STRATEGY RESEARCH PROJECT

A PROPOSAL FOR DESIGNING COGNITIVE
AIDS FOR COMMANDERS
IN THE 21ST CENTURY

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19990607 047

USAWC CLASS OF 1999

U.S. ARMY WAR COLLEGE, CARLISLE BARRACKS, PA 17013-5050

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The views expressed in this academic
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ABSTRACT

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TITLE: A Proposal for Designing Cognitive Aids for Commanders
          in the 21st Century

FORMAT: Strategy Research Project

DATE: 07 April 1999   PAGES: 47   CLASSIFICATION: Unclassified

Observations made during the Division Advanced Warfighting

Experiment at Fort Hood, TX in 1997 indicated that the

technology designed to assist commanders in the C2 process

actually impeded them. Designing soldier-centered technology

begins with a clear understanding of the cognitive processes

used by soldiers. There are three major decision making models:

Rational, Descriptive, and Naturalistic. Prior to commanders

making a decision, they must construct situational awareness.

Cognitive processes requisite for building situational awareness

include: detection, transformation, and reasoning. Cognitive

integration is essential to the process of transformation.

Three methods to investigate cognitive integration are

discussed. Suggestions are made for the design of automated

aids that will assist commanders in integrating data so that

they will be able to devote their resources to other cognitive

tasks.

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A PROPOSAL FOR DESIGNING COGNITIVE AIDS FOR COMMANDERS IN THE 21ST CENTURY

Army commanders at all levels will face new and unprecedented challenges on the battlefields of the 21st Century. The challenges will result, in part, from the infusion of technology into the command and control (C2) process. Our doctrine states that commanders have two primary tasks: leading and deciding. FM 100-5 describes decision making as "knowing *if* to decide, then *when* and *what* to decide."[1] Commanders at all levels - tactical through strategic - are decision makers. As we digitize the military, the decision making process is quickly becoming more complex, more difficult, and more taxing on cognitive resources. Digitization provides decision makers with unlimited access to data. However, decision makers do not make decisions based on data. Data must be amplified, interpreted, or integrated, within the situational context. This data analysis is performed by humans, who are, in most cases, unaided by technology. With more data available than ever before, decision makers easily can become overwhelmed. They need an aid that can assist them with contextually based data analysis. This aid can free them to reason at higher cognitive levels, and, as a result, make them better, more timely decision makers. This research paper investigates the decision making problems induced by digitizing the force, discusses the cognitive

processes that contribute to decision making, proposes methods

to study the processes that precede decision making, and

describes a possible soldier-centered solution.

IMPACT OF DIGITIZATION ON DECISION MAKING: AN ILLUSTRATION OF THE PROBLEM

During June through November 1997, the Army prepared for

and conducted the Division Advanced Warfighting Experiment

(DAWE) with the 4th Infantry Division. The division was,

arguably, the most technologically sophisticated ground maneuver

force in the world. Yet, in many ways, it was a model of

inefficiency. Three observations from that experiment reveal

three problems that can be attributed to the digitized

technology. All observations were made at one of the brigade

tactical operations centers (TOCs).

Observation #1 (Data Flow and Analysis)

Research conducted by Shattuck, et al., investigated how

data flowed within a brigade TOC and the types of analyses staff

personnel performed on the data.[2] The researchers found that one

of the most sophisticated brigade TOCs in the world still moved

approximately 89% of its data around using traditional means

(radio, telephone, paper, and face to face conversations). In

addition, the researchers also categorized the type of processing that occurred on data that flowed within the TOC. Types of processing ranged from transduction (i.e., changing the data from an incoming radio message to an entry in a paper log) to interpretation (i.e., applying higher order knowledge and cognitive skills to reason about the data). The researchers found that less than 30% of the data were processed beyond the level of transduction.[3]

Researchers attributed these results to two phenomena. First, the more data that flowed into and around the TOC, the less time the staff could devote to any one particular item. Therefore, the cognitive processing performed on the data was relatively shallow. Second, the clumsy automation encumbered the data analysis and communication processes. It was easier to write an incoming message on a piece of paper and take it to the other side of the TOC than it was to move it around electronically.

Observation #2 (Centralized C2 Structure)

Military organizations are hierarchical. At the tactical level, a senior decision maker – the commander – gathers data, reviews what he knows about the battlefield, and makes a decision. He has assistance in gathering and analyzing the data, but the final decision rests with him. During Simulation

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Exercise (SIMEX) 1, a training exercise prior to the DAWE, staff

officers frequently handed the brigade commander slips of paper

or briefed him face to face. On many other occasions, the

commander roamed around the TOC, looking at various ATCCS (Army

Tactical Command and Control System) computer screens (see

Figure 1). In most instances, what was brought to him (or what

he observed as he walked around) was low-level, unfiltered data.

Combat Service Support
Control System

Maneuver Control
System

All Source
Analysis System

Advanced Field Artillery
Tactical Data System

Forward Area Air Defense
Command and Control
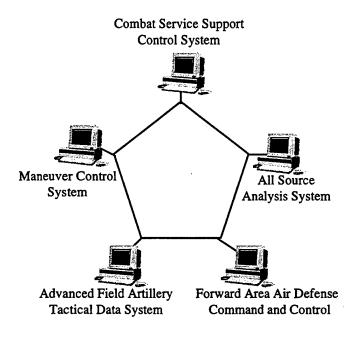
Figure 1. Major components of the Army Tactical Command and
Control System (ATCCS) architecture.

Just prior to the actual DAWE, the commander directed that

a wooden cabinet be built that could house six large TV

monitors.[4] On the screens, he wanted to view the ATCCS data.

During the DAWE, the commander spent much of his time studying

the monitors, as well, as a large paper map. The commander no

longer had to roam around the TOC, but there was still a

problem. The TV monitors displayed data, not information. In addition, the commander had bypassed the staff that was supposed to filter and analyze the data for him and now had to integrate the data himself. In fact, the array of TV monitors actually increased the cognitive workload, even though he no longer had to physically move around the TOC.

Observation #3 (Creating Situational Awareness)

The brigade commander encountered a problem during SIMEX 1. Not everyone in the TOC appeared to understand what was happening or what he was trying to accomplish in the tactical scenario. Using terminology that has become popular in the last few years, the staff did not have situational awareness. By the DAWE exercise he had solved the problem. He directed his staff to procure and install a high quality sound system with powerful speakers that could drown out all other noise in the TOC.[5] A few times a day, he explained to everyone in the TOC what was happening and what he was planning to do next. Although innovative, his solution bypassed not only his senior staff officers, but also all the technology in the TOC.

One might draw the conclusion from these three observations that the commander lacked the skill necessary to command a brigade equipped with the latest technology. On the other hand, the actions of the commander can be interpreted as providing

creative solutions to the problems that arose when the brigade was given technology that was less than optimal in its design. This paper presumes the latter explanation but does not view the adaptations implemented by the commander as suitable.

The large amount of data, coupled with no useful technological tools to reason about it resulted in staff officers delivering raw data to the commander. The commander's response was to try to streamline the process by centralizing the data. The commander made his decision making task more difficult because centralizing the data required him to perform both analytical and reasoning tasks. (In addition, these cumbersome displays not only would tether the commander to the TOC, but would make displacement of that TOC problematic.) The technology was poorly designed because it was not compatible with our doctrine, our organizational procedures, or the way that humans process data and make decisions. The following section provides findings from a review of the research literature on decision making and the processes that lead up it.

DECISION MAKING AND CONTRIBUTING PSYCHOLOGICAL PROCESSES

Decision Making

There are three general theoretical approaches to decision making in the literature. Each of these approaches relate well

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to the decision making methods found in Army doctrine. The first approach is based on **rational models of decision making**. These models describe how we *ought* to make decisions. Researchers eventually learned that most people didn't follow rational models in decision making tasks. Instead, it became clear that subjects were systematically influenced to make decisions that were less than optimal. As a result, researchers developed **descriptive models** of decision making. These models describe how subjects were influenced by *heuristics* and *biases* to make decisions.

Decision making research that led to the normative and descriptive models often was conducted in laboratory settings. People in the laboratory were not confronted with the dynamics of the real world nor would they have to implement and live with the decisions they had made. Many researchers began to investigate how decisions were made outside the laboratory by practitioners engaged in meaningful activities. These researchers developed **naturalistic models of decision making**. Each of these three categories of models - rational, descriptive, and naturalistic - will now be examined in greater detail. Following that, the models will be related to doctrinal descriptions of decision making.

Rational Models of Decision Making. Two roles are attributed to rational models: *normative* and *prescriptive*.[6]

Normative means that the models describe the choices of a hypothetical, ideal decision maker. Such a decision maker would be both omniscient and omnipotent. Prescriptive means that there is only one true rational choice. By systematically applying the rational model, a decision maker will be able to identify the correct choice.

Raiffa discusses decision making tasks by using the language of decision analysis. According to him, there are several steps involved in identifying the best outcome.[7] Figure 2 depicts a simple decision tree that illustrates the decision analysis method. Assume a commander is faced with having to decide which course of action to choose for an upcoming mission. The staff has developed three courses of action. The commander realizes that the best course of action is dependent upon what the enemy decides to do. According to decision analysis, there are four steps that should be followed.

First, *list the events that you expect to occur.*[8] Events are of two types: *choices* and *chances*. A choice event represents a decision that must be made among two or more alternatives. Choice events are depicted as squares. A chance event describes all possible alternatives in an uncertain environment. Chance events are depicted as circles. A chance event differs from a choice event in that the decision maker has no control over the outcome of a chance event. In Figure 2,

enemy activity illustrates a chance event. The enemy may decide to press the attack to the north or to the south.

Outcome Value

$(.7)5 + (.3)1 = 3.8$ Enemy Atks North (.7) 5

COA #1 Enemy Atks South (.3) 1

COA #2 $(.7)9 + (.3)2 = 6.9$ Enemy Atks North (.7) 9

Enemy Atks South (.3) 2

COA #3 Enemy Atks North (.7) 4

$(.7)4 + (.3)6 = 4.6$ Enemy Atks South (.3) 6

Steps in Building a
Decision Tree

1. Draw and label tree.
2. Assign outcome values
3. Assign probabilities.
4. Analyze tree and determine optimal choice.

■ = Decision Node   ● = Chance Node
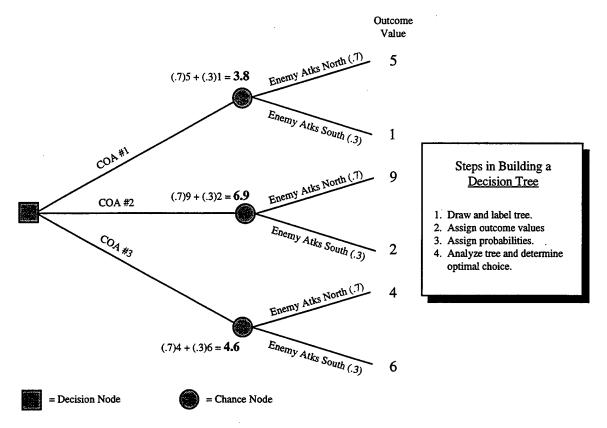
Figure 2. Decision tree depicting the rational decision making model for a commander prior to the onset of hostilities.

Second, *list the value of the possible outcomes.*[9] The criteria for assigning values are at the discretion of the decision maker. The commander might use criteria such as speed, accuracy, number of lives lost, or amount of equipment damaged. Outcomes can be actual figures (i.e., 35 soldiers KIA) or based on a relative scale (i.e., 10 = most desirable outcome; 1 = least desirable outcome).

Third, *list the probabilities of chance events.*[10] Total probability for all the branches originating from a node must total to 1.0. Determining the probabilities of how the enemy will attack into the sector can be a difficult task. The difficulty stems from the inherent uncertainty of the battlefield. Commanders may be able to reduce uncertainty but they will not be able to eliminate it.

Fourth, *analyze the tree and determine the optimal choice.*[11] Beginning at the right side of the tree, the outcome value of each branch is multiplied by the probability of that outcome. These figures are summed for each Chance Node. In Figure 2, the Chance Nodes along COA #1-3 have values of 3.8, 6.9, and 4.6. At the Decision Node, the decision maker should select the COA that has yielded the highest value - in this case, COA #2.

As previously stated, the prescriptive nature of the Rational Decision Making Model suggests that there is only one possible correct solution to the problem. Techniques such as decision analysis are designed to lead the decision maker to the 'right' answer. However, even in the simple example depicted in Figure 2, it should be obvious that there are several sources of error that could lead to an erroneous decision. Researchers realized that decision makers functioning in operational settings and faced with non-trivial problems often did not make the 'right' decision. In operational environments, decision

makers may not be able to list all possible outcomes or to make definitive assessments of the values or probabilities of the outcomes. Researchers began to develop an interest in how decision makers *actually* make decisions rather than how they *ought to* make decisions. This interest led to descriptive models of decision making.

Descriptive Models of Decision Making. At approximately 9:12 PM (local time) on 17 May, an Iraqi Mirage F-1 fired two Exocet missiles at the USS Stark while the frigate was operating in the Persian Gulf.[12] Prior to the attack, the Commander of the USS Stark initiated action to track and establish contact with the aircraft. However, he never gave the order to bring the ship's weapon systems to bear on the aircraft. As a result, 37 sailors were declared dead or missing and the ship was severely damaged.

Fourteen months later, on 3 July 1988, an Iranian A-300 Airbus carrying 298 people climbed into the sky and turned to enter a commercial air corridor. The USS Vincennes, operating in the waters of the Persian Gulf, detected the aircraft and attempted to identify it. The commercial airliner was mistaken for a hostile warplane. The Vincennes fired on the Airbus, killing everyone on board.[13] In the ensuing investigation, the commander of the Vincennes indicated that the attack on the Stark had played a part in his decision making process. His

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statement supports the idea that in operational settings decisions are not discrete events and decision makers do not rely solely on rational models. The outcome of one decision will influence or bias subsequent decisions.

Tversky and Kahneman conducted extensive research into the influences that lead decision makers to deviate from 'optimal' outcomes.[14] These consistent deviations are actually patterns of error known as *biases*. The researchers demonstrated that these biases arise when decision makers attempt to employ rules of thumb known as *heuristics*. Heuristics are valuable because they help us conserve limited cognitive resources. While, these cognitive shortcuts require fewer resources, they may rely on assumptions that ultimately prove to be invalid. The research of Tversky and Kahneman identified several heuristics and biases. Three of them are described below.

Availability Heuristic.[15] Decision makers may be influenced by their ability to recall or imagine events that are similar to the situation in which they now find themselves. The availability heuristic predicts that the recency or salience of their experiences will influence their assessment. The trend is to over-estimate the frequency of events and, therefore, ascribe inordinately high probabilities to these events.

Representativeness Heuristic.[16] Decision makers often rely on the extent to which the characteristics of a given situation

S are prototypical of a parent population *P1*. If there is a close match, the decision maker is likely to decide situation *S* is an instance of population *P1*. This process seems reasonable until the *base rates* are considered. (A base rate tells us how often an event is likely to occur.[17]) So, although the characteristics of situation *S* closely match population *P1*, this population is rarely present in the environment. Populations *P2* and *P3* contain only a few of the characteristics of *S* but they occur much more frequently than *P1*. The representativeness heuristic predicts that the decision maker would ignore the base rates and consider *S* to be an instance of *P1* because the characteristics are a close match.

Confirmation Bias.[18] Decision makers who have selected a course of action will interpret subsequent information in light of their decision. Therefore, new evidence that ought to disprove their decision is interpreted as supporting their decision.

Descriptive models explain how and why we deviate systematically from rational decision making strategies. Stated another way, descriptive models explain the consistent irrationality of decision makers. Like the descriptive models, naturalistic models also strive to accurately describe the decision making process. However, naturalistic models stress that decision makers are rational. According to naturalistic

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models, decisions are grounded in, and influenced by, the operational setting in which they occur.

Naturalistic Models of Decision Making. Naturalistic models are recent additions to the decision making domain. More accurately, perhaps, they represent a paradigm shift that led researchers out of the laboratory and into operational settings. In the laboratory, decisions tend to be studied as singular events. In operational settings, decisions are embedded in a complex process and are influenced by the events that precede the decisions, the organizational structure, and the environment. Researchers have identified eight characteristics of naturalistic decision settings.[19]

- Ill-Structured Problems.

- Uncertain, Dynamic Environments.

- Shifting, Ill-Defined, Competing Goals.

- Action/Feedback Loops.

- Time Stress.

- High Stakes.

- Multiple Players.

- Organizational Goals and Norms.

Several naturalistic decision making models have been proposed in recent years. While all of them are based on the eight characteristics listed above, they vary in their approach

to explaining how decisions are made in operational settings. One model that has been popular with military researchers is Klein's Recognition Primed Decision (RPD) Model[20]. Klein has used his model to explain decision making in a number of diverse domains. He has studied, among others, fireground commanders, army tank commanders, critical care nurses, and tournament chess players.[21]

RPD emphasizes situation assessment and values expertise. Rather than searching for the optimal solution, RPD asserts that decision makers in naturalistic setting engage in 'satisficing.' That is, they look for the first option that works rather than the best option. Decision makers consider alternatives serially. They engage in mental simulation to determine whether the alternative has merit. If the alternative does not fit the situation and cannot be tailored to fit, it is discarded and a new alternative is considered. There are four major steps in the RPD Model.

- Experience the Situation.[22] Is the situation familiar based on previous experiences? If not, the decision maker may need to gather more information or reassess the situation. (A platoon leader in Desert Storm observes an Iraqi armor formation.)

- Recognition.[23] The decision maker recognizes the situation as similar to one previously experienced. The match between the current and recalled situations can range from exact to only

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vaguely similar. In addition to recalling the situation, the decision maker also recalls the solution that was implemented. (The platoon leader recognizes the Iraqi armor formation as similar to an enemy formation he encountered at the National Training Center. He recalls that he used an arrowhead formation to penetrate the defensive position.)

- Mental Simulation.[24] The decision maker mentally simulates implementing the recalled solution in the current situation. If the decision maker cannot visualize any problems, the solution is implemented. However, if the decision maker visualizes problems in implementing the solution, the solution is modified. If, after modification, the mental simulation still reveals problems, the decision maker must recall the next closest match (step 2 above) and again mentally simulate implementing the solution. (The platoon leader mentally simulates his tanks attacking in an arrowhead formation. However, unlike the NTC, these positions are more dispersed and better fortified. He will have to request indirect fire to soften the enemy's defenses and direct his tank commanders to spread out the formation. He mentally walks through the attack with these modifications and is satisfied with the plan.)

- Implementation.[25] The feedback the decision maker receives

   from implementing the plan serves as input to the next

   decision that must be made.

   Decision Making in Doctrine. FM 101-5 describes the seven-

step military decision making process (MDMP).[26] These steps

include developing and comparing multiple courses of action.

The commander reviews the courses of action, the strengths and

weaknesses of each, and then selects the best course of action.

This is the same process described in the Rational Decision

Making section above. The commander's decisions may be affected

by heuristics and biases (also previously described) depending

upon the experiences and expertise of the commander. This

process most applies to the decision making that occurs prior to

implementing the plan.

   After the plan is implemented, the commander must still

make decisions because inevitably, unexpected events will occur.

In these instances, commanders are more likely to use

naturalistic decision making methods such as Klein's RPD.

However, Army doctrine (FM 101-5) does not acknowledge the

fundamental differences between the decision making that occurs

during the deliberate planning process and that which occurs

after the plan is implemented. The doctrine suggests that time

is the only factor that impacts on the process. Further, it

states that under time constraints, the same steps should be

followed but they should be modified. Command and General Staff College Student Text 100-9, while not doctrine, describes three decision making processes under constrained conditions: combat decision making; quick decision making; and, immediate action drills.[27] The latter two are performed exclusively by the commander and employ naturalistic decision making methods.

The research literature indicates that decision makers in operational environments described by the eight characteristics listed above (i.e., ill-structured problems; uncertain, dynamic environments; etc.) utilize naturalistic decision making methods. In developing aids to assist commanders in the decision making process, the methods embedded in these aids ought to parallel the methods used by actual decision makers. In this case, aids developed to assist commanders in those decisions that must be made after the plan is implemented ought to be based on naturalistic decision making. Essential to the naturalistic decision making process is understanding the current situation – in other words, having situational awareness.

Situational Awareness

Anyone who has been exposed to the Army's modernization program is familiar with the term 'situational awareness.' Junior enlisted soldiers in digitized TOCs refer to it as 'SA.'

Soldiers describe it as knowing where they are and where the friendly and enemy forces are. Most researchers agree that it's a good thing and that you will make better decisions if you have it. Stated differently, situational awareness is a precursor to decision making. But there is considerably less agreement on what it is and how you get it.

Situational awareness is not unique to the Army. Navy personnel who work on ships in combat operations centers use the term 'having the bubble' to indicate that "they have been able to construct and maintain the cognitive map that allows them to integrate such diverse input as combat status, information flows from sensors and remote observation, and the real time status and performance of the various weapons and systems into a single picture of the ship's overall situation and operational status."[28]

The commercial aviation industry has been concerned with the situational awareness of pilots for many years. Mica Endsley, a prolific researcher in situational awareness, defines it as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future."[29] Note that her definition has three components – perception, comprehension, and prediction. Some researchers (i.e., Klein) take issue with her description because it infers a linear

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process that does not match what seems to take place in the real world.[30] Others question her emphasis on outcome versus process. Her work emphasizes measuring whether or not people have achieved situational awareness. Perhaps more important than determining *if* people have it is to determine *how* they get it.

Understanding *how* people achieve situational awareness is essential to building automated aids. A well-designed aid should work in parallel with the cognitive processes that lead to situational awareness. Therefore, prior to building automated aids, we must identify and understand those cognitive processes that underlie or precede the attainment of situational awareness. The next section will discuss some of those cognitive processes.

Cognitive Processes Requisite for Situational Awareness

Our memory systems are generally thought to consist of three components: sensory memory, short term (or, working) memory, and long term memory.[31] Only a portion of the data sensed by our eyes and ears (as well as our other senses) is transferred to our working memory. We must attend to (focus on) a data element for it to be transferred. All other data fades from our memory system within a few seconds. Data are transformed and reasoned about in our working memory. Relevant elements of long term memory (rules, procedures, schema, etc.)

are transferred to working memory to help process the data.
Unfortunately, the capacity of working memory is very limited (7
+/- 2 elements).[32] This capacity is even more restricted during
periods of stress. These three memory components are integral
to the processes that lead up to decision making.

Before commanders or staff officers can make decisions
about the events unfolding on the battlefield, they should have
accurate situational awareness. They achieve this accurate view
by reasoning about the information they have received and then
they structure it in meaningful ways. Before they can reason,
the information has to be transformed from data. And, before
they can be transformed, the data have to be detected. These
processes - reasoning, transformation, and detection are
affected by both individual and environmental factors. Each are
essential considerations in designing a system that could assist
decision makers on the battlefield.

Detection. Military decision makers work in a complex,
dynamic, and data-rich environment. A data element will only be
transferred from sensory memory to working memory if we attend
to it.[33] What we attend to is a function of the characteristics
of the stimulus (or data element), the environment, and the
individual. How salient is the data element? Is it an auditory
or visual stimulus? Is it sufficiently different (i.e., louder,
brighter, etc.) from the surrounding environment to warrant our

attention? Have we been primed by our long term memory to look for a particular data element? Are we tired, sick, or afraid? Well-designed decision aid displays must discriminate between important and unimportant data. Data deemed important must be presented in a manner that will facilitate detection.

Transformation. After data are detected and transferred to working memory, they must be transformed into meaningful information. Endsley refers to this process where disjointed data elements are combined as comprehension.[34] Perhaps a better term is *cognitive integration*. This term suggests that combining the data is not an amorphous process but a function of both situational context and the experience level of the decision maker. An experienced commander whose subordinate units are about to engage the enemy in a frontal assault will more than likely integrate different data elements (or integrate the same elements in different ways) compared to a novice commander whose subordinates are in a terrain-oriented defense. As described at the beginning of this paper, battlefield automation systems display overwhelming amounts of data and provide little, if any, assistance to commanders in integrating the data. Decision aids should assist commanders in context-based integration so that they can free up limited information processing capacity to reason about the newly created information.

Reasoning. Fundamental to decision making is the ability to reason about that which we perceive and that which we know. Much of this reasoning involves pattern matching. In his RPD model (described earlier), Klein indicates that decision makers match patterns that have been constructed in working memory from what they have perceived with stored patterns.[35] Serfaty, et al., support Klein. "The expert's memory consists of an array of "patterns," with information items grouped and indexed by their relevance for problem solving in the domain of expertise."[36]

The literature reviewed indicates that people use rational, descriptive or naturalistic models when making decisions. Military decision makers overseeing ongoing battlefield operations are more likely to use naturalistic models (i.e., Klein's RPD Model). Many of these models stress that the decision makers should have situational awareness prior to making decisions. Situational awareness is constructed in our memory system by employing processes that include perception, integration, and pattern matching. Of these processes, there is little research that reports how military decision makers integrate low-level data in meaningful ways to form information that can be used in pattern matching. The next section describes a three-pronged approach to investigating cognitive integration.

INVESTIGATING COGNITIVE INTEGRATION

The most reliable research methods are those that employ converging methods. A single type of research may lead to an answer, but not necessarily the truth. Sound research should be both valid and reliable. The findings will be even more robust if a variety of methods are used to surround - or converge on - the truth.[37] There are at least three methods that can be used to converge on the role of cognitive integration in decision making.

Single Scenario Simulations

Many researchers make a distinction between expert and novice decision makers. Determining what those differences are is useful for training novices and for developing aids to assist commanders in decision making. Using a single scenario simulation is one method to discern these differences. The expert group would consist of former brigade commanders (armor or infantry) who have excelled either in combat or at the NTC. The novice group would consist of (armor or infantry) officers of similar grades with no command experience. Each officer would be given an operations order, maps, overlays, and other products that would give them the ability to embed themselves in

the tactical scenario (i.e., movement to contact). The officers

would then be presented with a series of situation reports.

Each situation report would alter the situation in some way and

require them to make a decision. Presented with an array of low

level data, they would be forced to select a subset of the data,

integrate it, and use the newly constructed information to match

patterns and make decisions. Measurements would include

identifying which data are selected and why, how they are

integrated, and what patterns the integrated data form. The

expectation is that the integration patterns of experts and

novices would be significantly different.

Multiple Scenario Simulations

Commanders are faced with a multitude of tactical scenarios

- attack, defend, envelop, delay, etc. The set of low level

data that is integrated in a movement to contact may differ from

the set integrated in another tactical situation. It is

important, therefore, to explore multiple scenarios to determine

if there is a data set that is particularly relevant for a given

scenario. In these simulations, expert commanders would be run

through protocols similar to the one described above. However,

in this case, each commander would be asked to participate in a

variety of mission types. The data sets they use and the

integration they performed would be compared across mission types.

Cross Domain Observations

Researchers often make the mistake of concentrating on a single domain. Much can be learned from studying other domains. While other domains may appear to have little in common with military C2 on the surface, at theoretical or abstract levels they may be remarkably similar. The observations made and the lessons learned from other domains can be used to develop solutions to problems identified in the military domain. It is essential to identify those characteristics of the cognitive integration task that define the domain and those that are merely present in the domain. For example, defining characteristics in the tactical military domain commanders might include data overloaded and virtually exclusive use of visual and auditory modalities. A less important characteristic might include the environment (tent or track versus office building). Once the defining characteristics are determined, other relevant domains can be identified and studied.

The findings from these three types of studies will yield converging evidence that will surround the truth about cognitive integration and the role it plays in building situational awareness prior to decision making. The next step is to apply these empirical findings to the design of a soldier-centered

decision aid. The final section of this paper describes some

characteristics essential to such a system.

CONSIDERATIONS IN DESIGNING AN AID TO ASSIST COMMANDERS WITH COGNITIVE INTEGRATION

Engineers or computer programmers who have no military

experience develop most of the military's technological systems.

The result is that the Army fields systems that are technology-

or machine-centered. Norman states, "Today much of science and

engineering takes a machine-centered view of the design of

machines and, for that matter, the understanding of people. As

a result, the technology that is intended to aid human cognition

and enjoyment more often interferes and confuses than aids and

clarifies."[38]

Technology-centered solutions often result in clumsy

systems. These systems aid humans during periods of routine

activity when the cognitive demand is minimal. However, when

the system is stressed due to increased demands or failure, the

cognitive demands on the human escalate and the technology

provides little relief.[39] The alternative to a technology-

centered system is a soldier-centered system. In a soldier-

centered system, the focus is the soldier (including the

physical and cognitive capabilities and limitations), the system

in which the soldier operates, the task that has to be performed, and the environment in which it is performed. This is the starting point. The system is then built around the soldier (rather than building the system and then selecting and training soldiers to operate it).

This paper described the methods and processes involved in decision making. It also described the role of situational awareness and the cognitive processes that contribute to situational awareness, including cognitive integration. Finally, converging methods to study cognitive integration were described. These theories and the results of the proposed research should form the foundation of the system developed to aid commanders in cognitive integration. The system should be based on a naturalistic decision making model; it should integrate low level data into patterns consistent with the context; and, it should facilitate the commander's ability to match the pattern of integrated information with patterns they have stored in memory. There are two approaches in the field of artificial intelligence (AI) that would be useful in developing this aid.

Intelligent Agents

Most TOCs operate on a data-push system. Commanders, sitting at the top of the organizational hierarchy, are fed a

continuous stream of data by staff officers. Most of the data

are sent to the commander not because the commander wants or

needs them but because the staff officers felt obliged to keep

their boss informed. The result is that the commander is

overwhelmed with low-level data that he is unable to process or

reason about. An alternative to the push system is a pull

system. System designers can develop intelligent agents or

knowbots that search computer systems for low level data

elements that are needed to build the informational patterns for

the commander within the context of the mission.[40] When located,

the data are pulled up and integrated for the commander.

Case-Based Reasoning

A veteran observer-controller (OC) at the National Training

Center (NTC) may have seen as many as 40 brigades rotate through

the maneuver box. His vast experience has afforded him the

opportunity to build a robust schema with respect to movement to

contact operations. He has the ability to look at patterns of

data and immediately discern what is happening because he can

relate the current situation back to a previous rotation in

which a similar pattern had emerged. When this type of

cognitive processing is built into an AI system it is known as

case-based reasoning.[41] This AI tool can be used to assist the

commander in comparing the patterns identified and confirmed by

the commander with previous patterns for similar scenarios stored in memory. The key to developing a successful aid is to build it so that it complements and supports the cognitive activities of the decision maker.

CONCLUSION

The Department of the Army continues to invest heavily in technologically-laden systems for the battlefields of the 21st Century. The technology will increase the range of weapons systems, increase the speed at which soldiers and logistics move around the battlefield, and improve the ability to communicate with one another. Concomitant with these changes is a dramatic increase in the amount of raw data available to the commander. Current C2 systems are impressive in their ability to move data, but the tasks of analysis, synthesis, and integration are still left to humans. A commander will not be able to intrude upon the enemy's decision cycle unless he has some assistance. It is time for us to begin developing soldier-centered systems that complement human cognitive activity. These systems must be intuitive to operate. The goal of developing soldier-centered systems begins with the systematic, empirical investigation of human cognitive activity as it occurs in operational settings. This may slow development and fielding of these systems, but

ultimately it will result in more effective commanders who make

more timely decisions.

Word Count: 5,997

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