TRAINING IN DISTRIBUTED VIRTUAL ENVIRONMENTS[1]

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Abstract. The U. S. Army is developing distributed interactive simulation (DIS) systems for combat training and military concept development, testing, and evaluation. The early emphasis and implementation has been on linking vehicle simulators, without providing for the training or participation of dismounted soldiers (Knerr, et al., 1994). The Army Research Institute for the Behavioral and Social Sciences (ARI) and Defence Research and Development Canada are investigating distributed training for dismounted soldiers. Unlike vehicle simulators, where the crew are able to interact within the simulator unimpeded by the simulation technology, simulators for dismounted combatants interpose the limitations of simulation technology between team members. Any effect this has on the acquisition of team skills is exacerbated in distributed simulations because interaction between team members will be further limited. To investigate the nature and severity of this situation, the reported experiment addresses the development of team coordination under conditions of either distributed or local mission rehearsal. In the virtual environment (VE) scenario two person teams search buildings for hazardous materials and neutralize them while being opposed by computer generated forces. Each participant is trained to standard criteria on all tasks and activities before the team is formed and mission rehearsals begin. Each team then performs eight missions with an after-action review (AAR) after each mission. Mission sessions are distributed over several days. The preliminary data show improvement in team overall performance in the number of rooms searched, time to perform collective tasks, and hazardous materials disarmed. We anticipate that teams trained using distributed simulation, having more limited opportunities to interact away from the mission and AAR, will not develop the same levels of performance achieved by those teams trained in the same location.

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TRAINING IN DISTRIBUTED VIRTUAL ENVIRONMENTS

Distributed interactive simulation is increasingly being used for military training, concept development, testing, and evaluation. Because military simulations have historically concentrated on vehicles, the Army Research Institute for the Behavioral and Social Sciences (ARI), supported by the University of Central Florida Institute for Simulation and Training (IST) has established a research program in Virtual Environment (VE) technology in order to investigate its application to the training of dismounted soldiers. The program goals are to "improve the Army's capability to provide effective, low cost training for Special Operation Forces and Dismounted Infantry through the use of VE technology and ICS [Individual Combatant Simulation]" (Knerr, et al., 1994, pp.10-12). Similarly, Defence Research and Development Canada is exploring these technologies to so that the benefits of virtual simulation can be extended to dismounted combatants.

Teams are different from groups, mobs, or collections of individuals. Teams are two or more individuals with a common goal that requires coordinated, interdependent, and adaptive performance (Salas, et al., 1992). This broad definition implies many widely ranging factors that can and may affect team performance. The common (team) goal requires that a set of individual and collective tasks be performed during a specific time frame. The nature of the tasks dictate the required resources, individual skills, and team interdependence. As the task required interdependence increases, communication between members becomes more crucial in achieving the group's goals.

Team Training

Current methods for training and testing dismounted teams on tasks that require interacting directly with the environment are costly and effortful. Typical small unit exercises require gathering soldiers and sending them to a training site. The training site may require extensive development to be suited to training & rehearsal activities, and cannot easily be altered to present new environmental challenges. Additional challenges are imposed by personnel constraints. VE systems will be able to provide effective and less costly alternatives for training and testing dismounted soldiers. VE simulations allow multiple players and computer generated forces to mimic the behavior of troops, indigenous populations, and enemy forces. VE simulations allow multiple simulated terrain's and built up areas, enabling the training to focus on tasks and activities, without becoming constrained by unchanging physical arrangements. In addition, VE-based training would support a wide range of alterations in the situation, so the team members could practice coordination skills in a number of scenarios and environmental conditions.

The VE platform also opens the door for an entirely new type of team training -- one in which the individual team members may be physically in different cities, states, or countries, but can still train with one another as if they were in the same locale. However, such a situation may hinder the necessary communications between teammates. While immersed in a virtual environment, the team members are able to see each other's represented body and movements and communicate through the use of microphones and headphones. However, during an After Action Review (AAR) of their mission performance, distributed team members may have no communication, or may only able to communicate over a phone line, with no visual input or feedback. In these situations, because vital interpersonal interactions (Salas et al., 1994) are reduced relative to face-to-face AAR, it is possible that teams trained via distributed simulation will show a decrement in individual and team performance.

It is the objective of the present study to investigate whether teams whose members are trained in simulators in the same physical location will perform differently than teams whose members are trained in simulators situated in remote locations with more restricted non-exercise interactions. It was decided that the framework for the team missions should be generic, with tasks and activities that represented a wide range of individual and collective tasks.

Synthetic Mission Scenario

Because virtual environments can be used to simulate a multitude of training scenarios and/or terrain's, the present study employs a set of synthetic tasks based in a terrorist/hostage situation and multi-room building environments that should easily generalize to other environments and training situations. The basic goal of the missions is to search the building, find hostages, neutralize opposing forces, and disarm canisters containing hazardous materials. The individual activities are moving, shooting, and communicating in the restricted VE. The teams also have to coordinate individual activities to accomplish collective tasks. The most important of these is gas canister disarming. Canister disarming requires one participant to monitor the gas canister state and communicate that information to the other for a time-driven disarming task. The partner must use the information to disarm the canister, with feedback provided by the monitoring team member. Either team member can then "cap" the canister to render it completely safe.

Training & After Action Review

Before participating in a team exercise, each team member must be trained to a consistent standard. Otherwise, the team data might be unduly biased by individual learning in the individual and collective tasks. With standardized training as a background, changes in team performance over time can be attributed primarily to improvements in team skills and coordinated activities.

One ubiquitous training technique in the military is the After Action Review (AAR, Brown, et al., 1998). This is a classic and basic learning principle that is often referred to as knowledge of results or feedback, and used in many different ways as an instructional approach. The military uses this technique to review the decision points, key situational factors, and other actions made during an exercise. During this program, the AAR is used to review the activities performed during the mission, and correct or improve performance speed and accuracy. In the AAR the participants learn how well they did, exactly where the decision process was not optimal, and can review stimuli that may have been missed or used inappropriately.

METHOD

Participants

Due to the distributed nature of the experiment, the participants were drawn from two separate populations. The participants in Orlando were students from the University of Central Florida, which included Reserve Officer Training Corp students. The participants in Toronto were co-op students from a number of universities that were working at the Defence and Civil Institute of Environmental Medicine. None of these participants were otherwise employed in this research, and all participants were kept unaware of the distributed team focus of the research. Each location recruited both male and female participants with normal or corrected-to-normal vision, and their ages ranged from 18 to 40 years. No teams were formed that had female participants in both roles. Participants received monetary compensation for all time spent in training and mission rehearsals.

Materials and Equipment

Virtual Environment. The VE is rendered at all sites on the Silicon Graphics Onyx^{tm} and Reality Engine systems, with MotionStar sensors used for tracking, and Virtual Reality VR8 helmet used for visual display. The participants viewed a color, stereoscopic view of the VE. Stereo sound was provided through earphones. The sound included voice communications between the participants and the experimenter, and sound effects. These were door openings, grenade explosions, and gunfire. The software was written by the UCF Institute for Simulation and Training (IST) using Performer, C++, and Java.

Networking. The simulation sites were networked using several technologies. Simulation data was exchanged over an ISDN line. Voice communications between the players during the mission rehearsals and the AARs were carried on commercial telephone lines.

Procedures

Training. Each participant was trained to specific criteria on all tasks in a single 4-hour session at least one day prior to the team exercises. During the training, they learned to move through the VE, operate all equipment, and follow all communications protocols required in the mission rehearsals. The training concluded with practice on the coordinated team tasks with an automated partner. All participants were trained to perform both roles on the team: team leader (TL) and equipment specialist (ES). Each role has specific duties within the mission context. Once assigned to a team, the participant did not change their role or team-mate. In order to minimize any adverse effects of immersion in the VE, participants spend a maximum of 12 minutes in the environment at one time with a minimum 30 minute recovery time between immersions.

Mission Rehearsals. Following training to criterion, each participant was assigned to a team and given a role on that team (assigned at random, within location counterbalancing of team roles). The team returned for two sessions during which 8 mission rehearsals were performed (four during each session). In each mission rehearsal the team moved through a ten-room building searching for and securing gas canisters. Each building has a unique floor plan with hallways and rooms that contain varying numbers of opposing forces, neutral bystanders, and gas canisters. The complexity (based on opposing forces, environment complexity, canisters and their armed states) was balanced across the different scenarios to the greatest extent possible. The order of scenarios was randomized such that no scenario repeatedly followed another, and no scenario started or ended the mission orders more than once.

After Action Review. At the conclusion of each mission rehearsal the team conducted a ten minute AAR. The experimenter acted as a reviewer, replaying critical segments of the mission rehearsal where performance was sub-optimal. The experimenter would provide a written example of the correct protocol, and the participants were instructed to discuss what happened, why it happened that way, and how they could do better during the next mission. In the local condition, team members communicated face-to-face with the reviewer and with one another during the AAR. In addition, after completion of the AAR, team members had time to communicate with each other on an interpersonal level concerning non-mission topics. In the distributed condition, the reviewer was in the same room as one team member, but the other team member was located at a different laboratory. In this condition the team members communicated only by voice during the AAR replay (played simultaneously at each location). Distributed team members did not have an opportunity for any discussion after the AAR.

RESULTS

The data analyzed in this paper are focused on task performance only, using an overall task outcome measure and collective task process measures. The primary task outcome measure presented here is the number of rooms successfully completed in a mission scenario. The task process measures include the mean time to search a room, the average time to conduct the collective door entry routine (opening the door, using a concussive grenade, and entering the room), and the average time to check, disarm, and neutralize armed gas canisters in each mission (a collective task requiring detection of the canister state and code by one member, and disarming the canister by the other).

Repeated measures analyses of variance (RP-ANOVA's) will be used to address the changes across the missions and to investigate differences between the local and distributed groups when all data has been collected. At this point, only partial data is available for the RP-ANOVA's, and the descriptive statistics from that data will be presented in the tables..

The average number of rooms correctly searched during missions definitely increases over repeated missions for both distributed and local teams, as shown in Table 1. A significant difference over missions was found in the RP-ANOVA ($F=21.831$, $p<.001$, N(local)=6, N(distributed)=5). No significant interaction was found between the repeated missions and locality, nor was there a significant difference between the local and distributed teams.

Table 1
Mean & Std. Deviation for Number of Good Room Searches per Mission by Networking Condition

Mission	**1**	**2**	**3**	**4**
Local	3.33	5.71	6.43	7.29
Std. Dev.	1.51	1.38	1.72	1.25
Distal	3.2	4.4	5.4	6.6
Std. Dev.	1.1	.89	.89	1.34
Mission	**5**	**6**	**7**	**8**
Local	6.29	7.86	7.57	8.71
Std. Dev.	1.38	1.95	1.9	1.38
Distal	5.8	6.8	7.2	6.4
Std. Dev.	1.1	.84	.84	.89

The average search time for rooms decreases over repeated missions, as shown in Table 2. A significant difference was found over the changes between the first mission and the last ($F=14.426$, $p<.001$) for the teams. There was no significant interaction between the repeated missions and locality, nor was there a significant difference between local and distributed teams.

Table 2
Mean & Std. Deviation for Search Time Per Room by Networking Condition

Mission	**1**	**2**	**3**	**4**
Local	84.6	55.03	52.95	48.91
Std. Dev.	25.54	12.19	11.48	13.54
Distal	82.68	73.3	60.4	54.21
Std. Dev.	22.45	24.94	6.59	12.32
Mission	**5**	**6**	**7**	**8**
Local	53.05	42.87	39.79	39.14
Std. Dev.	15.18	8.96	10.11	8.2
Distal	55.02	44.91	43.18	44.94
Std. Dev.	10.28	6.17	2.04	5.73

The average time for the door-opening collective task also decreases over repeated missions, as shown in Table 3. The decrease in time to perform the collective activity over mission rehearsals is significant, ($F=9.202$, $p<.001$). No significant difference between the local and distributed teams was found. However, a significant interaction was found between the repeated missions and location of team members ($F=2.78$, $p=.014$).

Table 3
Mean & Std. Deviation for the Time to Open Door & Enter Rooms over Scenarios by Networking Condition

Mission	**1**	**2**	**3**	**4**
Local	12.27	11.22	8.78	8.8
Std. Dev.	4.4	3.89	1.38	1.89
Distal	17.96	9.08	10.50	8.23
Std. Dev.	7.67	.91	2.56	1.64
Mission	**5**	**6**	**7**	**8**
Local	8.51	9.8	8.51	8.15
Std. Dev.	1.17	2.42	1.56	.89
Distal	7.99	8.91	7.93	8.18
Std. Dev.	1.17	1.71	.92	1.68

The average time required for the team to successfully disarm discovered (armed) canisters (from checking the canister state through the collective disarming procedure) decreased over mission rehearsals for both local and distributed teams, as shown in Table 4. Note that only one of the five distributed teams successfully disarmed a canister in the initial trial and the number of canisters varied during the missions, therefore an RP-ANOVA is not appropriate.

Table 4
Mean & Std. Deviation for the Time to Disarm Armed Canisters (Detection through Capping) by Networking Condition

Mission	**1**	**2**	**3**	**4**
Local	56.91	46.75	39.07	41.44
Std. Dev.	23.91	16.28	11.34	20.57
Distal	43.81	62.8	44.0	43.45
Std. Dev.	*	17.45	15.11	6.2
Mission	**5**	**6**	**7**	**8**
Local	40.11	30.62	34.97	29.58
Std. Dev.	13.04	7.3	15.87	3.76
Distal	42.53	36.22	34.98	32.58
Std. Dev.	3.2	9.37	7.72	4.09

* one canister successfully disarmed in this mission.

DISCUSSION

The intent of this research is to investigate changes in task and team outcome and process measures over mission rehearsal trials, and eventually be able to address relationships between task processes and outcomes and the team processes and outcomes. The performance differences, if any, would then be based in differences in the subtle team formation processes. These would include cohesion or trust in the team members capability to perform portions of the collective task, communications about the performance of the tasks, and tendencies to correct and improve performance through overt adjustments.

The results presented in this paper focus exclusively on the mission tasks, not the team work characteristics (shared mental models, cohesion, communication). The task information concerns the successful completion of mission steps or tasks (quality and quantity), and the overt performance process measures (time and errors). There is clear evidence in our initial data that task performance improves over mission trials. Our initial finding that teams improve in both task outcome and task process measures is not surprising. Humans that practice any task with attention and feedback will improve their performance.

The preliminary data also show that there is no apparent difference in performance between the local teams and the distributed teams, with one exception. Overall, the distributed team performance on a number of measures is not significantly different from the local team (based on incomplete numbers in our current sample). The significant interaction between the mission sequence and team member location is not immediately apparent from an inspection of the means (see Table 3). As the data presented are based on initial data, and more data are expected in the near future, a firm conclusion could not be drawn in any case. One possible explanation is that the distributed teams simply started at a distinct disadvantage in cooperative behavior during the first mission. The distributed teams were not given the opportunity to even be introduced prior to beginning the first mission, and worked out the initial cooperative aspects of this collective task during the first few opportunities to perform it. Why this collective task would be more sensitive to this proposed phenomenon than the other collective tasks is not clear.

We will complete data collection and analysis shortly, and conduct further analyses on possible differences in the teamwork outcomes and processes. Further, the relationship between the task measures used (those reported here and others) and the teamwork measures (e.g. communication analyses, personality variables, and team ratings) will also be analyzed.

It is clear that distributed training and rehearsal will be used in the future. The central issue for trainers is whether distributed teams in Virtual Environments learn and improve in the same manner and amount as local teams in the same simulation. These issues are critical to the development and fielding of distributed systems for training dismounted soldiers. Our preliminary data shows no difference in the task measures analyzed to date. This could be very good news for training developers wishing to use distributed simulation for the rehearsal of collective and cooperative tasks. The training analysis and development process can be eased if the developer does not have to alter the instructional approach to include or emphasize team cohesion and communication skills for the distributed trainees in addition to the skills and knowledges being rehearsed.

REFERENCES

Knerr, B. W., Goldberg, S. L., Lampton, D. R., Witmer, B. G., Bliss, J. P., Moshell, F. M. & Blau, B. S. (1994, Spring). Research in the use of virtual environment technology to train dismounted soldiers. Journal of Interactive Instruction Development, 6(4), pp. 9-20.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. I. (1992). Toward an understanding of team performance and training. in Teams: Their Training and Performance, R. Swezey & E. Salas, (Eds.), Ablex Publishing, Norwood NJ, 3-55.

Brown, B. R., Nordyke, J. W., Gerlock, D. L., Begley, I. J., & Meliza, L. L. (1998). Training Analysis and Feedback aids (TAAF Aids) Study for Live Training Support (Study Report 98-04). Alexandria, VA: United States Army Research Institute for the Behavioral & Social Sciences.