Instructional Strategies for Training Dismounted Infantry in Virtual Environments

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ABSTRACT

This paper describes the results of the first experiment conducted with the Fully Immersive Team Training (FITT) research system. The objective of the experiment was to examine instructional strategies involving how and when to give guidance during team training with Virtual Environments (VEs). 118 college students participated in the experiment. Two-person teams engaged in search missions in VEs depicting building interiors. The teams were composed of either two participants or a participant and an experimenter's confederate. Before attempting missions all participants studied a printed-text mission training manual that described mission procedures and received training on how to move and interact in VEs. Teams engaged in 1 or 2 practice missions and a test mission. 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 participants quickly learn to use the FITT interface to move in, and interact with, the VEs; and that performance of mission procedures improved with practice. Relative advantages and disadvantages of the instructional strategies, and lessons learned, are discussed.

Author Biographies

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INTRODUCTION

There is a growing effort to develop methods to use immersive Virtual Environments (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 improvements in immersive VE technologies and the recognition that members of small dismounted units will face greater responsibilities and challenges in both combined arms combat and in contingency operations. These challenges include new missions, changing doctrine, and new and increasingly sophisticated equipment. In addition to supporting Army training requirements, an individual virtual simulation could support mission planning and rehearsal, and also the conceptualization, design, and testing of new equipment, doctrine, and organization. Looking beyond the benefits of traditional simulator-based training such as safety, flexibility, repeatability, and cost effectiveness, VE based training has the potential to offer learning conditions, such as providing multiple viewpoints and various levels of abstraction, that can not be created with conventional training. However, maximizing positive transfer from VE training to real-world performance, and avoiding negative transfer, requires improvements not only in VE technology but also in our knowledge of how to design and use VE training systems.

To acquire this knowledge, 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. 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. Under this program thirteen experiments involving over 500 human participants have been conducted. This previous research, summarized by Knerr et al. (1998), involved immersing participants in a VE one at a time.

This paper describes our first experiment in which two individuals are immersed simultaneously in the same VE. In this experiment, traditional instructional strategies, involving how and when to give feedback to trainees, were implemented using the Fully Immersive Team Training (FITT) research system. (An I/ITSEC paper by Parsons et al. (1998) described in detail the technical design of 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. The paper is organized as follows: the FITT is briefly reviewed, the research design and procedure are outlined, the instructional strategies are described, results are summarized and discussed, conclusions and implications for future research are presented.

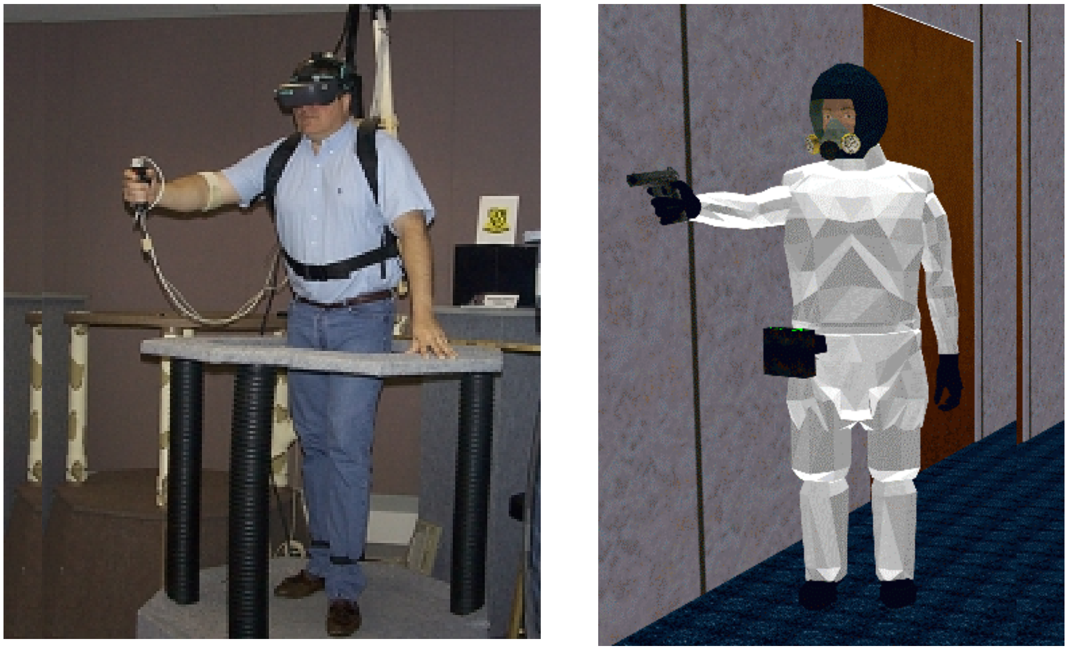

Figure 1. Participant in FITT pod and corresponding HAZMAT-suited avatar in the VE.

REVIEW OF THE FULLY IMMERSIVE TEAM TRAINING (FITT) RESEARCH SYSTEM

FITT was developed to support research on the use of distributed Virtual Environments (VEs) for team training. The FITT system allows two participants to conduct building searches under Hazardous Materials (HAZMAT) conditions. Figure 1 shows one of the HAZMAT suited avatars. The team members communicate with each other and an off-site mission commander through simulated radio networks. To move through the VEs, the participants march in-place within a safety pod. Figure 1 shows a participant in one of the two FITT pods. The search procedures involve cognitive aspects of infantry operations in built up areas, special weapons and tactics teams missions, and emergency search and rescue in urban areas. The search missions are complicated by limited air supplies and computer-generated forces such as looters, terrorists, and innocent bystanders.

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 wears protective clothing and a breathing apparatus, and carries a tranquilizer dart gun that can temporarily incapacitate the enemy.

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.

The FITT system incorporates automated data capture and many functions to support mission playback, such as the ability to view the playback from any angle, and at any speed, with synchronized audio from the team and higher radio networks.

The FITT replay station is shown in Figure 2.

Figure 2. Mission Replay station.

EXPERIMENTAL PROCEDURE AND DESIGN

Participants were recruited from local colleges and scheduled two at a time. If one did not show up 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. 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 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 in 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.

Next, the participants read the mission training manual. The training manual was developed to introduce naive participants to the mission procedures. The 2300 word, thirteen-page training manual included a mission overview, learning objectives, task descriptions with graphics, and mnemonics 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. 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 of equivalent difficulty. 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

Table 1. Research Design

Group	Training Phase		Test
Demonstration	Watch Demonstration	Practice	Test
Coaching	Practice With Coaching	Practice With Coaching	Test
Replay	Practice	Critique During Replay	Test
Control	Practice	Practice	Test

then the test mission session. In a similar manner, in place of a second practice mission session the Replay group teams watch 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.

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. However, the time limit reduced flexibility in applying the instructional strategies. For example, in the replay and coaching groups there were situations in which we might want to pause the mission, or mission replay, in order to discuss a critical event.

INSTRUCTIONAL STRATEGIES

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 one strategy would be significantly superior to the others, but rather that each would have relative strengths and weaknesses.

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 after-action review 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.

No 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.

RESULTS

The results section begins with background information on the research participants. Next, performance measures are presented. The performance measures are treated as two categories. 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 for analysis for both categories of performance measures. Performance on the practice missions is also described. In addition to the performance measures, participants’ ratings of several characteristics and dimensions of teamwork are presented. Occurrence of simulator sickness is discussed briefly.

It should be noted that participant “no-shows”, experiment drop-outs from simulator sickness, and assorted data capture problems resulted in a data set lacking sufficient size, and other desirable psychometric properties, conducive to standard statistical analyses.

Participant background information

Age of participants ranged from 17 to 54 with an average of 21. Fifty-two (55%) were women and 42 (45%) were men.

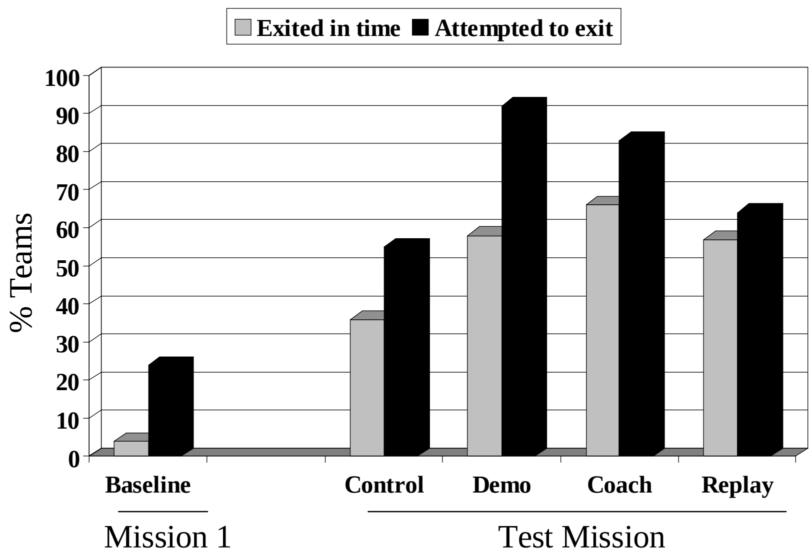

Figure 3. Percentage of teams per group that exited within the time limit or at least attempted to exit. Baseline represents the first mission for the control group and replay group combined.

Performance data

Exiting the building within the time limit. Figure 3 presents the percentage of teams per group that exited within the time limit or at least attempted to exit. 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.

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).

Comparison of the baseline scores to the control group test mission addresses the question "Do teams improve with practice even without external guidance?" Control group teams were about 9 times more likely to exit in time during the test mission than the baseline teams in the first practice mission.

For the test missions, we combined the instructional strategy groups for comparison with the control group. An instructional strategy team was about 2.5 times more likely to exit in time than a member of the control group.

During data collection we noticed that some teams that failed to exit in time attempted to exit but failed, whereas others didn't 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 several teams that attempted to exit but failed "Maybe we have time to search one more room" were their last words. Teams could also become lost in attempting to retrace their paths. Figure 3 presents the percentages of teams who at least attempted to exit. Looking at the practice effect, the control group teams were about 2 times as likely to attempt to exit during the test mission than the baseline teams during their first mission. For the test mission, a member of the control group was 3 times more likely to fail to attempt to exit than a member of an instructional strategy group.

Procedural Tasks. Percentage of procedures performed correctly and number of rooms entered out of total possible for the first and test missions are shown in Figure 4. In a general sense, the percentage score represents the accuracy with which the teams perform in contrast to the number of rooms searched which represent 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

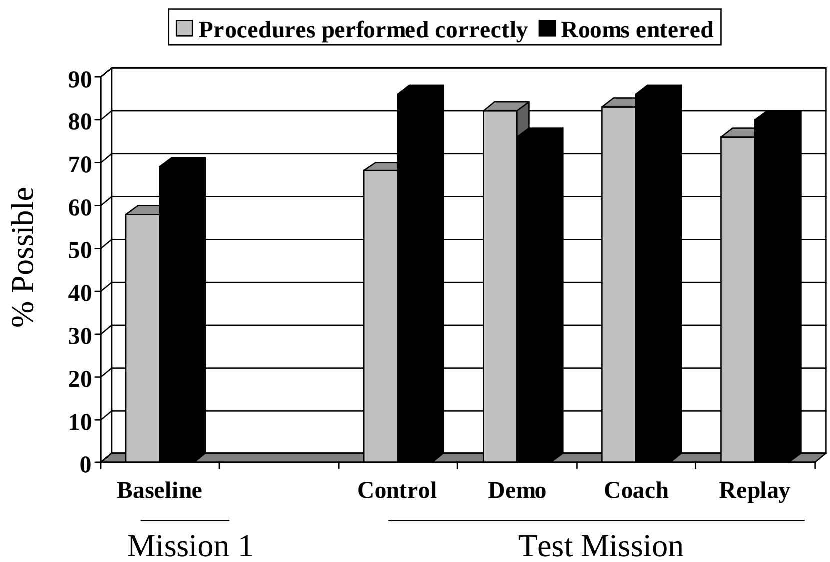

Figure 4. Percentage of procedures performed correctly and number of rooms entered out of total possible for the first and test missions. Baseline represents the first mission for the control group and replay group combined.

strategies versus control) were not statistically significant.

Participant Ratings of Team Processes

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". The mode for all but two of the characteristics was 3.00 or "good". The mode for the other two characteristics was 4.00, the maximum value. Thus, in general the participants reported a high level of satisfaction with their participation in the team experience. The characteristic with the highest mean score was 'participation' with a 3.49. The two lowest scoring characteristics were 'communication' and 'leadership' with a mean score of 2.95 each.

During interviews, participants indicated that the most difficult aspect of communication was remembering the call signs and other format aspects of radio communication. In general, most participants indicated that the most difficult aspects of the mission were remembering the specific procedures. Among the factors identified as the easiest aspects of the mission were walking in the VE and using the equipment.

The second questionnaire, adapted from Eitington, (1996), consisted of 8 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”. The mode for all but one statement was 3.0 , “agree”. The mode for the other statement was 4.0, “strongly agree”. Again, 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.

Simulator Sickness

About 9% of the participants withdrew from the experiment because of simulator sickness. Given that each mission was relatively brief, only about 8 minutes in the Head Mounted Display 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. Mild eyestrain was the most frequently reported symptom for the participants who completed the experiment.

DISCUSSION

Overall

Remember that this was the first experiment we conducted with FITT. In general the FITT seems to function well as a system for researching team training using immersive VEs. Cognitive aspects of the mission, and not the mechanics of using the VE interface, are the greatest challenge to most participants. Most participants reported 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 a team leader even after 3 practice missions. This is not necessarily a bad thing, for comparable real-world tasks some individuals would struggle if placed in a leadership position.

The FITT system for walking in the VE worked very well. FITT uses a 'walk-in-place' locomotion paradigm. Magnetic position sensors are attached to Velcro bands and attached at both ankles. In addition to the ankle sensors, a lightweight wooden pack frame is also worn by the particpant. The pack frame provides support for a magnetic position sensor mounted between the shoulder blades for sensing body orientation. The frame also acts as a wire guide for sensor cables. Locomotion in the direction of the participant's body orientation is achieved by raising and lowering the feet to a user definable threshold height. Crossing this threshold signals that a step is being taken. This locomotion system has two strong points: The participant's vestibular and ocular systems are always in accord, and the system requires little trainup time for a novice.

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 number of rooms searched measure, and our subjective evaluations of team performance, indicate that, on average, teams not in the demonstration group actually assumed a faster tempo than the demonstration group. The tempo conveyed in the demonstration apparently emphasized accuracy over speed. 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. An implication 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. Lesson learned: “Less can be more”. In addition, because performance at the beginning of the first practice mission tended to include many errors, coaching was vulnerable to being too negative.

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 which 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.

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 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.

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 in separate cities.

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.

ACKNOWLEDGEMENTS

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