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Cognitive Readiness

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PREFACE

This study was conducted for Office of the Deputy Under Secretary of Defense for Science and Technology (ODUSD(S&T)) under the "Cognitive Readiness" task. Technical cognizance for this task was assigned to Dr. Robert Foster, Director for BioSystems, ODUSD(S&T).

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EXECUTIVE SUMMARY

The following working definition of cognitive readiness is used in this paper:

> *Cognitive readiness* is the mental preparation (including skills, knowledge, abilities, motivations, and personal dispositions) an individual needs to establish and sustain competent performance in the complex and unpredictable environment of modern military operations.

The concept of cognitive readiness may be of special relevance and significance for those who must adapt quickly to rapidly emerging, unforeseen challenges. Both individuals and units can be prepared to perform many of the essential tasks that are anticipated as necessary for accomplishing the missions assigned to them. However, their readiness to acquire the additional capabilities needed to meet the unexpected, unforeseen challenges that inevitably arise in today's uncertain operational environment will contribute substantially to the success of their operations. Such readiness is a cognitive capability, which can be found and measured to an appreciable extent in both individuals and units.

We identified 10 psychological components or theoretical mechanisms underlying the concept of cognitive readiness. We reviewed the research literature to determine the extent to which each component can be enhanced by instruction and then assessed. These components and research findings concerning their trainability are

- **Situation awareness.** Situation awareness is generally defined as the ability to perceive oneself in relation to the enemy and the environment. Situation awareness has been shown to improve with practice and instructional feedback.
- **Memory.** Memory is described as an active, reconstructive process supported by two underlying theoretical mechanisms: encoding specificity, which stresses the importance of external and internal cues, and transfer-appropriate processing, which stresses actions performed during encoding and retrieval. Tradeoffs exist between instruction used to enhance the retention and speed of initial acquisition. Conditions of learning, particularly those providing over-learning, can be designed to enhance retention.
- **Transfer of training.** Transfer of training is described as the ability to apply what is learned in one performance context to another performance context. Massive amounts of practice with feedback will enhance "low-road" transfer

requiring little cognitive mediation. Training in forming mindful, conscious abstraction will enhance "high-road" transfer, which requires cognitive mediation.

- **Metacognition.** Metacognition refers to the executive functions of thought, particularly those pertaining to knowledge and regulation of one's cognitive processes and progress toward accepted goals. Metacognitive skills can be enhanced by exercises designed to increase the awareness of self-regulatory processes.
- **Automaticity.** Automaticity refers to processes that are performed rapidly, requiring few attentional resources. Practice with feedback and overlearning can produce automatic processing in many tasks.
- **Problem solving.** Problem solving transforms goals and subgoals into a plan of action by processes such as trial-and-error, proximity, fractionation, and knowledge-based referrals. Techniques for problem solving matched to goal and situation categories can be successfully taught, as can the information base needed for "strong" problem-solving methods, which depend on acquired knowledge.
- **Decision-making.** Decision-making is described as the selection of tactical and strategic plans, which are frequently primed by the recognition of learned patterns. Formal instruction in decision-making techniques may improve the quality of decisions, but some aspects of successful decision-making are determined by individual dispositions.
- **Mental flexibility and creativity.** Mental flexibility and creativity can be cast as problem-solving—applying "strong" methods (based on acquired knowledge and skills) to well-defined, structured tasks and applying "weak" methods to poorly defined, ill-structured, chaotic tasks. Creativity may be more closely associated with the "weak" methods. The research is unclear as to whether these weak methods can be trained directly. It seems more likely that native abilities determine the facility with which people apply appropriate weak methods (i.e., achieve "creative solutions") to novel situations.
- **Leadership.** Leadership appears to consist of motivational patterns and a combination of technical, conceptual, and interpersonal skills, the last being the most difficult to acquire and measure. However, technical and conceptual skills needed by leaders can, to an appreciable extent, be taught. Interpersonal skills and patterns of motivation required for leadership appear to be more dependent on native abilities and are thus more difficult to teach.
- **Emotion.** Emotion must be channeled and controlled if military personnel are to perform complex tasks under the stress and confusion that accompany modern military operations. Deeply engaging, sensory immersing simulations

provide promise for training warfighters to retain critical pieces of information and to perform under highly stressful conditions.

This brief review is intended to continue and motivate discussion of cognitive readiness, not conclude it. It suggests that cognitive readiness is a tractable, measurable, and relevant construct that can and should be included in assessments of readiness. Relevant findings and suggestions are available from behavioral research and, if focused on the issue of cognitive readiness, can be used to elaborate the concept, develop methods to train and measure it, and help ensure its availability for military operations.

I. INTRODUCTION

"Cognitive readiness" is a concept that occasionally receives attention and concern from the U.S. defense community. This paper is intended to continue and motivate discussion of this concept, which we suggest is significant and worthy of careful consideration. In this paper, we briefly discuss this concept and assess its relevance, value, and feasibility as a goal for military training and as a practicable component of measured readiness. We identify and review some basic concepts underlying cognitive readiness and then describe research findings that suggest how these concepts apply to readiness assessment and training. We finish by discussing research needs and opportunities for implementing the concept of cognitive readiness to enhance operational effectiveness.

A. READINESS vs. EFFECTIVENESS

Cognitive performance is a significant matter for readiness and effectiveness. It may be best to begin by contrasting the concepts of readiness and effectiveness. *Effectiveness* refers to the summative evaluation of a unit or an individual performing a military operation. It is usually measured as performance on some outcome or outcomes associated with mission (especially combat mission) success. *Readiness*, in contrast, refers to the **potential** of units or individuals to perform well in combat or in other military operations. It is usually measured by assessing a subset of hypothetical elements or components of effectiveness. Thus, readiness represents an estimate or prediction of effectiveness.

Clearly, effectiveness is a more direct measure of operational competence. However, reliable measures of effectiveness are only available after the fact—after the operation the unit was intended to perform has been carried out. Further, the unique circumstances of every engagement limit the information these measures can provide about overall unit effectiveness. Assessments of field performance at live simulation centers provide surrogate measures of effectiveness, but such measures are expensive to obtain and limited in the range of operational environments they cover. Assessments of performance in constructive and virtual simulations complement those obtained from the field, are less expensive to obtain (e.g., Orlansky et al. 1996), and allow measurement of some capabilities that cannot be obtained in the field; however, their relationship to operational effectiveness is indirect. Readiness measures provide additional, practicable options for assessing unit capability, preparation, and likely mission performance.

Readiness measures may be superior to effectiveness measures obtained from real-world operations in terms of their diagnostic value. Conventional readiness measures are divided into logical components of performance. Effectiveness measures, in contrast, are often presented as global assessments of unit success. The componential and analytic nature of readiness measures makes possible the diagnosis of specific deficiencies in unit or individual performance.

Based on these considerations, measures of cognitive readiness should be practical and feasible to obtain, predictive of success across a full range of likely missions, and sufficiently multidimensional to be diagnostic.

B. UNIT READINESS

Presently, all U.S. military units, regardless of Service, are periodically evaluated for combat readiness. Overall unit readiness (C) is defined as the lowest rating that the unit receives on four major components: personnel (P), equipment on hand (S), equipment serviceability (R), and training (T). Each of these component measures is based on a set of data elements. For instance, the S-rating is based partly on the quantity of reportable equipment listed in the unit's property book.

Two components (P and T) of the overall readiness measure relate directly to individual performance and training. The P-rating provides objective data on assigned personnel, including the percent of service members who are qualified in their military occupation specialty (MOS) and who have attained the skill level required by their present duties. This component provides a rough estimate of certified competencies possessed by individuals assigned to a unit. The T-rating reflects training resources available to the unit and the training events it has completed. An example of the various data elements included in the T-rating reports is the availability of training resources, such as ranges, facilities, aids, devices, simulations, and simulators. P and T elements are both rated on a four-point scale and indicate the impact that resource constraints may have on unit readiness.

Although some components of the existing readiness measures assess (at least indirectly) the knowledge state of unit members, the data are aggregated at the unit level and therefore provide limited information on individual service personnel. The measures do not directly assess the cognitive skills and abilities that underlie the performance of individuals and their units.

C. DEFINITION OF COGNITIVE READINESS

In developing the concept of cognitive readiness, writers have emphasized the requirement to perform in the modern battlespace, which is characterized as complex, dynamic, and resource limited (Etter, Foster, and Steele 2000). The implication is that individual Service members must be mentally prepared to sustain performance while facing combat stressors such as information overload, information uncertainty, social isolation, fatigue, physical discomfort, and danger. This environment requires more than simple endurance. It requires the individual to be flexible, and even creative, in responding to the challenges presented by the surrounding chaos of military operations.

As implied by the adjective "cognitive," the primary factors that determine cognitive readiness are psychological in nature. This is not to deny that other factors, such as sociological and health variables, can affect cognitive readiness. However, we regard such variables as catalysts that facilitate or inhibit cognitive readiness, rather than primary factors. At the same time, these psychological factors are not limited to those directly associated with traditional cognitive (i.e., intellectual) variables, but include other factors, such as personality and disposition, motivation and emotion, and beliefs and attitudes.

Given this background, we provide the following working definition:

> *Cognitive readiness* is the mental preparation (including skills, knowledge, abilities, motivations, and personal dispositions) an individual needs to establish and sustain competent performance in the complex and unpredictable environment of modern military operations.

The concept of cognitive readiness may be of special relevance and significance for those who must adapt quickly to rapidly emerging, unforeseen challenges. In the ordinary course of training, both individuals and units can be prepared to perform many of the essential tasks that are anticipated as necessary for accomplishing the missions to which they may be assigned. Such preparation can be accomplished and assessed in advance of specific operations. However, the readiness of individuals and units to acquire the additional capabilities needed to meet the unexpected, unforeseen challenges that inevitably arise in today's asymmetric operational environments remains an essential component of their preparation. Their readiness to rise to these challenges will contribute substantially to the success of their operations. Readiness of this sort concerns their ability to expect the unexpected and be ready to deal with it rapidly and successfully. Metrics for readiness of this sort are necessarily keyed to more abstract capabilities than those that are now included in readiness assessments. Nonetheless, they may be as important to operational effectiveness as those now being considered. This paper suggest that the current state of the art allows them to be identified, acquired, and measured to an appreciable extent for readiness assessments of both individuals and units. It also suggests that if this can be done, serious consideration should be given to deciding if it should be done.

II. COMPONENTS OF COGNITIVE READINESS

Given our operational definition of cognitive readiness, we can now turn to psychological mechanisms that may comprise it. Our intent is to reduce the general notion of cognitive readiness to more specific components in order to identify methods for measuring and enhancing the construct, providing training for it, and assessing its value as a readiness measure. The following review focuses on research that suggests new and nontraditional approaches for enhancing readiness through more thorough consideration of human cognition. These approaches emphasize the capabilities of cognitive readiness to bring new concepts to bear on the problem of measuring and enhancing operational readiness.

A. SITUATION AWARENESS

Situation awareness is a relatively new concept in military performance and is generally defined as the ability to see and understand oneself in relationship to the enemy and the environment. Endsley (1988) provided a more detailed, three-level definition of situation awareness as (1) the perception of elements in the environment within a volume of time and space, (2) the comprehension of their meaning, and (3) the projection of their status in the near future. Among the complex behaviors and processes involved in cognition, situation awareness represents the initial perceptual analyses that precede decision and action.

Much of the situation-awareness literature has been devoted to the design of appropriate displays and interfaces intended to enhance an individual's situation awareness. In that regard, Endsley (1998) proposed that designers perform a structured analysis to determine the functional requirements of situation awareness at all three levels, including the basic data needed, the integration of the data in order to understand the system state in light of goals, and the projection of the data as future trends and events.

Although situation awareness has implications for system design, awareness is a product of human perception and cognition—not just a hardware/software capability, as implied by some system developers. In that regard, Endsley (1998) reviewed several procedures for measuring the situation awareness of performers. The one he favored requires that a battle scenario be periodically stopped (presumably, this is a simulated engagement that permits such interruptions) in order to quiz participants on the location of battlespace elements, their meaning, and likely courses of action (COAs) in the near future. The participants' responses can be compared with ground truth to provide an objective measure of awareness. Endsley concluded that this approach to measuring situation awareness has content and predictive validity.

The fact that such performance measures exist suggests that situation awareness may be a trainable skill. According to most models, repeated practice and feedback on the situation awareness task implicit in the measurement process described above should improve subsequent decisions and actions. The extent to which such training generalizes to the full range of military operations is an issue for future research.

B. MEMORY AND TRANSFER OF TRAINING

Memory and transfer of training are two processes that are central to cognition and individual performance. Research on these processes dates back before the turn of the previous century. For instance, Ebbinghaus (1885/1913) established the basic finding that training beyond established standards of performance (i.e., overlearning) enhances long-term retention in memory. More recent reviews of the literature confirm that overlearning is the most potent variable in long-term memory performance (Gardlin and Sitterley, 1972; Hagman and Rose, 1983; Schendel, Shields, and Katz, 1978).

The following brief review identifies some modern research on memory and transfer of training to highlight their application to cognitive readiness. As discussed below, memory and transfer of training have similar implications for cognitive readiness.

1. Memory

The modern concept of the nonlinear battlespace emphasizes the unpredictability of battle conditions. The chaotic nature of battle all but ensures that the conditions under which individuals learn tasks will differ from the conditions under which they must perform them. This is important because research clearly suggests that memory may fail under conditions where learning and recall conditions are dissimilar. Two theoretical mechanisms are commonly advanced to explain this phenomenon:

- **Encoding specificity hypothesis.** This hypothesis, initially advanced by Tulving and Thomson (1973), states that memory is best when the conditions of memory retrieval are congruent with the conditions of original learning. Seemingly irrelevant changes in learning conditions, such as changes in location or environment, can have a negative effect on recall performance.

- **Transfer-appropriate processing.** Memory performance increases as the match between the processes of encoding and the processes of retrieval increases (Morris, Bransford, and Franks 1977). This concept is very similar to the encoding specificity hypothesis; however, while the encoding specificity hypothesis stresses the role of external and internal cues, the transfer-appropriate processing stresses the processes or actions that the learner performs during memory encoding and retrieval.

Both theories predict that memory will likely fail if conditions at recall do not match those at original learning. To prevent such memory failures, Druckman and Bjork (1991) offered the following training strategies:

- **Provide contextual interference during training.** Interspersing target tasks with other unrelated tasks during learning or even creating inconsistent cues sets up interference that slows learning but increases transfer and retention.
- **Increase variety and variability in training.** Adding varied examples in verbal learning and variability of practice conditions in motor learning can (again) slow original learning but increase transfer and retention.
- **Reduce augmented feedback.** Although augmented or information feedback increases the original learning of a motor skill, it has a negative effect on transfer and retention. Training must be designed to reduce or eliminate augmented feedback systematically so that performance does not become dependent on this additional source of information.

Although these three strategies appear to be quite different on the surface, all three tap the same underlying mechanism for preventing memory failure—that is, they

> … teach processes that can be called on by a posttraining task at a later time, particularly if the posttraining task and setting differ from the training task and setting. That is, such procedures induce "transfer-appropriate processing" … that result in a more elaborated mental representation of the task—a prepresentation that can, to some extent, be used in a different context. The learner is better prepared, so to speak, not only to perceive the similarities between the training task and the different versions of that task in posttraining contexts, but also better equipped to perform by having achieved the more generalized declarative and procedural knowledge demanded by that category of task (Druckman and Bjork, 1991, p. 47).

Thus, research on memory appears to have specific implications for the context and process of military training. The dilemma is that even though these training strategies have positive effects on skill retention, they often have negative effects on skill acquisition. That is, methods that enhance memory often slow the learning process. The costs and benefits of each approach should be assessed in military training settings to determine if its beneficial effects on retention compensate for the extent to which it may prolong initial learning.

2. Transfer of Training

Transfer of training refers to the ability to apply what is learned in one context to some other context. In military training, the initial learning context is usually some form of classroom instruction or simulation training, whereas the criterion context may be a field exercise or actual combat.

Salomon and Perkins (1989) suggested that there are two qualitatively different types of transfer of training processes, which they called low-road and high-road transfer.

a. Low-Road Transfer

Low-road transfer is the form that most trainers would recognize as "typical" transfer of training. The defining characteristic of low-road transfer is that it occurs automatically (i.e., without conscious thought or mediation by internal or external representations). This form of transfer occurs as the direct result of large amounts of practice. One negative aspect is that overlearning the original task may restrict the range of transferred skills. However, low-road transfer can lead to generalizable and flexible skills if the original learning takes place in a variety of contexts. In general, skills acquired through low-road transfer are gained through a gradual, incremental process instead of sudden, discontinuous gains or "jumps" in performance.

Certain military skills can and should be acquired through low-road transfer. These skills include fundamental procedures that must be performed quickly and do not require conscious control. Examples include basic skills related to gunnery, vehicle control, and aircraft maneuvering. Many of these skills are currently trained via simulators that are designed to provide massive amounts of practice and feedback at relatively low cost.

b. High-Road Transfer

In some ways, high-road transfer of training is the reverse of low-road transfer. Whereas low-road transfer is automatic and reflexive, high-road transfer requires conscious control. Also, low-road transfer does not require an internal or external representation of the to-be-transferred skill. In contrast, high-road transfer requires the learner to decontextualize and re-represent the original information in a more general form that subsumes cases other than those experienced in training. The process through which this decontextualization occurs is called “mindful abstraction.” This process of abstraction can occur either during original learning or at memory retrieval during the transfer task. Although this process has the potential to increase the amount and range of transfer, it may, like approaches that enhance memory retention, slow the original training process.

Although low-road transfer of training is required for performance of many essential military skills, high-road transfer is necessary to achieve the levels of flexibility implied by the cognitive readiness concept. The problem is that the processes through which high-road transfer is promoted or achieved (e.g., “mindful abstraction”) are not well defined and, therefore, are difficult to train. In a follow-on article, Perkins and Salomon (1992) suggested concrete methods that instructors can use in the classroom. For instance, instructors should make the learning situation more like the criterion situations to which transfer is desired in order to help students “bridge” from specific contexts to more general conceptualizations that enhance high-road transfer. Such pedagogical examples offer promise that the concept of high-road transfer can be applied to military training and education.

C. METACOGNITION

Metacognition refers to the executive functions of cognition, particularly those pertaining to knowledge and regulation of one’s cognitive processes. A highly developed metacognitive competence is the capacity to bring an automated (unconscious) skill under conscious cognitive control. In other words, people should be aware of their own cognitive processes during task performance. Brown (1987) maintained that this self-awareness of internal routines is the highest form of human intelligence. With reference to the relevance of metacognition for education, Hacker (2001) stated that “… the promise of metacognitive theory is that it focuses precisely on those characteristics of thinking that can contribute to students’ awareness and understanding of being self-regulatory organisms, that is, of being agents of their own thinking” (p. 50).

As initially conceived by John Flavell (1976), metacognition was thought to be a set of age-dependent competencies that arise at certain stages of development. Soon after the introduction of the concept, researchers began to question whether the development of metacognitive skills could be enhanced through instruction. The answer appears to be “yes.” For instance, Palincsar and Brown (1984) reported that metacognitive skills can be trained through the use of reflective questioning (e.g., What just happened in the last paragraph?) and group collaboration while teaching reading to school children. Schoenfeld

(1987) demonstrated similar results while using reflective questioning (e.g., Does that answer make sense?) to teach mathematics to schoolchildren.

There are numerous lists of metacognitive skills (e.g., Hacker, 2001). Among the many metacognitive skills that have been identified, the following seem especially pertinent to the military concept of cognitive readiness:

- **Self-monitoring and assessment.** The ability to monitor and manage one's own thinking and actions.
- **Focusing on essentials of tasks.** The ability to filter out irrelevancies and direct attention to variables that affect performance.
- **Planning.** The ability to understand task goals and devise an appropriate plan of action.
- **Using strategies.** The ability to evaluate individual COAs in terms of their consequences. (Strategies here refer to schemes for individual action, not to plans for military operations.)

From these descriptions, one would assume that such skills are characteristic of high-performing military personnel. Further, research suggests that components of metacognition can be enhanced by education in the K–12 context. Unfortunately, there has been practically no research on the trainability of metacognition in the context of military education and training. Thus, while metacognition appears to be a desirable component of cognitive readiness, the extent to which it can be trained in military settings remains an open issue.

D. AUTOMATICITY

Conscious, deliberate human information processing is often represented as being slow and demanding continual attention. This view fails to capture the rapid performance of tasks that seem to require little attention, as demonstrated by the fact that such tasks can be performed in parallel with other conscious and effortful tasks. For example, driving or walking can be conducted while simultaneously engaging in more attention-demanding tasks, such as listening, comprehending speech, or even conversing with others.

To account for both kinds of phenomena, Shiffrin and Schneider (1977) proposed that they represent two distinct types of cognitive processing that can occur together and interact. Controlled processes are slow, serial, and require attention. Perhaps the defining feature of controlled processes is that they are subject to conscious monitoring. In contrast, automated processes are fast and require few attentional resources. Again, perhaps the defining feature of these responses is that they are "ballistic"—that is, they are executed from start to finish as a unit with little or no conscious monitoring.

For novel tasks, performance during the early stages of learning is characterized by the predominance of controlled processing. With large amounts of practice (i.e., over-learning), elements of the task that consistently map stimuli onto responses become automated. The mapping schemata are based on categories of stimuli and responses that either pre-exist in the performer's memory (e.g., numbers, nouns, colors) or are "chunked" together through practice. Other aspects that are not consistently mapped remain under consciously controlled processes. For most complex tasks that have aspects of both consistent and variable mapping, expert performance is characterized as a combination of automatic and controlled processing.

Automated processing (or automaticity) is commonly measured using one of two general methods. The first is the dual-task method, where the performer is asked to perform a primary task (the one being measured) simultaneously with a relatively easy secondary task. Examples of secondary tasks include shadowing or repeating a word stream presented over headphones and finger tapping when a designated signal is presented along with other distractors. Dual-task performance is then compared with performance of the secondary task alone (single-task condition). If the primary task is under controlled processing, performance of the secondary task suffers under dual-task conditions because both tasks compete for a limited pool of attentional resources. On the other hand, if the primary task is automated, secondary task performance under dual-task conditions will be close or equal to single-task performance because the primary task requires little or no attentional resources. A consistent finding from dual-task studies is that performance on the secondary task decreases as the difficulty of the primary task increases (e.g., Allport, Antonis, and Reynolds, 1972).

The second method for measuring automated processing is in the context of visual or memory search tasks. In this paradigm, the subject is trained on a set of target items. He or she is then given a display set of items that include both targets and distractors and is required to identify the target. Targets and distractors are related according to one of two paradigms. In the consistent mapping paradigm, targets and distractors are drawn from different types or categories (e.g., numbers and letters) that do not overlap. In the varied mapping paradigm, the two types overlap, with targets being distractors on some trials and vice versa. The classic Sternberg paradigm is a varied mapping task. His results showed response time to be a linear function of target set size, suggesting an underlying serial control process (Sternberg, 1966). Studies using consistent mapping typically show nonlinear effects of set size that become essentially flat after practice (e.g., Schneider and Shiffrin, 1977), suggesting that, with practice, processing becomes automatic and requires little or no attentional resources.

Automaticity has a complex effect on transfer of training. For low-road transfer, where the learning task can be consistently mapped onto the transfer task, the development of automaticity enhances transfer. However, when the original task cannot be consistently mapped onto the transfer task, automaticity can retard transfer. For instance, Fisk, Lee, and Rogers (1991) provided subjects with practice on targets and distractors in a visual search task and then reversed them (i.e., old targets became distractors and old distractors became targets). Results demonstrated that once responses to stimuli have become automated, changes to the stimuli had a negative effect on performance.

E. PROBLEM SOLVING AND DECISION-MAKING

Like memory and transfer of training, problem solving and decision-making are closely related areas of research that have similar implications for cognitive readiness.

1. Problem Solving

The 1960s and 1970s were seminal in advancing the scientific study of problem solving. Miller, Galanter, and Pribram (1960) demonstrated that problem solving can be cast as an analysis of task goals and subgoals. Newell and Simon (1972) showed how means-ends analyses can be used to transform this analysis into a plan of action. Since then, several researchers have sought to use models developed by theoreticians to derive study strategies and educational practices that are intended to improve thinking skills. For instance, Hayes (1981) enumerated four methods for searching for problem solutions that can be used in a variety of situations:

1. **Trial-and-error.** This method entails searching through alternative solutions, with no a priori information on the likelihood of the solutions' success. This method is effective only in situations with relatively small problem spaces.
2. **Proximity.** The trial-and-error method does not require the problem solver to "look ahead." Proximity methods are an incremental improvement in that they involve looking exactly one step ahead in the process. The problem solver determines whether each step takes him or her closer to the desired solution.
3. **Fractionation.** Problem solvers use this method when they divide a problem into a sequence of smaller steps or subgoals.

4. **Knowledge-based methods.** This method includes a wide range of techniques that are based on the problem solver's prior knowledge of the problem domain.

Hayes referred to the first three problem-solving methods as "weak" methods, which apply across many problem domains. He referred to the last method (knowledge-based) as a "strong" method. Strong methods draw on the extensive portfolio of knowledge, skills, and techniques that professionals develop to conceptualize a specific field of interest. Examples include techniques based on the Periodic Table in chemistry and the harmonic structure of music. There is no question that strong methods must be included in instruction, but there is an ongoing debate concerning whether weak methods can or should be explicitly trained. The next section suggests that weak methods play an important role in creativity and mental flexibility. However, it remains to be seen whether these attributes are inborn characteristics of problem solvers or are skills that can be acquired through education and training.

2. Decision-Making

The military follows a formal model of decision-making to create and implement tactical and strategic plans. Based on economic theories of utility maximization, this method assumes that users are (1) completely informed about all major COAs that apply to a given situation, (2) sensitive to differences that distinguish the COAs, and (3) rational in their choice of COAs so that the plan's utility is maximized (Slovic, Lichtenstein, and Fischoff, 1988). These assumptions are not unreasonable if the planners are given sufficient time to implement the decision-making process. However, the assumptions become increasingly untenable in time-critical situations. For instance, the standard planning and decision-making process worked well for the preparation phase of Operation Desert Storm, but it was not useful once operations were started (Orlansky and Thorpe, 1992; Fallesen, 1995).

Slovic, Lichtenstein, and Fischoff (1988) pointed out that most classic decision-making theories are prescriptive in intent. That is, they identify formal, systematic procedures for selecting COAs that are logically consistent with the user's expectations and goals. Edwards (1977) demonstrated that techniques based on classic decision-making theory are trainable and, under favorable conditions, improve the quality of individual or group decision-making. Such approaches fare less well as descriptive theories of how people make real-world decisions. For instance, Simon (1956) argued that decision-makers do not actually choose COAs by maximizing utility; rather, they choose alternatives by selecting the first alternative that is generally workable, a process that he termed "satisficing."

To address the need for descriptive model of decision-making, Klein (1989) developed a model intended to depict the processes that expert performers actually use to make decisions in real-world situations and under realistic time constraints. According to his model, termed "recognition primed decision-making," a decision-maker initially assesses the situation in an attempt to recognize familiar patterns. Once an alternative is generated from memory, the decision-maker mentally simulates its implementation in the present situation. If the outcome is acceptable, or "satisficing" in Simon's parlance, it is implemented. If the outcome is not acceptable, the decision-maker discards it and either modifies the alternative or generates another alternative from memory.

Research indicates that experienced performers use some form of a recognition-driven decision-making process without explicit instruction to do so. It is not clear, however, that this approach to decision-making is optimal. For instance, Dawes, Faust, and Meehl (1989) reviewed the literature on complex and ambiguous clinical phenomena and found that the diagnoses of experienced clinicians are often inferior to automated diagnoses based on established relationships between observed conditions and outcomes. Further, we do not know if recognition-primed decision-making can be trained directly or if its use can be facilitated through the accretion of experiences that form the basis of the recognition process. Finally, the reliance of this theoretical process on prior experience may be problematic when the decision-maker is faced with a novel situation that requires creative decisions.

Researchers have noted individual differences in decision-making skills and abilities. Some of these individual differences may be caused by education and training. For instance, Nisbett et al. (1987) showed that graduate training in psychology and medicine produced greater improvements in statistical reasoning than did similar training in either law or chemistry. These researchers also demonstrated that relatively brief training on statistical reasoning may improve the quality of everyday decision-making. Other individual differences appear to reflect individual disposition. For example, the quality of decisions is affected by the degree to which individuals seek or avoid risk and their personal aspirations or goals (Markham and Medin, 2002).

F. MENTAL FLEXIBILITY AND CREATIVITY

There is a considerable history of research on mental flexibility and creativity. Unfortunately, this field has not lived up to its promise of yielding insight into complex cognitive processing. In a recent article, Klahr and Simon (2001) provided some needed clarity to this field by translating flexibility and creativity concepts into problem-solving terms. They viewed creativity as requiring the application of both "weak" and "strong" (knowledge-based) methods to the task of discovery, but they suggest that the essence of creativity may be more closely associated with the former "weak" methods than with the latter "strong" methods.

In the context of military training and education, strong methods tap the knowledge and skills that are traditionally taught in military schools. Thus, strong methods refer to the use of specific facts and procedures (e.g., organizational structure, maneuvers in air-to-air combat, surveillance techniques) that apply to a single Service or Branch and to the application of military subjects and techniques across Services and operational situations. Strong methods are important in distinguishing competent military professionals from interested laymen.

Weak methods, on the other hand, can potentially distinguish a competent performer from a creative genius. Klahr and Simon (2001) maintain that weak methods are particularly appropriate for ill-structured problems where the starting state, end state, operators, and/or constraints are not well defined: "The more creative the problem solving, the more primitive the tools. Perhaps this is why such 'childlike' characteristics, such as the propensity to wonder, are so often attributed to creative scientists and artists" (p. 79). Weak methods may be particularly appropriate for the ill-structured problems presented by the chaos of modern military operations.

One interesting example of a weak method taught in military courses is war gaming. This is a general method by which participants think through a proposed solution step-by-step while others who are knowledgeable of threat strategy and tactics (e.g., intelligence officers, weapons specialists) propose countermeasures. War gaming can reveal serious weaknesses in plans and even suggest possible modifications. War gaming itself is easily understood and does not require extensive military training to apply. Furthermore, this technique is generally applicable and has many civilian applications, such as the use of a stand-in to role-play the opponent when preparing for a debate or even the use of the "devil's advocate" position to identify gaps in arguments.

War gaming is an example of a weak method that has been developed in a military context and successfully exported to other problem domains. At the same time, weak methods associated with other problem domains can be used in the military. One such method concerns scientists' reactions to surprise. Klahr and Simon (2001) argued that the hallmark of a creative scientist is the ability to accept, rather than deny, surprising results and use them to explore further the phenomena that produced them. This skill would seem to be the essence of what is meant by "mental flexibility." Military personnel do not usually have an opportunity to "explore" a phenomenon in the scientific sense. Nevertheless, reacting to surprise is clearly a useful military skill. In this context, it could be redefined as the capability to recognize when a situation is not going as expected, to understand the root cause of the problem, and to react accordingly.

In summary, when a situation (usually scientific in nature) is contrived to facilitate the discovery and use of weak methods, research indicates that problem solvers will use these methods and performance will benefit. The research is less clear about whether these methods can be trained directly and later used in representative, uncontrived situations. It seems likely that the facility with which people apply appropriate weak methods (i.e., achieve "creative solutions") to novel situations is determined, at least in part, by a set of native abilities, such as curiosity, propensity to wonder, and so forth.

G. LEADERSHIP

There is a long and multifaceted history of behavioral research on leadership. Van Fleet (1996) identified over 4,000 references related to the specific topic of military leadership, many dating from before World War II. Yukl (1989) examined recent literature identifying individual traits that predict leadership performance. He sorted these traits into two broad categories: motives and skills.

1. Motives

Research indicates that successful managers are characterized by certain patterns of motivations. However, no single pattern typifies all leaders. The pattern observed and reported depends on the taxonomy of motives and measurement instrument employed. For instance, Miner (1985) used a sentence-completion task to measure six separate motives:

1. Positive attitude toward authority figures
2. Desire to compete with peers
3. Desire to be actively assertive

4. Desire to exercise power
5. Desire to stand out from the group
6. Willingness to carry out routine administrative work.

In contrast, McClelland (1985) employed the Thematic Apperception Test, where respondents make up stories based on a series of ambiguous pictures of people. The researcher then codes the stories with respect to three abstract motivations:

1. Need for power
2. Need for achievement
3. Need for affiliation.

Yukl (1989) summarized such research by observing that successful leadership in large hierarchical organizations is characterized by a dominant concern for socialized (as opposed to personalized) power. This motive puts organizational interests above personal interests. Further, the leader motivated by socialized power is more likely to use a participative, coaching management style as opposed to authoritarian, coercive style.

2. Management Skills

Yukl (1989) pointed out that "… it is not enough to have the appropriate motivational pattern; a person also needs considerable skill to be an effective leader" (p. 191). In that regard, Yukl identified three basic categories of management skills:

1. **Technical skills.** This category refers to knowledge about methods directly related to the job and the ability to use the methods in realistic contexts. In problem-solving terms, this category corresponds to Klein's (1989) and Klahr and Simon's (2001) strong knowledge-based methods discussed earlier.
2. **Conceptual skills.** This category includes the higher-order thinking skills that roughly correspond to weak problem-solving methods and metacognitive skills, discussed earlier.
3. **Interpersonal skills.** This unique and wide-ranging category includes three subtypes of skills.
   a. Knowledge and skill in interpersonal processes (empathy and social sensitivity)
   b. Communication skills (speech fluency and persuasiveness)
   c. The ability to establish relationships (tact, diplomacy, social knowledge/ skills).

The first two categories, technical and conceptual skills, overlap substantially with other content areas discussed in this paper. The interpersonal skills, in contrast, provide a unique set of competencies. However, measurement of these skills remains a challenge. Measuring these skills with written tests has achieved only limited success. Measuring these skills through role-playing exercises, using situations in which no one is designated as the leader, has achieved somewhat better success.

Interpersonal skills also appear difficult to acquire. Yukl (1989) emphasized that lectures or texts on social sensitivity, charm, tact, persuasiveness, and so forth are not effective. Limited success has been achieved by showing films and videotapes to illustrate critical incidents in interpersonal relations. The most effective approach is one in which trainees get opportunity to practice techniques and receive feedback. Role-playing has been an effective approach when it is combined with videotaping for subsequent self-evaluation.

Schroeder et al. (1986) had considerable success training interpersonal skills for leaders using videodiscs, which are functionally equivalent to today's CD-ROMs. They used videodisc presentations and interactions to simulate interpersonal situations (e.g., taking charge, providing performance counseling, dealing with insubordination, handling verbal abuse) and then to provide feedback on learner responses and decisions in these situations. Their approach turned out to be generally more effective than using programmed text or "live" (with human actors) role playing.

H. EMOTION

The topic of emotion is important because military personnel are expected to perform complex tasks (maintain cognitive effectiveness) under conditions likely to evoke strong emotions, such as anxiety and fear. There are at least two general types of theories about the effects of emotions on performance. The first is that emotion provides an important class of contextual stimuli that must be considered in training design. The second is that emotions provide information that either provides input to or results from cognitive processes.

1. Emotions as Context

The first theoretical approach regards internal states, including emotions, as being no different from external conditions for learning and performance. Given this interpretation of emotions, both encoding specificity and the transfer-appropriate processing hypotheses would predict that performance improves when training conditions match criterion test conditions. In fact, findings related to "state-dependent learning" appear to confirm this prediction. These studies indicate that criterion performance is best when the learner's internal state during the study matches that during the test, even if the state generally depresses performance. For instance, Eich et al. (1975) had two groups of college students learn a list of 48 words. One group *learned* the words while under the influence of marijuana, and the other group learned the words while under the influence of a placebo. The two groups were further subdivided into those *tested* under the influence of marijuana or a placebo. Thus, the design specified four separate subgroups defined by the factorial combination of study conditions (intoxicated vs. sober) and test conditions (intoxicated vs. sober). As expected, the results indicated that the two subgroups that were tested while sober made fewer errors than the two subgroups that were tested while intoxicated. However, comparison of the two subgroups that were tested while intoxicated indicated that those who studied while intoxicated by marijuana made fewer errors than those who studied while sober.

So-called "mood-dependent" effects further extend these results to emotional states. For instance, Bower (1981) reported a study in which college students learned a list of words while either in a hypnotically induced happy or sad state and then, 10 minutes later, were tested for retention. As in the Eich et al. findings, Bower's results indicated performance improved when the test conditions matched the learning conditions.

From these results, one would predict that performance under emotionally arousing combat conditions would be improved by training under identical, or at least similar, arousing conditions. Given this interpretation of emotions, both encoding specificity and the transfer-appropriate processing hypotheses clearly predict that performance under emotionally arousing conditions will be optimal when training occurs under similar emotional conditions. In the past, technology and ethical constraints have acted to limit the degree to which training evokes the strong emotions associated with combat. Some have claimed that immersive simulation technology (i.e., simulations that involve multiple sensory modes—sounds and smells as well as visual stimuli) has the ability to evoke strong emotions. For instance, Shilling, Zyda, and Wardynski (2002) cited research showing that high-fidelity surround sound increased physiological responses to a video game. It remains to be seen, however, whether the emotions evoked in immersive simulation are similar in quality and intensity to those experienced in combat. Ironically, to the extent that immersive simulation technologies are able to elicit strong emotions like those in combat, ethical considerations may constrain the use of these technologies for training and research. Nevertheless, these new immersive training technologies provide an environment where warfighters can develop automaticity and develop confidence to perform under highly stressful conditions.

2. Emotions as Cognitions

In contrast to the notion that emotions are simply contextual stimuli, the second approach regards emotional states as providing input to cognitive processes. For instance, Schwarz (1990) advanced the idea that emotions provide important information for tuning cognitive processes. Positive emotions (e.g., happiness) indicate that the situation is safe, triggering superficial heuristic processing of information relying on preexisting knowledge. Negative emotions (e.g., sadness) indicate that something is amiss and that more detailed or systematic processing is required. The form of processing that is most effective depends on the nature of the task. Tasks that require specific actions and attention to detail would benefit from negative moods, whereas those that require originality and creativity would gain from positive moods.

An alternative to Schwarz's (1990) position that emotions are input to cognition is the idea that emotions are output from cognitive processing. Ortony, Clore, and Collins (1988) were particularly influential advocates of the latter position. Their position, commonly referred to as the OCC model, is that emotions are the result of the cognitive appraisal of three general features: events, agents, and objects. The outcome of the appraisal is a valenced reaction (i.e., a nonspecific positive or negative response) that may be described as either pleased/displeased with events, approving/disapproving of agents, or liking/disliking objects. The exact nature of the emotion depends upon the emoter's focus of attention. For instance, the emotion identified as "resentment" is experienced when the person is displeased about an event that is desirable for another.

The OCC model provides a structure for defining 22 distinct emotions. The purpose is to provide a theory that is not only internally consistent and externally valid, but also computationally tractable. It is the latter characteristic that makes the OCC model particularly appealing to those interested in creating more realistic intelligent agents to emulate human behavior and performance.

According to the OCC model and most theories of human affect, emotions are unlearned subjective experiences (like color or pain). Thus, except in cases of extreme emotional dysfunction, people have no need to be trained to experience affective states properly. On the other hand, some recognize the value of better understanding the causes of one's own emotions and being able to recognize emotional states in other people. That was partly the reasoning behind Marsella and Gratch's (2001) development of emotional agents for the Mission Rehearsal Exercise project. This project presents a realistic and emotionally evocative scene where the human trainee assumes the role as the commander of a platoon involved in an accident concerning a civilian child. The trainee interacts with a simulated person who is apparently the child's mother. An intelligent agent that embodies an emotional component based on OCC theory controls the mother's behavior. The purpose of including emotions is to increase the realism of the scenario and provide practice in making decisions in an emotionally evocative situation.

III. CONCLUSIONS

This review suggests that cognitive readiness is an integrative concept that pulls together diverse themes related to performance improvement and sustainment. It also suggests that cognitive readiness is a serious candidate for inclusion in routine measures of readiness in so far as it can be trained and measured. It may be essential in determining the capabilities of individuals and units to adapt rapidly to the unpredictable exigencies and challenges of modern asymmetric military operations.

A. REVIEW OF COMPONENTS

Standard techniques of readiness assessment involving materiel, supplies, equipment, personnel, and training resources, along with tallies of the training activities completed, are helpful in measuring military readiness. However, they provide an incomplete view of readiness in general and cognitive readiness in particular. This paper has briefly discussed how cognitive readiness can and, perhaps, should be used to expand our measurement and understanding of military readiness.

Table III-1 lists 10 components of cognitive readiness that are identified and discussed in this paper. It summarizes the relevance of each component to military operations, ways in which it can be measured, and ways in which it might be trained. The table also suggests several recurring themes, indicating that cognitive readiness may be understood as a combination of three basic abilities to:

1. Recognize patterns in chaotic situations (situation awareness, memory, transfer of training).
2. Modify problem solutions associated with these patterns as required by the current situation (metacognition, flexibility, and creativity).
3. Implement plans of action based on these solutions (decision-making, leadership, automaticity, and control of emotions).

Table III-1 also suggests that, to a significant extent, components of cognitive readiness are measurable and trainable. Techniques to achieve this end should be developed and employed. However, some aspects of cognitive readiness are not amenable to training,

Table III-1. Summarized Components of Cognitive Readiness

Component	Relevance	Measurement	Pedagogy
Situation Awareness	The ability to perceive and comprehend all relevant elements of the current military situation and to project status into near future.	Simulated operations that can be interrupted to compare participants' perceptions with "ground truth."	Repeated practice and feedback improves situation awareness.
Memory	The ability to recall and/or recognize patterns in operational problems for which there are likely solutions.	Direct testing of knowledge and skill retention or interrupting simulated operations (as above) and assessing retention of recommended COAs.	Tradeoffs exist, but conditions of learning can be designed to enhance retention. Overlearning can enhance retention.
Transfer of training	The ability to apply knowledge and skills learned in one context to another context.	Assess the application of learning to contexts different from those in which the learning occurred. Assess abstraction of principles from experience.	Massive amounts of practice with feedback will enhance "low-road" transfer. Training in forming mindful, conscious abstraction will enhance "high-road" transfer.
Metacognition	The ability to monitor, assess, regulate, and enhance one's own cognitive processes.	Determine the accuracy with which individuals regulate or monitor their own performance in instruction and operations.	Most cognitive skills can be enhanced by exercises designed to increase awareness of self-regulatory processes.
Automaticity	Allows very rapid responses (e.g., to emergencies) that do not substantially impair other cognitive processes.	Determine the ability to complete successfully the tasks in dual processing or visual/ memory search modes.	Overlearning can produce automatic processing in many consistently mapped tasks.
Problem solving	The ability to analyze the current situation, understand goals, and develop a COA to reach them.	Determine the probable success of proposed plans of action when given successively more difficult situations to deal with and goals to achieve.	Techniques matched to goal and situation categories can be successfully taught as can the knowledge base needed for "strong" problem-solving methods.

Table III-1. Summarized Components of Cognitive Readiness (Continued)

Component	Relevance	Measurement	Pedagogy
Decision-making	Similar to problem solving, but the emphasis is on reviewing different plans of action, assessing the probable impact of each, selecting one, and committing resources to it.	Assess competency in formal methods by success in identifying and selecting COAs likely to achieve targeted goals consistent with given utilities. Directly assess quality of decisions vis-à-vis outcomes.	Instruction in formal decision-making techniques may improve the quality of decisions, but some aspects of successful decision-making are determined by individual dispositions.
Mental Flexibility and Creativity	The ability to generate, adapt, and modify COAs rapidly, as required in response to variable situations.	"War gaming" that assesses the ability to devise plans and actions that differ from "school solutions" and adapt to rapidly changing, unfamiliar situations.	Knowledge and skills to widen the range of options considered in military operations can be taught, but higher levels of creativity are more likely to be caused by native abilities.
Leadership	Patterns of motivational, technical, and interpersonal knowledge and skills that encourage and support others in carrying out a designated plan of action.	Role-playing exercises contrived to provide assessments of leadership and leadership readiness. Different groups and different goals require assessments of ability to adjust leadership style as needed.	Technical and conceptual skills can, to an appreciable extent, be taught. Interpersonal skills and patterns of motivation are more dependent on native abilities and are more difficult to teach.
Emotion	The ability to devise and select appropriate COAs despite states of heightened emotion and stress.	Performance in deeply engaging, sensory immersing simulations can be used to assess the ability to overcome emotion and stress.	Deeply engaging, sensory immersing simulations may train warfighters to retain critical pieces of information and perform under highly stressful conditions.

and a better approach might be to improve techniques to select and acquire talented people who can achieve higher levels of cognitive readiness.

B. IMPLEMENTATION ISSUES

The first effort in implementing the concept of cognitive readiness should be devoted to the development of content-valid measures of cognitive readiness for use in empirical research. These measures would likely be multidimensional. One approach to developing such measures would be to collect accounts of behavior in critical incidents from people who have had operational experience. These accounts might be collected from detailed histories of military operations and/or from personal recollections. The accounts should include the impact of cognitive readiness on an operational outcome such as combat success. They could then be subjected to analysis in order to establish (1) the dimensions of cognitive readiness exhibited and (2) the range and type of impact that cognitive readiness has on individual and unit outcomes.

Given content-valid measures of cognitive readiness, the next step would be the development of interventions that increase cognitive readiness in needed areas. So far, we have focused on training as the most obvious intervention for increasing cognitive readiness, but training may not always be the best approach. Some components of cognitive readiness may not be trainable at all, while others may be trained, but only at great expense in time or cost.

At least two other classes of interventions can be used in lieu of or in addition to training. The first class of nontraining interventions is based on human-factors engineering. Such interventions are concerned with the design or redesign of military systems (including both system hardware and job procedures) to enhance their consistency with known human capabilities and limitations. Operator displays designed to increase situation awareness are examples of such human-factors interventions intended to increase cognitive readiness.

A second class of nontraining interventions concerns personnel selection and classification. Some aspects of cognitive readiness, such as leadership traits, may be innate patterns of behavior rather than acquired (trainable) skills. For such aspects of readiness, it may be better to use assessment procedures to identify individuals who are more cognitively ready than others. At the least, it may be better to develop assessment procedures to identify individuals who have a high potential for various levels of cognitive readiness and thereby reduce the amount and type of training that must be provided.

In practice, combinations of interventions often provide the most promise. For instance, new displays can provide the potential to increase situation awareness, but operators must be trained to use these displays to realize that potential. Similarly, job applicants can be assessed for leadership traits, but training is still required to help applicants understand how best to use their capabilities to perform the many different tasks they will encounter.

Etter, Foster, and Steele (2000) noted the potential for advanced distributed learning (ADL) technologies to improve cognitive readiness. These technologies are intended to make training and decision-aiding available anytime and anywhere they are needed or desired (see http://www.aldnet.org). Their potential is based primarily on the sophisticated learning and practice environments that technology-based instruction—such as computer-based instruction (CBI), intelligent tutoring systems (ITSs), tutorial simulations, and networked simulations—makes accessible.

Overall, it seems reasonable to conclude that cognitive readiness is a tractable and relevant construct that can and should be included in assessments of readiness. Clearly, we are at an early stage of thinking about cognitive readiness and much remains to be done if it is to become a routinely considered aspect of readiness assessment. However, as this paper suggests, many findings from behavioral research can be used to elaborate the concept of cognitive readiness, develop methods to train and measure it, and implement capabilities to help ensure its availability for military operations. More must be done, but much is available on which to build.

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GLOSSARY

ADL	advanced distributed learning
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
CBI	computer-based instruction
CD-ROM	compact disk-read only memory
COA	course of action
IEEE	Institute of Electrical & Electronics Engineers
ITS	intelligent tutoring system
MDT2	multi-service distributed training testbed
MOS	military occupation specialty
ODUSD(S&T)	Office of the Deputy Under Secretary of Defense for Science and Technology
VIRTE	Virtual Technologies and Environments
VISTA	Videodisc Interpersonal Skills Training and Assessment

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Cognitive readiness is described as the mental preparation an individual needs to establish and sustain competent performance in the complex and unpredictable environment of modern military operations. Relevant components of cognitive readiness are identified as situation awareness, memory, transfer of training, metacognition, automaticity, problem-solving, decision-making, flexibility and creativity, leadership, and emotion. These components were determined to be measurable and capable of enhancement through training. It was concluded that cognitive readiness contributes significantly to success in military operations and that it should be routinely included in assessments of readiness.

15. SUBJECT TERMS

automaticity cognition, creativity, decision-making, memory, mental flexibility, metacognition, military training, personnel selection, problem-solving, readiness, situation awareness, transfer of training

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