CONSIDERING HUMAN REQUIREMENTS IN TRAINING SYSTEM DESIGN: A VISION FOR THE 21ST CENTURY

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The United States Navy views the future in terms of asymmetric threats, which can impede its access to the littorals. To counter these threats, the Navy seeks to exploit modern digital information technology to establish knowledge superiority over potential adversaries thus maintaining the tactical advantage. To date, there has been little discussion about the role of human operators and decision makers in these strategic and operational constructs aside form vague references to the "knowledgeable warfighter" and "reach back" knowledge centers that augment the on-scene tactical view. Moreover, the standard practice of combat systems and training systems design – thinking about the human last – almost inevitably results in sub-optimal performance, and can potentially lead to disaster during crisis or conflicts (particularly given the complexity just described).

This paper describes how the current vision for future naval warfare translates into specific human performance requirements. We then describe several emerging training technologies that will be useful in meeting the unprecedented demands that our warfighters will confront. We conclude with recommendations for science and technology investments in training and human performance that we believe are crucial for success in the 21st century.

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INTRODUCTION

Since the fall of the Berlin Wall and the dissolution of the Soviet Bloc nearly a decade ago, the United States has repeatedly assessed the strategic, doctrinal, and operational architectures for military forces in the "post-Cold War era." Most of these assessments have been focused on broad-spectrum warfighting requirements and force structures, and mixes for major theater wars, smaller-scale contingencies, and crisis-response. Others have addressed novel operational concepts for 21st century forces. Very few, if any, however, even begin to focus on the implications of these emerging strategic, doctrinal, and operational architectures for human performance requirements and training, which, in large degree, will be of critical importance to success in future crises and conflicts.

For example, beginning with the publication of *…From the Sea* in 1992/1993, the U.S. Navy and Marine Corps have sought to redefine and articulate the strategic and operational frameworks for naval forces. In close succession, the Naval Services also published *Forward…From the Sea* (1994), *Operational Maneuver From the Sea* (1996), the *Navy Operational Concept* (1997), and *Ship-to-Objective Maneuver (1997).* These, moreover, have been shaped by key "joint vision" documents — *Joint Vision 2010* (1996), *Concept for Future Joint Operations* (1997), *21st Century Challenges and Desired Operational Capabilities* (1997), and *Joint Vision 2020* (2000) — promulgated by the Chairman of the Joint Chiefs of Staff. More recently, the Navy has sought to expand the conceptual thinking of Network-Centric Warfare and Net-Centric Operations, a new mode of warfare for the information age — which will have significant implications for the "human element" in future crisis and conflict. Thus, in several Navy draft vision and maritime concept papers there is an expanding discussion about the "knowledgeable warfighter" and "self-synchronization," but little focus on the education, training, and supporting technologies and systems needed to ensure that future warfighters are indeed "knowledgeable" and can effectively and efficiently "self-synchronize" to achieve operational and strategic objectives.

That said, *Joint Vision 2020* has taken a new tack and is much more explicit (if still at a macro-level) in its discussion of the "human element," particularly in command-and-control in an information-dominated architecture:

> …we must carefully examine three aspects of the human element in command and control. First, leaders of the joint force must analyze and understand the meaning of unit cohesion in the context of widely dispersed units that are now envisioned. Second, decision-makers at all levels must understand the implications of new technologies that operate continuously in all conditions when human beings are incapable of the same endurance. Third, as new information technologies, systems, and procedures make the same detailed information available at all levels of the chain of command, leaders must understand the implications for decision-making processes, the training of decision makers at all levels, and organizational patterns and procedures [pp. 32-33].

The purpose of this paper is to focus attention on the need to address training and human performance topics and issues as integral elements of the processes by which the U.S. Armed Services articulate future strategic and operational architectures and frameworks. Our specific perspective will be on emerging architectures for naval warfare. To do this, we first provide an overview of some of the major implications for human performance derived from key strategic- and operational-level trends and drivers, i.e., joint and littoral warfare, network-centric warfare/operations, and reduced manning. Next, we discuss training solutions that address this set of demands. In particular, we will describe scenario-based training, embedded/deployable training, continuous learning and distributed training as potential solutions. While they do not represent an exhaustive list, these approaches hold promise as a means to prepare warfighters for the unprecedented demands that the future holds for them. Finally, we conclude by offering specific recommendations for research and technologies that must be developed in order to meet the challenges ahead.

NAVAL WARFARE FUTURE TRENDS AND DRIVERS

Several critical trends and "drivers" are both explicit and implicit in the aforementioned and other "vision" and "capstone" publications and white papers. They have already shaped and will in the future continue to affect the Navy and Marine Corps' ability to achieve the objectives of the U.S. national security and national military strategies. They include:

- Joint and combined operations with coalition partners that require a thorough and shared understanding of doctrine, operational art, and tactics.

- The shift in focus from open-ocean warfighting against a peer competitor to warfighting in the littorals, confronted with adversaries presenting asymmetrical threats to traditional U.S. naval strengths.

- The emerging concepts of Network-Centric Warfare and Net-Centric Operations that will place significant demands on widely dispersed naval forces closely linked in diverse "grids."

- The inexorable demand for affordability and lowest-possible total ownership costs, which are driving significantly smaller crew sizes in major warships.

The overarching focus of the emerging vision of Joint and combined warfare is one of achieving and sustaining full-spectrum dominance. This will be achieved through the "independent application of dominant maneuver, precision engagement, focused logistics, and full dimensional protection." Full spectrum dominance implies that U.S. forces — either alone or in concert with coalition partners and allies — will be able to conduct prompt, sustained, and synchronized operations with combinations of assets tailored to specific situations and with access to and freedom to operate in all domains — sea, land, air, space, and information. The Services acknowledge that achieving this goal will require the steady infusion of new technologies and modernization, although such technological and material superiority will not alone suffice. More important will be the development of doctrine, organizations, training, and education that will develop and sustain leaders and people who can effectively use the technology and equipment that will enter service in the years ahead.

Success in future crises and conflicts, moreover, will be based upon information superiority, which is much more than the mere accumulation of more or even better information. Superiority in the information domain of war, when translated in superior knowledge and decisions, will provide U.S. forces with a competitive advantage — better decisions arrived at and implemented faster than an opponent can react, at a tempo that allows the force to shape the tactical and operational situation to achieve strategic results. Organizational and doctrinal adaptation, relevant and focused training and experience, and the proper command-and-control mechanisms and tools are critically important. The Joint Force of the future will use superior information and knowledge to achieve decision superiority, to support advanced command-and-control capabilities, and to reach the full potential of dominant maneuver, precision engagement, full dimensional protection, and focused logistics. Rapid and dispersed operations will require highly skilled people who are part of cohesive teams and yet are capable of operating independently to meet the commander's intent. The evolution of information operations and the global information environment may ultimately require a distinct warfare mission area and the appropriately designed organizations and trained specialists. Ensuring future operational success will require an understanding of the emerging nature of organizational collaboration and the compelling demands on the "human in the loop" — particularly the needs for continuous learning and training.

The second of these trends is the result of a renewed emphasis on naval warfare in the littorals. The Navy Department's dramatic sea change in focus from Cold-War "open-ocean, blue-water" operations against the Soviet and Warsaw Pact navies to littoral warfighting does not mean "brown-water" operations. It does, however, mean that naval forces are likely to be committed to crisis and conflict characterized by severe battle space compression (a significantly reduced threat-reaction time), increased ambiguity with respect to contact identification and intent, extreme time pressure and increasing levels of information overload in operations relatively close to shore, against adversaries who will emphasize "asymmetrical" strategies, tactics, and weapons (e.g., mine warfare) that directly attack U.S. strategies and concepts of operations. Already, U.S. Navy battle groups and

Navy-Marine Corps amphibious ready groups are deployed to coastal regions, where they operate for extended periods of time, over the horizon, some 25-100 nautical miles offshore, and usually in a Joint and increasingly in a combined (multinational) force. The 1999 Operation Allied Force — a 79-day crisis/conflict operation against Yugoslav forces — may serve as a model for future littoral warfare campaigns.

There are two predictable outcomes of this littoral warfare trend. First, due to compression of the battlespace, decision-makers will have less time to react to threats. Thus, decision-makers will be forced to gather, process, integrate, interpret and use more information in a shorter period of time. Second, ambiguity with respect to target identification and intent will be increased. Essentially, it will be increasingly difficult to sort out the tactical picture inasmuch as any contact can represent a potential threat. Moreover, the existence of asymmetric threats means that crews will need to maintain vigilance, and deal with a wider range of cues before responding. It is also likely that the range of missions faced by the battle group will be more varied — from humanitarian support and non-combatant operations to full-scale combat. Crews will be required to cope with changing demands with little or no impact on operational and personnel tempo mandates. Further, new missions—such as land attack in the case of the new DD21 Land-Attack Destroyer—will need to be conducted along with more traditional ones. Consequently, we will need decision-makers that can maintain accurate situational awareness, make rapid decisions, adapt to new situations and cope with ambiguity to an even greater degree than they do today.

A third principal trend in warfare is the movement toward "network-centric" operations, which is itself a response to three inescapable military trends that shape future operational capabilities:

- A shift in emphasis toward Joint, effects-based combat
- An increasing reliance on better knowledge of adversaries
- Increasing use of off-board sensors to dominate the envelope management battle and overcome concealment, and deception, and enable our use of remote fires

The Naval War College has described the Network Centric Operations concept as the emerging theory of war for the information age, and is postulating it as the organizing principal for future naval forces. More about human and organizational behavior than simply technology, Network Centric Operations will use information technology to network warfighters. Network Centric Operations can be broadly described as deriving power from the rapid and robust networking of well-informed, geographically dispersed warfighters. They create overpowering tempo and a precise, agile style of maneuver warfare. Using effects-based operations, the aim is to sustain access and to decisively impact events ashore. Network Centric Operations focus on operational and tactical warfare, but they impact all levels of military activity from the tactical to the strategic.

Network Centric Operations pair networking and information technology with effects-based operations to achieve the full potential of Network Centric Warfare. Effects-based operations executed by a sensor-rich, networked force give the nation's naval forces the ability to "lock out" enemy options and "lock in" our own success. The underlying theme of Network Centric Operations is that fundamental changes in the value and use of information can dramatically improve our ability to produce an Information and Knowledge Advantage. This goal is not new. Information and knowledge have always been crucial, but Network Centric Operations couple technological innovations with new warfighting concepts to dramatically enhance our ability to exploit them for decisive success. Information and Knowledge Advantage expands the doctrinal idea of information superiority to include not only current, and often real-time, battlespace information, but also a rich foundation of regional knowledge of the adversary's operational history, doctrine, culture, and mindset. This change is also essential if effects-based operations are to reach beyond merely destroying targets. These operations demand knowledge of how an enemy operates and what he values, allowing the force to focus on those critical areas that provide maximum impact. Network Centric Operations will also depend on a decentralized command philosophy. Tactical units will be able to self-synchronize their actions and will require less direct tasking from higher authority. Because critical information (including commander's intent) will be widely shared, units will be able and expected to act with greater independence.

No matter how Net-Centric Operations are defined in the future, they will place unique demands on human operators. These include the requirement for teams who are physically dispersed to quickly constitute in response to a mission, and then rapidly share information, coordinate, and make decisions. Such coordinated behavior requires team members to hold shared situational awareness—a state that is more difficult to maintain when team members are distributed (Gualtieri, et al. 1998). This type of warfare also demands new training paradigms, where team members can be easily linked, can practice critical missions and tasks, and quickly receive feedback, even across vast distances.

Likewise, the focus on effects-based warfare has particular implications for human performance requirements. First, if naval forces are going to affect the beliefs of an adversary, it suggests that we understand him—his culture, politics, value system, religion, world view, and the like to a greater degree than we do today. The concept of a "knowledgeable warfighter" has been raised to capture this notion. Specifically, the Navy and Marine Corps will need to develop and nurture regional experts in various parts of the world, and then use these experts to advise traditional strategic and tactical planning—a requirement explicitly called out in *Joint Vision 2020.* At a minimum, our "red cells" will need to be better and more fully informed about how the enemy thinks and how he can be induced to change those beliefs. If such a vision is to be a reality, new mechanisms to provide continuing knowledge and manage such knowledge within the naval community must be sought.

A final trend is for increasing demands that 21st century military systems accomplish their goals with significant reductions in total ownership "cradle-to-grave" costs — research and development, acquisition, operational and maintenance/upgrade, and disposal costs. A direct implication of this trend can be seen in efforts to reduce crew sizes on modern combatants. For example, both the DD21 and next-generation aircraft carrier (CVNX) have requirements for significantly smaller crews (Cannon-Bowers, Bost, Hamburger, Crisp, Osga & Perry, 1997). It is clear that fiscal constraints are driving the military to find more efficient and less expensive ways of doing business. Because personnel costs represent a formidable 60% of total ownership costs on the average ship, reducing crews sizes can generate substantial savings. For example, reducing only nine positions from the traditional combat information center could save as much as $1.3 billion dollars throughout the lifecycle of DD21 (Campbell, Cannon-Bowers & Villalonga, 1997).

However, reducing crew sizes will come at a cost in terms of human performance, particularly as the automated systems will be expected to perform all the time, beyond an individual's level of endurance. Thus, the knowledge, skills and attitudes (KSAs) required to perform each task must be well specified. In addition, in a smaller crew the contribution of each crewmember is relatively greater than in a larger crew where redundancy in expertise and endurance can be anticipated. This has several implications for human performance and the management of human resources. First, it will be necessary to understand in detail which crewmembers hold particular competencies. Second, when a crewmember leaves the platform, mechanisms to quickly replace the cadre of knowledge and skill represented by that member must exist. It will no longer be the case that several other crewmembers are "waiting in the wings" to fill that gap. In addition, crewmembers will have to be more adaptable, since they will be expected to confront changing missions. All of these factors suggest that the management of human resources - in terms of knowledge management, detailing, assignment and training—must be enhanced. Finally, in a reduced crew size environment it is likely that crewmembers will not have spare capacity to devote specifically to training. Therefore, training systems will need to be developed that are easy to use, available, meaningful, and engaging, as well as maximally effective. Quality of life issues also dictate that training systems provide sufficient challenge, variety and even enjoyment for trainees. In this future, the Navy and Marine Corps' people will require a multitude of skills and organizational flexibility to apply those skills, a fact-of-life clearly recognized by *Joint Vision 2020.*

In summary, trends in warfare architectures are clearly driving training and human performance needs. (Table 1 shows the predicted human performance drivers that are associated with expected changes in naval warfare in the future.) Clearly the "how we fight" strategic and operational architectures must be built on a clear understanding of their implications for training and management of human resources. This is not meant to be an exhaustive list; instead, we chose to highlight those requirements that are most amenable to training solutions. In addition, there are many other implications of the trends discussed here for hardware, software, policy, and the like, which we will not address. Our focus here is on human performance issues, only.

TRAINING SOLUTIONS

Scenario-Based Training

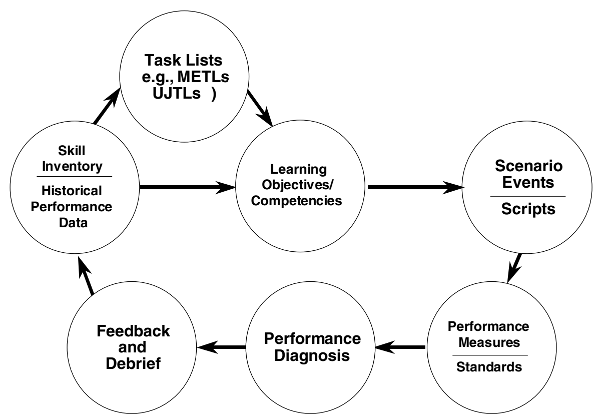
Several of the human performance demands shown in Table 1 are related in one way or another to decision making. Based on several years of research under the Tactical Decision Making Under Stress (TADMUS) program (see Salas & Cannon-Bowers, 1998) as well as other work, several conclusions regarding the manner in which experts make decisions in complex environments are beginning to be drawn. First, evidence suggests that expert decision-makers recognize patterns of cues in the environment that trigger a response (Klein & Zsambok 1997; Cannon-Bowers, Pruitt & Salas, 1996). In fact, it has been argued that experts rely on templates stored in memory that become available based on assessment of a current situation. For example, chess masters appear to have memorized a large number of potential arrays (patterns) of chess pieces. When a familiar pattern appears, the master is able to use his/her knowledge of that pattern to predict several moves ahead in play before making a decision. What is remarkable about this type of performance is how rapid and error free it can be, even though there are literally thousands of potential chess patterns. Obviously, the game of chess is different from warfare in many ways, however, evidence that this pattern-based strategy holds in high performance environments also exists (see Klein, 1997). For example, recognition primed decision making seems to be used by Aegis Commanding Officers, fire ground supervisors, cockpit crews and critical care nurses (Klein & Zsambok, 1997; Cannon-Bowers & Salas, 1998).

Table 1
Requirements for human performance and human systems in future strategic and operational frameworks

1. More rapid decision making in a "knowledge-centric" and "reach-back" environment
2. More flexibility/adaptability—platform level
3. Increased ability to deal with ambiguity
4. Detailed understanding of crew member competencies
5. Rapid replacement of competencies due to rotation
6. More flexibility/adaptability—individual level
7. Better mechanisms for managing human resources (knowledge management)
8. Higher speed learning
9. Higher degrees of shared battlespace (situational) awareness
10. Better distributed teamwork and coordination
11. Better distributed decision making
12. More knowledgeable warfighters

The implication of the research just described is that in order to develop decision makers who can respond quickly and who are able to maintain situational awareness while dealing with ambiguity, they need to be exposed to many instances of the task so that appropriate cue pattern-strategy associations can be developed. Since the actual experience of warfighers will vary significantly, relying only on real-world experience will not insure success. Instead, it seems clear that simulation is a promising mechanism to augment the experience of a warfighter. Using simulation, warfighters can be exposed to many examples of potential situations. However, research also indicates that simple exposure to a task, without appropriate instructional features, will not ensure training success. Instead, a systematic approach is required. One such approach, called scenario-based training (SBT) provides a framework in which to accelerate the proficiency of expert warfighters (Oser et al. 1999). Figure 1 graphically describes the SBT cycle.

Figure 1. Conceptual model for advanced embedded training.



*Oser, et al. 1999. Reproduced with permission from JAI Press Inc.

According to figure 1, SBT begins with careful specification of the tasks that must be performed in support of the mission. Such task lists are typically available (e.g., Navy Mission Essential Task List; Universal Join Task List; etc.). However, delineating tasks is not sufficient as input to an instructional system. Instead, it is crucial to understand what human competencies (i.e., KSAs) are required to accomplish those tasks, and in turn, the learning objectives that flow from them. Learning objectives should specify in detail what *underlies* effective task performance--e.g. what does a person need to know; what skills does he/she need to posses; when are these skills appropriate and so forth. For example, communication skills, which can be defined in various ways depending upon the particular task being trained, may be targeted as an important learning objective for an exercise (there are likely to be several learning objectives for any given exercise, but not so many that it becomes difficult to measure progress on them). Once the learning objectives have been specified, these can be used to aid in the design of the scenario. Specifically, the trainees must be given a chance to practice the skill and to demonstrate whether or not they have mastered it. Therefore, the next step in the process is to script events into the scenario that elicit the targeted behavior (which are consistent with learning objectives).

Once the scenario is scripted, a measurement system must be in place to assess whether the learning objectives have been mastered. This step is often overlooked or oversimplified, but is a crucial step in the training process because it defines specifically the underlying knowledge and skill to be imparted by training, and how these will be measured. It also provides a basis for diagnosis. In training, it is imperative to determine not only *whether* appropriate performance was exhibited, but also *why* it was (or was not) exhibited. It is only when such information is available that appropriate feedback can be provided. Hence, it is as important to measure the process by which decisions are made, as it is to measure the outcome of those decisions. For example, a team may reach a correct decision, in spite of poor communication skills. If they are only reinforced for the positive outcome (i.e., the correct decision), they will not attempt to improve communication in future exercises. Eventually, such poor communication could be the cause of an error that results in a bad outcome some time in the future. Hence, the goal of training should be to provide the decision-maker with a repertoire of effective templates and strategies which, over time, result in the best outcomes.

Given that a measurement system is in place and is diagnostic, the next step in the process (see Figure 1) is to provide feedback and debrief. As noted, feedback is the mechanism by which trainees improve their performance. Feedback can be given at the individual or team levels. Typically, individual-level feedback pertains to aspects of task performance, while team feedback focuses on the ability of members to work effectively together (Bowers et al. 1998). Feedback can be provided on-line (i.e., while the scenario is being conducted), or given after the exercise in a post-exercise debrief. More will be said about both types of feedback in subsequent sections.

A final step in the SBT process is to carefully document and record the outcome of training. Frequently, this step is omitted, so that information from one training session is not used to structure the next. Ultimately, this practice is wasteful and does not optimize allocation of training resources. Instead, a "deficiency-based" approach, which documents those KSAs that have been successfully demonstrated and those that need further attention, is a more efficient way to structure training. Moreover, keeping detailed records of current crew competencies can aid in preparing new team members. As noted, in smaller crews, the ability to rapidly replace needed KSAs is paramount to the smooth functioning of the platform. This final step in SBT can aid this process and better able senior leaders to manage workforce competencies.

Deployable/Embedded Training

For purposes here, we define deployable training broadly as any training that can be made readily accessible in the operational environment. Embedded training refers more specifically to training that is contained within the platform or weapon system; hence it is a subset of the broader category of deployable training. Turning first to deployable training, it is clear that advances in networking, simulation, software and training technology are combining to make distance learning (i.e., learning that relies on remote or distributed instructional resources) a reality. Clearly, society in general is beginning to embrace web-based instruction as a cost effective means to disseminate knowledge. Likewise, the Department of Defense also has a strong interest in this area, and is sponsoring work in Advanced Distance Learning (ADL) as a means to exploit the potential it offers.

For our purposes, the important feature of deployable training—whether it is piped onto the platform over a network or a stand-alone system—is that it can help to keep warfighters up-to-date on the latest information required for mission effectiveness. As noted, the concept of a knowledgeable warfighter is central to the vision of future naval warfare. Only through easy to use, accessible learning systems will it be possible to achieve this goal. In fact, the potential for rapidly transferring knowledge to remote forces is virtually unlimited. The challenge is to provide such knowledge in a manner that is *useful* to the warfighter (in terms of quantity, timeliness, and format). Simply “pushing” information to the user is likely to result in overload and confusion; further research is needed to ensure that knowledge dissemination is done properly.

In contrast to more general deployable training, embedded training typically has the more specific goal of training crewmembers to operate a particular system and/or to run exercises for the purpose of team training. Embedded training systems always involve some mechanism for the weapons to be switched off (for obvious safety reasons), while allowing realistic stimuli to be inserted into the system. From a training standpoint, embedded training has several advantages:

1. Embedded training allows crews to "train the way they fight". From a learning standpoint, this is beneficial since trainees can focus on the subtle cues in the environment and not be distracted by superficial differences in fidelity. This is not to say that low-fidelity simulation does not have a place in training; it most certainly does. However, when the purpose of training is fairly advanced--to train higher-order skills in a realistic environment, embedded training is an excellent solution.
2. Embedded training can be used to accelerate proficiency by exposing trainees to many examples of plausible scenarios. For reasons documented above, providing multiple examples of cue patterns and consequences can help to augment a warfighter's experience and speed his/her path to expertise. However, if this potential benefit of embedded training is to be realized, it presumes a scenario generation capability that allows local personnel to quickly and easily develop new scenarios (consistent with a systematic process such as SBT described above). Without such capability, embedded training will fall short of its ability to support the development of expertise (especially flexibility) in warfighters.
3. Embedded training, if properly equipped, can be used to rapidly bring new crewmembers up to speed. Again, when the contribution of each crewmember is high, mechanisms to tailor and individualize training for that member are imperative. With appropriate instructional features, embedded training can be tailored to the trainee's needs.
4. Embedded training increases accessibility to training. For all of the reasons previously noted, this is an important consideration for future systems since the speed at which operators can learn is crucial success factor in the complex environment we expect. However, if embedded training is difficult or time consuming to use, burdens the crew, or takes personnel away from their already busy jobs, it will be ineffective. On the contrary, future training systems must not only be realistic and challenging (even fun), they must also be *easy to use*.
5. Embedded training can support both on-line assessment and feedback. As suggested above, there are occasions when quick, corrective feedback is most useful for learning. For example, if an operator is suboptimizing use of his/her console, intelligent keystroke analysis routines can immediately provide feedback to that effect. In such cases, waiting until a post -exercise debrief may be too long since the operator cannot remember the particular keystroke sequences he/she was using at any particular point. Therefore, providing rapid feedback would be justified in this case. Once again, this ability presumes that intelligent algorithms exist to support performance measurement and the choice of feedback. The ability to develop such algorithms is moving ahead, but further effort is required if truly intelligent embedded training is to become a reality.

Continuous Learning Environments

Developing viable deployable and embedded training systems is one step toward achieving a continuous learning environment, but only represents a part of the challenge. A *continuous learning environment* is defined as one in which the organization trains continuously and naturally, consistent with a culture of continuous improvement (Tannenbaum et al. 1998). In a continuous learning environment, training is not seen as an event; rather it is a natural part of every experience, evolution and episode of performance. In some cases, formal training is not available and "learning by doing" becomes the only mechanism for improvement. For example, underway replenishments are not typically practiced by the crew. Therefore, when they occur, they should be seen as occasions for improvement. In other cases, like combat team performance, formal training can be augmented by using actual evolutions as a basis for team debrief and feedback.

In order to implement a continuous learning environment, several elements are needed. First, research suggests that a "climate for learning" is a key enabler of continuous learning (Tannenbaum et al. 1998; Bowers et al. 1998). Such a climate is characterized by: a) agreement on the part of team leaders and team members that improving continuously is a valued activity; b) tolerance for mistakes as long as they are treated as an opportunity to improve and are corrected; and c) willingness on the part of team leaders to admit to, and discuss their own errors when appropriate. These factors have been associated with more constructive debriefing sessions, and ultimately, improved performance.

A second element that enables continuous learning is the setting of goals (or learning objectives) for performance evolutions. For example, when a team is about to navigate out of a difficult channel, the Commanding Officer could set specific goals for the team (in terms of time, accuracy, or the like). Once set, research has shown that such goals are extremely motivating to team members (Locke & Latham, 1990).

A third element for continuous learning is measurement--it is impossible to know whether or not a team is improving without continuous assessment of performance. During the evolution, performance on key objectives (goals) must be tracked and recorded so that it is clear whether the team reached its goals. As with the SBT approach, measurements must be developed based on the specific goal set prior to the evolution.

A final element in continuous learning is (again) targeted feedback. Targeted feedback alerts team members to performance problems and helps them to understand how to remedy these in future performance.

Recently, navy researchers have been perfecting a team feedback technique called guided team self-correction (this technique has also been called Team Dimensional Training; see Smith-Jentsch, 1998). Briefly, this is a technique that trains team leaders, instructors and team members the appropriate way to observe and correct their own errors. When properly implemented, team self-correction can be a powerful means for team members--who are in an excellent position to assess their own team's performance--to take control of their own learning process. In fact, on going research suggests that team self-correction has applicability to a wide variety of military tasks. Overall, team self-correction represents one mechanism to implement continuous learning in operational environments.

Distributed Training

A final vision for future training involves training distributed teams. In order to understand the challenges presented by this, it might be fruitful to consider what we know about any high performance team (i.e., whether or not they are co-located). First, it has been shown that individual proficiency is a necessary, but not a sufficient condition for effective team performance (Salas et al. 1999). Instead, optimal team performance requires that members hold specific teamwork KSAs to augment their task competency. Second, we know that in high stress environments, effective teams often rely on implicit coordination strategies. Implicit coordination refers to team members' ability to execute coordinated behavior without having to communicate or discuss it. For example, the no-look or blind pass in basketball is considered an example of implicit coordination. In this case, two team members are assessing cues in their environment (the configuration of players, time left on the clock, importance of the game, etc.) and *predicting* what their teammates will do. Likewise, in any combat situation, team members need to accurately predict the information needs of their teammates and provide such information without being asked.

The ability to predict teammates' needs rests on two factors: *shared* knowledge among team members and adequate knowledge of teammates. Shared knowledge refers to task and team-related knowledge that team members have that enables them to anticipate the needs of teammates (Cannon-Bowers et al. 1993). It enables team members to reach similar assessments of critical cues and to arrive at what has become known as shared situational awareness or shared battle space awareness. Shared knowledge typically develops over time as team members become more familiar with the task environment and demands of the job. In fact, researchers have studied a concept called "interpositional knowledge", which is particularly important in tasks where there are high degrees of role specialization and task interdependence among team members. In such cases, team members are more effective when they understand the task demand on other team members.

The second factor, adequate knowledge of teammates, refers to the familiarity that team members have of one another's strengths, preferences, styles, etc. For example, knowing that a team leader expects information in a certain format saves time in stressful situations. It has been shown that teams in which members have high degrees of teammate knowledge are more effective than teams where such knowledge is low (Smith-Jentsch et al. 2000).

Several training strategies have been shown to help foster shared knowledge and teammate knowledge in teams (e.g., guided team self-correction; team leader training, cross training; see Cannon-Bowers & Salas, 1998). A driving question becomes then, what happens to shared and teammate knowledge development when team members are physically dispersed? Furthermore, what mechanisms exist that will allow team members in separate environments (who come from different backgrounds and may never have worked together before) to achieve rapid shared battle space awareness? Unfortunately, not much research has been conducted on this important question. It is likely, however, that the development of shared knowledge and teammate knowledge will be more difficult when team members are separated. To address this problem, our best recommendation for training in such cases would be to attempt to make use of all of the factors we have discussed: a systematic approach to scenario-based training with maximal exposure to exercises; abundant access to easy to use, organic training systems; and a culture that supports continuous learning. In addition, features such as distributed debriefing systems and distributed performance assessment systems are needed.

REQUIRED SCIENCE & TECHNOLOGY INVESTMENTS

There are a number of areas related to human performance and training that require further investment if the goals of future naval warfare are to be reached. These include:

- Distributed team decision making—we need to better understand the mechanisms of team decision making when members are physically dispersed. This includes understanding how shared battlespace awareness is quickly achieved and maintained, as well as procedures for assessing performance and providing feedback over the network.
- Intelligent tutoring—technology for providing instructorless training (i.e., that uses intelligent software to measure, diagnose and remediate performance) must be further developed. Any attempt to provide widespread distance learning requires this capability.
- Human performance modeling—the ability to model expert decision making processes is a key enabler for developing intelligent training and decision support systems. For example, accurate models will help us determine when and where information is needed to support decision-making. Progress in this area is being made, but further advances are required.
- Computer generated forces—if meaningful SBT is to be achieved, then realistic, intelligent adversaries and teammates must be developed. Only when warfighters are able to practice against realistic computer generated forces will the full potential of simulation be reached.
- Advanced distance learning—it is easy to "jump on the bandwagon" of ADL; however, to make it truly useful to warfighters, we need to better understand this emerging capability. Research is required to determine how best to optimize learning opportunities over the network.

CONCLUSIONS

It is clear that the vision for future naval warfare has significant implications for human performance and training. In this paper we have attempted to highlight a few of the many training technologies that may provide solutions. It is hoped that as we move to achieve the goals of the future force, that interest and investment in human performance and training grow as a means to help meet the challenges of the 21st century.

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