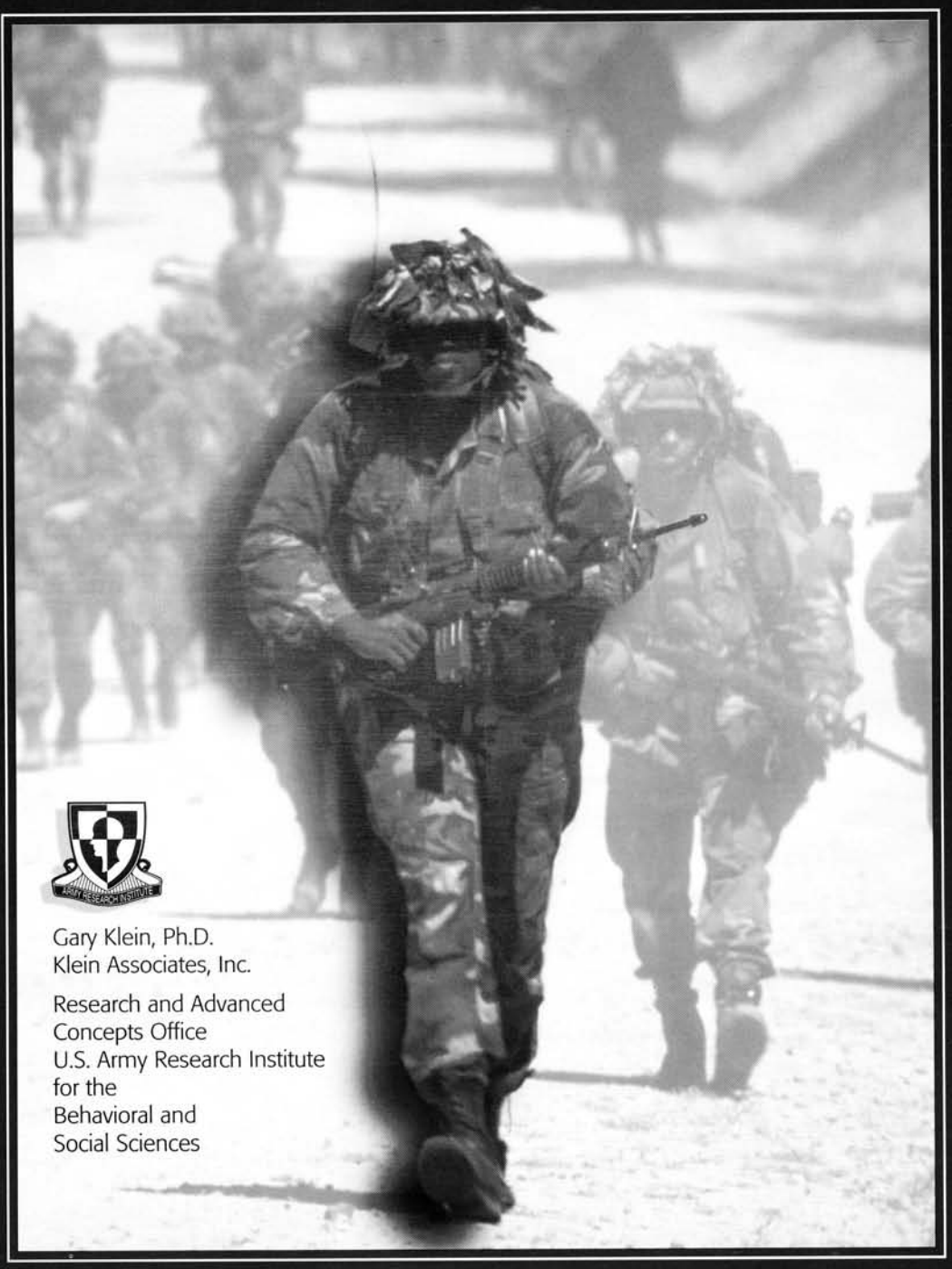
Making Decisions in Natural Environments



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Research and Advanced
Concepts Office
U.S. Army Research Institute
for the
Behavioral and
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This report surveys the field of naturalistic decision making (NDM) and shows its potential for supporting the needs of the U.S. Army. The report is written from the perspective of a researcher who has been active in developing models and methods in this new approach. The objective is to show the value of NDM for helping the Army address current challenges, including its use of information technologies, its need to downsize forces, and a change in its expected missions.

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EXECUTIVE SUMMARY

Because traditional decision research programs have not been very successful in addressing operational needs, the U.S. Army Research Institute for the Behavioral and Social Sciences approximately 10 years ago began to sponsor an alternative line of investigation into Naturalistic Decision Making (NDM). The objective of this report is to show the value of NDM for helping the Army address current challenges, including its use of information technologies, its need to downsize forces, and a change in its expected missions.

The goal of NDM research is to examine the way people make decisions under operational conditions. The focus is on field studies rather than on laboratory settings where naive subjects perform artificial tasks. NDM research is about how people use experience to make decisions under time pressure, shifting conditions, unclear goals, degraded information, and team interactions. Currently, NDM research is being conducted in domains such as aviation, battle command, health care, and process control, looking at both individuals and teams, and sponsored by all branches of the military along with other federal agencies and commercial sources.

The NDM framework appears to have great potential for application to Army needs. The framework addresses the specific decision requirements (critical and difficult judgments and decisions) within a domain and determines why these are difficult and what cues and strategies are needed to handle the difficulties. This decision-centered approach has been used to design better training programs and better human-system interfaces. The NDM framework also emphasizes training for team decision making, and it has implications for better mission rehearsal methods.

During the 10 years in which it has been emerging as a line of inquiry, NDM research has contributed to a number of important changes in decision research. These include:

- de-emphasis of the Rational Choice model (because it cannot be used in most field settings),
- de-emphasis of the heuristics and biases approach (because the findings do not seem to generalize outside the laboratory),
- de-emphasis of laboratory experiments (because artificial tasks with naive subjects do not result in useful findings),
- greater appreciation of expertise in decision making,
- greater use of recognitional decision models,
- growing investigation of situation awareness,
- modification of FM 101-5 (to encourage recognitional strategies along with analytical ones),
- use of decision requirements for training and design, and
- increased attention to team decision making.

Taken together, these changes signify a major shift in the study of decision making and a strong potential for applying NDM findings to the operational problems facing today's Army.

INTRODUCTION

The Naturalistic Decision Making (NDM) framework is emerging at a critical time for the U.S. Army. Within the past decade, several different challenges have changed the importance of decision making. First, the explosive growth of information technologies created an opportunity for the Army to dramatically improve its battle command function, which will require changes in the decision cycle. Second, the continual downsizing of the Army will force soldiers to broaden their responsibilities to include greater decision making at all levels. Third, the list of possible missions has increased, to include both war-making and peacekeeping operations, rather than the one overriding mission of protection from an assault from the USSR; as a result, commanders are more likely to be rushed into battle with less knowledge of the situation.

These changes add up to an Army that is less likely to be following systematic procedures. The unpredictable implications of information technologies will call for continual improvisation and adjustment. The downsizing will call for increased initiative. The increased types of missions will call for greater adaptability. The Army may no longer be able to carefully plan its training programs and design its systems to meet known requirements. The commanders and soldiers of the future will have to rely more heavily on decision skills.

Fortunately, the field of NDM research has been making rapid strides to meet these needs. Attempts to apply traditional decision research, whether for training or for design of decision aids, had proven very disappointing. These efforts continued through the 1970s and 1980s. When ARI realized that the traditional approaches were not going to meet the needs of the Army, it shifted its attention to NDM as a more promising approach. Eleven years ago, in 1985, the basic research program of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) began its investment in decision-making research that has emerged as the NDM framework.

The support provided by ARI has been leveraged into a major research and development paradigm. During the period 1985-1990, ARI was the primary source of funding for research projects and was the sole sponsor for the first conference on NDM (held in 1989). Subsequently, we have seen a rapid spread of interest and application. The second conference on NDM, held in 1994, was sponsored by the Army, Navy, Air Force, and the National Aeronautics and Space Administration (NASA) and featured a presentation by a U.S. Marine Corps Major General, describing the importance of NDM to battle command. From a small handful of researchers in 1985, today there are probably more than 100 active investigators working in Europe, Asia, and the United States.

This report surveys the field of NDM and shows its potential for supporting the needs of the U.S. Army. The report is written from the perspective of a researcher who has been active in developing models and methods in this new approach.

DEFINITION OF NATURALISTIC DECISION MAKING

Naturalistic Decision Making has been defined as "The way people actually make decisions." This may seem simple and straightforward, but it has deeper meaning than one might expect. The traditional decision research paradigms that preceded NDM did not study what people actually did. Instead, these paradigms relied on artificial laboratory experiments to investigate the ways that people differed from the optimal solutions arrived at through mathematical and statistical analyses. They studied what people did not do, rather than the decision strategies they actually used. This has limited the usefulness of traditional studies for explaining what happens under real-world conditions.

The left-hand column of Table 1 lists the central features of NDM, as follows.

Expertise

In most settings, novices are not going to be making critical decisions. NDM research investigates the way people use their experience to make key judgments and decisions. Traditional studies prefer to use novices because it is easier to control for experience by eliminating it and using novel tasks.

Descriptive

Rather than beginning with an analytical strategy and testing whether people use it, or trying to prescribe how people should be making decisions, NDM research tries to understand and describe what experienced decision makers do. The premise of the NDM approach is that we must appreciate the strategies people are using, to help train and support them. Because NDM research concentrates on tasks for which there is no right answer, the strategies used by experts are treated as the standard. In contrast, traditional research often has relied on tasks where optimal analytical strategies could be defined using statistical and logical methods. Because subjects rarely followed these strategies, the traditional approach is prescriptive because it recommends training subjects to use the optimal strategies. If we insist on forcing people to use unnatural strategies, they either will become confused and ineffective or they will reject the support.

Broad Focus

There is much more to successful decision making than picking the right option or estimating the likelihood of hypotheses based on the quality of the evidence. Experienced decision makers can size up situations and recognize how to respond. They usually do not spend time comparing options, which is what traditional decision research has focused on. Therefore, NDM research places more emphasis on situation awareness than on comparing options. It also is concerned with the way people generate options and solve problems. Naturalistic settings usually involve all these processes. Laboratory researchers prefer to keep these phenomena distinct and to study decision making in the absence of situation awareness and problem solving.

Table 1
Features of Naturalistic Decision Making Research

Positive Features	Contrasts
• Studies experts	• Studies novices
• Tries to describe	• Tries to evaluate
• Takes a broad focus Choosing actions Situation awareness Problem solving	• Takes a narrow focus Choosing between alternate actions Estimating the probability of hypotheses
• Task context: field settings Time pressure Shifting conditions Unclear goals Degraded information Subtle cues and patterns Team interactions Organizational constraints High stakes	• Task context: laboratory settings Ample time Stable conditions Stated goals Precise information Clear inputs Individual tasks Individual tasks Low stakes
• Focuses on cognitive processes	• Focuses on analytical strategies
• Relies on Cognitive Task Analysis	• Relies on performance measures

Task Context

To capture the task context, NDM research is typically performed in field settings, or at the least in challenging simulations. NDM researchers try to understand how people handle time pressure, shifting conditions, unclear goals, degraded information (i.e., missing, ambiguous, or erroneous data), subtle cues and patterns, team interactions, and organizational constraints. These are the defining features of naturalistic settings. Laboratory studies generally try to eliminate these types of anomilies. Traditional decision research is usually performed using artificial tasks under limited-context laboratory conditions. Because traditional researchers want to study how people use analytical methods, they make sure subjects have sufficient time. Shifting conditions make data hard to interpret, as do unclear goals, so traditional decision researchers tend to use tasks that are simple and stable. Degraded information poses a problem of figuring out how subjects are interpreting the data, so it is easiest to make sure all subjects are clear about the information that is available. For that reason, subtle cues are avoided as well. Teams are difficult to study in the laboratory, so most research examines individual subjects, free of organizational constraints.

Cognitive Processes

NDM research often tries to understand how cognitive processes such as memory and attention affect the strategies people use. In contrast, traditional decision research often is disconnected from cognition.

Cognitive Task Analysis

Most NDM studies rely on methods for investigating the ways people are thinking about the tasks they perform. Traditional decision research is usually confined to performance measures of reaction time, errors, and the like.

The appeal of the traditional decision approaches is that they are **systematic**. More important, the Rational Choice approach (to identify alternative options, compare their strengths and weaknesses, and choose the best) offered the promise of a set of **general** decision strategies that could be trained and evaluated. The Rational Choice strategy was **analytical**, so the basis of the decisions could be articulated. Finally, traditional, laboratory research permitted **quantifiable** theories and predictions that could be tested.

The current success of the NDM framework is largely because it generated its own models of decision making. These models have had high face validity and empirical support. Today, several models of NDM exist. One of the best known is the Recognition-Primed Decision (RPD) model.

THE RECOGNITION-PRIMED DECISION MODEL

Besides stimulating the development of the NDM framework, the Basic Research Program of ARI also sponsored the research that generated the RPD model. The RPD model described how people could use experience to make decisions without comparing any options at all. The model was based on interviews and observations of fireground commanders working with difficult and challenging incidents. In the first such study, more than 30 incidents were examined, each containing an average of five nontrivial decisions. The commanders were working against severe time pressure; more than 80% of the decisions were made in less than a minute. The stakes were high — poor decisions could result in loss of lives and property. Information quality was uneven, goals shifted, and conditions changed. The situational dynamics changed an average of five times in each incident studied. Klein, Calderwood, and Clinton-Cirocco (1986) expected that the commanders would have to resort to a limited comparison between options and were surprised to discover that the commanders reported they were not making any comparisons at all.

These findings raised two key questions: First, how could the commanders be sure of carrying out effective courses of action without generating a set of options from which to choose? Second, how could the commanders evaluate a course of action without comparing it to others? Klein et al. (1986) carefully examined the interview data and the 156 decision points probed, and developed the RPD model based on the fireground commanders' own accounts.

The answer to the first question (how the commanders did not have to generate a set of options) was that the commanders could use their experience to size up a situation and thereby recognize the typical reaction to take. They could generate a reasonable option as the first one considered. They were not trying to find the optimal solution, but rather to quickly arrive at a workable solution that could be enacted in time to arrest the spread of a fire that might be growing exponentially.

The answer to the second question (how the commanders could evaluate an option without comparing it to others) was that once the commanders identified a typical course of action, they would evaluate it by mentally simulating it to see if it would work in the context of the situation they were facing. If the course of action was found to be satisfactory, it would be initiated without any further delay. If they found any flaws, they would switch to a problem-solving mode to repair the flaws. If they could not repair the flaws, they would reject the course of action and consider the next most typical reaction, repeating the process until they found a workable option.

The RPD model is shown in Figure 1. The simplest case is where a decision maker sizes up a situation, forms expectancies about what is going to happen next, determines the cues that are most relevant, recognizes the reasonable goals to pursue in the situation, recognizes a typical reaction, and carries it out. This is probably also the most common case. We consider this a decision because reasonable alternative courses of action could have been taken. Other decision makers, perhaps with less experience, might have selected these alternatives. Therefore, a decision point hypothetically existed even though the decision maker did not treat it as such.

The second panel of Figure 1 shows a more difficult case, where the decision maker is not certain about the nature of the situation. Perhaps some anomaly arises that violates expectancies and forces the decision maker to question whether the situation is perhaps different than it seems. Another possibility is that the uncertainty might be present from the beginning. Here, decision makers must deliberate about what is happening. We have found that one strategy they use is to build a story that explains the various pieces of information. If there are competing interpretations of the situation, the decision maker may try to build a story for each and appraise which story is the most consistent and plausible.

The third panel of Figure 1 shows that once commanders arrive at an understanding of a situation, they will recognize a typical course of action and then evaluate it by mentally simulating what will happen when they carry out the action. In this way, if they spot weaknesses in their plan, they can repair the weaknesses and improve the plan. This is probably a better strategy than generating a large set of options and comparing these to find the best one. The evaluation that uses mental simulation can, perhaps, produce a better course of action instead of settling for picking one from a set.

The RPD model hypothesizes that with experienced decision makers:

- The first option they consider is usually workable so they do not have to generate a large set of courses of action to make sure of getting a good one.

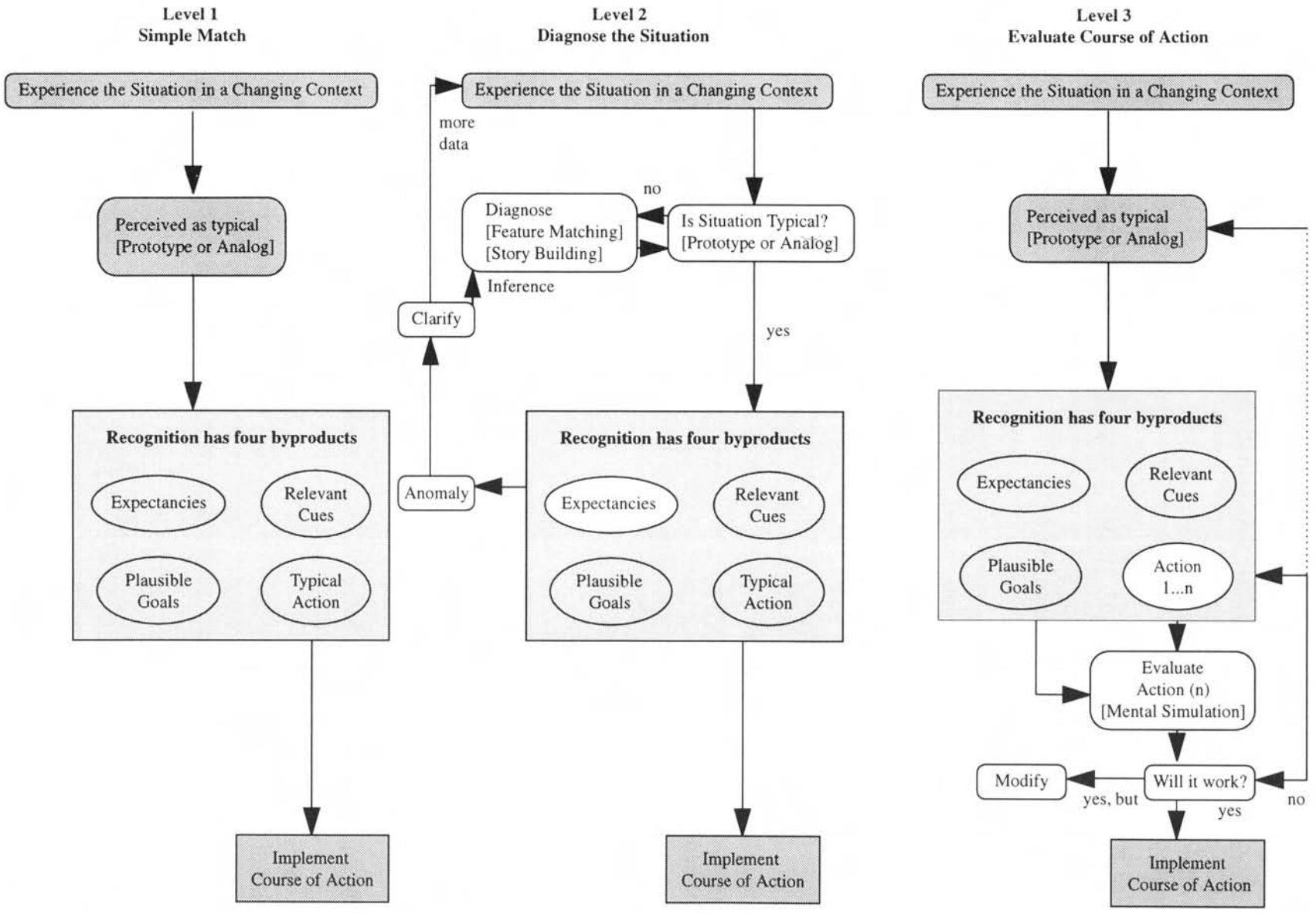

Figure 1. Recognition-Primed Decision Model.

- Comparing options is not a goal. They generate and evaluate options one at a time instead of comparing their advantages and disadvantages.

- Finding a workable course of action is a goal. They are trying to find the first option that works, not the best one.

- Evaluating an option occurs by imagining how it will be carried out, not through formal analyses and comparisons.

- Options can be strengthened by imagining the option being carried out, spotting weaknesses, and finding ways to avoid them. (Rational Choice models just select the best without seeing how it can be improved.)

- The focus is on the way they assess the situation and judge it as familiar, not on choosing between options.

- The emphasis is on being poised to act quickly, rather than being paralyzed until all the evaluations have been completed.

Since it was first proposed in 1985, the RPD model has received a great deal of support. Klein (1989) has summarized the data from studies with tank platoon leaders, design engineers, urban and wildland firefighters, and brigade-level military planners, showing that the RPD model accounts for most of the decision points (between 50% and 95% of the decisions made by experienced personnel), whereas Rational Choice (i.e., comparisons between options) rarely occurs.

The initial studies of the RPD model have been replicated several times, with consistent support for the RPD model and the general NDM approach. For example, Kaempf, Wolf, Thordsen, and Klein (in press) have shown that in actual incidents of anti-air warfare in Navy AEGIS cruisers, the Commanding Officers and Tactical Action Officers primarily relied on recognitional decision strategies; comparison between options occurred less than 5% of the time. Mosier (1990) studied videotapes of flight crews reacting to malfunctions and emergencies in a high-fidelity simulator. Pascual and Henderson (in press) conducted simulated exercises using experienced officers in the British Army. Randel, Pugh, Reed, Schuler, and Wyman (1994) conducted simulated exercises with Navy electronic warfare technicians. In a variety of domains, including high time pressure (urban firefighters) and low time pressure (design engineers), individuals (design engineers) and teams (wildland firefighters, commercial aviation crews), military (Army, Navy) and paramilitary (firefighters) and nonmilitary (commercial pilots, design engineers), decision makers rarely use Rational Choice methods.

Moreover, the RPD process seems a superior strategy in naturalistic settings. Rational Choice methods cannot stand up against the time pressure, ill-defined goals, and inconsistent data. The RPD process can and does. It lets the decision maker short circuit option comparison by relying on experience to generate a reasonable course of action at the outset. The RPD model asserts that people can use experience to generate a reasonable course of action as the first one considered. Is this a valid claim? Klein, Wolf, Militello, and Zsambok (1995) tested this

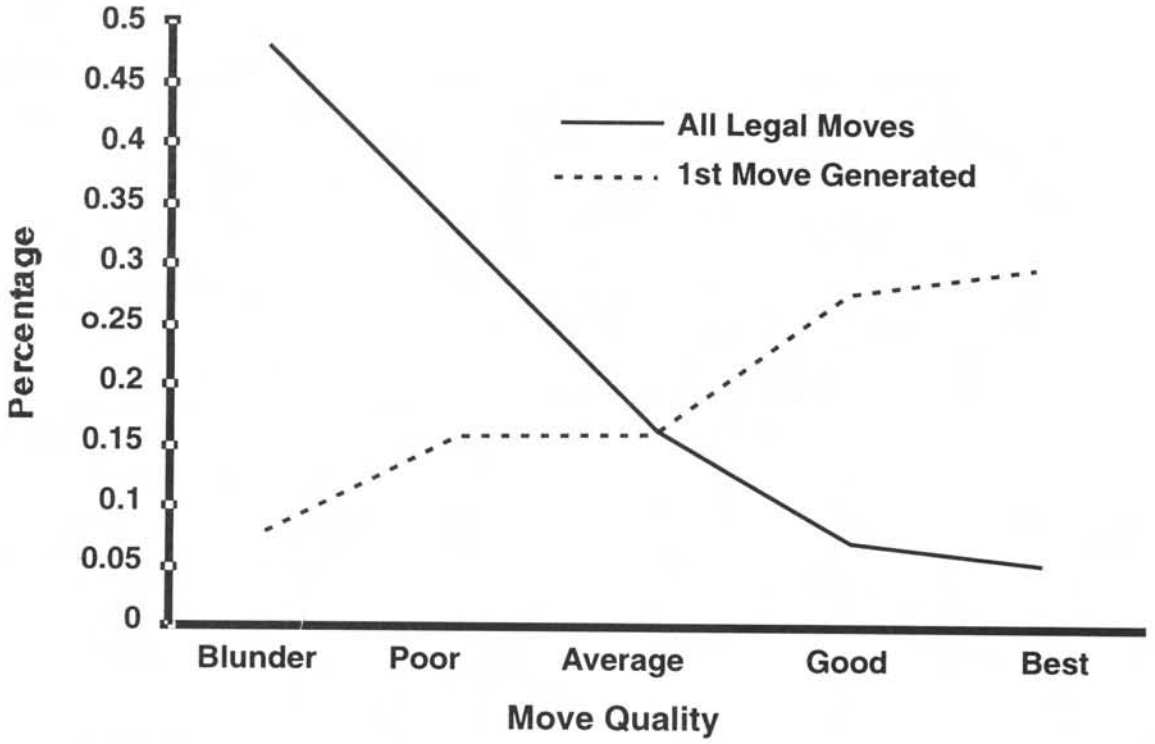

Figure 2. Percentage of first moves and all possible moves receiving each of five move quality ratings.

hypothesis in a study that used 16 skilled chess players. They presented the chess players with difficult positions and asked them to think aloud while trying to find a good move. The researchers recorded the very first move that each chess player mentioned, despite how many they ultimately considered or which one they selected. Afterward, the chess players rated all of the legal moves in each diagram. Figure 2 shows that most of the legal moves were rated as poor ones. However, the very first move that the chess players considered was rated very high, using the players' own assessments. This means that, according to their own standards, the first moves were good ones.

Still, we might wonder how good these first moves were, by objective standards. To investigate this issue, we used board positions taken from games analyzed by panels of chess Grand Masters. The Grand Masters awarded points to those options they deemed playable. Table 2 shows that the Grand Masters awarded points to only 20 out of 124 legal moves. If the participants in the study had been selecting randomly from legal moves, they would have shown the same pattern. However, they showed the opposite pattern. Of the 64 first moves (16 participants and four board positions each), 41 were moves that had received Grand Masters points, about two thirds instead of one sixth. Therefore, using objective criteria, we find that skilled decision makers can generate good options as the first ones they consider. These findings confirm the claim made by the RPD model that people can use experience to recognize typical reactions that are usually satisfactory.

Klein (1989) also has speculated about the boundary conditions for using recognitional decision making and those for using Rational Choice method. These are shown in Table 3. When time is short, the decision makers are experienced, the conditions keep changing, and the goals are ill-defined, a recognitional strategy is appropriate. On the other hand, if the decision makers are novices, have ample time, have to justify their choice to others, need to resolve conflicts among team members with different priorities, have to find the best option, and are working with a task requiring a great deal of computational complexity, then a Rational Choice strategy makes sense. We find people using a rational choice strategy in many operational settings, such as selecting a weapons system during a competitive procurement and prioritizing research areas to allocate funds.

Table 2
Frequency of Subjects' First Generated Moves vs. All Legal Moves by Acceptability Level

	First move generated by the subjects	All legal moves
Acceptable moves (Grand Master points were awarded)	41 moves	20 moves
Unacceptable moves (No Grand Master points were awarded)	23 moves	104 moves

To summarize, the RPD model was developed based on field studies of the way that experienced personnel actually made decisions. The model describes how people can use experience to react rapidly and how they can make good decisions without having to contrast options. The model has been tested and supported by different research teams working in a great variety of settings. Because of work such as this, we have a better idea of the way people actually make decisions.

The RPD model is not synonymous with NDM research. There are other NDM models. Moreover, the RPD model is incomplete—it does not cover teams, organizations, or issues of managing workload and attention, and so on. In addition, the RPD model does not describe the strategies people use when they do have to compare options in naturalistic settings. The significance of the RPD model is that:

- it appears to describe the most frequently used decision strategies,
- it explains how people can use experience to make difficult decisions, and
- it supports the observation that people can make effective decisions without going through a Rational Choice strategy.

Table 3
Boundary Conditions for Different Strategies

	Singular	vs.	Comparative
Time Pressure	x		
Experience Level	x		
Dynamic Conditions	x		
Ill-defined Goals	x		
Justification			x
Conflict Resolution			x
Optimization			x
Computational Complexity			x

Prior to the RPD model and others like it, traditional decision researchers speculated that under certain task conditions people would not use a Rational Choice strategy, but no one presented a coherent idea of what the alternative might be. Most researchers assumed that it would be a defective version of the Rational Choice strategy or some sort of random process. The description of the RPD model provided a firm counter-example to Rational Choice and made it easier for NDM researchers to take naturalistic decision strategies more seriously.

Cognitive Task Analysis methods have been essential to the study of the RPD model and other NDM processes. Cognitive Task Analysis addresses the cognitive aspects of performing tasks rather than the observable steps and procedures. One of the research areas funded by ARI in the mid-1980s was the development of better tools for eliciting and representing knowledge. Cognitive Task Analysis methods had existed prior to this time and were being developed and refined in a number of settings. The thrust of the ARI research was to develop Cognitive Task Analysis tools that could support research programs in NDM. Because NDM focuses on the perceptions and strategies used by experienced decision makers, one of the keys to successful research programs was to develop and make available more powerful and reliable methods. For example, a Critical Decision method developed and evaluated under ARI funding concentrates on difficult and challenging decision points and uses these to probe for the cues, patterns, and inferences that people make. This method has been used in dozens of different projects and domains.

There are many Cognitive Task Analysis techniques, including interview methods, observation methods, computer simulation approaches, along with more traditional behavioral strategies. The different Cognitive Task Analysis tools are now being used to identify requirements and to provide materials for projects in training and in system design; they appear to have applicability for personnel selection, root-cause analysis and accident investigation, technology transfer, organizational reengineering, and even market research.

One of the drawbacks of most of the Cognitive Task Analysis methods is that they are labor intensive and require the observers and interviewers to be carefully trained. A new generation of methods is being designed that will be more efficient to use, although less powerful (Crandall, Klein, Militello, & Wolf, 1994). Another drawback of most Cognitive Task Analysis methods is that they rely on subjective data, primarily introspections of the people being interviewed. People may distort their explanations because of poor memory or for other reasons. All experimental methods have drawbacks that must be considered. We have learned to use Cognitive Task Analysis data as a rich source of ideas, hypotheses, speculations, and insights—an invaluable window into the mind of the decision maker.

THE RANGE OF NATURALISTIC DECISION MAKING RESEARCH

From 1985-1990, the ARI Basic Research Program funded work by Janet Kolodner from Georgia Tech on Case-Based Reasoning, Raanan Lipshitz from the University of Haifa on the decision strategies used by Army command and control officers, Ken Hammond from the University of Colorado on the decision strategies used by weather forecasters and also the effect of stress on decision making, and Martin Tolcott of Decision Sciences Consortium on ways of improving the decision making of Army intelligence officers, along with Klein Associates' research projects described previously. It continues to support the work of Len Adelman of George Mason University on the decision strategies used by technicians operating Patriot missile batteries. All these researchers had been active prior to the ARI initiative, and several of them, particularly Ken Hammond, had been identified with other approaches to decision research. By bringing them together for annual program reviews, ARI could gain a critical mass of professionals who had similar interests and goals, thereby sparking the NDM movement.

Other researchers had been working within the NDM framework (i.e., the features described in Table 1) prior to 1985. Jens Rasmussen of RISO Laboratory in Denmark had been studying nuclear power plant operators and Joseph Wohl of MITRE had been describing Navy command and control officers, to name just two prominent examples of work done in the period 1975-1985. Jim Shanteau of the University of Kansas and his colleagues had been investigating proficient decision makers in a variety of fields. An earlier example would be the work of Adriaan de Groot in 1935, who studied the decision making of chess Grand Masters. The NDM approach did not come out of nowhere. Rather, it has served as a rallying point for researchers who did not adopt the traditional approaches to studying decision making. In so doing, it has focused and clarified the commonalties among these efforts and accelerated the exchange of ideas and methods.

At present, NDM research is being pursued in a range of settings for many different sponsors. Research projects can be classified into five categories:

- cognitive process studied: situation awareness, decision making, and/or problem solving,

- domain studied: aviation, technical tasks, battle command, health care, business/industry, process control,

- decision-making unit studied: individuals or teams,

- objectives of the study: investigate, improve training, improve human-system interface design, and

- sponsor: Army, Navy, Air Force, Marines, Federal Aviation Administration, NASA, the National Institutes of Health (NIH), and others.

The five categories are useful for comparing different projects, and most projects will fall within a single cell, but few researchers will be so neatly categorized. The Defence Research Agency of the United Kingdom (Pascual & Henderson, in press) has both investigated the situation awareness and the decision making of British Army command and control officers. ARI has both investigated and tried to improve the performance of battle command officers, with regard to situation awareness, decision making, and problem solving (Fallesen, 1993). The Navy Personnel Research and Development Center (Randel, Pugh, Reed, Schuler, & Wyman, 1994) investigated both situation awareness and decision making of Navy electronic warfare technicians. Stokes, Kenper, and Kite (in press) have examined the effects of stress on both situation awareness and decision making of pilots.

Several researchers are doing work that has both basic and applied implications. NASA/Ames and NIH are sponsoring research about the way anesthesiologists make decisions in teams (Xiao, Mackenzie, and the LOTAS Group, 1995; Gaba, 1991); the work has both basic and applied implications. Similarly, there are both basic and applied implications to the work of Lia Di Bello (in press), of the City University of New York, who studied people working with complex software systems. She has performed intensive observations of factory workers using process control software systems, and also transportation departments relying on complex software systems, both of which fall within the domain of process control. The Air Force's Armstrong Laboratory (Waag and Bell, in press) has established a research program on situation awareness in F-15 pilots. This work also is being used to develop individual and team training for pilots. David Noble (1993; Noble & Flynn, 1993), of Engineering Research Associates, started with a series of investigations into the decision making of Navy battle command officers, and the project led to the development of a decision support system. Mumaw, Roth, and Schoenfeld (1993) of Westinghouse have been modeling the decision making of nuclear power plant operators, to advance the field of simulation of cognitive processes, and also to provide better interfaces and decision support systems.

For other research projects, the crossover incorporates work on individuals and teams. NASA's Ames (e.g., Orasanu, 1990; Mosier, 1990), working in the field of aviation, is examining situation awareness, decision making, and problem solving, studying both individuals and teams. Daniel Serfaty, working at APTIMA, studying the training of battle command officers, has addressed individuals along with teams (Serfaty, Entin, & Volpe, 1993); this work has been sponsored by the Army and Navy.

Several researchers have worked in more than one domain. Marvin Cohen of Cognitive Technologies, Inc. has studied decision making in commercial flight crews, provided decision training to Navy AEGIS officers, and provided situation awareness training to Army battle

command officers (e.g., Cohen, Freeman and Thompson, in press; Cohen & Freeman, 1996). At Ohio State University, David Woods and his colleagues' research spans aviation, health care, and process control (Woods, Johannesen, Cook, and Sarter, 1993). Phil Smith, at Ohio State University, examines both training and decision support system for health care, and aviation. Eduardo Salas and his colleagues (Jan Cannon-Bowers, Caroline Prince, Joan Hall Johnston) at the Naval Air Warfare Center/Training Systems division are training individuals and teams, including AEGIS commanders and aircrews (Cannon-Bowers, Salas, & Converse, 1992; Driskell, Salas, & Hall, 1994; Prince, Chidester, Cannon-Bowers, & Bowers, 1993; Salas, Cannon-Bowers & Johnston, in press). Researchers are finding that they benefit from working in several domains because they learn from the similarities and differences and better appreciate the nuances of each individual domain.

Some NDM researchers and practitioners are primarily aiming to solve operational problems. Aer Lingus is actively presenting individual and team training for commercial pilots (Johnston, 1992). The National Fire Academy has incorporated the RPD model into training programs for fireground commanders (Mirabella, Satterfield, & Wood, 1995), and was among the first to implement NDM in training. The U.S. Marine Corps is using NDM to improve training for battle commanders (Schmitt, 1996).

Recently, the Navy initiated a large-scale research program called Tactical Decision Making Under Stress (TADMUS). This is an NDM project studying situation awareness and decision making of individuals and teams in platforms such as AEGIS cruisers. One goal of TADMUS is to improve the human-system interface; a second goal is to improve individual and team training for decision making performance.

The interested reader is directed to Klein, Orasanu, Calderwood, and Zsambok (1993) or Zsambok and Klein (in press) for additional references. ARI sponsored the first book and cosponsored the second.

FRAMEWORK FOR APPLYING THE NATURALISTIC DECISION MAKING APPROACH

How does NDM research help the Army do its job? If the NDM movement does not offer direct implications for improving Army decision making, then we must judge it a failure no matter how reasonable the definition and features. It may be early to expect an extensive track record of NDM applications but we should at least be able to predict what these applications are likely to be.

This section explains why the NDM approach is more likely to provide useful applications for the Army than traditional decision research. However, there is a paradox that needs to be considered: The initial impetus behind the NDM movement was to **describe** what people actually do, whereas the motivation behind traditional decision research was to **improve** the way people make decisions. Therefore, NDM research should have **less** applied value than the traditional research, rather than more.

The traditional decision research tried to identify a Rational Choice method (generate a range of options, identify evaluation criteria, evaluate each option on each criterion, calculate the results, and select the option with the highest score) that could help people make better decisions. These steps are a general strategy intended to prescribe better methods than people ordinarily use. The classical approaches to decision making are centered around application. They are general because they try to improve process, regardless of content area.

A second traditional approach to decision research involves the demonstration that subjects in laboratory experiments often show biases because of the way they use heuristics; e.g., shortcuts in reasoning. This heuristics and biases approach appears to have applied potential. If we can describe these biases, we can take steps to train people to overcome them or to build decision aids to detect and alert the operators to decision biases or to take other steps. These are also improvements that should generalize across different content areas.

In contrast, NDM research tries to describe the strategies proficient decision makers are using and does not have any central claims that would lead to implications for improving decision quality. It does not make sense, for example, to train naturalistic strategies such as the RPD model, because the model describes what people already do.

There are several reasons for expecting NDM research to result in applications that will improve decision quality more than the traditional approaches to decision making. These are shown in Table 4.

Table 4
The Applied Potential of Naturalistic Decision Making

- Classical methods do not apply in naturalistic settings
- NDM tries to support, rather than replace the strategies ordinarily used
- Experienced decision makers can be used as standards for performance
- Decision requirements can be context-specific

Classical methods do not apply in many naturalistic settings. Attempts to apply the context-free strategies have largely met with failure. General strategies must be weak strategies because a one-size-fits-all strategy would not fit any specific setting very well. As we have seen, the constraints of naturalistic settings such as time pressure, inadequate information, shifting conditions, ill-defined goals, and so forth typically make it impractical or impossible to apply methods for Rational Choice. Literature reviews have turned up many instances of failure to train people to use Rational Choice strategies (e.g., Howell, 1991; Means, Salas, Crandall, & Jacobs, 1993; Zakay & Wooler, 1984). Some studies have even shown higher performance from subjects using unsystematic strategies than subjects trained and directed to use Rational Choice strategies (e.g., Driskell et al., 1994). Further, attempts to build decision aids using the Rational Choice model have been largely unsuccessful, and some primary sponsors of this research during the past 25 years have admitted their disillusionment (e.g., Tolcott, 1991). The decision

aids were brittle and became less helpful as the problem became more complex, which was when help was most needed. When some of the conditions listed in Table 1 are relaxed, then we would expect that a Rational Choice method would be useful. Hammond and Adelman (1976) describe a successful use of a Rational Choice strategy for selecting a type of bullet for use by the Denver Police Department, to satisfy the needs of police officers and citizens. Time pressure was low, expertise was low, the problem was stable, and different stakeholders were involved. A number of Army situations may be amenable to Rational Choice methods, even though most operational settings will not be suited to Rational Choice.

Turning to the studies of heuristics and biases, studies are now showing that experienced decision makers do not show the types of biases found under the restricted laboratory conditions (e.g., Christensen-Szalanski, 1986; Fraser, Smith, & Smith, 1992; Gigerenzer, 1987; Lopes, 1981). At present, it is unclear how much of an impact these heuristics have on less-experienced decision makers. Debiasing methods have not been empirically demonstrated to be effective.

When the decision maker is experienced, then we should try to help with situation awareness. When the decision maker is inexperienced, then even Rational Choice strategies are not likely to be successful because naturalistic settings usually do not allow Rational Choice strategies to be used and because novice decision makers are likely to make errors in applying these strategies. Moreover, in many cases, people wrestle with choices that have little consequence. If decision makers can easily distinguish which of two options is superior, they will not need to perform the analyses. If the options are very close together and their strengths and weaknesses are well balanced, then it usually will not matter which one is selected. Decision makers will find it hardest to make choices as the differences between the choices diminishes, but as the differences diminish the implications of the choice also diminish.

NDM tries to support, rather than replace, the strategies ordinarily used. It is easier to help decision makers better employ their own strategies than to try to replace these strategies with more formal ones. Further, in most operational settings, the more formal and analytical strategies cannot be efficiently applied, which would make decision makers reluctant to adopt a new set of strategies.

Experienced decision makers can be used as standards for performance. NDM researchers tend to study the more experienced decision makers and try to identify how they can make effective use of their experience. Often, the strategies and cues used by experienced decision makers can serve as criteria against which to measure the actions of novices. Therefore, even in situations where researchers cannot define the statistical or logical optimal strategy, they can use the processes found in experienced decision makers as performance standards.

Decision requirements can be context-specific. Decision requirements are the critical and/or difficult judgments and decisions within a task. Investigators can use Cognitive Task Analysis to identify these decision requirements. For each, the analyses can describe the reasons why these are difficult, along with the cues, patterns, inferences, and strategies used by proficient personnel to overcome the difficulties.

The advantage of using decision requirements is that they are context-sensitive. They do not try to prescribe a generic method for making decisions. Instead, the approach is to look at the ways that experienced decision makers make decisions within their own domains. Rather than searching for general methods, practitioners can search for the decision requirements of the specific situation. What matters is not just **how** people think (their strategies), but also **what they think about** (the content).

Decision requirements become the target of interventions. If a battle command function is studied and shows that inexperienced commanders have difficulty interpreting the intent of enemy forces, judging where to place reserve units, or setting priorities for air assets, these would become the decision requirements. If the studies identify the factors that make these judgments and decisions difficult, these would be highlighted for training programs (e.g., in designing scenarios) and decision support systems (e.g., for organizing human-system interfaces). If we can learn how proficient commanders work around the difficulties, we can use this information for training and for system design as well. Such an approach would have higher face validity for users, who would see the immediate benefits of the interventions. It would also have greater likelihood for transferring to the operational environment, because the intervention would be oriented around the barriers and difficulties that users encounter in the field.

TOOLS AND TECHNIQUES FOR USING DECISION REQUIREMENTS

Given the assumptions described in the previous section, the NDM framework can be applied in several areas, as listed in Table 5. In covering the topics presented in Table 5, the greatest emphasis is on the decision-centered training of individuals, because there are many potential interventions that could quickly be adapted for use by Army units. The other applications are also important though they are not covered in the same level of detail.

Table 5
Applications of NDM Research

- Decision-centered training of individuals
- Decision-centered training of teams
- Decision-centered design
- Mission rehearsal
- Doctrine
- Decision-Centered Training of Individuals

Decision-Centered Training of Individuals

Decision-centered training of individuals refers to the use of decision requirements in designing training programs and training devices. For the past 20 years, systems approaches to training such as the Instructional System Design (ISD) procedure have been dominant in the Army. The objective of ISD is to take complex tasks and decompose them into basic elements,

specifying the initiating and terminating conditions for each element or subtask, and measure the success of training by the achievement of performance criteria. This has worked fairly well, despite the effort needed to conduct a full-scale ISD study. However, approaches such as ISD are mostly used for procedural tasks (e.g., setting up equipment) and not for judgment and decision tasks. As long as the bulk of Army training covered procedures, ISD was satisfactory. Now that the Army may need to train judgment and decision making, ISD may need to be supplemented. The potential of NDM work is to provide guidance for exactly those skills where ISD is insufficient.

Currently, the ARI Research Unit at Fort Leavenworth is developing a Battle Command elective on Practical Thinking, as part of an experimental course to be offered at the Command and General Staff College. Part of the impetus for this work has been the recognition of the opportunities for focused decision training generated by the NDM perspective. The approach taken for this component is consistent with the NDM framework. At other sites, such as the National Fire Academy, the RPD model is being used as a basis for revising the curriculum to improve the decision training. The U.S. Marine Corps is also developing strategies for putting the RPD model into action, as will be discussed.

The NDM application of training individuals can be divided into decision skills (Table 6) and training methods (Table 7). Table 6 presents the types of decision **skills** that would be emphasized within an NDM framework for training individuals. None of these skills is generic. Each must be trained within the context of the operational setting in which it is needed.

Table 6
Decision Skills That Can Be Trained

- Situation awareness, pattern matching, and cue learning
- Typical cases and anomalies
- Mental models
- Time horizons
- PreMortem strategy and Crystal Ball strategy
- Managing uncertainty and time pressure

Situation awareness, pattern matching, and cue learning. The ARI Research Unit at Fort Leavenworth is sponsoring applied research by Marvin Cohen on the training of situation awareness. This training includes strategies for considering alternative hypotheses and explanations of what is happening, so soldiers become less likely to fixate on a single explanation. Previous research has found that errors may arise when a decision maker forms an initial hypothesis and then explains away inconsistent facts. The situation awareness training is aimed at helping officers to judge when they are explaining away too much so that they can begin to search for different explanations.

In using recognitional strategies, decision makers must be able to notice patterns, trends, and critical cues. These patterns and cues can be identified using Cognitive Task Analysis

methods and can be established as training objectives, using scenarios, simulations, or even low-level interventions such as video clips. Such training should help soldiers size up situations quickly. The training also can be designed to sharpen the soldiers' ability to detect critical cues and to make fine discriminations. Currently, Army training already centers around common schemas such as "advance to contact" and "hasty defense." Each schema presents its own judgment and decision requirements, and these can be trained in conjunction with the exercises.

Typical cases and anomalies. Proficient decision makers have had so many experiences that they have learned to recognize typical cases. The different interventions listed next in Table 7 can be organized to speed up the ability to recognize typical cases and patterns. At the same time, the training should make it easier for soldiers to detect anomalies. These anomalies are often the early warnings to begin taking precautions or preparing for contingencies.

Mental models. Many NDM researchers (e.g., Cannon-Bowers et al., 1992; Orasanu, 1990) are investigating methods for teaching mental models to help trainees see situations the way experts do. These may be mental models of the task, the equipment, the teamwork, or other considerations. The idea of training mental models is to provide a stronger basis for appraising situations.

Time horizons. One finding of NDM research is that more proficient soldiers and officers can see further into the future in planning their actions. Therefore, we can establish as a training requirement the design of scenarios, exercises, and feedback around chains of events to enable trainees to anticipate more effectively. ARI has taken the initiative in exploring ways of improving the time horizon of commanders as a way of improving leadership (Jacobs & Jaques, 1991).

PreMortem and Crystal Ball strategies. These techniques have been developed and used to evaluate plans and situation assessments. They are discussed later in greater detail, in the section on mission rehearsal, but they also can be used as training methods.

Managing uncertainty and time pressure. The U.S. Marine Corps has applied the RPD model and the ideas of NDM to develop and initiate training that calls for rapid tactical situation assessment and reactions under uncertainty. The Marine Corps calls this "Quick Decision Training." The goal of this training is to develop metacognitive skills so that trainees can overcome the desire for more information and gain an ability to better manage the time cycle.

What sorts of **methods** would be promoted by the NDM framework? Thus far we have identified several interventions, as listed in Table 7. Each of these interventions reflects a way of using decision requirements to improve the way individuals are trained to make better decisions. Each intervention is a way of helping to strengthen the skills aforementioned.

Table 7
Methods for Training Individuals to Make Better Decisions

- Design of training scenarios
- Cognitive feedback within the After-Action Review (AAR)
- Cognitive modeling and expert/novice contrasts
- Lists of common decision failures
- Test and Evaluation techniques
- On-the-Job Training methods
- Training device specification

Design of training scenarios. Decision requirements can tell us which judgments and decisions need to be emphasized and which contextual factors create the most difficulty. This information can be used to guide the development of scenarios. Often, people develop training scenarios to present the right level of difficulty, without having clear objectives about the nature of the challenges. By using decision requirements, scenario developers can get the structure they need. We must remember that Practice Training. Simply providing soldiers with an opportunity to practice does not **necessarily** translate into better and more meaningful training. Often, increased practice will translate into skill development. However, there have been too many instances in which exercises were poorly conceived and did not take advantage of important opportunities to train decision skills. Sometimes, exercises are designed so carelessly that they teach the wrong thing, namely, habits that will be dysfunctional on the battlefield. In contrast, naturalistic decision strategies can be used to systematically shape scenarios. The U.S. Marine Corps is incorporating NDM exercises into the curriculum at professional schools and at the noncommissioned officer level.

Cognitive feedback within the After-Action Review (AAR). After completion of an exercise, we can use decision requirements to show soldiers where they went right and where they went wrong in making judgments and decisions. Currently, AARs concentrate on the specific actions taken. This is important, but it misses the opportunity to use the AARs to teach why the mistakes were made so that the decision makers can learn what they are doing wrong. We have observed in many settings (e.g., Command and General Staff College, U.S. Army War College, armor training at Fort Knox, rotary wing training at Fort Campbell) that a limited amount of time is budgeted for the exercises, leaving little opportunity for the AAR. Because of this, soldiers might learn poor habits during the exercise, **and** get a chance to practice these poor habits, without ever learning that they are doing things wrong. If the AAR also covered the decision process—the way the soldiers handled the decision requirements—then the effect of the training exercise could be greatly leveraged at little cost. We would not want to see additional training in decision making—it is best to embed such training in the context of the exercises already being run and to use the opportunities to provide feedback about the decision processes.

Cognitive modeling and expert/novice contrasts. Sometimes it is possible to present trainees with information about how experienced soldiers make certain types of decisions. This can let the trainees see what is possible, what cues and relationships the experts notice, and how

the experts differ from the trainees in the way they size up situations. Materials can include contrasts between the way experts and novices frame the same situations. Cohen, Freeman, and Wolf (in preparation) have explored this strategy in a project for the Navy using Tactical Action Officers, and we expect to see more work in this area.

Lists of common decision failures. We have found that some trainees do not take training as seriously as they should because they do not appreciate the types of decision failures that can occur. Cognitive Task Analysis methods can document actual failures in judgments. In a sense, the study of military history encompasses an attempt to identify and learn from previous successes and errors. Recent research has shown that simply presenting case histories and examples is not optimal because trainees may not appreciate what they are supposed to conclude. Instead, the examples can be placed within a context of the decision processes.

Test and Evaluation techniques. When a clear set of decision requirements has been developed, it can be used to establish criteria for measuring the cognitive performance of soldiers. The decision requirements can provide a basis for assessing the ability of trainees to rapidly detect anomalies, respond at the appropriate time horizon, notice that expectancies have been violated, and determine that events did not occur.

On-the-Job Training (OJT) methods. NDM research shows that expertise involves many subtle aspects of situation awareness. It is not always feasible to incorporate all aspects into training programs. The cost of schoolhouse training is expensive, and transfer to the field is problematic. Therefore, OJT is likely to assume greater importance. ARI is sponsoring a research program to identify the primary aspects of OJT and to use these to increase the impact of its own field exercises. Much of this work can be traced directly to NDM studies that showed the importance of contextualized practice over prescribed decision strategies. Klein Associates has recently studied the use of OJT with an Army National Guard unit.

Training device specification. The design of training devices can be guided by decision requirements. The identification of decision requirements will help to specify the type of training that should be supported by a training device, thereby driving the device features. We are currently performing a project for the Naval Air Warfare Command/ Training Systems Division to show how to use decision requirements to specify training device features for sonar operators. In addition, decision training also can be provided using extremely low levels of fidelity. The Quick Decision exercises used by the Marine Corps are paper-and-pencil tasks that manage to create high levels of time pressure and uncertainty and have received enthusiastic use for improving decision skills.

Decision-Centered Training of Teams

The NDM framework has been useful for focusing on team decision making. Traditional decision research programs have concentrated on individuals rather than teams. For example, the concept of shared mental models, developed and applied by Orasanu and Salas (1993), Cannon-Bowers et al. (1992), and others, is being used in the Navy to train teams. Prince et al. (1993) have developed several well-accepted team training programs for the Navy. Helmreich (1986) has expanded his initial Crew Resource Management program from use in commercial

aviation to a wide array of domains. Zsambok, Klein, Kyne, and Klinger (1992) have developed a team decision training module that has been institutionalized at the Industrial College of the Armed Forces. In addition, ARI has conducted an active research and development program in conjunction with the Command and General Staff College. Salas et al. (in preparation) have concluded that expert teams can be developed by:

- fostering shared or compatible mental models of the task and of the roles of each team member,
- training the team members on teamwork skills such as situation awareness, leadership, and compensatory behavior,
- providing experience for teams to function under the types of stressful conditions they will encounter, by cross-training (letting the team members practice on the roles and tasks of others), and
- showing leaders how to maintain shared situation awareness.

Decision-Centered Design

Decision-centered design refers to the use of decision requirements in designing information management systems and human-system interfaces. Currently, the dominant methods are a **systems-centered design** approach (focus on the technology, not on the user's needs and abilities) and a **data-centered design** approach (identify all the relevant information and pack it into the displays).

In contrast, the NDM approach identifies the decision requirements in a given job or task and uses these in the conceptual design stage to help guide the process. The impact of decision-centered design has been shown in several projects. For example, Klinger, Andriole, Militello, Adelman, Klein, and Gomes (1993) redesigned the AWACS Weapons Director's interface. The new interface resulted in a performance improvement of approximately 20% after only 4.5 hours of practice, compared to the performance of the same Weapons Directors using their regular interface on which they had received more than 1,000 hours of practice. Another successful design project (Miller, Pyle, & Shore, 1993) was for a decision support system for weaponeers. Klein (1993) describes more fully the use of decision requirements for system design.

Currently, the NDM framework is being applied to design issues within the context of efforts for Digitization of the Battlefield. The Army Research Laboratory (ARL) is seeking to use the NDM approach to help shape its participation in this effort. A 2-day workshop on NDM was presented to ARL, and as a result, the NDM perspective was incorporated as part of a special panel reviewing ARL plans for supporting the Digitization of the Battlefield program. The premise is that the NDM framework will be useful in guiding system design and human-system interface efforts.

The NDM perspective greatly influenced the NATO Research and Study Group RSG.19 in their development of a framework for Cognitive Analysis, Design, and Evaluation (COADE) (Essens, Fallesen, McCann, Cannon-Bowers, & Dorfel, 1995). This work, cosponsored by ARI, has incorporated NDM into concepts for system design.

The U.S. Marine Corps is investigating ways to use NDM and recognitional decision-making concepts in designing regimental Command Posts. The objective of this effort is to improve the battle command function by taking advantage of the findings of NDM research.

Mission Rehearsal

Within the RPD model, mission rehearsal corresponds to the process of mental simulation for evaluating a course of action. Research supported by the ARI Research Unit at Fort Rucker showed that for helicopter crews, mission rehearsal largely consisted of running through the steps and sequence of the plan, rather than trying to anticipate ways that the plan might run into trouble. We have identified an active form of mental simulation called a PreMortem exercise. The PreMortem strategy is to assume that the plan has already failed and enlist the expertise of the planners to explain the most likely reasons. Instead of trying to pretend the plan is robust, the planners can demonstrate their experience and credibility by finding weaknesses. We have used the PreMortem exercise in many planning settings because of its value in identifying weaknesses at the outset of the implementation. Furthermore, the PreMortem strategy has been expanded as a mechanism for mission rehearsal by ARI and was recommended by the ARI Research Unit at Fort Rucker, AL, for use during Operation Desert Shield. (The lead time was not sufficient to put this strategy into effect during the Persian Gulf War.) This type of active mission rehearsal was an outgrowth of NDM research and the RPD model in particular. Another strategy is the Crystal Ball method (Cohen, Freeman, & Thompson, in press), which uses mental simulation to help Army commanders consider alternate explanations for a situation and make better use of conflicting information. This method has been studied at the Command and General Staff College at Fort Leavenworth, KS.

Doctrine

One of the most important impacts of NDM research is on doctrine. Previously, doctrine has been clear in promoting the Rational Choice model. Commanders have long recognized that the Rational Choice model was not used by their staff members, particularly under field conditions. The latest version of Field Manual 101-5, Command and Staff Procedures, (U.S. Army, 1986) no longer solely advocates the Rational Choice model. Instead, several decision-making approaches and processes are now offered. These include the Rational Choice model, called the Deliberate Decision Making process, to cover conditions in which analytical strategies are needed. A second model presented in FM 101-5 is for combat conditions, in which the mission has begun and naturalistic conditions preclude the use of the Deliberate Decision Making process. Yet another strategy described in the new FM 101-5 is for quick decisions, in which the commander and one or two staff members accomplish the planning. A fourth strategy is a troop-leading procedure, to help officers at the level of lieutenants prepare to assess the situation and respond.

The use of these different strategies is contingent upon factors such as experience level and the time available. The range of strategies reflects an appreciation for the need to enable the commander to become more autonomous during combat decision making.

The range of strategies is consistent with the need to establish a tighter decision cycle and use information technologies to speed the planning and reaction processes. With the adoption of these new guidelines, the Army has recognized that the Rational Choice model usually slows the decision cycle and was not being applied effectively. The staff usually generated only a single plausible course of action anyway and then generated a few "dummy" actions to comply with the requirement. This did not result in better plans, but it did waste time and effort.

The U.S. Marine Corps is also considering the modification of its battle command strategy to reflect the realities of recognitional decision making. These changes are in reaction to NDM research. The Marines are seeking to adopt a doctrine centered on decision making as the fundamental act of command, a doctrine that emphasizes NDM over rational, analytical strategies. The parallel developments in the Army and the Marines will enable the two services to maintain consistent philosophies and thereby increase the effectiveness of the joint operations.

This section has identified a range of methods for improving Army decision making. The basis for many of these methods is the use of decision requirements. There are additional ways of using decision requirements; e.g., for personnel selection (using decision skills as a more naturalistic test of abilities than other techniques), but these have not yet been closely examined.

Three challenges facing the Army were described at the beginning of this report. First, the growth of information technologies creates its own difficulties for system design and for training soldiers to use these technologies to make better decisions. The NDM framework seems to have much to offer in helping to place these technologies in service of the decision makers rather than forcing decision makers to adapt to the technologies. Second, the downsizing of the Army will increase the responsibilities of soldiers throughout the chain of command. The NDM framework should be useful in preparing soldiers to handle these responsibilities. Third, the unsettled nature of world events and the shifting role of the military will increase uncertainties and make preparedness more difficult. The NDM framework may be valuable in preparing the Army to handle these uncertainties.

CONCLUSIONS

During the past 10 years, the development of NDM has led to:

- **De-emphasis of Rational Choice model.** This was the dominant model 10 years ago, the source of guidance in designing training and decision aids. Today, military sponsors have learned its boundary conditions and have realized its limitations for most field settings. Although the Rational Choice model has not been rejected for applications where it can be used, military funding for research on this model has largely disappeared.

- **De-emphasis of the heuristics and biases approach.** Although initially promising, military sponsors have found that it does not transition out of the laboratory effectively.

- **Confirmation of recognitional decision models.** Ten years ago field researchers understood that people did not use a Rational Choice model, but did not have alternative accounts of how decisions were made. The RPD and other naturalistic models provided an alternative account. The existence of these alternative accounts enabled practitioners to accept that decision makers could use their experience to recognize courses of action rather than analyzing and comparing them.

- **Suspicion of laboratory experiments.** Ten years ago laboratory research was defined as the standard for quality. Today, we have learned that many laboratory studies do not readily generalize to operational settings. One must be more critical in accepting and using their findings. We have become more open to the value of conducting field studies, and the number of researchers working in naturalistic domains is increasing.

- **Appreciation of expert decision making.** Ten years ago, the traditional research community was busy documenting the failures of subjects in handling laboratory tasks and questioning the capabilities of unschooled decision makers. Today, we have developed more respect for skilled commanders because of the models and studies of NDM. We have a better understanding of the role of experience in decision making. Studies showing that proficient decision makers can quickly generate effective options have changed our understanding of expertise.

- **Investigation of situation awareness.** Ten years ago researchers concentrated on how subjects compared different options. Today, situation awareness has become a topic of increasing attention because we have realized that the way a decision maker evaluates a situation is more important than the strategies used to calculate the best option.

- **Modification of the doctrine regarding decision making.** Ten years ago FM 101-5 specified the Rational Choice model as the standard for military decision making. Today, FM 101-5 encourages the use of recognitional strategies where these are more appropriate.

- **Use of decision requirements.** Ten years ago researchers sought to use generic techniques such as the Rational Choice model to improve decision making. Today, we know that these generic techniques have met with limited success. We are turning to context-driven decision support strategies, such as defining the critical and difficult judgments and decisions that people must make and applying these decision requirements to the development of training programs and design improvements.

- **Emphasis on team decision making.** Ten years ago most researchers ignored issues of teamwork because these were difficult to study under laboratory conditions. Today, the U.S. military supports an increasing number of projects on teamwork and team decision making, reflecting the realization that most NDM settings involve teams.

- **The decision research community has undergone some major changes during the past 10 years as a direct result of the NDM framework.** Many of these changes are dramatic in their implications. We are now equipped with an array of tools and techniques for improving decision making in the types of field settings where the Army and the other military services must operate.

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