THE APPLICATION OF ADVANCED TECHNOLOGY TO SURFACE WARFARE TRAINING

by

Kent E. Williams, Ph.D.
Ship Analytics, Incorporated
North Stonington, Connecticut 06359

Richard E. Reynolds, Ph.D.
and
Eduardo Salas, Ph.D.
Human Factors Laboratory
Naval Training Equipment Center
Orlando, Florida 38213

ABSTRACT

The Human Factors Laboratory of the Naval Training Equipment Center is developing a demonstration/research surface warfare training simulation system for combat officers. The system integrates and expands the automated instructional software features developed for the Submarine Advanced Reactive Tactical Training System (SMARTTS) with portions of the tactical modeling originally developed for the Naval Tactical Game (NAVTAG) in a real time simulation environment. The objectives of the Surface Warfare Advanced Training Technology (SWATT) Research and Development Facility are twofold: (1) to demonstrate the feasibility of applying advanced training techniques and software/hardware technology to surface warfare trainers and (2) to evaluate as well as to enhance tactical team/individual decisionmaking performance against multiple threats. This paper briefly discusses the evolution of SWATT, its characteristics, and the relationship of its technological features to improvements in tactical decisionmaking training. Key research issues employing SWATT are also discussed.

INTRODUCTION

Because of the evolution of threat and counterthreat capabilities within both the U.S. and Soviet fleets, numerous and complex pressures are being imposed upon Navy decisionmakers. The complexity of communications, sensors, weapons, EW and CM/CCM systems provides a highly time stressed environment in which Navy tactical decisionmakers must generate alternative tactical procedures and make a choice from these alternatives. Learning to make an appropriate tactical decision requires extensive training in order to develop and maintain decisionmaking skills. The at-sea environment is extremely costly for conducting the training exercises required to cover the range of tactics which the decisionmaker may encounter during a wartime engagement. Therefore, shore-based simulators have been developed for the various surface warfare schools to provide the necessary experience for the acquisition of decisionmaking skills. However, many of these are limited in terms of their flexibility to keep up with the evolution in warfare technology.

In view of the above, the concept of a low cost, standalone, combat, decisionmaking trainer with modifiable software would provide a flexible approach to tactical training. This concept was the impetus for the design and development of the Surface Warfare Advanced Training Technology (SWATT) program.

THE INTEGRATION OF SMARTTS AND NAVTAG

The SWATT concept evolved from the integration of the Submarine Advanced Reactive Tactical Training System (SMARTTS) instructional technology and the Naval Tactical Game System (NAVTAG) models including air, surface and subsurface platforms with their associated weapons and sensor characteristics. In order to understand the features of SWATT, both SMARTTS and NAVTAG characteristics are basically described herein.

SMARTTS Characteristics

The SMARTTS has been developed as the "training subsystem" of the 21A41A submarine combat system trainer. The SMARTTS design is that of a generic training subsystem, which combined with the traditional simulation subsystem and associated tactical equipment, form the training device. SMARTTS embodies a variety of training-related features that are essential to an effective training process.

Major capabilities developed as part of the SMARTTS training subsystem include: (a) automated assistance for exercise development; (b) automatically generated and recorded performance indicators; (c) visual feedback displays for presentation of performance indicators and tactical variables, in the attack center and in the classroom; (d) alternative tactics capability for rapid generation of alternative sets of actions; (e) automatic instructor cues based on scenario events; (f) student entered time flag, automatically recorded, to indicate points of concern during replay; (g) automatic interactive target providing computer control of a target platform, responding to ownship actions; (h) an exercise library containing a large number of exercises, each of which can be automatically loaded and started in the system; (i) simultaneous and independent operation of classroom and attack center subsystems; (j) fast-time and real-time classroom simulation subsystem for support of prescenario and postscenario briefing sessions (e.g., feedback); (k) exercise playback presenting a wide variety of tactical variables and performance indicators as occurring during the scenario; and (l) an instructor console located near the fire control party in the attack center, providing a wide range of monitoring and control capabilities for the instructor.

NAVTAG Characteristics

NAVTAG is a microcomputer-based shipboard wargaming device. It provides a medium for reinforcing knowledge of U.S., Allied, and threat naval forces. The game typically involves two officers and a Game Director. The Game Director is responsible for selecting an exercise or building a new scenario from an editing system. The Game Director initiates play and monitors the players actions. The game is played by two or more officers each of whom control the activities of one or more platforms. NAVTAG includes surface, submarine, and air warfare models including a wide variety of platform sensors, weapons and countermeasures. Environmental factors may also be manipulated in a game. NAVTAG progresses through a series of game turns, each game turn simulates 1 minute of real time during which actions taken by players are updated. In complex exercises, the game turn may take longer than 1 minute to execute.

For the development of SWATT, only a portion of the NAVTAG models are being employed. However, these models are upgraded to perform in real time as opposed to the 1 minute game turn.

The SWATT System

The SWATT device integrates the characteristics of SMARTTS and NAVTAG described above, and expands their instructional capabilities and decisionmaking feedback displays. The SWATT system is, therefore, being designed to:

1. Reduce the high overhead of manpower to operate and maintain full mission tactical trainers for surface warfare.

2. Automate many of the elements typically requiring human operators to conduct training exercises.

3. Improve the effectiveness of training through the application of empirically proven learning techniques.

4. Promote more effective interaction between instructor and student by providing the instructor with automated functions to assess trainee performance and formulate appropriate exercises to enhance the acquisition of skills and knowledge associated with trainee needs and proficiencies.

5. Provide a simulated environment with the flexibility to implement a variety of tactical engagement configurations to improve alternative tactics formulation and decisionmaking on the part of the tactical officer.

6. Serve as a research facility to investigate techniques and technology to improve the decisionmaking training process for tactical officers.

7. Provide a standalone low cost flexible unit for uses such as the training of naval reserve officers in tactical command of FFG-7s.

The SWATT research/demonstration system consists of a two station, dynamic simulator. One station is operated by the instructor. The other station is operated by the trainee. The success of the SWATT demonstration depends heavily on the design of the student station. The chosen design is capable of providing the student with rapidly changing tactical information in a timely and efficient fashion. The "information environment" in the Combat Information Center (CIC) is simulated, rather than attempting to reproduce in exact detail, the physical environment of the CIC. Additionally, the student can respond to this changing tactical situation in a highly efficient manner. It is unacceptable to require the student to engage in "input" tasks which place heavy demands on his time or require concentration to details. Toward this end, a number of new displays and student interaction devices are incorporated. The student station consists of (1) all ownship controls, (2) status boards, (3) tactical geoplot, (4) LAMPS MKI controls, and (5) feedback displays. Additionally, all commands and control of ownship weapons are available at the student station as higher level commands as they would be given in a real CIC environment. For example, SHOOT LOOK SHOOT when given as a command is implemented by the weapons control officer module which models the monitoring of the firing doctrine.

From the instructor station, the instructor can implement the following capabilities: (1) selection of trainer operating mode; exercise preview, exercise run, alternative tactics, and exercise playback, (2) scenario modification, (3) environmental change, (4) control of tactical geoplot, (5) control of feedback displays, (6) control of ownship for demonstration purposes in alternative tactics mode, (7) control of LAMPS MKI for demonstration purposes in alternative tactics mode, and (8) control of target platforms.

SWATT and Tactical Decisionmaking Training

Since tactical decisions are based upon dynamic events which can encompass a reasonable degree of variation, there are no well defined procedures which can be applied to cover each and every tactical engagement. Consequently, when providing a medium for decisionmaking training, a fair degree of realism in terms of the variation of states and actions must be made available to the trainee. Decisionmaking can be likened to learning how to solve problems, in this case, problems of a tactical nature. SWATT provides the necessary variation in experience (i.e., multiple threat configurations) in order to train this kind of problem solving behavior.

Intelligent Platforms. Some of the critical features of SWATT include the multithreat Intelligent Platforms (IPs). The IPs consist of a surface hostile target of the KRESTA I class, a subsurface hostile target of the Charlie II class, an air hostile Hormone B helicopter and an air friendly SH-2 LAMPS MKI helicopter. The significance of IPs in the training environment is that they eliminate manual control of targets by a human operator and provide flexibility, realism and variation in the tactical decisionmaking training situation.

The implementation of IPs provide the student with the variation and changing reactive dynamics which will promote the enhancement of cognitive processes necessary for making appropriate decisions. The IPs essentially behave as artificial expert platform commanders. This capability would be manpower intensive if each target were operated by individuals possessing expertise in the tactical decisionmaking process required for operating each platform. By modeling these experts such manpower is not required; however, the realism and variation in maneuvering of such targets is preserved. The stereotyped behavior which would be the case given preprogrammed targets is consequently avoided.

What is important about the implementation of IPs in decisionmaking training is that, given the wide variety of action sequences which can occur in a dynamic situation, information relative to common states which are either advantageous or disadvantageous can be identified. In short, in the midst of variation the trainee is taught to identify those states which are advantageous or disadvantageous with respect to certain actions. The trainee is therefore learning the value of specific states and the organization or pattern of these states which provide a tactical advantage or tactical disadvantage.

<u>Decisonmaking Feedback Displays</u>. The key attributes which make up the information for decisionmaking are displayed to the trainee on his feedback monitor. Figure 1 shows a snapshot of one dynamic Engagement Tactical Advantage feedback display for a FFG-7 versus an aircraft. This display is formatted into regions for sensor, targeting, weapons and damage data. Functions are employed to calculate the tactical advantage for each variable by target type. Color and location indicate an advantage or disadvantage in the engagement. The color green indicates advantage to ownship in the "TO OS" column of the display; red indicates advantage of the target selected in the "TO TG" column and yellow indicates a draw under the "DRAW" column of the display. The target number and problem time is displayed in the upper right-hand corner of the figure. The decisionmaking training on the part of the student can then be driven toward recognizing and identifying these variables, their values, and the success of specific outcomes given action choices selected by the student.

<u>SWATT Performance Measures</u>. The following performance measures were derived from a job/task analysis and validated by the staff of the Surface Warfare Officers School. A rationale for the measure is cited in each case.

1. <u>Response time elapsed from target detection to weapon system assignment</u>. This measure requires calculation of the elapsed time from a new detection message until the time a

ENGAGEMENT TACTICAL ADVANTAGE	TARGET XXXX TIME XX:XX:XX		
FFG VS AIRCRAFT	TO OS	DRAW	TO TG
SENSORS			
RANGE AT TIME OF ACTIVE DETECTION	■		
PROBABILITY OF COUNTERDETECTION		■	
TIME TO CLASSIFY FROM DETECTION	■		
TIME TO IDENTIFY FROM CLASSIFICATION	■		
TIME TO LOCALIZE FROM IDENTIFICATION			■
TARGETING			
RANGE TO TARGET AT FC ASSIGNMENT		■	
ACCURACY OF FC SOLUTION		■	
TOTAL TIME OF LAUNCHER AVAILABILITY			■
USE OF WEAPONS VS AIR TARGETS			
RANGE AT SAM/ASM	■		
PROBABLITY OF SAM/ASM HIT		■	
RANGE AT GUN FIRING			■
USE OF COUNTER MEASURES			
TIME TO GO AT CHAFF LAUNCH	■		
RANGE TO GO AT GUN FIRE		■	
TIME TO GO MISSILE LAUNCH	■		
RANGE OF MISSILE AT EVASIVE MANEUVER			■
SUMMARY SCORE	6	5	4

Figure 1. Sample Engagement Tactical Advantage Display

weapon system is assigned to that target number. The response time of the student in evaluating and assigning a counter to a threat is perhaps the ultimate determinant of his success in defending his ship. Failure to counter the threat will logically result in his own destruction and by implication failure of task completion.

2. Response time from target missed to re-engagement with appropriate weapon. This measure requires calculation of the elapsed time from a target missed message from the tactical data base to the time of assignment of another weapon to counter the threat. This measure presupposes the failure of the first weapons assignment to counter the threat and serves to measure the timeliness and effectiveness of the student's postfiring evaluation process and reaction to continued threats.

3. Target threat prioritization. A time remaining until to impact or "time to go" calculation as to all hostile targets is required for this performance measure. The calculations must be then rank ordered with the highest priority always falling to the target with the shortest time to impact. In order to make most effective use of his counters and minimize scheduling conflicts among ownship's assets, targets must be prioritized. The closest target may not necessarily be the one posing highest danger due to relative speed differences, therefore time to impact on ownship best determines the order of engagement.

4. Threat engaged by multiple counters. A simple recording of number of weapon system assignments against a threat target is required for this measure. One is acceptable if the target is hit, not acceptable if the target is missed. Since survival through the practice of defense in depth is the goal, targets must be engaged at ranges which will permit re-engagement with a different weapon system should the first fail. Proper exercise of available options is measured by this indicator.

5. Range of target at weapon predicted intercept point. The fire control solution of the tactical data base represents the calculation of this performance measure. To promote defense in depth and effective asset employment, target threats should be engaged at the outer edges of the weapons envelope concerned. Longer ranges of predicted intercept points help assure a second shot if required.

6. Range of target at time of first fire control assignment. The new detection message for an ownship fire control system is used for the calculation of this performance measure. Establishment of an early fire control solution at the outer boundaries of the fire control system detection envelope facilitates the long-range weapon predicted intercept point of the prior measure. This measure is a necessary precondition to the prior and gauges asset employment.

7. Weapon blind zones not compensated for. This measure requires the recording of whether a target assigned to a weapon system comes within a launcher firing cutout zone which precludes weapon firing. Even though a valid fire control solution may exist, target trajectory may carry it within an angular zone which the weapon cannot reach. The presence of this measure denotes the failure to maneuver the ship so as to ensure target engageability.

8. ESM infomation reaction time. This measure requires measuring the time interval between receipt of an ESM new detection message and the implementation of a classification change by the student. Classification and threat evaluation is at the very core of the tactical decisionmaker's responsibilities. Unless the threat is evaluated as such, it cannot be engaged and the reaction time of the student in performing this function may well be critical in his ability to successfully engage the threat.

9. Unique emitter recognition. This measure requires the flagging of a new detection message for a unique emitter which denotes a target to be a missile platform. The elapsed time from receipt of the information by the student to a classification change identifying the target as a missile platform is then recorded. As missile platforms pose a greater threat to ownship survival than non-missile platforms, a higher engagement priority must be accorded them. If permitted by the rules of engagement and possibly given the applicable weapons envelope, it is preferred to destroy the carrier platform prior to its initiation of a weapons release action dangerous to ownship.

10. Torpedo countermeasures utilized. This performance measure requires the recording of SLQ-25 use and/or an evasive maneuver in the presence of a hostile torpedo target. As ownship's capabilities to engage a torpedo threat are nonexistent, the presence or absence of countermeasures will be determinative of survival.

Question Interrupts. Question interrupts are an option selectable by the instructor upon exercise initialization. Questions in multiple choice answer format will be presented to the student for resolution as a function of preprogrammed criteria. The automatic question interrupts will be directly related to information critical to effective decisionmaking in accordance with the instructional objectives. Table 1 contains a sample listing of question interrupts in the multiple choice answer format.

When a question is presented as a function of a significant event occurrence in the engagement, the system automatically freezes and a reaction time clock is initialized. The clock continues counting until the student selects an alternative. Upon making a choice, the clock stops and the response is recorded along with the student's reaction time. If the response is correct, the word "correct" is displayed adjacent to the selected alternative. If an incorrect response is made the reaction time and the incorrect response are recorded and stored; a prompt is presented by displaying the phrase "Incorrect Try Again." All other responses after the first incorrect response are recorded and stored along with the correct response when it is indicated. Reaction time measures on

TABLE 1. SAMPLE QUESTION INTERRUPTS

1. What platform is correlated with racket symbol number ____?
2. What is the highest priority threat associated with racket symbol number ____? (only for surface ship emitters)
3. What is highest priority threat engagement at this time?
4. For track number ____, what is the most effective counter?
5. For track number ____, what is your backup if most effective counter is not engageable?
6. What other missiles can be associated with racket symbol number ____ aside from worst case?
7. What sensors are associated with track number ____?

responses subsequent to the first incorrect response are not required.

The reaction time measure reflects the accessibility or strength of association of each response in the semantic network of the student's long-term memory.

Alternative Tactics. The instructor may demonstrate one or more alternatives to a tactic which the student employed during an exercise. To initiate this submode, the instructor selects the alternative tactics mode on his console at any time during an exercise or playback. The exercise or playback immediately "freezes" and returns to the start. The instructor rapidly advances to the point in the simulation where he wants to demonstrate the alternative tactic. At this point, the instructor takes control of whatever platform (i.e., either ownship or LAMPS) he is using to perform the alternative tactic. Intelligent Platforms that are in the automatic operation state respond to the alternative tactic performed. During Alternative Tactics, feedback displays show the student's performance during his original tactic, as well as the performance of the current alternative tactic.

Digitized Speech Output. The instructor station and the student station each contain a speaker or headset connected to a data-to-voice converter. During a training session, messages automatically triggered by the occurrence of significant tactical events are sent to a Digital Equipment Corporation DECtalk Text-to-Speech System and converted to speech. The DECtalk unit has a virtually unlimited vocabulary and is augmented with a SWATT-specific dictionary for more precise pronunciation of special terms. DECtalk can be instructed to speak with a variety of voices: pitch, rate, and the pattern of pauses can all be controlled. The computer generated speech output provides the student with messages originating internal and external to the CIC typically transmitted during a tactical engagement. For example, acknowledgement of receipt and execution of tactical commands (from the ASWO, WCO, etc.), are transmitted by way of computer generated speech. This further reduces the trainer overhead by eliminating the delivery of communications by the instructor or another party.

SWATT RESEARCH ISSUES

The SWATT system, designed as a demonstration/research tool, will allow the thorough investigation of advanced training technology as applied to surface tactical team and individual decisionmakers. Three selected broad based research issues critical to the naval training community are briefly addressed below.

First, an area of difficulty in training tactical decisionmaking is the identification of errors and localization of faults. Such training requires that an instructor be expert in tactical doctrine and capable of monitoring the trainee's processing of information prior to a decision choice. Obviously, such monitoring is beyond the capability of any instructor, since the information being selected and picked up by the trainee comes from diverse sources and cannot always be determined by even the most expert of instructors, except for that case where the trainee would continuously identify, by an ongoing protocol, all of the information which he is attending to. This would place inordinate constraints upon the trainee while he is working through a tactical problem in real time.

However, a planned research project will investigate a plausible solution; modeling an expert tactician and making this resident in the software of the training system. To accomplish this, tactical doctrine would be reviewed and a library of tactical production rules created.[1,2] The expansion of SWATT to house the "expert tactician" would provide precise feedback in terms of error identification and fault localization to the trainee, a feature which is currently not implemented in the training of tactical decisionmaking.

Second, technological advances in the area of team training are in need of further development. A recent review of team training by Denson[3] concluded that: (1) the technology of team training is poorly developed; (2) cooperation, coordination, and communication are the important parameters in team training; and (3) lack of adequate assessment/measurement techniques is an area for much needed development.

Crews, in the absence of specific operating rules, will devise means of working together to the benefit of the team and will develop positive accepting attitudes toward team members. It is hypothesized that such a development takes place as a result of reducing uncertainty through the understanding of team members strengths and weaknesses. This transformation can only take place as a result of knowing what to expect of others in the team and knowing what is expected of one's self as a team member. Team performance then is not just simply knowing the roles of others but creating reliable expectations of how others will perform in the team situation.

Given that individual member expectations, while interacting within a team, is a key concept to the development of team performance, training technology can be developed to promote a common reference of expectation among each individual of a team. Furthermore, this could be accomplished at an individual level in the absence of other team members[4]. In order to train individuals to form a common knowledge base in terms of team member expectations, an entire team could be simulated employing an artificial intelligence (AI) production system (see Nilsson[2], for an explanation of production systems). Each member of the team would then be modeled to a specific level of expertise. Any individual team member could then interact with the expert team during various training exercises. The trainee would then be exposed to a controlled level of team member expertise and would develop expectations in terms of what to expect of whom and when to expect it. This type of training experience would create a given level of expectation on the part of the trainee.

Each individual in a team could be exposed to the expert team. Each in turn would develop expectations based upon a common level expertise of team member interaction. Each individual in turn would also be trained to a specific criterion level of performance while interacting with the simulated team in order to ensure individual skill level development. Later when all individuals making up the team are exposed to a team training situation they will have had a common experience in terms of what to expect from their other team members. This will promote an accelerated development of team coordination skills.

A third research area of SWATT deals with training evaluation/effectiveness issues. Although there are many features to be evaluated in this emerging system (e.g., question interruption, decisionmaking feedback displays, performance improvement), SWATT would allow the empirical derivation of Goldstein's training validities.[5] He outlines four types of validities: (1) training validity, determined by performance results after the training program; (2) performance validity, determined by positive transfer of training from the program to on-the-job performance; (3) intra-organizational validity, determined by performance results from other type students within the same organization; and (4) inter-organizational validity, determined by performance results from students of a different organization (i.e., the generalizability of the training program). The establishment of these validities would provide the internal (i.e., SWATT enhances performance of the surface tacticians) as well as the external evaluation (i.e., SWATT enhances performance of other combat tacticians) needed in emerging training systems.

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ABOUT THE AUTHORS

DR. KENT E. WILLIAMS is an Experimental Cognitive Psychologist with Ship Analytics, Inc. He has managed a variety of training systems research in both the commercial and military marine industries. Dr. Williams is currently directing applications of advanced concepts to training technology for Ship Analytics. He holds his Ph.D. degree from the University of Connecticut.

DR. RICHARD E. REYNOLDS is an Experimental Psychologist with the Human Factors Laboratory, Naval Training Equipment Center. He has directed programs in maintenance training, surface and subsurface warfare training and aircrew training. He holds a Ph.D. degree in Experimental Psychology from Miami University.

DR. EDUARDO SALAS is a Psychologist with the Human Factors Laboratory, Naval Training Equipment Center in Orlando, Florida. He has done research on training evaluation, human performance assessment, skill acquisition and personnel psychology. He holds a Ph.D. in Industrial/Organizational Psychology from Old Dominion University.