallway. Exercising the right turn rule, you would search this room (#2) and mark the doorway when you exit. Proceeding north, there is a doorway on the left side of the hallway. Because it is on the left, you will pass that room for now. Proceeding north, you reach the end of the hallway. There is a doorway straight ahead to the north and the hallway turns to the right (East). Using the right turn rule, you would turn right and proceed to the next doorway (room#3). Exit 3 and mark the doorway. A right turn takes you to room #4. After 4 the hallway is a dead end. Turn around and proceed west. The doorway on the left (Room#4) will be marked with an X because you already searched that room. Search and mark #5, and #6. When you exit room 6 you could turn left or go straight ahead. You have already searched the rooms to the left. Go straight (south) . Search and mark the room on the right (#7). Proceed south to room #1 . You have finished the search for this building.

Example of Room Search Sequence



Movement Procedures

Hallway Movement Technique

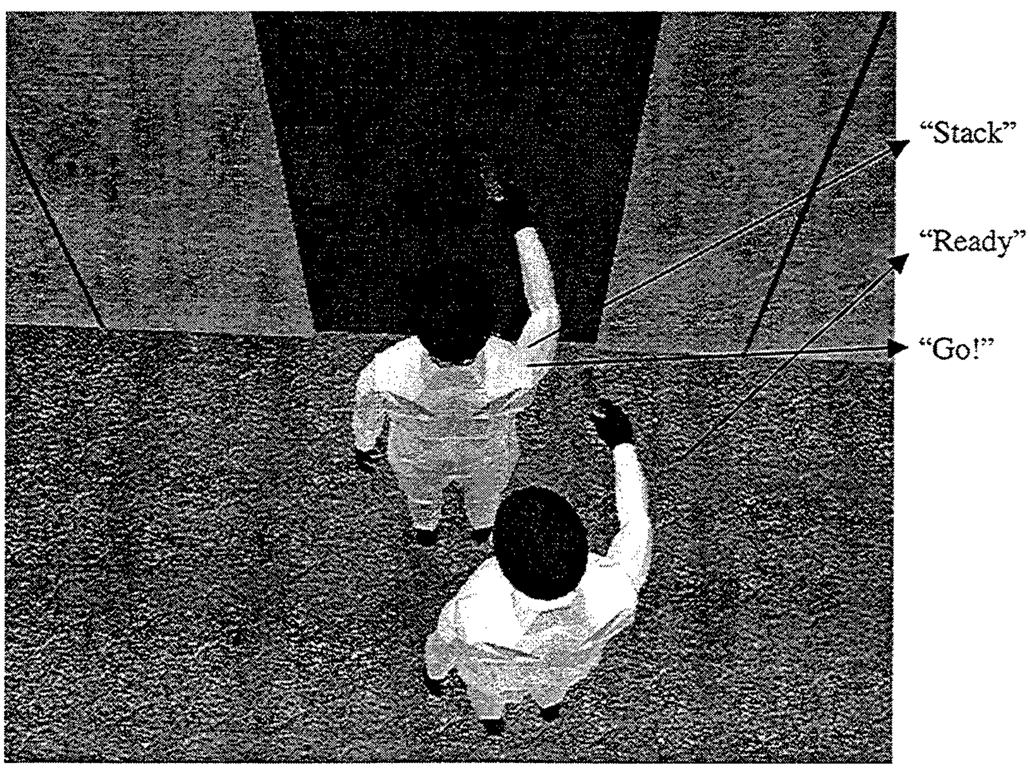
The Team will move through hallways in single file with the Team Leader in front. The Equipment Specialist should walk about 10 feet behind the Team Leader. The Equipment Specialist guards the team's back by frequently looking to the rear. The Team Leader should not get too far ahead of the Equipment Specialist.

Room Entry and Exit

The team is most vulnerable to ENEMY attack when entering and exiting rooms.

ENTRY

The Team Leader should move to face the door of the room being careful not to activate the door before the team is ready to enter. The Team Leader says "Stack" telling the Equipment Specialist to move directly behind the Team Leader. The Equipment Specialist says "Ready" when in position. The Equipment Specialist does not need to be exactly in line with the Team Leader, but should be aligned to move through the doorway. The Team Leader says "Go" and moves forward to activate the door. The Team Leader must move far enough into the room to allow the Equipment Specialist to move into the room. The Team Leader should initially scan the left side of the room and the Equipment Specialist should scan to the right.



EXIT

Before the team leaves the room the Equipment Specialist should select the Pistol.
The team should exit the room in single file, with the team leader in front. In the hallway, the Equipment Specialist will watch for ENEMY while the Team Leader selects the Paint Marker, marks the room just searched, and then selects the Pistol. The Team Leader will lead the team to the next room to be searched.

Communications Procedures

Each HAZMAT helmet contains a radio set with headphones and a voice actuated microphone. To talk over the radio just talk out loud. The radio set has no switches or manual controls.

Radio Call signs:

Sierra:	Mission Commander
Green1:	Team Leader
Green2:	Equipment Specialist

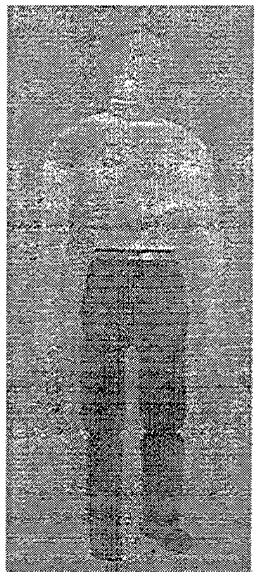
Except for a communications check at the beginning of each mission (explained later), team members will usually not use call signs when talking to each other.

The Team Leader will report mission progress to the Mission Commander. The Team Leader should always use the Commander's call sign "Sierra" (see - air - ah) at the beginning of any message for the Commander. The Equipment Specialist never talks to the Commander. Examples of radio communications are given later in this manual.

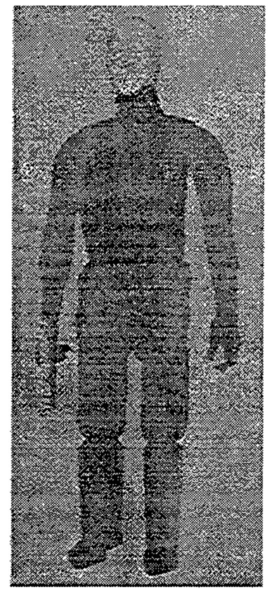
Actions on Contact

During the mission your team may encounter **ENEMY**.

ENEMY may be :

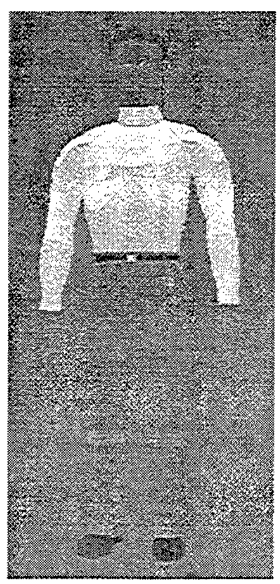


or



lightly armed looters **heavily armed terrorists**

You may also encounter



An innocent bystander (**neutral**).

An innocent bystander is reported as a "neutral".

Actions on Contact (continued)

When you first spot an ENEMY you should alert your partner by announcing "Contact Front !" (or Left, Right, Rear as appropriate). Do NOT assume that your partner has seen the ENEMY. Talk to each other! Shoot the ENEMY using your Pistol. Do not point your Pistol at your team mate or risk a shot that may hit your team mate or a member of another HAZMAT team that has mistakenly entered your area. Be sure of your target before you shoot.

After each encounter with the ENEMY the Team Leader should report to the mission Commander:

Team Leader: "Sierra" [Commander's radio call sign]
"this is Green1" [your call sign]

wait for Commander to answer

Commander: "Green1, this is Sierra"

the Team Leader will state: the number of ENEMY encountered, the kind of ENEMY, and the results of engagement

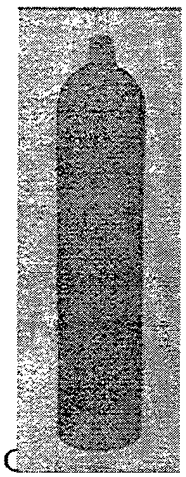
Team Leader: "Sierra, Engaged and neutralized 2 lightly armed looters, over"
Commander: "Good work Green Team, continue mission"

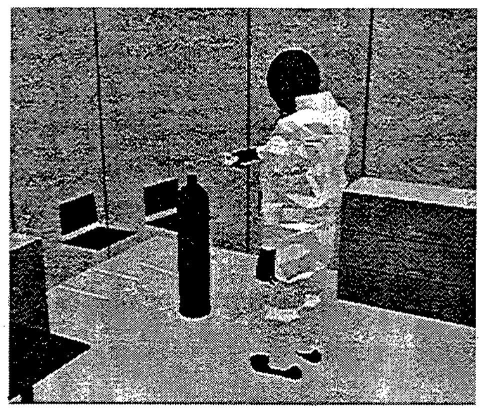
Shoot any ENEMY in a room before trying to find or deactivate canisters. The team leader must exercise judgment in that having each team member search separate sections of the room will produce a faster search but sacrifices security.

The Team Leader should report to the Commander when your team sees an innocent bystander (a neutral). You do not have equipment or time to help bystanders. A medical unit will be sent to evacuate them after you have finished your mission.

Deactivating Canisters

When a canister is found the Equipment Specialist will use the detector/deactivator (DELTA2) to determine if the canister is active and if so, to deactivate it. When the Delta2 is within about 5 feet of a canister the display will turn yellow if the canister is active. The display will turn red when within deactivation range. When the display is red the Equipment Specialist presses the trigger to deactivate the canister and the display will then turn green indicating a successful deactivation. If the Delta2 display does not register yellow or red near a canister that canister is a "dud". That is, it does not contain hazardous gas. The Equipment Specialist should inform the Team Leader of the status of each canister.





Beyond about 5 feet, the Delta2 display is "green" because gas, if any, is out of range.

At about 2 feet, the display turns Red if the canister is active.

When the Equipment Specialist triggers the Delta2, the display turns green, indicating deactivation.

Before leaving a room the Team Leader will report canisters that were detected.

(Team Leader)	"Sierra, this is Green1"
(Commander)	"Green1, go ahead"
(Team Leader)	"Found two canisters, deactivated one, the other was a dud."
(Commander)	"Continue mission"

Mission Preparation

You begin each mission from the back of an armored van. The letters PRIMED are on the inside of the van door to give you something to focus on while you make final adjustments to your helmet.

Both team members should check that their countdown timers are at "8:00", select the Pistol, and face the van door. The Team Leader will conduct a communications (commo) check with the Equipment Specialist:

(Team Leader): "Green2, this is Green1, commo check"

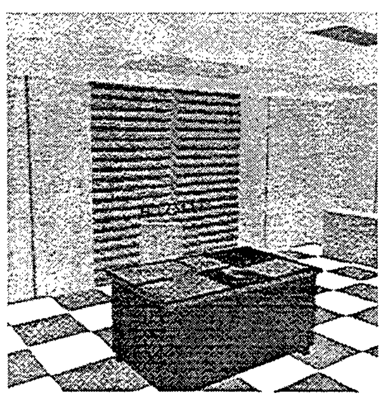
(Equipment Specialist): "Green1, loud and clear"

The Team Leader will tell the mission Commander that the team is ready:

(Team Leader): "Sierra, Green Team is ready"

(Commander): "Green Team, begin mission"

The van has been backed up to an opening in the building you are to search. The van door will open onto the first room to be searched. After both team members exit the van the door will close. Before eight minutes expire the team should be back at the van door. As the team approaches the door the Team Leader should inform the Commander that the team is at the door (the Commander will open the door by remote control). The Team Leader should tell the Commander when both team members are back inside the van.



Outside view of van door

Miscellaneous

The environment in which you will work is so noisy you must wear (simulated) hearing protection that blocks ALL outside noise. Therefore, you can talk to your teammate and/or mission controller only by the radio headset. You can not hear ENEMY, even if they shoot at you. If you are hit by ENEMY bullets, collide with objects, or open doors you may hear sound conducted within your suit.

Although your HAZMAT suit and body armor protect you from ENEMY weapons, you must deal quickly with ENEMY or else they may damage your equipment causing the mission to fail.

Do not attempt to move anything such as furniture or debris. Because of the heat and corrosive gas emitted by an active canister, a canister can not be hidden in or under anything.

Your Tranquilizer Pistol contains 10 darts per mission.

The Paint Marker contains enough paint for about 12 charges per mission.

The Delta2 has enough battery power to deactivate about 10 canisters per mission. Attempting to deactivate a canister that is already inactive wastes the battery of the Delta2.

If both team members shoot at and hit the same individual ENEMY that is at best a waste of ammunition and may complicate the work of the medical recovery team. However, it would be better for both to shoot than to have neither shoot and allow the ENEMY to shoot you.

Shooting ENEMY with your paint marker is a waste of paint and is scored as an error.

Do not cross into the search area of other teams. If other teams mistakenly enter your area, contact your Commander. The other teams use different radio frequencies, therefore you can not communicate directly with them.

Review:

Sierra:	Mission Commander
Green1:	Team Leader
Green2:	Equipment Specialist
Delta 2 :	detector/deactivator device
pistol:	tranquilizer dart gun
marker:	paint spray device
canister:	hazardous materials container
	a canister may be active: (live)
	a canister may be inactive: no longer a threat (dud)

P Preparation: conduct radio and air supply timer checks

R Right-turn rule: search rooms in correct order

I Inform your team mate and Commander about ENEMY and canisters

M Movement technique: move single file and "stack" before room entry

E Exit building (return to van) before time expires

D Detect and deactivate canisters (primary goal of mission!)