Paper Presented at the Human Factors and Ergonmics Society 49th Annual Meeting, October 2005, Orlando, FL

IMPROVING SITUATION AWARENESS THROUGH CROSS-TRAINING

Cheryl A. Bolstad, Haydee M. Cuevas, Anthony M. Costello
SA Technologies
and
Jennifer Rousey
Northrop Grumman - Space Systems Division

This study investigated how cross-training, particularly in a leadership role, may assist individuals in better understanding the task requirements of their fellow team members, and, thereby, increase their shared situation awareness. Data was collected from a training exercise at the Joint Personnel Recovery Agency. Participants were assigned to one of 4 teams (Navy, Army, Special Ops, or Joint Service) and completed a simulated exercise designed to mimic real life events in a recovery center. Each player was rotated though the various positions and teams such that everyone had a chance to be a team director (lead person) and a team member in each of the 4 teams. Situation awareness was measured during the exercise using the SAGAT technique. Overall, results suggest that cross-training may lead to improved situation awareness. Participants, on average, exhibited greater situation awareness following experience in the director role than prior to director experience.

INTRODUCTION

As the military undergoes significant changes including smaller, more deployable dispersed forces, the need to find new methods to analyze and assess team performance has increased significantly. Further, in this new modernized military, if soldiers are to function effectively in a distributed fashion, they will need similar mental models and a high degree of shared situation awareness. This paper presents the results of a study that investigated how training approaches, cross-training in particular, may assist individuals in better understanding the task requirements of their fellow team members, and thereby, increase their shared situation awareness.

Shared Mental Models

Shared mental models can be defined as "knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and, in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members" (Cannon-Bowers, Salas, & Converse, 1993, p. 228). Research has shown that when team members possess similar mental models their team performance is enhanced (Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Conversely, when teams are not allowed to generate shared mental models, they perform significantly worse (Bolstad & Endsley, 1999). Shared mental models are thought to aid team members in their ability to anticipate information needs of other members, increase coordination between individuals, and reduce the need for explicit communication (McCann, Baranski, Thompson, & Pigeau, 2000).

Situation Awareness

Shared mental models are also crucial to achieving a team's situation awareness (SA) (Stout, Cannon-Bowers, & Salas, 1996). Mental models provide individuals with the ability to attend to and process the relevant elements in the environment, a means of integrating the elements to form an understanding of their meaning, and a mechanism for projecting future states based on the elements' current state – the three principle components of situation awareness (Endsley, 1995).

For this research project, we were interested in measuring *shared* SA, rather than *individual* SA, as most military environments involve teams of

individuals working together towards a common goal. In general, shared situation awareness is defined as "the degree to which team members possess the same SA on shared SA requirements" (Endsley & Jones, 1997). Team members need to develop and maintain high levels of shared SA in order to function effectively and efficiently.

Cross-Training

One method of increasing shared mental models and shared situation awareness is through cross training. Cross-training involves training each team member on the duties and tasks of the other team members. Several studies have shown that team members who are cross-trained outperform teams that are not (Bolstad & Endsley, 1999; Volpe, Cannon-Bowers, Salas, & Spector, 1996). Cross-trained teams also exhibit more taskwork- and teamwork-specific knowledge (Cooke, Kiekel, Salas, Stout, Bowers, & Cannon-Bowers, 2003). However, few studies have been able to demonstrate that cross-training leads to better SA (e.g., Bolstad & Endsley, 1999).

Present Study

To address this issue, data was collected from a training exercise in the summer of 2004 at the Joint Personnel Recovery Agency (JPRA), a subordinate activity of U.S. Joint Forces Command. As the Department of Defense (DoD) executive agent for personnel recovery, JPRA is responsible for the shaping, planning, preparation, execution, and repatriation of personnel recovery, such as POWs (prisoners of war). Recovery centers are staffed all over the world.

For this exercise, data was collected at the Personnel Recovery Education and Training Center (PRETC), where servicemen are trained to staff the recovery centers. The servicemen, comprised of both enlisted and officers of the Navy, Army, Marines, and Air Force, attend a two-week training program followed by a one-week simulated exercise designed to mimic real life events in a recovery center.

The primary objective of this study was to assess how cross-training (i.e., familiarizing team members with other members' duties and tasks) may impact situation awareness. In particular, it was hypothesized that experience in the 'lead person' role on a team (team director) would lead to increased SA. As such, the experiment was designed to ensure that every participant had at least one opportunity to be team director.

METHOD

Participants

A total of 16 active servicemen and 3 DoD contractors (mean age = 33.85) participated in this study. Four individuals had some prior experience working at a military recovery center.

Design

Participants were assigned to one of four teams: Navy, Army, Special Ops, or Joint Service. Each player was rotated though the various positions and teams such that everyone had a chance to be the director (lead person) and a member in each of the 4 teams. A fifth team (white team) acted as the higher headquarters and controlled the exercise.

Unfortunately, during a time of war, the PRETC is very busy training individuals to staff recovery centers and was unable to meet the experimenter's requests for a control group or a full cross-training design (each person experiencing all the roles). Nevertheless, this study did help the PRETC determine if their training procedures were effective.

As discussed previously, cross-training was manipulated with regard to Director Experience (Pre-Post), that is, serving in the role of lead person on a team. The dependent variable was percent correct performance on a situation awareness measure (SAGAT), described next.

SAGAT Query Development

The Situation Awareness Global Assessment Technique (SAGAT) is an objective measure of situation awareness designed to elicit information from all three levels of SA – perception, comprehension, and projection (Endsley, 2000). Utilizing a concurrent memory probe technique, SAGAT involves: first, temporarily stopping

operator activity at randomly selected times and removing task information sources; next, administering a set of queries that target individuals' dynamic information needs (SA requirements) with respect to the domain of interest; and, then, resuming the exercise (Endsley, 2000).

The foundation of a successful SAGAT data collection effort rests on the efficacy of the queries. Before queries can be developed, operators' SA requirements must first be defined. This task is accomplished through a goal-directed task analysis (GDTA). The GDTA seeks to uncover the goals operators have in a particular domain, the decisions that must be made to achieve these goals, and the dynamic information requirements needed to support these decisions (for more information on GDTA, see Endsley, Bolte, & Jones, 2003).

One-on-one interviews, each lasting approximately two hours, were conducted with six instructors at PRETC. A GDTA was then developed using the interview notes, which, in turn, served as the basis for the SAGAT queries. Seven queries were created based on the fidelity of the exercise and the criticality of certain information requirements, as identified by the instructors (see Table 1). Additionally, a SAGAT query set was created for the white team participants to serve as the answer key, as real time data could not be recorded from the exercise.

Table 1
SAGAT Queries

SAGAT Query
1. How many isolated incidents are you aware of?
2. How many of these isolated incidents have been verified and validated as actual incidents?
3. Who is the SMC (SAR Mission Coordinator) for each incident?
4. Indicate the number and status of the isolated personnel (IP) for each incident. *(OK, slightly injured, severely injured)*
5. What is the current tactical situation around the IPs for each incident? *(high threat, medium threat or low threat)*
6. What appropriate Joint Task Force and subordinate staff sections are aware of this incident?
7. What additional assets do you require to conduct a recovery?

Scenarios and SAGAT Administration

The exercise consisted of five different scenarios over a three-day period. In each scenario participants encountered a varying number of recovery incidents, ranging from 3 to 12. During the simulated exercise, the scenarios were stopped randomly three times to collect SAGAT data, for a total of 15 stops.

In order to obtain independent assessments of their SA, no communication was allowed between the participants during SAGAT administration. Participants' responses to the SAGAT queries were compared to ground truth (as taken from the white team SAGAT answers), providing an objective measure of the degree to which their perceptions and assessments of the current situation were accurate.

Procedure

At the start of the first scenario, participants were randomly assigned to one of 4 teams (Navy, Army, Special Ops, or Joint Service). During the 3-day exercise, participants rotated through the teams and every participant had at least one opportunity to be a team director. SAGAT was administered at random times throughout the scenarios, as previously described.

RESULTS

SAGAT Scoring

The correct answers to the queries were recorded by the white team director while participants were completing the SAGAT battery. The white team director could view any material he needed and confer with other white team participants to complete the answer key. Responses to the majority of SAGAT queries were scored as either correct or incorrect based on acceptable tolerance bands. Thus, the data is binomial and a transformation to the SAGAT response measure (Y'=arcsine (Y)) was applied in order to conduct Analysis of Variance.

Director Experience (Pre-Post)

To create a cross-training score, individual query scores were coded as either occurring *before* receiving Director Experience (Pre) or *after* receiving Director Experience (Post). The scores were then averaged for each participant. A one-way ANOVA was conducted, with Director Experience (Pre-Post) as the independent variable and SAGAT performance as the dependent variable. Results revealed a significant main effect of Director Experience (F (1, 6090) = 36.28, p < .0005). Participants, on average, answered 26% of the queries correctly prior to director experience and 33% of the queries following director experience.

However, it may be that just gaining experience as the exercise progresses could account for the improved performance. Indeed, a one-way ANOVA, with scenario as the independent variable, revealed a significant main effect of scenario on SAGAT performance, (F (4, 6086) = 27.07 p < .0005). Overall, SAGAT performance increased significantly from the first three scenarios to the last two scenarios (see Figure 1).

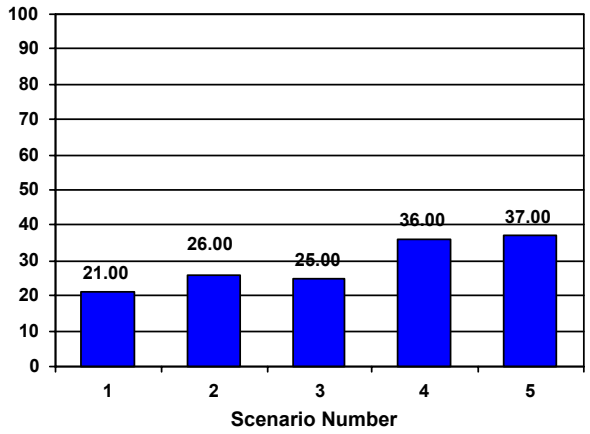

Figure 1. SAGAT percent correct by Scenario.

To further examine this finding, a 2*5 factorial ANOVA was performed, with Director Experience (Pre-Post) and Scenario (1-5) as the independent variables. Results revealed a significant interaction between Director Experience and Scenario, (F (3, 6082) = 8.28 p < .0005), indicating that performance across the scenarios varied significantly depending upon participants' director experience (Pre-Post). Specifically, participants who were directors in the first scenario answered 34% of the queries correctly in the second scenario compared to 24% for those without initial director experience (see Figure 2). Participants with director experience also did better in scenarios 3 and 5, but not in scenario 4.

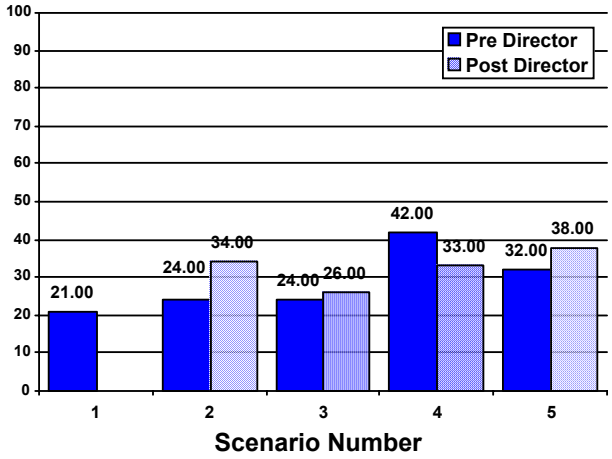

Figure 2. SAGAT percent correct by Director Experience (Pre-Post) and Scenario.

DISCUSSION

While research has shown that cross-training may foster shared mental models among team members, few studies have demonstrated that cross-training leads to better situation awareness. The data from this study provides some initial support for the use of cross-training, particularly in a leadership role, to improve SA. Participants, on average, exhibited greater situation awareness following experience in the director role than prior to director experience.

However, a question that still remains is whether cross-training in other team member roles may similarly favorably impact situation awareness. Accordingly, further research exploring the effects of full cross-training designs is warranted to better understand how such training may foster shared mental models and shared situation awareness, and how these impact team performance.

ACKNOWLEDGEMENTS

Work on this paper was prepared through participation in the Advanced Decision Architectures Collaborative Technology Alliance sponsored by the U.S. Army Research Laboratory (ARL) under Cooperative Agreement DAAD19-01-2-0009. The views and conclusions contained herein, however, are those of the authors and should not be interpreted as representing the official policies, either expressed or implied of the ARL or the U.S. Government. Correspondence concerning this paper should be addressed to Cheryl A. Bolstad, Ph.D., SA Technologies, 76 Lillian Court, Forest Hill, MD 21050, email: cheryl@satechnologies.com.

REFERENCES

Bolstad, C. A. & Endsley, M. R. (1999). Shared mental models and shared displays: An empirical evaluation of team performance. *Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting*, 213-217. Santa Monica, CA: Human Factors and Ergonomics Society.

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan, Jr. (Ed.), *Individual and group decision making* (pp. 221-246). Hillsdale, NJ: LEA.

Cooke, N. J., Kiekel, P. A., Salas, E., Stout, R., Bowers, C., & Cannon-Bowers, J. (2003). Measuring team knowledge: A window to the cognitive underpinnings of team performance. *Group Dynamics, Theory, Research and Practice, 7(3),* 179-199.

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors, 37(1)*, 32-64.

Endsley, M. R. (2000). Direct measurement of situation awareness: Validity and use of SAGAT. In M. R. Endsley & D. J. Garland (Eds.), *Situation awareness analysis and measurement* (pp. 147-173). Mahwah, NJ: LEA.

Endsley, M. R., Bolte, B., & Jones, D. G. (2003). *Designing for situation awareness: An approach to human-centered design*. New York, NY: Talyor & Francis.

Endsley, M. R., & Jones, W. M. (1997). *Situation awareness, information dominance, and information warfare* (AL/CF-TR-1997-0156). Wright-Patterson AFB, OH: United States Air Force Armstrong Laboratory.

McCann, C., Baranski, J. V., Thompson, M. M., & Pigeau, R. A. (2000). On the utility of experiential cross-training for team decision-making under time stress. *Ergonomics, 43(8),* 1095-1110.

Stout, R. J., Cannon-Bowers, J. A., & Salas, E. (1996). The role of shared mental models in developing team situational awareness: Implications for training. *Training Research Journal, 2*, 85-116.

Stout, R.J., Cannon-Bowers, J.A., Salas, E., & Milanovich, D. M. (1999). Planning, shared mental models, and coordinated performance: An empirical link is established. *Human Factors*, *41(6),* 61-71.

Volpe, C. E., Cannon-Bowers, J.A., Salas, E., & Spector, P. E. (1996). The impact of cross-training on team functioning: An empirical investigation. *Human Factors, 38(1),* 87-100.