Toward Assessing the Impact of TADMUS Decision Support System and Training on Team Decision Making

Joan H. Johnston, Ph.D. and Carol Paris, Ph.D.
Naval Air Warfare Center Training Systems Division
Code 4961 12350 Research Parkway
Orlando, FL 32826-3275

C.A.P Smith, Ph.D.
Space and Naval Warfare Systems Center
RDT&E Division, Code D44210
San Diego, CA 92152-5001

Abstract

This paper reports on the collaborative research plans for the last thrust of the Tactical Decision Making Under Stress program sponsored by the Office of Naval Research. Findings from the research will be used to develop principles and guidelines for combining training with decision support, and applications to advanced technology development research.

1 Introduction

In its first seven years, the Tactical Decision Making Under Stress (TADMUS) research program, sponsored by the Office of Naval Research, was highly successful in demonstrating the separate impact of training and decision support on combat team performance (Cannon-Bowers & Salas, 1998). The last two years of the TADMUS program have been focused on conducting team research to assess the *combined impact* of training and decision support. This paper is an update on the research plans, progress, and lessons learned on the collaborative effort among Navy labs (Naval Air Warfare Center Training Systems Division and Space and Naval Warfare Systems Center), Academia (San Diego State University), Industry (Sonalysts, Inc.), and fleet end users in developing the plans for the final research thrust.

2 Background

Previous research has shown that the TADMUS training interventions and the DSS have improved performance under stress (Cannon-Bowers & Salas, 1998; Kelly et al., 1996). In the case of TADMUS training some experiments were conducted with individuals, but most were conducted with three- and five-person teams. The DSS research thrust involved evaluating the impact of the DSS on the performance of the Commanding Officer (CO) and Tactical Action Officer (TAO) dyad. A major task for this last experiment was to develop and conduct research, whereby, the two major TADMUS interventions (DSS and training) would be linked together in a final demonstration of effectiveness for tactical decision making teams. The teams represent the ship's air defense combat team, which is composed of the CO, TAO, Air Warfare Coordinator (AAWC), Tactical Information Coordinator (TIC), Identification Supervisor (IDS), and Electronic Warfare Supervisor (EWS). The main hypothesis for the experiment is that teams provided the TADMUS DSS and training will perform significantly better than the control. It is expected that compared to the control group, trained teams using DSS will: a) be more timely and accurate in the Detect-to Engage (DTE) sequence (i.e. team decision making), b) report more accurate threat priorities, c) use more effective teamwork processes (information exchange, supporting behavior, initiative/ leadership, and communication), d) perceive less workload and mental stress, and e) perceive greater utility of DSS for making decisions.

3 Approach

The next section outlines the experimental approach including details on design, participants, the task, research conditions, measures, and procedure.

3.1 Design and Participants

The experimental design is between groups with multiple combat scenarios as post-tests. Eight six-person teams performing on the Decision Making Evaluation Facility for Tactical Teams (DEFTT) simulator (control group) will be compared with eight six-person teams provided DEFTT, DSS and training (experimental condition). In addition, in 1998, five such teams participated in a *DSS-only condition*, without the training component, in order to refine and validate the experimental protocol. Team members are experienced Navy department head students at Surface Warfare Officer's School (SWOS). The research protocol for the current effort is based on over six years of team research at SWOS and other combat team training facilities (Johnston, Koster, Black, & Seals, 1998; Johnston, Poirier, & Smith-Jentsch, 1998; Kelly et al., 1996).

3.2 The Task and Research Conditions

The 6-person Combat Information Center (CIC) Air Warfare (AW) teams (TAO, CO, AAWC, TIC, IDS, and EWS) perform the detect-to-engage (DTE) sequence on four 30-minute Persian Gulf AW scenarios. The scenarios are event-based with time-tags in order to track specific expected team behaviors throughout (Oser et al., 1998). The four teams in the control group condition perform their watchstation task assignments on a PC-based combat training system that simulates shipboard CIC AW displays (DEFTT) (see Johnston, Koster, Black, & Seals, 1998 and Johnston, Poirier, & Smith-Jentsch, 1998 for details). In the DSS condition, the TAO and CO were each assigned to a DSS, while the remaining team members worked on the same DEFTT watchstations as the control group. Head sets are worn to support verbal communications among team members and with role players who read a script. The DEFTT system and the DSS run in tandem with each other, but the software does not communicate. Any minor discrepancies in scenarios depicted on each system are handled by roleplayers. All research participants have had at least 48 hours of DEFTT experience prior to the experiment.

3.2.1 Control Condition: DEFTT-Only

In the DEFTT-only condition the six team members use DEFTT to perform their individual task assignments. The TAO and CO interact with the AEGIS Display Screen (ADS) simulation. The TIC, IDS, AAWC, and EWS each have a Command and Decision display. In addition, the EWS has a SLQ32 simulated display. All information is unclassified. The research protocol for this condition was based on the typical combat training simulation strategy the Department Head Students receive during their six month curriculum at SWOS.

3.2.2 Experimental Condition: Combined DSS and Training

Decision Support System. In the experimental condition the TAO and CO are assigned the DSS (see Morrison et al., 1998 for details). Prior to conducting scenario runs the TAO and CO receive a 45 minute computer-based tutorial that describes display functions and allows point and click practice. For scenario runs DSS operates as a standalone, but is synchronized to run in tandem with DEFTT. The same DEFTT displays are assigned to the other team members as in the control condition. Any minor discrepancies in scenarios depicted on each system is handled by role players. The San Diego State University eye tracking system is used to track TAO scan patterns on the DSS. Pilot testing of DSS with DEFTT and eye tracking was conducted with five teams in

1998 in order to refine the research protocol and timing of procedures.

Training Strategy. Overall, it would take approximately 12 ½ hours to conduct all of the TADMUS training strategies together (see Cannon-Bowers & Salas, 1998). It would have been an impossible and needless task to demonstrate the combined effectiveness of the training for the current experiment. Therefore, the training strategy for the current effort was based on a need to integrate the *most effective* training innovations into an efficient program that could be implemented within the limited research protocol established at SWOS. Many lessons learned during previous training experiments led to the decisions made to refine and develop the current training. Training priorities were established based on a literature review of TADMUS training interventions (McCarthy et al., 1998). Three main competencies were documented based on the learning objectives identified in the TADMUS literature: a) Decision Making (35 Learning Objectives), b) Teamwork (31 Learning Objectives), and c) Stress Management (11 Learning Objectives). Therefore, by way of prioritizing training content, decision making and teamwork skills were chosen as the primary competencies to train.

Secondly, TADMUS training strategies were reviewed in terms of the types of learning methods that were used (e.g., lecture/videotape, computer based training (CBT), scenario-based training, behavior modeling and demonstration, performance feedback). In most cases, a combination of these strategies were used. Therefore, a two-step approach for training decision skills and teamwork skills competencies was taken. First, multimedia based training (CBT and videotape) was chosen as an efficient and effective way of teaching declarative knowledge at the individual level. Two training modules were developed based on this approach: Decision Making Skills Training and Team Dimensional Training (TDT). The Decision Making Skills Training adapted training developed from critical thinking research (Cohen et al., 1998), as well as other research on naturalistic decision making and training (Zsambok & Klein, 1998). TDT was developed and validated under previous TADMUS research, and later refined under a separate 6.3 research program for shipboard instructor training and support (Smith-Jentsch et al., 1998).

Scenario-based team training (including behavioral modeling, performance feedback, and team self-correction) was developed based on results of research on critical thinking training, team leader training, team adaptation and coordination training, and team self-correction training. These strategies have demonstrated that individuals can apply and practice previously learned declarative knowledge in a team environment (Cohen et al., 1998; Serfaty & Entin, 1998; Smith-Jentsch et al., 1996; Tannenbaum et al., 1998). Next is a detailed description of each of the modules.

Decision Making Skills Training (Duration 2 ½ hours). Students participate in a two and one half hour CBT for decision making skills. The interactive computer-based curriculum is comprised of seven modules using multiple CIC vignettes that have events instantiated with workload and ambiguity, team requirements, and decision requirements typical to the CIC. Vignettes are presented to students in which they are asked to apply the knowledge they are developing throughout the CBT. The CBT enables students to understand and develop a common language on decision making that they can transfer to the scenario-based team training environment. Testing is embedded in the training to ensure students meet minimum knowledge requirements. At the end of training students are provided a booklet that serves as a quick reference study guide for decision making skills.

Team Dimensional Training (Duration 30 minutes). Students receive a workshop comprised of a 10 minute videotape on Teamwork Skills and Teamwork Dimensions and a 20 minute instructor facilitated training, with the support of CBT, to learn and practice identifying specific CIC teamwork behaviors. Students receive a TDT Booklet to use during the facilitated training, and as a quick reference study guide for teamwork skills.

Scenario-Based Team Training using DSS (Duration 2 ½ hours). Immediately following the TDT workshop, students assemble in the DEFTT laboratory to begin scenario-based team training. The objective of this training is to enable students to conduct structured scenario pre-briefings and debriefings (via team self-correction). The training is designed to enable members to identify and implement effective teamwork process behaviors and decision making skills during scenarios. First, the team conducts a scenario situation update for a TADMUS scenario and then proceed to their respective watch stations. During scenario run observers record good and poor examples of teamwork behaviors on the TDT Debriefing Guide. In addition, observers evaluate and record student performance on the DTE sequence for the three critical events in the scenario using a Scenario Event Summary Sheet. Following scenario run, the team is provided the Scenario Event Summary Sheet for performance feedback.

Next, an instructor/facilitator leads the team through a scenario recap and discussion of their DTE performance ***using the DSS as an aid to illustrate scenario ground truth and discuss decision making strategies***. For example, Rules of Engagement call for verifying that an inbound aircraft is clear of its territorial airspace before a warning is issued. To make matters even more complicated, in littoral environments like the Persian Gulf, a potentially hostile aircraft will often be within its weapons release range of ownship before leaving its territorial airspace. Situations such as these create substantial time pressure, and are often mishandled by relatively inexperienced students. The DSS permits the participants to replay and pause the scenarios at these crucial junctures. This feature facilitates discussions that help the team plan how they will handle similar situations in the future. In addition, the DSS debrief provides ***cross training*** by familiarizing all team members with information the TAO and CO have available to them on the DSS during a scenario. Cross training research has shown team communications improve when members know what information needs to be passed to other team members (Blickensderfer et al., 1998).

Following DTE debriefing, the last step in the process is an instructor leads the team in a structured debrief using the TDT Debriefing Guide. The instructor guides the students in a team self-correction process for identifying teamwork performance improvements.

The second training scenario run allows the team to take responsibility for practicing and demonstrating the structured pre-briefing and debriefing strategy. First, the team member designated as the CO conducts the structured pre-briefing using teamwork performance objectives identified in the previous debrief. Next, the team performs a second TADMUS scenario run. During scenario run, observers record good and poor examples of teamwork behaviors on the TDT Debriefing Guide. In addition, observers evaluate and record DTE performance on the Scenario Event Summary Sheet. Following scenario run the team is provided the Scenario Event Summary Sheet as feedback. With minimal facilitation from the instructor the designated CO leads the team through a scenario recap and discussion of their DTE performance. The CO directs the instructor to manipulate scenario recap on the DSS. Then, the CO leads the team in a structured debrief using a blank TDT Debriefing Guide. The team members have to recall specific instances where their performance was good and poor, and engage in team self-correction to identify teamwork performance improvements. Following these activities, teams receive feedback from observers and instructors on their debriefing performance.

3.3 Measures

3.3.1 Air Defense Warfare Team Performance Index (ATPI)

The ATPI provides a set of scores on team behaviors related to the DTE sequence (Paris et al., 1998). It provides diagnostic information with respect to team-level decision making based on Marshall's (1995) theory and research on decision schema (identification, elaboration, planning and execution). A paper-based tool is used by SMEs to record whether or not, and when, team members performed event-based actions required by a scenario. Video and audio tapes enable transcriptions of communications for further analyses.

A major challenge in this research effort has been achieving adequate rater agreement on the ATPI (Johnston et al., 1997). Therefore, significant efforts have been directed at tool redesign and rater training. To improve the tool's sensitivity it was modified to incorporate a similar measurement strategy that Marshall et al. (1998) used in their research on CIC teams. Marshall's research showed that certain Team DTE behaviors (e.g., level 1 queries, warnings, covering, and engagement) should be evaluated with respect to both Planning and Execution. Marshall determined that team members communicate their planning, but communication of their execution of actions may be delayed, and could have an impact on overall team effectiveness. This is an important issue for performance diagnosis and subsequent remedial training. Team members should gain knowledge during debriefs on how their behaviors had an impact on the final outcome (to engage or not engage).

Secondly, rater training was improved. First, raters were brought to concensus on how they would evaluate each stage of the DTE process. Then, they developed concise and clear details for the rating criteria. Last, a rater training notebook was developed as a quick reference guide so that raters could refresh their memory prior to evaluating transcripts of team communications.

3.3.2 TAO/CO Threat Prioritization

Periodic situation updates are requested by an observer during each scenario run to obtain TAO/CO threat priorities and threat levels. Comparison of updates between the control and experimental conditions will be made in order to identify the impact of the DSS and training on threat priorities.

3.3.3 Air Defense Warfare Team Observation Measure (ATOM)

ATOM provides a set of scores on four dimensions of teamwork behaviors: Supporting Behavior, Leadership/Initiative, Information Exchange, and Communications (Johnston et al., 1997). A paper-based tool is used by trained raters to record teamwork performance. Video and audio tape enable transcriptions of communications for further analyses. Comparisons will be made between the control and experimental conditions to determine differences in teamwork. In addition, team behaviors in the DSS-alone condition will be compared to the other two conditions to determine the impact of DSS on teamwork behaviors.

3.3.4 NASA TLX

Perceived workload and fatigue will be measured with the NASA TLX (Likert scale version) to determine perceived stress differences among conditions and across scenarios.

3.3.5 Briefing Protocol Analyses

As a manipulation check, team communications during scenario briefings for the control group and experimental group will be analyzed to determine the impact of training and DSS on briefing strategies.

3.3.6 Eyetracking Metrics

Using the SMI EyeLink System, the eye movements of the student assigned to the role of TAO are tracked throughout DSS training and DSS scenario runs. Pupil dilation and point-of-gaze data are collected for both left and right eyes, sampling at a rate of 250Hz. The point of gaze data consists of the horizontal and vertical coordinates giving pixel location for each observation. Using the procedures developed by Sandra Marshall and her research group, the pupil dilation is analyzed using wavelet theory to produce estimates of cognitive workload. These estimates show how workload changes during the course of the scenario. The point-of-gaze data shows the usage of the different parts of the DSS. The overall percent of time spent in every region for each scenario is tabulated, as well as the use of the regions during several minutes that have been identified as critical points in the scenario. For the critical events, the cognitive workload will be correlated with the eye movements to determine when and where the highest levels of mental effort occur.

3.4 Procedure

3.4.1 Control Condition

The DEFTT-only condition involves DH student participation for a single day. At the beginning of the day informed consent forms are completed and team members respond to a demographics questionnaire in order to determine level of expertise. Team members with the most CIC expertise are assigned as TAO and CO. Following selection, team members are trained on their respective watch stations. A training administrator provides an introduction to CIC watch station responsibilities and DEFTT functions. Next, training scenarios are used to familiarize DEFTT operators with system functions, operations, and team interactions. Information packets are provided to members that develop a context and rationale for the research scenarios (e.g., environmentals, geopolitical, situation update, ROE, threat matrix, etc.). Following DEFTT familiarization training on two training scenarios team members participate in four posttest scenarios that are counterbalanced across teams. At the end of each scenario session team members fill out the NASA TLX, and are provided with the Scenario Event Summary Sheet to use for review in their debrief. At the end of the day, students are provided feedback on performance after the last scenario as a way to ensure they received training value for their efforts.

3.4.2 Experimental Condition

The experimental condition involves DH student participation for two days. The first day requires students to participate in the CBT for decision skills. The second day is similar to the control condition protocol with the addition of DSS, TDT, and scenario-based team training. While four students learn DEFTT functions the TAO and CO students participate in a 45-minute DSS CBT tutorial. Eye tracking calibration takes place during DSS practice. Next, students receive the TDT training followed by the scenario-based team training using the same two training scenarios as in the control condition. Then, team members participate in the four posttests. At the end of each scenario session team members fill out the NASA TLX, and are provided with the Scenario Event Summary Sheet and the TDT debriefing guide to use for review in their debrief along with the DSS. At the end of the day, students are provided feedback on performance after the last scenario as a way to ensure they received training value for their efforts.

3.5 Progress and Summary

In this paper we have described the research protocol and plans for conducting the final experimental thrust for the TADMUS program: conducting a demonstration of the combined effect of the TADMUS DSS and training on tactical team performance. To date four teams have completed the experimental condition and four teams have completed the control condition. The remaining four teams in the experimental and control conditions will participate in June 1999 and September 1999, respectively. Including the DSS only condition, the total number of participants to date is 78. Data analyses are in the process of being conducted. Products from this effort will include:

- Principles and guidelines for integrating training and decision support systems,
- Designing diagnostic tools for evaluating team tactical decision making performance,
- Developing and conducting rater training and concise documentation of rater guidelines,
- Developing computer based training for decision skills and team performance,
- Developing and Conducting Scenario-Based Training,
- Application of gaze patterns to identify effective decision support strategies,
- Utilizing the DSS display capabilities for training and debriefing team decision making, and
- Efficacy of eyetracking technology for assessing human cognition and performance

3.6 Transition Plans

A number of significant transitions of TADMUS research methods are currently in progress. Specifically, the Science and Technology Reduced Manning Initiative sponsored by the Office of Naval Research is conducting a demonstration of comparing fully manned shipboard AW CIC teams to teams performing on a newly developed CIC console that will require fewer AW team members—the Multi-Modal Watchstation (Campbell et al., 1997). It is a joint program of academia, industry and four DoD labs: Naval Air Warfare Center Training Systems Division, Space and Naval Warfare Systems Center, Naval Surface Warfare Center, and Naval Underwater Warfare Center. The research program includes basic, applied, and advanced technology development initiatives. The following transitions are direct applications from the TADMUS program: 1) a modified ATPI to be used as an on-line/realtime measurement tool, 2) the ATOM will be used in its current form, 3) rater training for the ATPI, 4) event-based scenario development with two levels of stress, 5) Decision Support System display components, and 6) other TADMUS research protocol components (i.e., research team preparation, prebriefing materials, role player scripts, etc.).

In addition, the ATPI is being developed as an electronic performance support tool to aid the reduced manning researchers with real time team performance evaluations. The paper-based device will be modified and applied to a handheld PC to improve reliability and ease of ratings. Data input, data reduction, and data presentation interfaces will be developed to speed recovery of data analyses.

References

Blickensderfer, E., Cannon-Bowers, J.A., & Salas, E. (1998). Cross training and team performance. In J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress: Implications for individuals and teams (pp. 299-311). Washington, DC: APA.

Cannon-Bowers, J.A., & Salas, E. (Eds.) (1998). Making decisions under stress: Implications for individuals and teams. Washington, DC: APA.

Campbell, G.E., Cannon-Bowers, J.A., & Villalonga, J. (1997). Achieving training effectiveness and system affordability through the application of human performance modeling [CD-ROM]. Proceedings of the 19th Interservice/ Industry Training, Simulation, and Education Conference, Orlando, FL, 763-770.

Cohen, M.S., Freeman, J.T., & Thompson, B. (1998). Critical thinking skills in tactical decision making: A model and training strategy. In J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress: Implications for individuals and teams (pp. 155-189). Washington, DC: APA.

Johnston, J.H., Koster, A., Black, E., & Seals, M. (1998). A learning methods approach to designing team training simulations: Lessons learned from the Tactical Advanced Simulated Warfare Integrated Trainer (TASWIT—Device S14A13). Proceedings of the Command and Control Research and Technology Symposium, Monterey, CA, 721-730.

Johnston, J.H, Poirier, J., & Smith-Jentsch, K.A. (1998). Decision making under stress: Creating a research methodology. In J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress: Implications for individuals and teams (pp. 39-59). Washington, DC: APA.

Johnston, J.H., Smith-Jentsch, K.A., & Cannon-Bowers, J.A. (1997). Performance measurement tools for enhancing team decision making. In M.T. Brannick, E. Salas, & C. Prince (Eds.), Assessment and management of team performance: Theory, research, and applications (pp. 311-330). Hillsdale, NJ: LEA.

Kelly, R. T., Hutchins, S.G., & Morrison, J.G. (1996). Decision process and team communications with a decision support system. Proceedings of the Command and Control Research and Technology Symposium, Monterey, CA, 186-203.

Marshall, S.P. (1995). Schemas in problem-solving. London: Cambridge University Press.

Marshall, S. P., Wilson, d.M., Knust, S.R., Smith, M.E., & Garcia, R.J. (1998). Shared decision making knowledge in tactical situations. Proceedings of the Command and Control Research and Technology Symposium, Monterey, CA, 693-699.

McCarthy, J.E., Johnston, J.H., & Paris, C. (1998). Toward development of a tactical decision making under stress integrated trainer [CD-ROM]. Proceedings of the 1998 Interservice/Industry Training, Simulation, and Education Conference, Orlando, FL, 818-904.

Morrison, J.G., Kelly, R.T., Moore, R.A., & Hutchins, S.G. (1998). Implications of decision-making research for decision support and displays. In J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress: Implications for individuals and teams (pp. 375-406). Washington, DC: APA.

Oser, R.L., Gualtieri, J.W., & Cannon-Bowers, J.A. (1998). Enhancing training systems design: Implementing an event-based approach. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, Santa Monica, CA, 1309-1313.

Paris, C., Johnston, J.H., & Reeves, D. (1998). A theoretical framework and measurement strategy for training team tactical decision making. Proceedings of the Command and Control Research and Technology Symposium, Monterey, CA, 700-708.

Serfaty, D., Entin, E.E., & Johnston, J.H. (1998). Team adaptation and coordination training. In J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress: Implications for individuals and teams (pp. 221-245). Washington, DC: APA.

Smith-Jentsch, K.A., Payne, S.C., & Johnston, J.H. (1996). Guided team self-correction: A methodology for enhancing experiential team training. In K.A. Smith-Jentsch (Chair), When, how, and why does practice make perfect? Paper presented at the 11th annual conference of the Society for Industrial and Organizational Psychology, San Diego, CA.

Smith-Jentsch, K.A., Zeisig, R.L., Acton, B., & McPherson, J.A. (1998). Team dimensional training. In J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress: Implications for individuals and teams (pp. 271-297). Washington, DC: APA.

Tannenbaum, S.I., Smith-Jentsch, K.A., & Behson, S.J. (1998). Training team leaders to facilitate team learning and performance. In J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress:

Implications for individuals and teams (pp.247-270). Washington, DC: APA.

Zsambok, C.E., & Klein G. (Eds.) (1997). Naturalistic decision making. Mahwah, NJ: LEA.