TRAINING CRITICAL THINKING FOR THE BATTLEFIELD

VOLUME II: TRAINING SYSTEM AND EVALUATION

by

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13. ABSTRACT (Maximum 200 words): The three volumes of this report describe research findings on three closely related fronts: (1) Development of a theory of the cognitive skills that individuals need to make effective decisions in fast-paced and uncertain environments; (2) development and testing of methods for training critical thinking skills on the battlefield; and (3) development of an advanced system architecture to support adaptive instruction and feedback in critical thinking training. Theory development focused on mental models and critical thinking about mental models in a team context, where initiative might be necessary. Training addressed mental models and critical thinking on three major themes: purpose, time, and maneuver. The training was utilized and successfully tested in an advanced tactics course at the Command and General Staff College. Finally, algorithms were developed to simulate both rapid recognitional responding and more reflective reasoning when time is available.			
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TRAINING CRITICAL THINKING FOR THE BATTLEFIELD

EXECUTIVE SUMMARY

Research Requirement:

Instructors at Army schools and officers in the field agree that current Army education and training do not adequately address decision making skills. What is lacking is a system of training that combines advanced instruction in flexible thought processes (going well beyond doctrinal publications), immediate relevance to Army applications, opportunity for practice in realistic scenarios, and detailed, individualized feedback (not available in current simulators) – and that accomplishes all this despite severe limits of costs, and time and availability of both instructors and students.

The present research had three main objectives:

(1) Develop and extend a theory of the cognitive skills that individuals need to function effectively in fast-paced and uncertain domains.

(2) Develop methods for training those skills in the context of Army battlefield decision making. Improve the ability of Army tactical staff officers to grasp the essential elements of a complex, uncertain, and dynamic situation, visualize those elements in terms of their organization's goals, and take action in a timely and decisive manner.

Test the effectiveness of the training. Does the training improve critical thinking skills? Does it improve the quality of decisions?

(3) Develop a system architecture to support adaptive instruction and feedback in critical thinking training. The architecture should be able to simulate both rapid responses to familiar situations and more reflective responses to novel and uncertain situations.

The training method, like the theory of cognitive skill it is based on, should be readily applicable to a wide spectrum of domains where individuals work in uncertain and dynamic organizational contexts.

Procedure:

Work proceeded on three parallel and closely related tracks: (1) cognitive theory and research, (2) critical thinking training and training evaluation, and (3) advanced modeling and simulation of critical thinking A separate volume of this report addresses the methods and findings of each of these tracks.

In the first track, previous theoretical work was extended in several ways to meet the needs of critical thinking training development: A review and analysis of existing literature on uncertainty handling, additional analysis of interviews with Army staff

officers, and extension of a theory of critical thinking to support algorithm development and to address initiative in teams.

In the second track, we developed and evaluated critical thinking training. We laid the groundwork for training development, by surveying Army training needs and identifying relevant skills for training. We then developed training content and incorporated it into a training delivery system. The training was evaluated in two stages, at Army posts around the country and in a class on advanced tactics at the Army Command and General Staff College, Leavenworth, KS.

In the third track, we developed a computer architecture and algorithms to simulate human critical thinking. These algorithms can serve as the basis for adaptive feedback in future training development.

Findings:

The project introduced innovative statistical methods for discovering the cognitive structure and thinking strategies utilized by decision makers, and employed these methods to analyze several dozen interviews with active-duty Army officers. The Recognition-Metacognition model of critical thinking was extended to address mental models and critical thinking in a team context in which initiative may be required.

A training package was developed with approximately 500 screens. The training addresses three major battlefield thinking themes (purpose, time, and maneuver) and looks at both mental models and critical thinking for each – making a total of six major modules. The training utilizes conceptual instruction, practice in exercises, and historical examples. Graphical interactive techniques were developed to train officers to use both the knowledge structures and decision making strategies characteristic of more experienced decision makers. The training was incorporated into a delivery system that is accessible either through CD-ROM or over the World Wide Web, and is suitable for classroom instruction, training in the field, or distance learning.

The training was tested with active-duty officers in Army posts around the country and at the Command and General Staff College. A very short period of training has been consistently found to significantly affect on both (1) variables related to critical thinking processes and (2) participants' decisions in a military scenario. With respect to critical thinking processes, training increased the frequency with which participants used both proactive tactics and contingency planning, and the frequency with which they referred to the higher-level purposes of the mission. The effect on decisions was dramatic. Participants significantly increased their use of three key tactical elements after training, and also increased their use of combinations of those tactical elements to counterbalance problems with the individual elements.

An advanced computer architecture was designed and partially implemented to support adaptive feedback in critical thinking training. The architecture consists of two interacting components: a reflexive subsystem, which simulates rapid recognition and retrieval of appropriate responses in familiar situations, and a reflective subsystem, which identifies critical uncertainties in the reflexive system and implements strategies for resolving them.

Utilization of Findings:

This project represents an unusually high degree of success both in terms of original research, successful practical application, and commercial potential. The project introduces, develops in detail, and tests a variety of methods for improving decision making skills (i.e., the derivation of training objectives from expert decision processes, a theory of those processes, research techniques for developing training content by modeling expert mental models and decision processes, graphical interactive techniques for conveying this type of content, flexible computer and web-based media, and highly adaptive feedback and guidance. The project addresses immediate Army needs for effective and economical methods for improving the battlefield decision making skills of officers at every level of command, in the schools, in the field, and at home. Its products are already being put to use by instructors in advanced courses at the Command and General Staff College. The training methods have demonstrated enormous commercial potential in a large number of fields, including business, medicine, and aviation. The underlying mental model and decision making technology has even wider potential, for web-based intelligent information retrieval and evaluation.

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CHAPTER 1
INTRODUCTION

The Persistence of Uncertainty

A U.S. military handbook published in 1939 states, “The art of war has no traffic with rules, for the infinitely varying circumstances and conditions of combat never produce exactly the same situation twice.” Though perhaps slightly exaggerated, this precept sounds a useful warning, at least in the short and middle terms (and probably much longer), against the persistent dream of achieving “near-perfect knowledge and information of the battlefield” (Ullman & Wade, 1996, p. 9).

Uncertainty in military operations has many causes, not simply the “fog and friction” of combat described by Clausewitz, or deliberate enemy deception, but also novel missions and mission environments, on the one hand, and the unexpected effects of new technology, on the other. Recent military missions have involved operations other than war, joint and multinational regional theaters, and littoral operations. U.S. military personnel have had to navigate between competing and sometimes inconsistent diplomatic, civil, and military objectives in ill-defined missions, and to work within unclear or highly restrictive rules of engagement. “Situation assessment” in such missions means keeping track of blurred and shifting distinctions between friend and foe, guessing the ambiguous intent of armed “bystanders,” and ferreting out guerilla fighters in urban or mountainous terrain. In these missions, military personnel have had to overcome communication difficulties and cultural clashes, work with both unstable governments and dissident groups, and to undertake many traditionally non-military tasks, such a police work. Coordinating among own troops, allies, and assisted populations is often more of a challenge than dealing with the “enemy.”

Another driver of uncertainty is the expansion of the battlespace through increases in both force dispersal and operational tempo. The last century saw the introduction of motorized, armored, airborne, undersea, unmanned, and space-based platforms. These developments could not have occurred without parallel improvements in sensor and communication technologies. Yet information technology has not fully offset the effects of increasing dispersal and independent action. There is an inescapable tradeoff between amount of information collected and transmitted versus the time it takes for the appropriate human operator to receive it, comprehend it, and react. The unintended consequence has been increasing uncertainty, if not about the enemy, then about the status and even the intent of one’s own forces. New high-bandwidth communication technologies (such as the Force XXI Battle Command, Brigade and Below Program) will almost certainly continue this trend, by passing more initiative and decision-making responsibility further down the levels of command.

New technology and new ways of operating have also increased uncertainty in the business world. In the internet economy, the cost of producing an additional copy of an information product is miniscule, and potential customers are overwhelmed by information options. The result is fierce competition for customers’ attention, leading to drastic price cutting or free distribution. These investments will pay off in future profits only if a stable base of customers can be created, but such a base is constantly threatened by the possible entry of new competitors and rapidly evolving new technologies.

Technology-based businesses must choose between reliance on open standards to attract a base of customers and to increase the overall size of the market, and development of proprietary products to lock customers in and retain control. Technologies that were intended to increase the accuracy and timeliness of information have shaped a business environment in which uncertainty has increased dramatically.

In the Army as well as business there is a need for training that supports the human's ability to handle uncertainty under time stress. Despite this need, instructors at Army schools and officers in the field agree that current Army education and training do not adequately address decision making skills. What is lacking is a system of training that combines advanced instruction in flexible thought processes (going well beyond doctrinal publications), immediate relevance of the training to Army applications, opportunity for practicing skills in realistic scenarios, and detailed, individualized feedback (which is not available in current simulators). Moreover, all this must be accomplished despite severe limits of costs, and time and availability of both instructors and students.

The present research had three main objectives:

(1) Develop and extend a theory of the cognitive skills that individuals need to function effectively in fast-paced and uncertain domains.

(2) Develop methods for training those skills in the context of Army battlefield decision making. Improve the ability of Army tactical staff officers to grasp the essential elements of a complex, uncertain, and dynamic situation, visualize those elements in terms of their organization's goals, and take action in a timely and decisive manner.

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Overview of the Report

This report is divided into three volumes, corresponding to the objectives described in the last section:

Volume I	Basis in Cognitive Theory and Research
Volume II	Critical Thinking Training Training Evaluation
Volume III	Advanced Simulation System for Training

In this introduction, we briefly describe each part of the report. For convenience, the introduction is repeated at the beginning of each volume.

Volume I: Basis in Cognitive Theory and Research

CTI's critical thinking training has several key features:

(1) Unlike many other approaches, it is not based exclusively on formal models of how people ought to think, but on observed differences in decision making strategies between more and less experienced decision makers.

(2) Instruction does not present a set of abstract, disembodied thinking strategies, but trains the targeted skills in a concrete way, embedded within the specific decision making domain.

(3) Training does not simply focus on the individual, but includes an emphasis on decision making within a group context, in which communication is often imperfect or impossible.

In Volume I, we trace the theoretical and research background for the development of such a critical thinking training strategy. Chapter 2 contrasts different views on decision making strategies and strategy selection. Recommendations for handling uncertainty have been dominated until recently by general purpose rules derived from the formal axioms of decision theory. From this point of view, researchers have tended to interpret actual human performance in terms of biases, or systematic deviations from decision theory's formal constraints. In the past 15 years, however, a critical mass of empirical and theoretical work has accumulated that focuses more directly on the knowledge and skill that experienced decision makers apply in real-world tasks, and on strategies that enable them to exploit that knowledge (Cohen, 1993). Chapter 2 traces some of the research threads that have contributed to this development, and which have influenced the present work.

Chapters 3, 4, and 5 describe the way that we have extended that research background in order to build a foundation for the present training. CTI has collected empirical data over several previous research projects that examined decision making in both Army and Navy battlefield environments (Cohen, Adelman, Tolcott, Bresnick, & Marvin, 1993; Cohen, Thompson, Adelman, Bresnick, Tolcott, & Freeman, 1995; Cohen, Freeman, & Wolf, 1996; Cohen, Freeman, & Thompson, 1998). In the Army, we interviewed nearly a hundred officers prior to the present project, occupying a variety of positions and ranks and possessing varying amounts of experience. The present report examines these data from a new point of view, focusing on insights that pertain specifically to *initiative* in a *team* context. This approach was well-suited to an opportunity to develop training for an advanced tactics course at the Army Command and General Staff College entitled *Initiative-based fighting* (developed by LTC Billy Hadfield).

Chapter 3 describes an innovative methodology for identifying knowledge structures, or mental models, from critical incident interview protocols. The methods categorizes judgments or decisions and then analyzes the correlations among the categories across incidents. Mental models are defined as co-occurring categories of information. The influence of other variables, such as level of experience, terrain, and unit type, on the use of these mental models can then be examined. This chapter emphasizes the use of mental models pertaining to *organizational purpose*; the *intent* not just of the enemy but of others in the same organization; *initiative* as an orientation of action to time; and team member *reliability*.

Chapter 4 describes a model of the cognitive strategies that tend to distinguish more effective from less effective officers in battlefield situations (Cohen et al., 1993; Cohen, Freeman, & Thompson, 1998). The model is based on the combination of rapid recognition of familiar situations together with the ability to think critically about the results of recognitional processes. Critical thinking, from this point of view, is not the use of abstract formal rules of thought, but is pragmatic and time-constrained reflection on the uncertainty in the immediate situation and plan. Critical thinking strategies include the identification of qualitatively different types of uncertainty (i.e., incompleteness, conflict, and unreliable assumptions), and the use of different uncertainty handling responses for each. Although the underlying principles of critical thinking are general across domains, the skills themselves are best-acquired in a specific application context, building on previously acquired domain knowledge of the decision makers.

Chapter 5 uses a (newly analyzed) military incident to illustrate how the theory applies to real-world decision making in a team context. The example emphasizes the ability to *think critically* about mental models in situations that require balancing the benefits against the risks of taking initiative. Critical thinking is not just an individual decision making skill. When exercised by a *team leader* and/or *team-members*, it can profoundly alter group dynamics and have important organizational implication.

<u>Volume II: Critical Thinking Training and Training Evaluation</u>

Volume II describes the transition from theory and research to the development of a training strategy (Chapter 6) and training content (Chapter 7), and the incorporation of that content into a computer-based training system (Chapter 8). It then describes the results of two empirical tests of the training system (Chapters 9 and 10).

Chapter 6 reports the results of a survey of Army training needs, and lays out the critical thinking skills to be targeted by the training based on the data, cognitive theory, and student needs survey. It lays out a training strategy based on this analysis, including such methods as instruction, practice, and feedback. Finally, it outlines the theoretical rationale for the training strategy, and contrasts it with training based on other conceptualizations of decision making skill.

Chapter 7 summarizes the training content itself. The training addresses both mental models and critical thinking about three major battlefield themes: purpose, time, and maneuver. It includes six major segments:

(i) mental models to represent the *purposes* of superordinate, subordinate, and coordinate units in an organization

(ii) critical thinking about organizational *purpose*,

(iii) use of action schemas called *time stances* to achieve the proper balance of initiative in achieving those purposes,

(iv) critical thinking about *time stances*,

(v) mental models used in *maneuver warfare*

(vi) critical thinking about *maneuver warfare*.

Chapter 8 describes an integration technology for incorporating the training content within a distributed learning environment. This technology permits distributed sharing of training system resources, interactive exercises, and collaborative, asynchronous learning. The chapter also describes an automated web-capable tutor that we used for testing and evaluation. The system, called *Training to Think Critically on the Battlefield*, can be distributed on compact disc for use on a personal computer or can be accessed over the World Wide Web. It can be used by instructors in the classroom, can be assigned as homework, and can support distance learning and learning in the field. In addition, we developed an authoring tool that permits the construction of new training sequences and interactive exercises, and developed a more advanced prototype system that provides adaptive feedback to trainees regarding critical thinking strategies.

The bottom line question regarding the training is, does it work? Does it improve critical thinking processes as intended, and do such improvements result in enhanced decision making? Training concepts were tested informally with active-duty Army officers at several different Posts, and at a variety of levels of rank and experience, on a continuous basis throughout the development process. Findings from these tests guided training development in an iterative fashion. A more formal test of the training was conducted with over 50 students of an advanced tactics course at the Army's Command and General Staff College. In both cases, training was delivered by computer running software from a CD-ROM.

Interim evaluation results are summarized in Chapter 9. Participants developed courses of action for a combat scenario prior to receiving training, and then revisited the scenario at several points during the training. Exposure to the training helped participants identify and fill information gaps in their plan, expose and evaluate hidden assumptions, and in many cases change their course of action.

Chapter 10 describes experimental tests of the training system with students at the Center of Army Tactics, Army Command and General Staff College. Training was associated with significantly more attention to higher-level purposes (e.g., regarding the larger spatial and temporal context of the unit's own mission), with a greater use of proactive tactics to achieve those higher-level purposes, with a greater ability to identify uncertain assumptions, and with a greater use of contingency plans or branches to handle those assumptions. Training also lead to significant changes in the courses of action that participants adopted. In sum, training influenced both critical thinking processes and the decisions to which they led.

<u>Volume III: Advanced Modeling and Simulation System for Training</u>

Volume III describes the development of an advanced computer architecture to simulate critical thinking performance and to support critical thinking training. The architecture has two interacting components:

(1) a reflexive subsystem, which simulates rapid recognition and retrieval of appropriate responses in familiar situations, and

(2) a reflective subsystem, which identifies critical uncertainties in the reflexive system and implements strategies for resolving them.

Chapter 11 provides an overview of how these two subsystems, working together, can provide the basis for adaptive instruction and feedback in critical thinking training.

The starting point of the reflexive subsystem was a system called *Shruti*, developed by Lokendra Shastri (Shastri & Ajjanagadde, 1993). Shruti combines speed, scalability, and representation of subtle but crucial relational aspects of real-world decision making. To accomplish this, Shruti utilizes rapid, parallel, neural processing, along with temporal synchrony for tracking the identities of objects and roles through relational inferences.

Chapter 12 describes Shruti and extensions of Shruti developed in this project. The extensions were necessary both to improve its representation of reflexive reasoning and to make it work in conjunction with the reflective subsystem. Among the extensions that we worked on were the following:

- integration of utility and belief so that Shruti can simulate decisions as well as inferences;
- mechanisms required for shifting attention, such as temporarily storing and integrating results through a series of attentional shifts; and
- implementation of supervised learning of link strengths through backpropagation.

Chapter 13 describes work performed in this project on a *reflective* subsystem, which critiques the conclusions of reflexive processing and guides its subsequent progress. Features of the reflective subsystem include:

- methods for identifying qualitatively different types of uncertainty based on activation patterns in the reflexive system;
- methods for identifying beliefs most likely to be responsible for different types of uncertainty;
- strategies for shifting attention to beliefs most likely to be responsible for uncertainty.

Uncertainty handling strategies include both domain-specific and more general methods for diagnosing possible causes of the uncertainty and the use of attention and assumptions to stimulate the activation of new information in long-term memory that might resolve the uncertainty.

For convenience, this Introduction is reproduced in all three volumes.

Guide for Readers

Happily, there are alternative paths through this report for readers who have specialized interests, or who wish to get the main points without all the detail. An abbreviated tour through the report that touches on the main areas might consist of the following:

Volume I		
	Chapter 4	Cognitive model of critical thinking that underlies the training design
	Chapter 5	A military decision making example to illustrate the cognitive model
Volume II		
	Chapter 7	Training Content
	Chapter 10	Evaluation of the training at Command and General Staff College
Volume III		
	Chapter 11	Overview of the advanced simulation model for support of adaptive feedback

Another way to break the report down into smaller chunks is by topic or by the reader's primary interest. For example:

Primary Interest	**Most Relevant Sections**
Army training	Chapter 5, to get a flavor of the research basis for the training from a concrete example Volume II
Cognitive Theory	Volume I Chapter 7, for application of the cognitive model to training Chapter 11, for a computational implementation of the cognitive model
Computational models of decision making	Chapter 4, for overview of the cognitive model Volume III

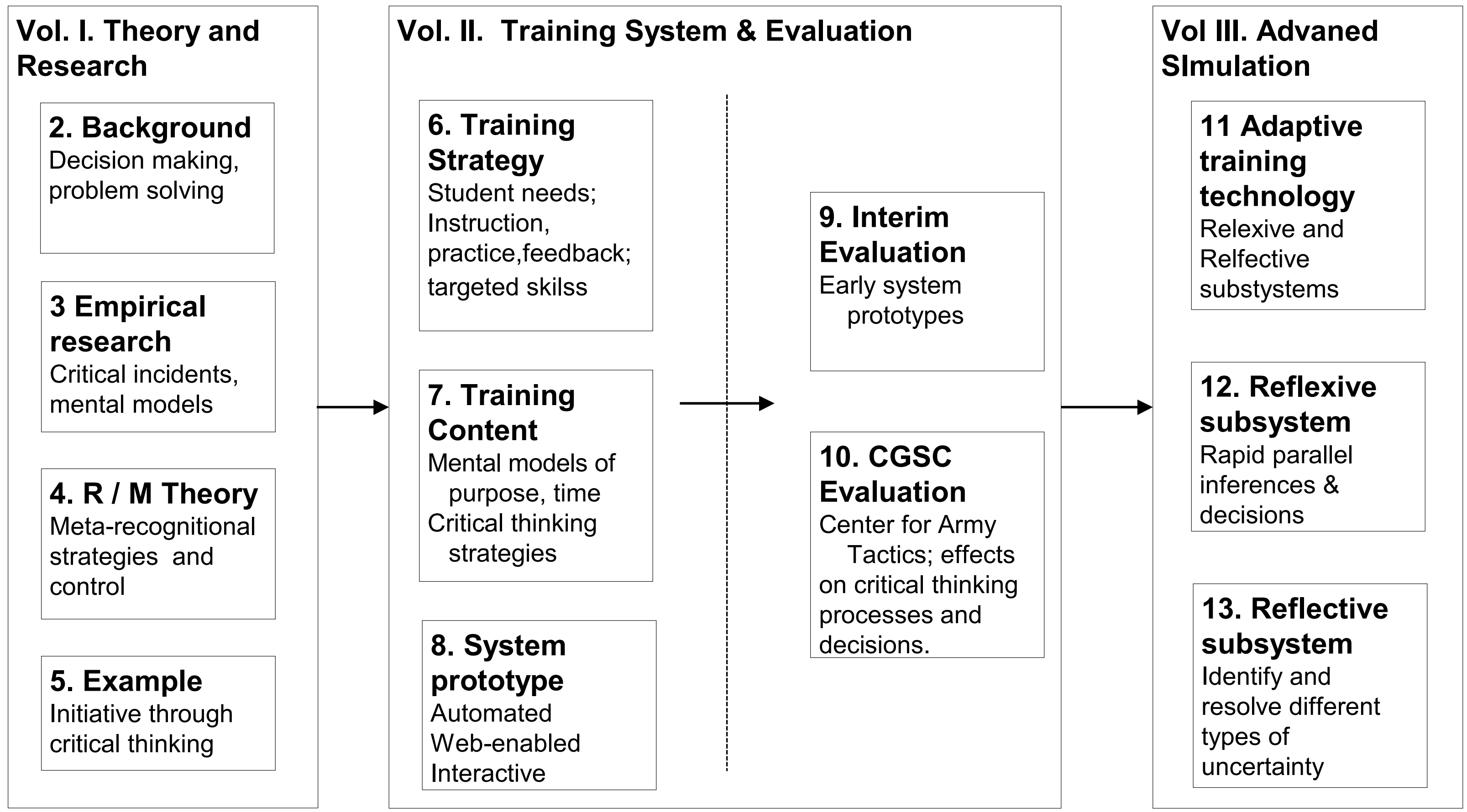

Figure 1. Structure of the report.

CHAPTER 6
TRAINING STRATEGY

According to Salas & Cannon-Bowers (1997), a training strategy orchestrates (1) *tools* (such as feedback and simulation) within (2) *methods* (such as instruction, demonstration, and practice), in order to convey (3) a *content*. In this chapter, we apply the research and theory described in Volume I, to develop a strategy for training the battlefield thinking skills of Army tactical command staff officers. In particular, the training strategy is based on the theoretical background described in Chapter 2, the research described in Chapter 3, and the Recognition / Metacognition model described in Chapter 4.

In developing a training strategy, attention must be paid to the underlying theoretical conception of decision making. Different theoretical conceptions are associated with differences in content, methods, and tools – in short, along each of the dimensions that characterize a training strategy. In this section, we briefly examine the implications of different models of decision making for the content, tools, and methods of training. We then move on to a more detailed look at a training strategy based on the extended R / M model.

Role of Theory in Selection of A Training Strategy

Table 1 outlines the most salient differences in content, tools, and method among training strategies based on (i) formal models of decision making, (ii) recognition-based models, and (iii) the Recognition / Metcognition model, respectively.

Formal and Recognitional Approaches to Training

From the point of view of formal models of decision making, the *content* of training is a set of general-purpose techniques (Baron & Brown, 1991). The principle *tool* for defining this content is logic or decision theory, regarded as normative models of thinking (e.g., Watson & Buede, 1987). The primary *method* of presentation is explicit classroom instruction, ranging from focus on formal algorithms (e.g., Laskey & Campbell, 1991), to focus on more qualitative issues such as problem structuring (e.g., Mann, Harmoni, & Power, 1991). Examples of decision problems are not emphasized as content, but are used as *tools* for a variety of purposes: i.e., to motivate the formal techniques during instruction (Adams & Feehrer, 1991), to demonstrate their generality across domains (Mann et al., 1991), and for paper and pencil practice in the component procedures. Problems are selected to illustrate the algorithm or technique that is currently being taught. Often, the problems are artificially prestructured rather than presented naturalistically; i.e., the available options and the probabilities and utilities of their outcomes are explicitly stated. There is typically little emphasis on the ability to match the appropriate method to problems of different types (Beyth-Marom, et al., 1991) or on time-stressed conditions, in which the full analytical method may be infeasible.

Table 1. Differences in training strategies typically associated with different views or models of decision making.

	Models of decision making		
	Logical / Probabilistic Reasoning	**Rapid Recognition**	**Recognition / Metacognition**
Content of training	General purpose formal modeling and reasoning techniques.	Specific situation - response associations.	Mental model types and critical thinking strategies.
Tools used in training	Normative model of decision processes. A small number of paper & pencil examples.	Compilation of cues and responses used by proficient decision makers. Realistic simulation of a large number of representative scenarios.	Cognitive model of proficient real-world knowledge structures & decision processes. Realistic simulation of a moderate number of challenging scenarios, mixed with more routine situations.
Methods of training	Explicit instruction. Practice with procedural feedback.	Little instruction. Practice with immediate feedback re correct response.	Explicit instruction. Practice with delayed or self-administered process feedback.

At the opposite extreme, decision training based on the recognitional point of view attempts to convey examples of decision problems and their solutions as the *content* of training, not general-purpose techniques. Rapid and direct retrieval of the appropriate response to a wide range of situations is the training objective, not choice of the optimal response from a set of alternatives. The primary *method* in recognitional training is practice with a large set of representative problems. Little or no attention is given to explicit instruction, and trainees are usually not encouraged to verbalize the reasons for their decisions during practice. Immediate feedback regarding the correctness of the trainee's response ensures that the situation and the response to be associated with it are represented simultaneously in working memory (Reiser, Kimberg, Lovett, & Ranney, 1992). Two additional features of practice may be used to develop rapid, automatic responding: "Overlearning" – produced by exposure to a large number of trials with consistent stimulus-response mappings (Shiffrin & Schneider, 1977), and practice under time-constraints (Schneider, 1985). *Tools* like high-fidelity simulation may be used to increase the similarity of training conditions to real-world task environments (Means, Salas, Crandall, & Jacobs, 1993).

Critical Thinking Training Strategy Based on the R/M Model

The R/M model yields an approach to training that is distinct from both formal and pattern recognition models. The *content* of critical thinking training is neither a small set of general-purpose methods nor a vast quantity of specialized patterns and responses. The focus is on a moderately sized set of mental model types (such as purpose, intent, team member reliability, and time orientation) and critical thinking strategies that critique and correct those mental models when direct recognitional retrieval is inadequate. Unlike specialized patterns, both the mental models and the thinking strategies are generalizable in many respects across domains that are characterized by (a) time constraints and (b) uncertainty about human action either within or outside the decision maker's own organization. Unlike general-purpose methods, they are most effectively taught by building on pre-existing familiarity with a particular domain (Kuhn, et al., 1988).

Methods for training for critical thinking include both explicit instruction and practice. Prior instruction on concepts and processing strategies has been found to facilitate learning during subsequent practice (Nickerson, Perkins, & Smith, 1985). In particular, such instruction can provide trainees a new conceptual framework for understanding the skills being trained. For example, the notion that problems can and should be solved by a mechanical application of decision rules must be replaced by a more flexible, iterative, and constructive approach to selecting an action (Brown & Palincsar, 1989). Making principles explicit also helps students transfer what they have learned to varied settings (Collins, Brown, & Newman, 1989).

Practice in critical thinking involves realistic, but non-routine situations, even if they are relatively improbable (Lesgold, Lajoie, Bunzo, & Eggan, 1992). As a result, trainees are exposed to more challenging situations than they would be likely to experience in a representative sampling of the domain. During practice, the explicit articulation of problem-solving strategies is encouraged, to foster reflective self-awareness (Schoenfeld, 1987; Scardamalia & Bereiter, 1985). Problem conditions may be varied – e.g., more and less time-stressed, more and less routine, more or less high stakes – so that trainees learn to decide when to rely on direct recognition and when to use critical thinking strategies.

Feedback focuses on appropriate processes rather than on correct responses. Indeed, the notion that there is a single "correct" answer may often be counterproductive in the kinds of ill-structured or novel problems for which critical thinking is appropriate (King & Kitchener, 1994). Immediate feedback may also be counterproductive. First, it short circuits students' efforts to understand the problem in depth. Delayed feedback, on the other hand, allows for discovery learning through free exploration of the problem (Bennett, 1992). Second, immediate feedback short circuits students' efforts to evaluate their own performance. Instead, trainees can be asked to provide, or at least control, their own feedback, to foster self-reflective skills. For example, trainees may participate in a group discussion after practice, in which they critique the performance of others and respond to feedback regarding their own performance (Schoenfeld, 1987).

A important *tool* for providing feedback is expert modeling of the thinking processes to be trained (Collins, Brown, & Newman, 1989; Druckman & Bjork, 1991). This, too, may be turned into a constructive exercise by asking trainees themselves to compare their own performance with the performance of the expert model (Bloom & Broder, 1950).

Table 2 outlines the essential features of a critical thinking training strategy based on the above guidelines. It shows tools, methods, and content associated with the R / M model. We will discuss critical thinking training *tools* in the remainder of this section, before turning to a more detailed overview of the training *content* in Chapter 7.

Table 2. Tools, methods, and content of the R/M critical thinking training strategy.

Tools	**Methods**	**Content**

• Cognitive task analysis (e.g., critical incident interviews)
• Theory-based definition of critical thinking skills
• Survey of training needs
• Interactive, graphical user interface
• Challenging practice scenarios
• Performance measures (process & outcome)
	• *Information-based:*
	  • Frame decision making as flexible & iterative
	  • Prepare students to use specific concepts & strategies during practice
	  • Demonstrate decision processes
	• *Practice-based:*
	  • Realistic, challenging tasks
	  • Mix with routine tasks
	  • Encourage verbalizing thought processes
	  • Regard feedback as a skill to be trained
	  • Guided practice with feedback and modeling of target behavior
		• Focusing on purpose
		• Critical thinking about purpose
		• Orienting to the enemy in time
		• Critical thinking about time orientation
		• Using initiative

Prescriptive Use of Cognitive Task Analysis [1]

The prescriptive character of *formal* approaches to reasoning is usually taken for granted. Formal approaches start with a mathematical or logical model of how decisions ought to be made. Training can then focus on the systematic errors, or "biases," that are discovered by comparing human behavior in laboratory tasks to such formal models (e.g., Fischhoff, 1982). By contrast, a naturalistic approach to decision research, like the R / M model, takes as its starting point the way people actually make decisions in real-world environments, as revealed in interviews, observation, and contextually realistic experimentation (Klein, et al., 1993). It may not be obvious what leverage can be gained from the latter research. In particular, can it generate *prescriptions* about how to think

[1] This section is based on Cohen, Freeman, & Thompson, 1998.

better or make better decisions? Can it help us identify the skills that critical thinking training should target? Will it eventually arrive where "normative" approaches based on logic and decision theory begin, and lead to training that can mitigate the shortcomings of ordinary thinking?

For a variety of reasons, it has been argued that the answer is *no*. First, there is the logical prohibition against deriving an *ought* from an *is*, a mistake which is called by philosophers, appropriately enough, the *naturalistic fallacy*. We cannot conclude that a particular decision process is the best one available simply because real decision makers use it. Second, naturalistic researchers allegedly view real-world decision making through rose-tinted glasses (Doherty, 1993). Indeed, some naturalistic decision researchers have criticized the idea, promoted by Kahneman, Slovic, and Tversky (1982) and others, that ordinary decision making is riddled by systematic errors or biases (e.g., Cohen, 1993). Third, there is an emphasis in naturalistic research on pattern recognition rather than on more explicit processes of reflective reasoning (Klein, 1993). It is not clear how a prescriptive framework could apply to rapid, relatively automatic processes. We can summarize these pessimistic points as follows: In naturalistic research, prescription is *impossible* because it would confuse what is and what ought to be, *unnecessary* because real-world decision making is already good enough, and *irrelevant* in any case because real-world decision making is intuitive rather than reflective.

We think each one of these claims is wrong or misleading. In this section and in Section 4, we describe a naturalistic training strategy for improving decision making skills which serves as a counterexample to all three of the objections itemized above:

With respect to point 3, the intuitive nature of decision making, the training strategy is premised on the importance of critical thinking skills that complement and go beyond pattern recognition. These skills monitor, verify, and improve the results of recognition in high-stakes and novel situations, when immediate action on a recognized response is not necessary. Critical thinking skills are inextricably tied to the recognitional processes they regulate, and do not represent an analytical *alternative* to recognition-based processing. However, such critical thinking strategies are subject to more deliberative control and explicit articulation.

With respect to point 1, the prohibition against deriving *ought* from *is*, the model that underlies the training is based on interviews with and observations of real-world decision makers. But it does not involve the naturalistic fallacy, because it does not indiscriminately infer what is desirable from what exists. Instead, the model of critical thinking skills is based on (a) comparisons between the decision processes of more and less experienced real-world decision makers, on the assumption that experience is correlated with proficiency; (b) comparisons between the decision processes of those explicitly judged to be more proficient and those judged to be less proficient by their peers, and (c) comparisons between decision processes used in tasks judged to be successfully accomplished and those used in tasks judged to be unsuccessful.

Cohen (1993), turning the tables, argues that the prescriptive character of formal models should not be taken for granted. Prescriptive claims are *arguments*. As such, they must be evaluated in part based on (1) formal properties that seem desirable. But they must also be evaluated with respect to considerations such as (2) the face validity and plausibility of the decision strategies to which they lead (Shafer & Tversky, 1989) and (3) correspondence with successful practice (L. J. Cohen, 1981; Goodman, 1965). A convincing prescriptive model must be sufficiently *close* to actual reasoning so that *deviations* from the model are interesting, hence, useful for training and decision aiding. In this vein, a more illuminating and useful tool for understanding and evaluating human reasoning may be provided by models of assumption-based reasoning (Harmon, 1986; Chapman, 1993; Cohen, 1993; Koslowski, 1996).

Finally, with respect to point 2, the naturalistic approach does not imply that real-world decision makers never make errors. Errors can be identified by examining discrepancies between more and less experienced, or more and less proficient, decision makers as identified by peers, or aspects of decision processes that are correlated with performance in real-world tasks that is judged to be less successful. Rather than denying the existence of errors, the naturalistic approach provides a more useful way of looking at errors. For example, they are not defined as deviations from the purely formal constraints of decision theory or logic. Such definitions prove unexpectedly slippery in any case, since deviations from one formal model may be consistent with a formal model that makes different assumptions – for example, about the goals or beliefs of the decision maker (Smithson, 1989; Cohen, 1993). More fruitful theoretical insights into the nature of reasoning errors may, once again, be provided by models of assumption-based reasoning combined with constraints on information processing resources (i.e., the inability to recall or attend to all the factors underlying a belief or decision).

For these reasons, cognitive task analysis serves as an essential tool in the development of a genuinely *prescriptive* critical thinking training strategy. The training content is based on critical incident interviews with active-duty Army officers, in which they described their actual experiences in combat and exercises. We analyzed these interviews to discover the officers' thinking strategies, ways of organizing information, and decisions (see Chapter 3 above). The training is based directly on differences in the way that more and less experienced officers handled similar types of situations, and indirectly on cognitive theory (summarized in the R / M model), derived jointly from that data and from the cognitive research literature.

Theory-Based Definition of Critical Thinking Skills

Based on the findings of the cognitive task analysis and theoretical model described in Chapters 3 and 4, the following skills appear to characterize proficient decision makers in the Army tactical decision making domain. Proficient decision makers:

1 Develop and use appropriate mental models.

1.1 *Purpose*: Develop and use models of higher-order or longer-term purposes. Frame decisions in a larger context.

1.2 *Time orientation*: Develop models of the relationship of own actions to enemy decision making cycle, and use these models to develop proactive, predictive, and reactive plans. Seize initiative with respect to other decision makers.

2 Adopt appropriate critical thinking strategies for these mental models.

2.1 Identify and seek to fill critical information *gaps* in models . For example, make expectations explicit and monitor events for consistency with expectations.

2.2 Identify and seek to resolve *conflicts* between situation understanding and observations, or between plans and goals. For example, mentally simulate plans to see if they achieve all goals; generate contingency plans, or branches, to compensate for risk

2.3 Identify and evaluate *assumptions* underlying situation models or plans. For example, construct a story that you must believe in order to accept a situation model or plan, and evaluate the story; if the story is implausible, try to develop an alternative mental model, and evaluate that.

2. 4 Determine when and if to commit to action based on available time, stakes, and uncertainty. *Regulate* critical thinking process by balancing costs and benefits.

Analysis of Current Training Shortfalls

As noted, the content of training was primarily based on a comparison of the knowledge representations and decision processes of more and less experienced officers in tactical decision making situations. In the present research, it was important to verify that the differences we identified were in fact perceived as important in the Army community. Therefore, prior to final development of training materials, we supplemented our analysis by two additional types of data:

- An independent evaluation of the quality of decision making in a subset of the critical incident interviews was performed by LTG Leonard Wishart (U.S. Army, ret). Analysis of the basis of LTG Wishart's evaluations clarifies the good and bad aspects of officers' decision processes
- We discussed perceived problems with current training methods with a number of instructors at the Army Command and General Staff College, Leavenworth, KA.

Independent Evaluation of Decision Making Skill

Table 3 provides examples of LTG Wishart's comments on two officers: MAJ A, whom he did not evaluate highly, and LTC B, whom he did evaluate highly. Based on such comments, in conjunction with other information in the protocols themselves, we identified relevant cognitive skills or deficiencies, as shown in the second column of the table.

As indicated by Table 3, General Wishart's evaluations confirmed the identification of critical thinking skills based on the R/M model.

Table 3. Illustrative comments from independent evaluation of critical incident interview, and inferred critical thinking skills.

	LTG Wishart's comments	**Inferred thinking skill or deficiency**
MAJ A	MAJ A did not have as clear an idea of the mission or its constraints as did LTC B	absence of understanding of higher-level purpose
	MAJ A did not actively go after information he thought the CG needed or he might need.	lack of critiquing to identify gaps or conflicts in knowledge failure to use predictive time orientation with respect to commander
	He took what was provided, asked some questions, analyzed it, and then provided the CG with his assessment.	limited critiquing of given information use of reactive time orientation with respect to information
LTC B	LTC B searched out new sources, new information…	critiquing to identify and fill gaps in information & to test predictions for conflict with events proactive time orientation with respect to information sources
	and appears to have looked for contradictions. He tried to anticipate changes…	critiquing to find and resolve conflict use of mental models of source reliability
	Conflicting information does not seem to disturb him; it is just one more piece to be examined and judged before reaching a decision	critiquing to identify assumptions underlying conflicting evidence
General comment	All tended to focus their attention early in the preparatory phase on those elements of METT-T which were generally fixed or about which more was known. Those things which could vary widely were ignored or given little attention.	Critiquing to identify gaps in model Critiquing to distinguish reliable from unreliable assumptions (with consequences for stability of situation) Decision not to allocate cognitive resources to problems for which stakes are not yet high and for which solutions would be unreliable

Discussions with CGSC Instructors

In conversations with us, several instructors at the Command and General Staff College (CGSC) expressed a strong need for instructional materials on decision making that go beyond Army doctrinal publications and the standard Military Decision Making Process (MDMP).

For example, an instructor in the Center for Army Tactics at CGSC is attempting to teach a more flexible thought process than the procedure-oriented MDMP. But he has been frustrated in his efforts to find appropriate teaching material in Army doctrinal publications or elsewhere. He feels that he is working against student habits acquired in other Army training. To date, he has relied largely on: (i) Readings in military theory and military history; (ii) Tactical Decision Games developed by the U.S. Marine Corps, with limited feedback in class; and (iii) larger scale simulator exercises (Janus). This instructor expressed enthusiasm for training that will combine clear *instruction* in flexible thought processes, *practice* in realistic scenarios, and detailed *feedback*.

Specific topics currently being emphasized by this instructor confirm the relevance of the thinking skills identified in our own analysis. Table 8 lists some of the topics addressed by this instructor and corresponding skills in the R / M framework:

Table 4. Correspondence between topics in Center for Army Tactics course and critical thinking skills in the R/M framework.

Course topic	Critical thinking skill
Nested concepts, i.e., s hierarchy of the tasks and purposes assigned to different friendly units	Mental models of higher-order purpose
Decentralized battle and the need for initiative, including in some cases deviation from mission	Critical thinking about higher-order purpose to identify potentially conflicting events or goals, and to modify plan if necessary
Aim to defeat the enemy's will	Proactive time orientation, i.e., mental models of enemy intent and of how friendly action can influence enemy decision making

Another CGSC instructor, at the Center for Army Leadership, has made a more explicit effort to train students in critical thinking. However, he has been forced to rely on general-purpose texts on logic, probability, etc. The abstract nature of the materials makes transfer to the battlefield difficult. These considerations provide support for a naturalistic approach to training that links concepts and principles closely to real-world applications in the relevant domain.

Practice Scenarios

Practice exercises are a crucial part of the critical thinking training. All exercises involve relatively realistic (though brief) military scenarios. A manual classroom version of the critical thinking training has utilized a scenario (centering on an imaginary island called Arisle) developed by Dr. Rex Michel at the Army Research Institute, Fort Leavenworth Field Unit. This scenario was also included in one version of the automated training system. The Arisle scenario is described in greater detail in Section 5, on the evaluation of the training.

A later version of the automated training, developed for use at the Command and General Staff College, utilizes a variety of scenarios adapted from the Tactical Decision Games feature published monthly in the *Marine Corps Gazette* (see also Schmitt, 1994). Each of the scenarios selected for use in the exercises addresses the issue of initiative in a context of uncertainty, time stress, and limited communication. Two of the *Marine Corps Gazette* scenarios were used as pretest and posttest for evaluation of the automated training system at CGSC. These two scenarios are described in detail in chapter 9.

Interactive, Graphical User Interface

We have developed a computer-based interactive training program for Army battlefield critical thinking, packaged as a stand-alone CD that runs under Microsoft Windows, and that can also be accessed by a browser on the World Wide Web. The program, which is called *Training to Think Critically on the Battlefield*, uses graphical interactive techniques to present concepts and provide practice and feedback. An early version of the training system has recently been assigned and evaluated in an advanced tactics course at the Army Command and General Staff College (Center of Army Tactics), Leavenworth, KS. We describe this system in more detail in Chapter12.

Hypotheses and Performance Measures

A final tool is represented by a set of performance measures used to evaluate the success of the training. These measures address both critical thinking skills –through process measures – and outcomes – through the agreement of trainees' decisions with those of a subject matter expert (SME).

As noted above, the skills to be targeted by R / M training were identified based on convergence of R / M theory, analysis of interview and problem solving protocols from Army officers, and identification of student needs through discussions at CGSC. Measures of these skills were developed to test the hypotheses listed in Table 5.

Table 5. Associated critical thinking skills, hypotheses, and performance measures.

Critical thinking skills	**Hypotheses**	**Measures**
Consider high level purpose	Training will increase the likelihood that officers refer to the purpose of superior echelons	Mention of purpose of units higher than one' own; whether higher-level purpose actually influences development of plan
Use time orientation effectively	Training will increase the likelihood that officers' will utilize proactive and predictive planning	Frequency of occurrence of proactive, predictive, and predictive-reactive (i.e., contingent) plans
Detect and fill gaps	Training will increase the breadth of essential factors that officers consider.	Number of different types of factors that officers mention when they are critical to the solution (e.g., enemy doctrine, enemy bridging equipment, slope of terrain, etc.); SME's assessment of relevance of factors
Detect and resolve conflict	Training will increase the number of conflicting information that officers (i) detect and (ii) attempt to resolve	Number of items of conflicting information referred to; whether a conflict is dealt with (e.g., by collecting information, explaining it, or developing a contingency plan); SME's assessment of appropriateness of resolution
Detect and evaluate assumptions	Training will increase the number of assumptions that officers (i) detect and (ii) evaluate.	Number of assumptions explicitly mentioned; whether an assumption is assessed for plausibility; SME's assessment of quality of trainee's judgment
Judge when to commit to action	Training will increase officers' confidence in their plans	Numerical assessments of confidence in preferred plan and any alternative plans that were considered
Improved outcomes	Training improves decisions and outcomes.	Agreement between trainee's plan and plan of SME; SME's assessment of quality of trainee's plan; increase in agreement among plans due to training

Previous Research Results

The present work is the latest in a series of projects in which Cognitive Technologies, Inc., has developed and tested critical thinking training for active-duty military officers. Table 6 summarizes previous research results in work for the Navy and the Army. Training has been tested at several Navy training facilities and at a number of Army posts around the country. Previous Army training has been oriented to individual officers, while Navy training has included both individual and team contexts. Both practice and evaluations in the Navy training were supported by an automated AEGIS Combat Center simulation. In addition, one of the Navy studies looked at the effect of critical thinking training on officers' interaction with a decision aid.

All studies include both measures of critical thinking processes and of the quality of decision outcomes. Critical thinking processes include the range of issues mentioned in the officers' reasoning (a test of filling gaps in mental models), identification of conflicts in evidence and among purposes, adjusting assumptions to explain the conflict, exploring alternative options that avoid the problems, and developing contingency plans in case problems occur.

Measures of decision quality include "accuracy," which reflects agreement with subject matter experts, as well as a measure of agreement among the trainees themselves. The latter is an indirect measure of accuracy, since if accuracy is higher after training, we would expect more agreement among trained officers than among untrained officers.

Table 6 shows that significant effects of critical thinking training have been found with all these measures. Changes were always in a positive direction, even when the effects were not statistically significant.

The evaluations to be reported below (Chapters 9 and 10) differ from the evaluations summarized here in some important ways.

- The Army training described here is much broader in scope than the previous Army training referred to in Table 6. That training covered a very small subset of the present training.
- The evaluation in Chapter 9 is an informal exploration of insights generated by the training, rather than a formal experiment.
- In the experiment reported in Chapter 10, the training is not delivered in to students by an instructor. Both the training and the pretest and posttest exercises had to be done by students on their own, using a CD-ROM.
- Moreover, in that experiment, the interactive aspect of the training program was not fully functional. As a result, the CGSC evaluation was handicapped by a delivery platform that was probably significantly less motivating than in previous studies.

The positive results reported below are all the more encouraging for the future of this type of training.

Table 6. Summary of previous research results.

Variable	Study 1 (Individuals / SWOS)	Study 2 (Individuals / NPS)	Study 3 (Teams / SWOS)	Study 4 Teams with DSS / SWOS & NraD	Study 5 Individuals / Army
Variety of issues considered	+ 7%	+30% *	+30%	+56% *	+38%
Conflicting evidence identified	+52% *	+58% *	+29%*	+44% *	+53% *
Explanations of conflicting evidence	+26%	+27% *	+ 5%	+31%	n/a
Number of alternative assessments considered	+10%	+41% *	+15%	+19% *	n/a
Accuracy	+42% *	+18% *	+55% *	+28% *	+19% *, +36% *
Agreement	+14%	+41%	n/a	n/a	n/a
Confidence	+13%	+20%	n/a	+ 2%	n/a
Frequency of contingency planning	+217% *	n/a	n/a	n/a	n/a
Subjective evaluations	73% positive	71% positive	88% positive	100% positive	77% positive

CHAPTER 7
CRITICAL THINKING TRAINING

CTI's critical thinking training system evolved through several iterations over the course of this research. The system whose evaluation is discussed in Chapter 9 was a relatively early version. By the time the training was used and evaluated at the Command and General Staff College (CGSC), as described in Chapter 10, the system had been significantly expanded, reorganized, and revised. After the experience at CGSC, additional modifications were made. An excerpted version of the latest version of the training will be found in the Volume II Appendix (produced as a separate document).

The most significant modifications after CGSC were (i) the addition of a third part dealing with maneuver warfare, (ii) minor revisions of the overall organization of the training material, (iii) editing of individual slides to improve clarity and appearance, and (iv) additional work on the programming of interactive exercises and their integration into the system. This work is, of course, not truly finished. Volume III of this report takes the first steps on a path of future evolution, in which dynamic simulation of critical thinking processes provides the basis for real-time adaptive feedback.

This training package is not a *general* course on logic, decision making, or critical thinking that just happens to use military examples. The lessons it teaches are fully embedded in realistic Army contexts and are motivated by tasks and challenges that arise in that context. The training aims to teach students how to think critically and to make better decisions *on the battlefield*. There are no abstract rules that officers must learn and then figure out how to translate and apply to the military field. The training design thus represents a tradeoff between optimizing for transfer to other domains (which might arguably require a more abstract approach) and optimization for application on the battlefield (which we pursued).

On the other hand, the training is not a mere repackaging of existing Army doctrine, tactics, techniques, or procedures. It adds value in several different ways.

- First, it is motivated by *general* theory about effective modes of thinking and deciding, backed by data collected in several different fields (described in Volume I). Thus, although *this* training is embedded in an Army context, similar training could be developed for other fields based on the same principles.
- Second, the training employs explicit instruction as well as practice (Chapter 6). Rather than implicitly insinuating critical thinking methods into the existing curriculum, the training attempts to *explicitly* articulate procedures and modes of thought that, when applied to battlefield decisions, should improve their quality. Through the instructional component, students learn to identify a distinct and coherent body of skills and dispositions that can be characterized as *battlefield critical thinking*.
- Thirdly, the training presents a large range of examples and exercises. For example, it draws on battlefield scenarios that range from platoon and company to theater-level command. This variety demonstrates the generalizability of the relevant principles.

In sum, although the training may not *optimized* for transfer to other domains, it might in fact facilitate transfer – through the explicit articulation of principles based on general theory and applied across a disparate set of Army battlefield contexts. It could even be argued that a solid foundation of critical thinking in a single field is the best preparation for transfer to other fields.

The main substantive topics of the training are:

(a) the role of *purpose* in friendly planning, and

(b) *time orientation* (or initiative) with respect to the enemy.

For each of these topics, the training addresses:

(i) *mental models* of the relationships relevant to purpose or time orientation, and

(ii) *critical thinking processes* for handling uncertainty about those mental models.

The training thus includes two main parts (purpose and time orientation), with two sections (mental models and critical thinking) in each part. A final, more advanced, integrative part applies the training to decisions about tactics, especially so-called maneuver warfare. This part is also divided into two sections, on mental models and critical thinking respectively. The outline of the training is as follows:

Part I. Purpose	
	1. Mental models of purpose
	2. Thinking critically about purpose
Part II. Time Orientation	
	3. Mental models of time orientation
	4. Thinking critically about time orientation
Part III. Initiative	
	4. Mental models in maneuver warfare
	5. Critical thinking about maneuver warfare:

Each of the six training sections contains (i) an introduction to the relevant concepts, using both verbal and graphical methods, (ii) examples and historical case studies of how the concepts apply, and (iii) interactive exercises with feedback (see Chapter 6). The training increases in difficulty as it progresses through the five segments.

Illustrations in this chapter are a relatively small sample of the approximately 500 content frames that have been incorporated into the training system. The training system screen shows frames of this kind, plus additional hyperlinks and navigational aids (discussed in Chapter 8 below).

Training Part 1: Purpose

Section 1: Mental Models of Purpose

Focus on higher-level purpose increases significantly with the experience of the decision maker and is closely associated with a proactive time orientation (see research described in Chapter 3, Volume I). This section of the training gives students conceptual and graphical tools for organizing their thinking about purpose. The main points of the section are that:

(i) an understanding of purpose should guide thinking about the situation and about one's own plans *at every stage*,

(ii) purpose should be looked at from *a variety of standpoints and levels*. It is not simply the immediate mission of your unit, but includes the purposes of adjacent and superior units,

(iii) officers should *monitor* not only the progress of their own unit, but success in the accomplishment of purposes by all relevant units, and

(iv) potential and actual conflicts between purposes at different levels should be anticipated, and, when they occur, recognized and dealt with.

Purpose in this wider, longer range sense provides the big picture within which critical thinking takes place throughout the Military Decision Making Process.

The training in this segment picks up and extends a notion that is already present in Army doctrine: that the concept of operations of each succeeding echelon is *nested* within the concept of operations of the higher echelon (*FM 100-5,* 1993, p 2-5). Instructors at CGSC have explored a useful technique for representing nesting, called a *nesting diagram* (Larson, 1998). The concept of nesting is usually familiar to CGSC students prior to taking this course, but nesting diagrams themselves are not.

We decided to begin the training with nesting diagrams, for several reasons. First, this type of diagram answers the requirement for a diagrammatic representation of mental models of purpose.[2] Second, the doctrinal rationale for nesting diagrams is clear to students, and beginning in this way increases overall acceptance of the training. For example, it provides a gradual and convincing lead in to diagrammatic mental models of enemy and friendly action, and other mental models. More generally, when discussing mental models, we have tried to stay as close as possible to existing Army documents and terminology. Finally, step-by-step instruction and practice in building nesting diagrams increased acceptance of the training by the CGSC instructors.

The training provides rules of thumb for constructing complete nesting diagrams. A complete nesting diagram must (i) link your own unit's purpose to the purpose of the unit two levels up, through the relevant sequence of supporting and main effort relationships, and (ii) show all supporting relationship among adjacent units (units that

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[2] It is interesting to note that General William E. DePuy (1988), a former Commander of the U.S. Army Doctrine and Training Command, used the term *mental model* in his discussion of nesting diagrams: "…a commander should construct a mental model for the subordinates to act within the vertical and horizontal planes the higher commander has created within the concept of the operation."

belong to the same unit one level up). Each connection in the diagram helps to locate your unit's purpose within the big picture by answering the question (i) why? or (ii) how?

Subsequent training requires students to construct their own nesting diagrams, based on an operations order received from superior headquarters. These exercises include, for example, training to handle missing information about purpose, and purposes that are not lined up with the organizational hierarchy.

Part I starts with nesting diagrams but then generalizes the idea of a *mental model* to include other useful knowledge structures (see Chapter 3, Volume I for the empirical basis of mental models as correlations among concepts in critical incident interviews). To emphasize the pervasive importance of purpose, the training defines a mental model as:

> *a succinct summary of events or ideas, which shows how each event or idea is linked to achievement of a purpose.*

Mental models can be verbal or graphical. Because of their links with wider purposes (i.e., the nesting diagram), every mental model serves as a tool to help decision makers stay focused on purpose at all stages, rather than only during the mission analysis stage. For example, Figure 2 shows the components of, and links between, three mental models relevant to planning and operations by a company command staff:

1. the *nesting diagram* describing purposes and tasks of the company and its adjacent and superior units,
2. the company *commander's intent* for accomplishing the purpose and tasks of the company (its mission) in the light of the entire nesting diagram, and
3. the *concept of operations* that is developed to carry out the commander's intent in the light of the entire nesting diagram.

This diagram can be extended to show the relationships of purpose to other documents, such as Intelligence Preparation of the Battlefield and synchronization matrices.

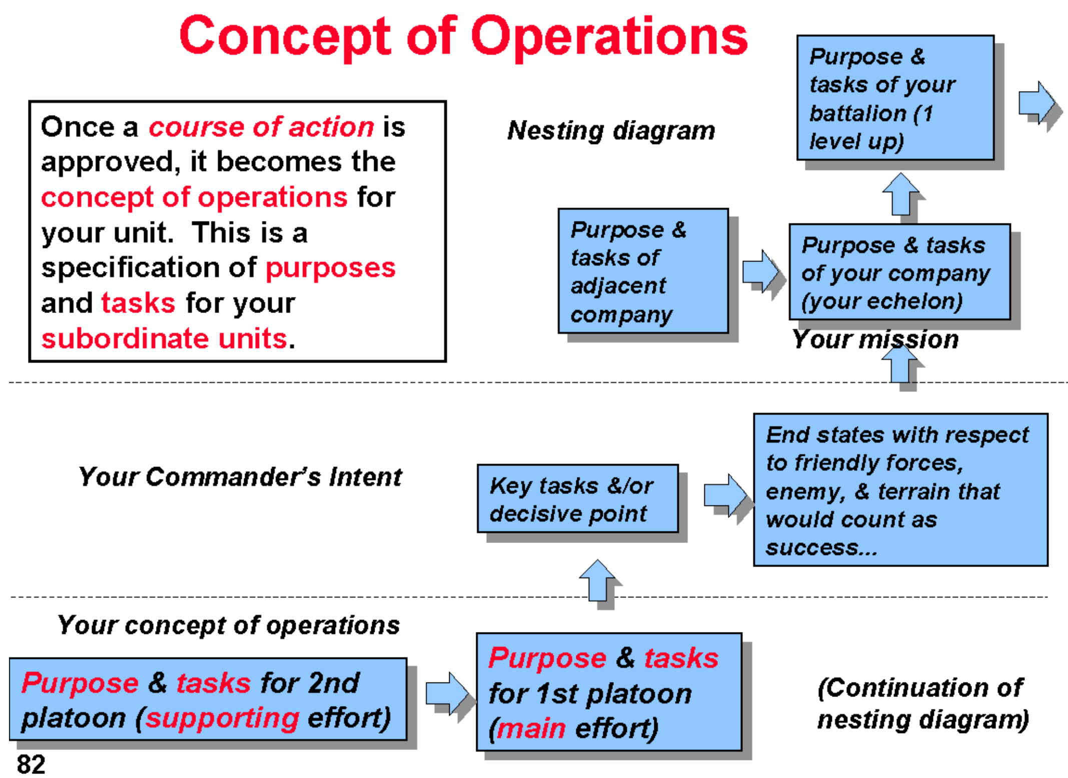

Figure 2. Three interrelated mental models. The *concept of operations* for a unit (bottom of the diagram) is a continuation of the *nesting diagram* (top of the diagram). The *commander's intent* (middle layer) is the link between them.

Critical Thinking about Purpose

The training also addressed critical thinking skills that go beyond simply building nesting diagrams: e.g.,

- recognizing and filling gaps in the diagrams,
- recognizing potential or actual conflicts between purposes at different levels, or between one's purpose and the task as specified,
- recognizing and evaluating assumptions required for the success of your plan, including assumptions about what the enemy and what other friendly units will do,
- monitoring the success of your own and other units in accomplishing their purposes, and recognizing conflicts between on-going events or actions and accomplishment of purposes.

These skills are essential elements of initiative. [3]

Figure 3 shows the three basic types of questions that critical thinking asks about a mental model. These correspond to the three qualitatively different kinds of uncertainty identified by the Recognition / Metacognition model (see Chapter 4, Volume I).

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[3] DePuy had a similar view of the usefulness of nesting in critical thinking: He stressed that an understanding of nested concepts makes possible "*agility*, depth, *initiative*, and synchronization" in battle.

In one exercise, for example, students are asked to construct a nesting diagram for a scenario called *Attack through Narrow Pass* (Schmitt, 1994). Students are provided with operations orders and the map shown in Figure 4. The battalion (in the lower right quadrant of map) plans to cross into Sanctuary Plain (in upper part of map) through Narrow Pass. Your platoon's task is to cross through Western Narrow Pass on the battalion left flank. However, you are surprised to observe enemy machine gun nests on the ridge and to hear sounds of a firefight from the battalion area.

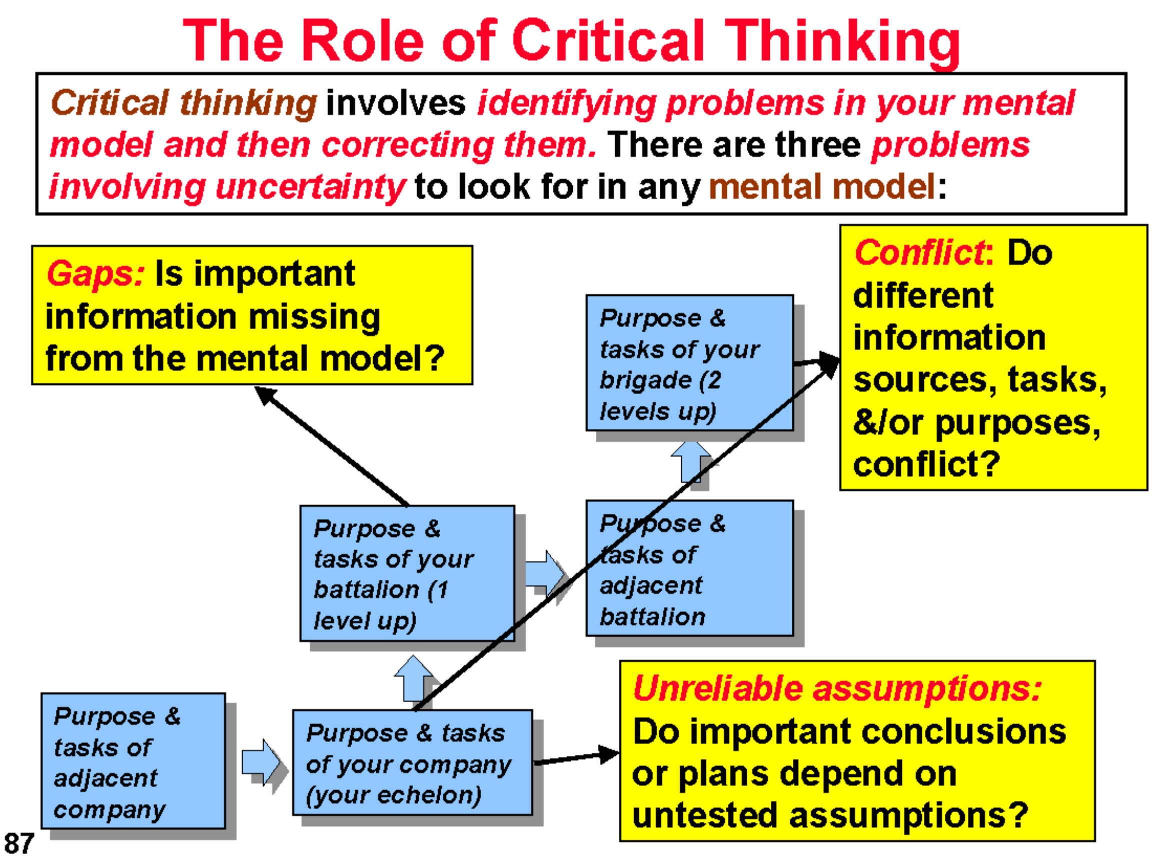

Figure 3. Three different kinds of uncertainty in mental models.

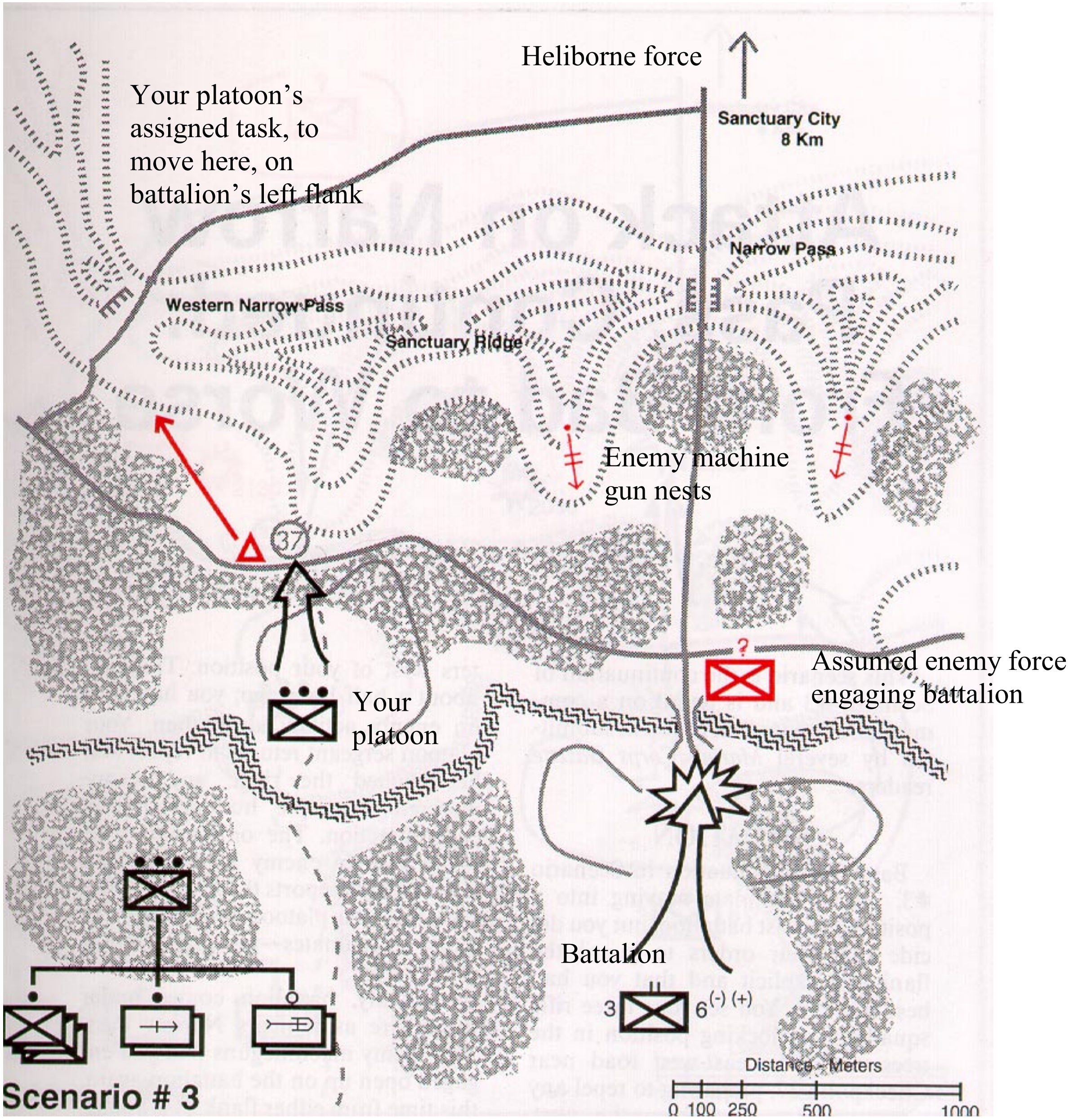

Figure 4. Annotated problem map for *Attack through Narrow Pass* scenario.[4]

This critical thinking exercise is typical of those provided by the training. These exercises first require students to critique and modify a plan in the face of surprising events. Students then receive feedback, and following that, see a new variant of the plan that appears to address shortcomings of the previous one. The students then critique and modify the "improved" plan. They receive feedback regarding the new plan, along with yet another variant of the plan to be critiqued and corrected. The training provides a diagram syntax used in these interactive exercises. It also indicates some features that can

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[4] Schmitt (1994). Reproduced with permission from Steve M. Crittenden, Managing Editor, *Marine Corps Gazette*, Box 1775, Quantico, VA 22134, 4 Feb 99. Explanatory annotations have been added (not in original or in training).

be used to "scaffold" student responses at early stages, and which can be removed in more advanced exercises.

Figure 5, shows a nesting diagram provided to students as feedback during this particular exercise (Figure 4). Students are asked to identify information *gaps* in the nesting diagram, as well as potential problems (or *conflicts*) in achieving the purposes shown in the diagram.

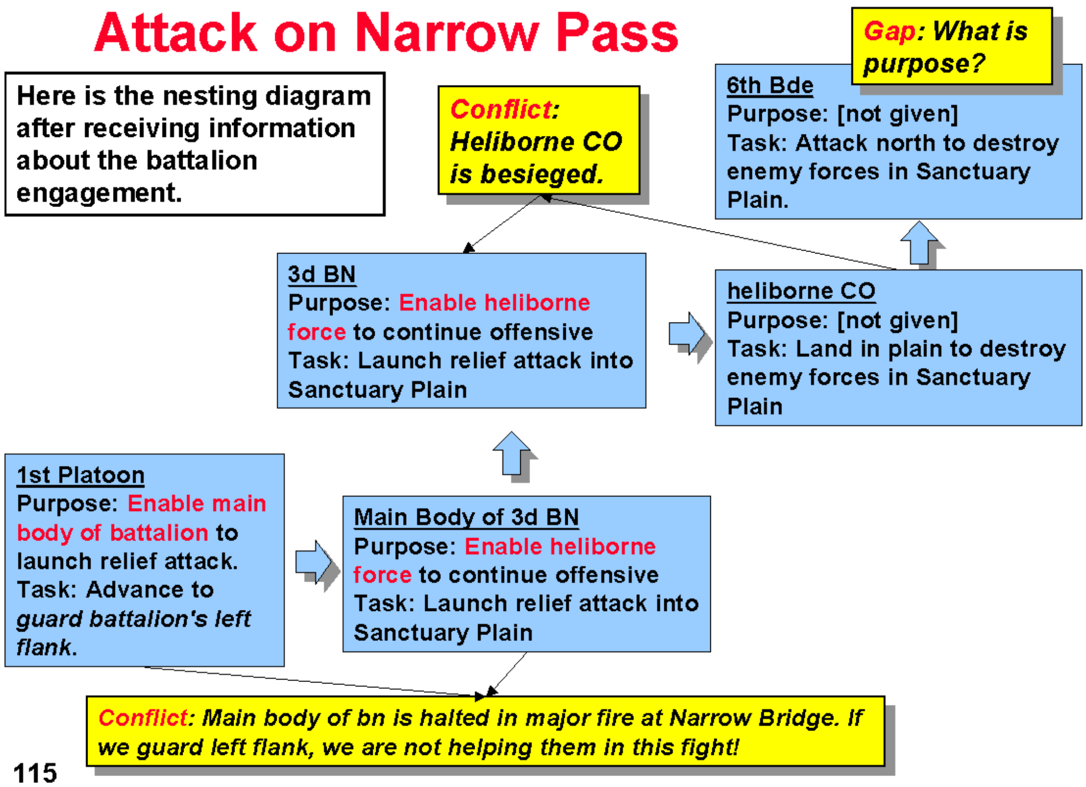

Figure 5. Part of an interactive exercise on (i) building a nesting diagram, and (ii) identifying problems with the nesting diagram, such as gaps and conflicts.

Figure 5 is an example of a conflict among purposes at different levels. On the one hand, your platoon's assigned task is to guard the battalion's left flank. On the other hand, the higher organizational purpose is to get the battalion into position to support friendly forces already in Sanctuary Plain. Achieving this battalion purpose is jeopardized by the fire fight, and the battalion may not make it into Sanctuary Plain. Under these circumstances, the platoon commander should not focus myopically on his own task. He should at least consider some alternatives, e.g., whether to help the battalion in its present fight, stick to the original task of guarding the left flank, or find some other option.

The goal is to teach officers to anticipate, recognize, and deal with these kinds of conflicts. Achieving your own unit's purpose may, in some circumstances, fail to support or even jeopardize the achievement of a higher unit's purpose. Therefore, a plan may be inadequate if it does not put the unit in a position to adapt its own actions to surprise or changing circumstances, to provide back-up for adjacent and superior units, and even in some cases to assume their tasks. Critical thinking is the key to deciding when it is appropriate or necessary to take initiative.

Mental models do not spring into existence as finished products. They evolve over time through a process of asking and answering the kinds of questions shown in Figure 3. This iterative process, which is a dialogue with oneself and others, is the essence of *critical thinking*. This section explains the I.D.E.A.S. cycle for handling uncertainty and illustrates it in a variety of examples and exercises.

I.D.E.A.S. is based on the Recognition / Metacognition model (Chapter 4, Volume I), and is an acronym for:

- *Identify* gaps in the mental model that are likely to have an impact on purposes. Fill gaps with new information if possible, or with assumptions if necessary.
- *Deconflict* to resolve significant conflicts between sources, lines of reasoning, or purposes. Resolve the conflicts with new information if possible, or with assumptions if necessary.
- *Evaluate* significant assumptions in your situation understanding or plan. If there is more than one interpretation of the situation, and / or more than one plan, which set of assumptions is most plausible?
- *Act* to correct any weaknesses in the situation model or plan that you accept.
- *Stop* critical thinking when the cost of time is greater than the potential benefit.

The following figures are a continuation of the *Attack at Narrow Pass* exercise, and are provided as feedback to trainees as they delve further into the scenario. In Figure 6, the decision maker considers *taking the initiative*. This option involves abandoning the original task (guarding the battalion's left flank) and instead moving to support the battalion in its current fight by attacking at Narrow Bridge. Such an action resolves the original conflict (the chance that the battalion will be unable to extricate itself from the firefight), but leads to *new* conflicts. First, the left flank of the battalion will no longer be protected from attacks by enemy forces that might come through Western Narrow Pass.

Second, the platoon will not be in a position to screen the battalion's movement to Western Narrow Pass if that becomes necessary.

These conflicts can be resolved by adopting *assumptions* as shown in Figure 7. The plan to support the battalion in the firefight is acceptable only to the degree that these two assumptions can be regarded as plausible: there is no enemy threat on the battalion's left flank, and there will be no further obstacles to crossing into Sanctuary Plain through Narrow Pass.

In the light of these problems, the decision maker might consider a different course of action, for example, continuing with the assigned task. The conflicts in this alternative can also be resolved by adopting assumptions, as shown in Figure 8. The original task can accomplish its purpose only if the battalion can handle the current fight by itself, or will call for help if needed. The choice between the two options (representing two different levels of initiative) depends on *which* set of assumptions (Figure 7 vs Figure 8) seems most plausible.

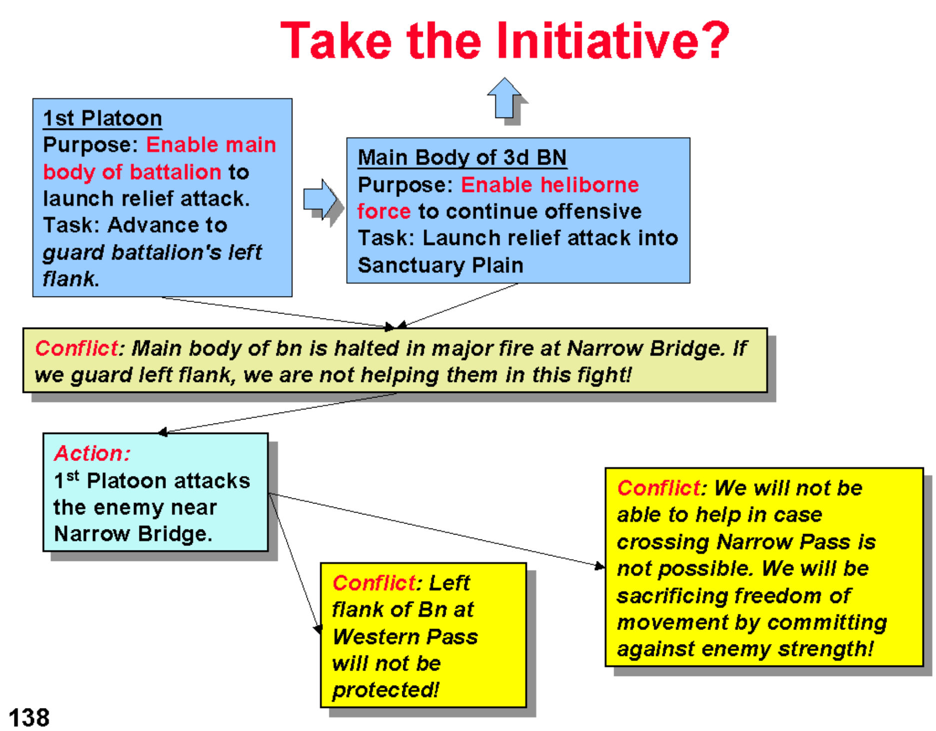

Figure 6. The commander considers a course of action (COA) to address the conflict of purposes discovered in Figure 5. He discovers that this COA leads to new problems.

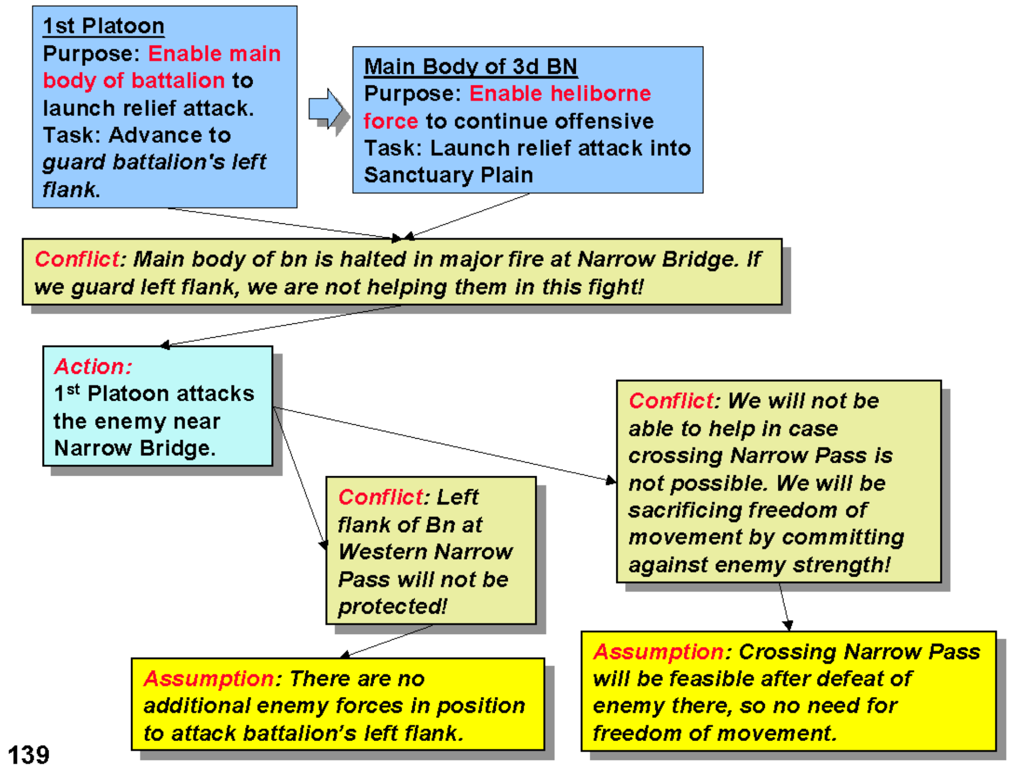

Figure 7. The COA is satisfactory if certain assumptions can be accepted.

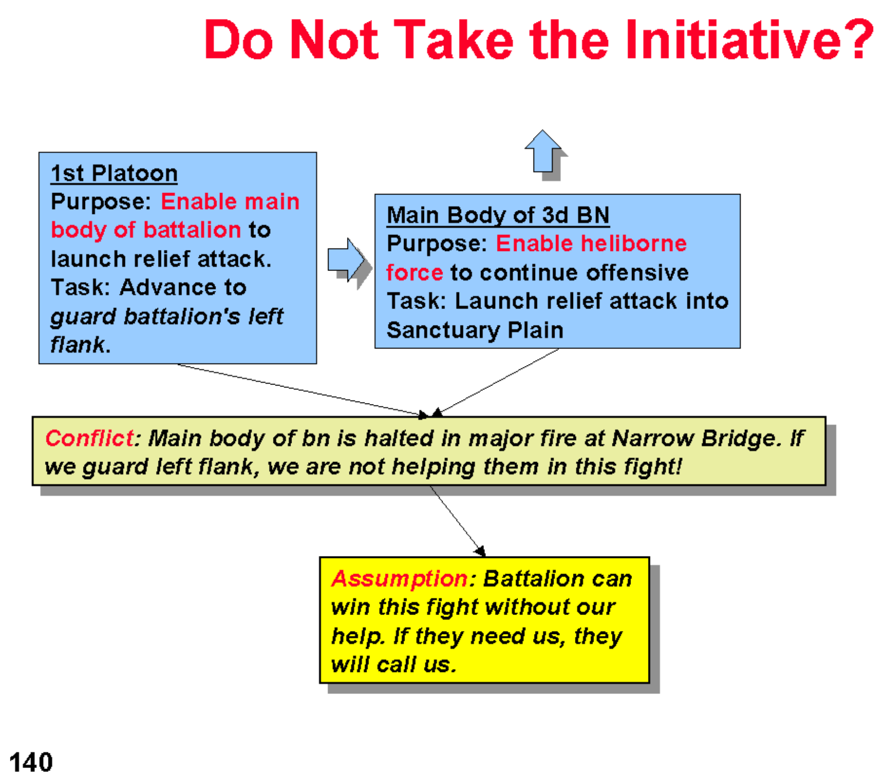

Figure 8. As a result of the problems, the commander considers another COA that resolves the conflict a different way. This COA also depends on an assumption.

An impasse of this kind can be a good occasion for *creative* thinking. Students are now asked to see if they can come up with additional options that avoid (all or most of) *both* sets of assumptions, and so have a greater chance of success. For example, one new idea might be for the commander to send part of his platoon up on the ridge between the two passes. From that location, it can fill gaps in information both about the presence of additional enemy forces on the left flank and about the battalion's current fight. From the ridge, the platoon will be in position to carry out a variety of contingencies: to support the current battalion fight by attacking enemy forces from the rear, to continue to protect the battalion left flank, or to screen battalion movements through the Western Narrow Pass. In other words, options are not prematurely foreclosed. As a result, there appears to be a greater chance that all purposes will be achieved.

The training also uses historical incidents, which increase interest in critical thinking on the part of some students. This section of the training includes a remarkable example of critical thinking about initiative and purpose by Ulysses S. Grant at Vicksburg. Awareness of the overall purpose led Grant to abandon his line of communications, deviate from virtually every part of his orders, and still achieve one of the pivotal victories of the Civil War.[5]

The section on critical thinking about purpose moves on to the introduction of a *devil's advocate* strategy. This strategy involves

1. imagining that a crucial assessment or plan will *fail to achieve its purpose*
2. forcing oneself to *explain how* that could happen
3. assuming that the explanation is wrong, and asking for another, and so on.

Students learn to kickstart their imagination by picturing an infallible crystal ball that persistently tells them their explanations of the failure are wrong, and demands that they generate another one (Figure 9). Each explanation corresponds to an *assumption* that is required for success of the plan. These explanations / assumptions can then be evaluated and dealt with, e.g., by collecting more information to confirm or disconfirm the assumption, by adopting another plan, adding branches, or accepting the risk.

Mental models amplify the power of the crystal ball strategy. For example, the crystal ball might insist that the plan will fail at a particular place in the mental model, and demand an explanation. It will then insist that the failure occurs at a different place in the mental model, and demand an explanation. In this way, students learn to use their mental models to identify a representative set of weaknesses in the situation model or plan (Figure 10).

[5] According to Civil War historian James McPherson (1996), Grant's Vicksburg campaign was "one of the most brilliant achievements of the war." For more details, see Miers (1955) or Catton (1960). Another reason for presenting such a case in detail is to illustrate how the concepts of mental models, purpose, and critical thinking can help extract lessons from military history.

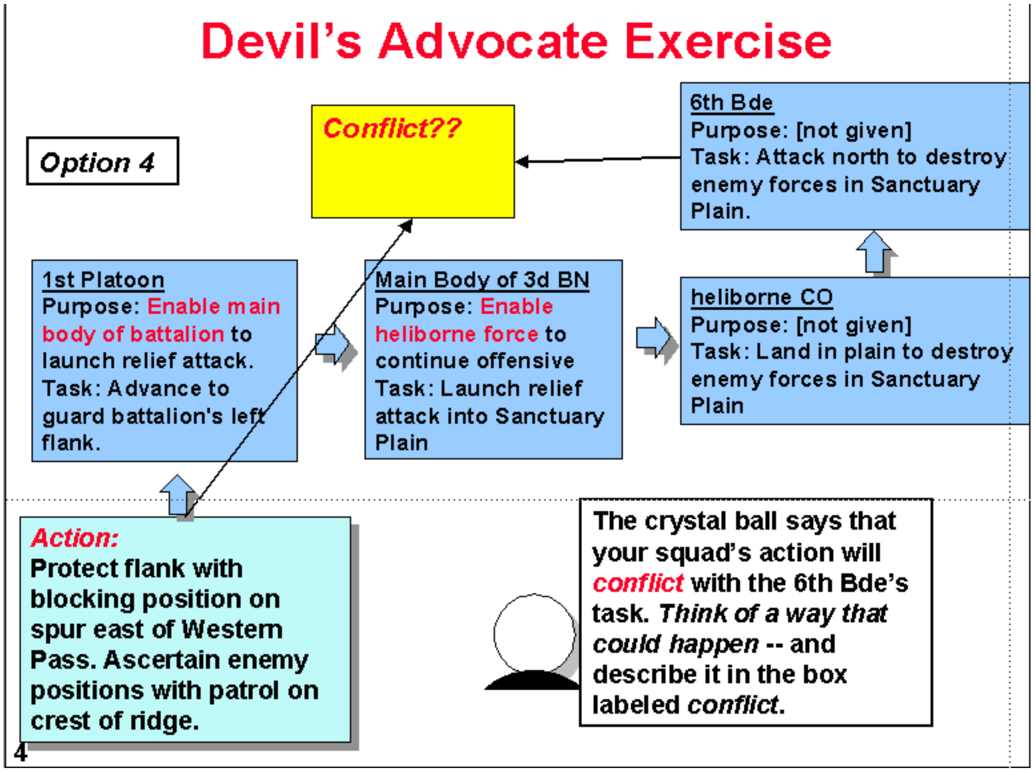

Figure 9. Part of interactive exercise on use of devil's advocate technique.

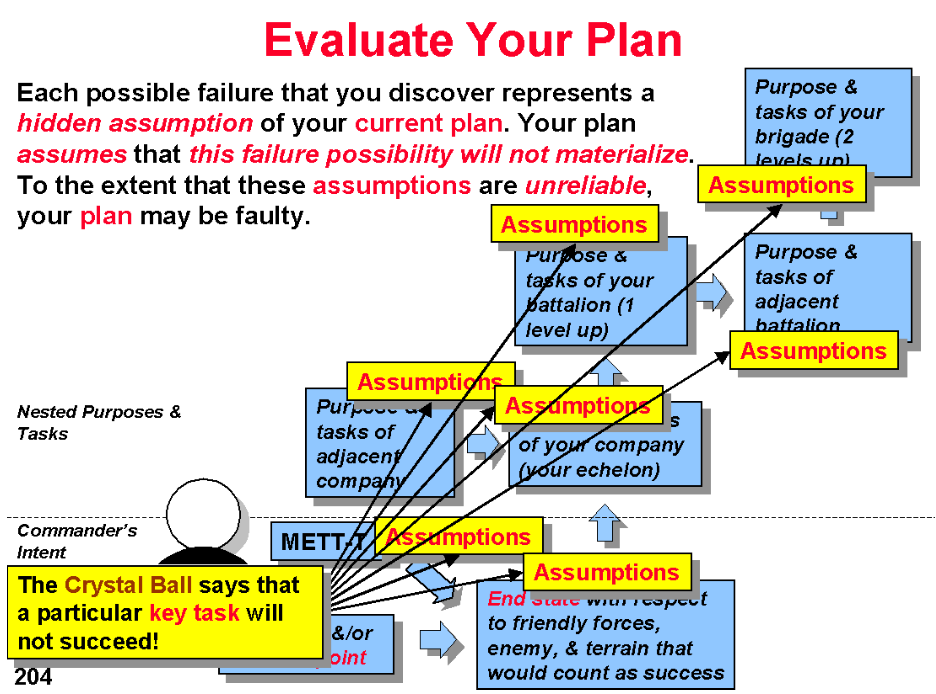

Figure 10. Using mental models to find flaws in situation understanding or plans.

Training Part 2: Time Orientation

Time orientation is how purposes get accomplished in the matrix of time and space (Chapter 3, Volume 1). It is the way decision makers use their awareness of purpose to seize and maintain the initiative. This part of the training shows how mental models can be elaborated to reflect the temporal relationship between one's own actions and purposes, and the actions and purposes of another agent (whether friendly or enemy). It defines three kinds of time orientation - reactive, predictive, and proactive – and the questions that must be asked to fill gaps in each kind of mental model. It then shows how critical thinking about time orientation models can effectively guide decision making.

Mental Models of Time Orientation

Friendly actions can influence, predict, or react to decisions of the enemy or other friendly units. Training explains these three time orientations – proactive, predictive, and reactive –in terms of two different dimensions of mental models (Chapter 3, Volume 1):

- *How* decision makers reduce uncertainty about another agent's actions. Predictive and reactive orientations *assess* what the agent will do next or has already done, while the proactive orientation tries to *influence* what the agent will do.
- *When* decision makers reduce uncertainty about another agent's actions. Proactive and predictive orientations reduce uncertainty *early* in the other agent's decision cycle, while the reactive orientation figures out what is happening late in the decision cycle.

This training extends the graphical mental modeling tools introduced previously. The horizontal axis now represents *time*, while the vertical axis continues to represent the hierarchy of *purposes* (Figure 11).

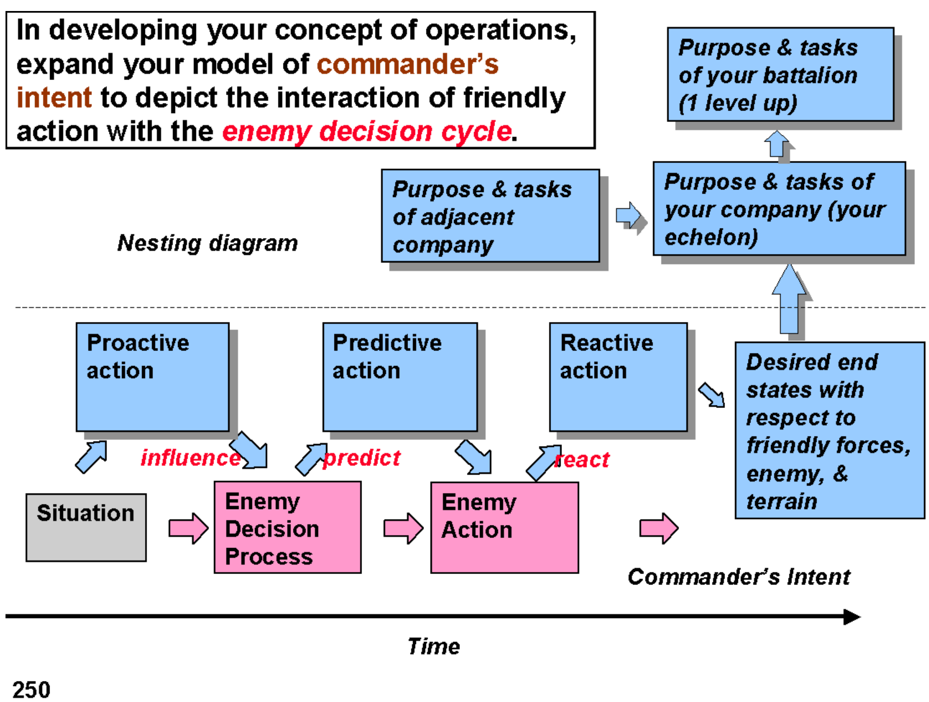

Figure 11. Mental model diagram includes relation of enemy and friendly action in time.

Figure 12 summarizes the three time orientation concepts.

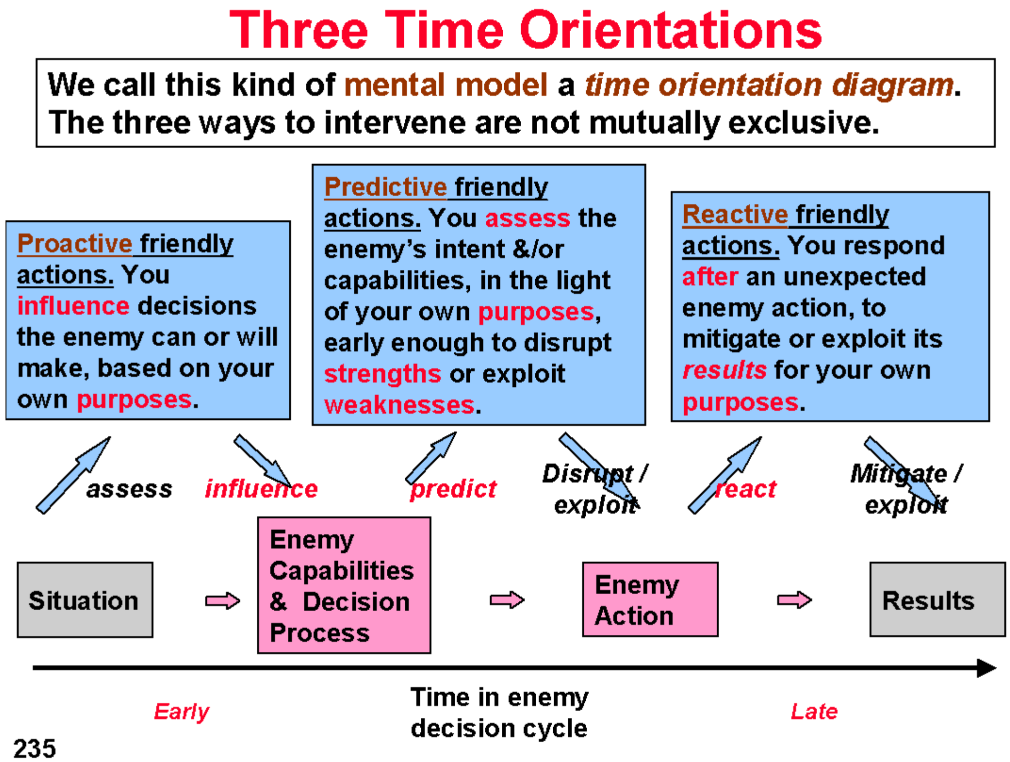

Figure 12. Summary of the three time orientation concepts in the context of a mental model diagram.

Students gain proficiency with the concept of time orientation by completing simple interactive exercises. One such exercise summarizes elements from the concept of operations at different echelons in Desert Storm (Scales, 1994; Clancy & Franks, 1997). Students must classify the cited elements as predominately proactive, predictive, or reactive.

The three time orientations correspond not simply to different structures, but to different thinking strategies. They differ in the critical thinking processes that construct them. In particular, the *sequence of questions* used to build a predictive mental model is significantly different from the sequence of questions used to build a proactive mental model. In developing a concept of operations, students learn to *ask questions* that enable them to explore proactive and predictive, as well as reactive, opportunities. In asking these questions, they fill in the "gaps" in a time orientation mental model. The same information can have a different significance to the decision maker depending on which sequence it belongs to.

For example, to create a predictive model, the decision maker works *forward* from cause to effect: from an analysis of the intent of the enemy to a prediction of enemy actions, and from enemy actions to the implications of those actions for enemy strengths and weaknesses and for the achievement of one's own purposes. Only then do predictive decision makers ask what they can do to disrupt or exploit the predicted action. To create a proactive mental model, on the other hand, the decision maker works *backward* from desired effects to potential causes: from own purposes to enemy actions that would be conducive to those purposes, to enemy intentions and decision processes that would lead to those actions. Finally, decision makers ask how they can influence those intentions and decision processes.

Students learn to ask these questions for themselves by a series of exercises of increasing difficulty. Students complete an exercise based on real-life incidents in Vietnam, drawn verbatim from McDonough's (1985/1996) account of his experiences there. The exercise requires students to answer questions corresponding to a time orientation from McDonough's account of events.

Critical Thinking about Time Orientation

The real power of thinking in terms of time orientation comes from seeing how each orientation addresses weaknesses in the others, through critical thinking. This section introduces students (1) to a better understanding of how proactive, predictive, and reactive orientations co-exist and provide mutual support, and (2) to a more sophisticated set of critical thinking strategies. The section focuses on problems or pitfalls that are associated with each time orientation, and how other time orientations can mitigate those problems. Correcting one kind of problem sometimes leads to other problems (see Chapter 4. Volume I), as plans are gradually elaborated and improved through critical thinking. The most effective plans ultimately involve several time orientations in a mutually supporting pattern.

Three patterns of mutual support are described and illustrated in this section of the training:

1. Using proactive and reactive methods to hedge against failed predictions.
2. Using predictive, and proactive methods to regain the initiative after reaction to surprise.
3. Using predictive and reactive methods to mitigate risk in proactive activities.

An example illustrates how critical thinking can discover problems in tactics based on a prediction of enemy action. Generally, for predictive tactics to succeed a variety of assumptions must be true. The example illustrates the use of a devil's advocate technique introduced earlier (the *crystal ball*) to ferret out these assumptions. The crystal ball says that your plan will fail, and repeatedly demands an explanation of how that could happen (what could go wrong). This technique gains power by leveraging the mental model. The question can be asked regarding each part of the predictive mental model in turn. For example, your plan will fail because of wrong estimates of enemy *intent*, because of the *actions* the enemy will use to carry out the intent, or because of the *outcomes* of the actions.

The exercise then turns from criticism the plan to improving it, and illustrates three different ways that problematic assumptions in the predictive mental model can be addressed, corresponding to the three different time orientations:

- using *proactive* tactics designed to influence the enemy and *make* the assumptions true;

- collecting more information to confirm that the *predictive* assumptions are correct;
- adopting contingencies or branches (a blend of predictive and *reactive* time orientations) in case the assumptions prove false.

This pattern is found often enough that it can be regarded as one typical *template* in which different time orientations provide mutual support. Proactive tactics are utilized to increase the chance that predictive assumptions will turn out to be true, while reactive tactics monitor for the unexpected. This template recurs in a variety of military tactical situations.

In a continuation of this example, the enemy behaves in a surprising manner, failing to cross the river to defend the command post and heading in a different direction than expected. This sets up a second typical template for mutually supporting time orientations, in which we transition from *reaction* to *prediction* to *proaction*. The initial reaction is designed to mitigate any immediate threat from the surprising enemy action. The next step is to predict any enemy weaknesses that the unexpected enemy action exposes or has itself created. In this case, failing to cross the river leaves m enemy command post relatively undefended on the other side. We can develop predictive tactics to exploit any opportunities that are identified. At the same time, we seek a way to use these opportunities to *create* new weaknesses, i.e., to *proactively* degrade the enemy's capability to pursue *future* operations. In this case, disrupting enemy command and control by destroying the command post will degrade the enemy's future warfighting ability. The result of this critical thinking process is a template for reaction to surprise that shifts as rapidly as possible from enemy to friendly initiative.

Two historical examples of reaction to surprise are described, which utilize this template. In one of these, U.S. Grant turned unexpected enemy action to friendly advantage: at Fort Donelson (Figure 13). This illustrates the use of surprise as an occasion for ferreting out incorrect assumptions about the enemy, since the surprise occurred because of a *failed prediction* regarding enemy intent and/or capabilities. When the enemy unexpectedly broke through the encircling Union forces, Grant first strengthened his line in reaction. He then predictively inferred an unexpected enemy weakness; and he was able exploit that weakness to achieve his original proactive goal of capturing the Confederate force in the fort.[6]

[6] For more on Grant at the Fort Donelson, see Conger (1996), Catton (1960).

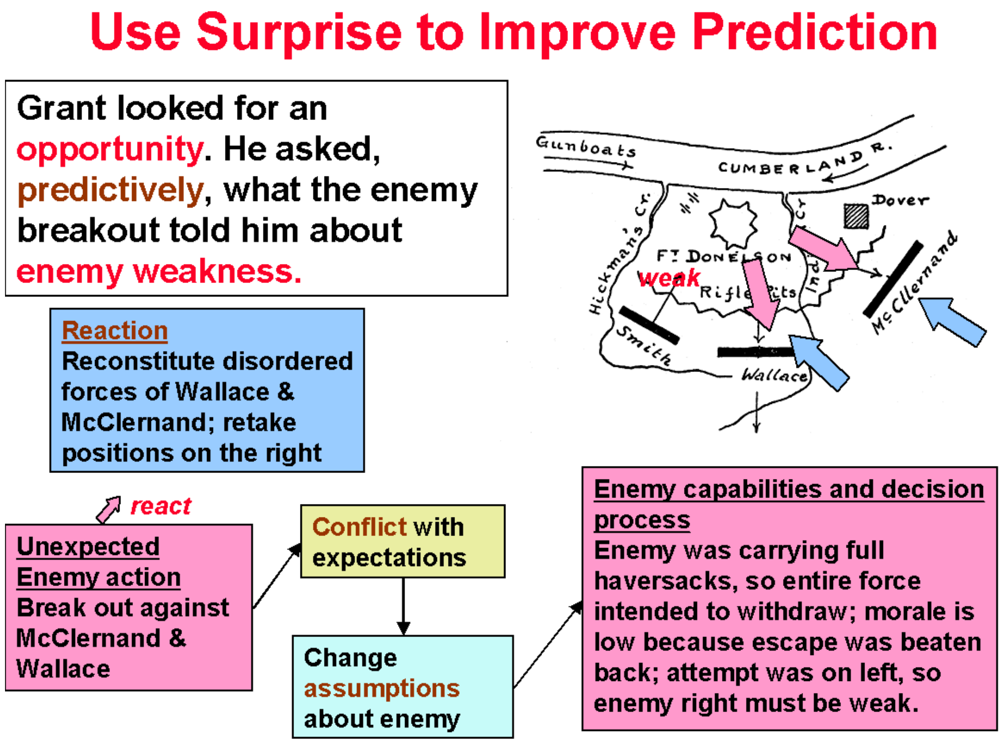

Figure 13. Grant used the enemy's breakout at Fort Donelson as an occasion for critical thinking about his assumptions.

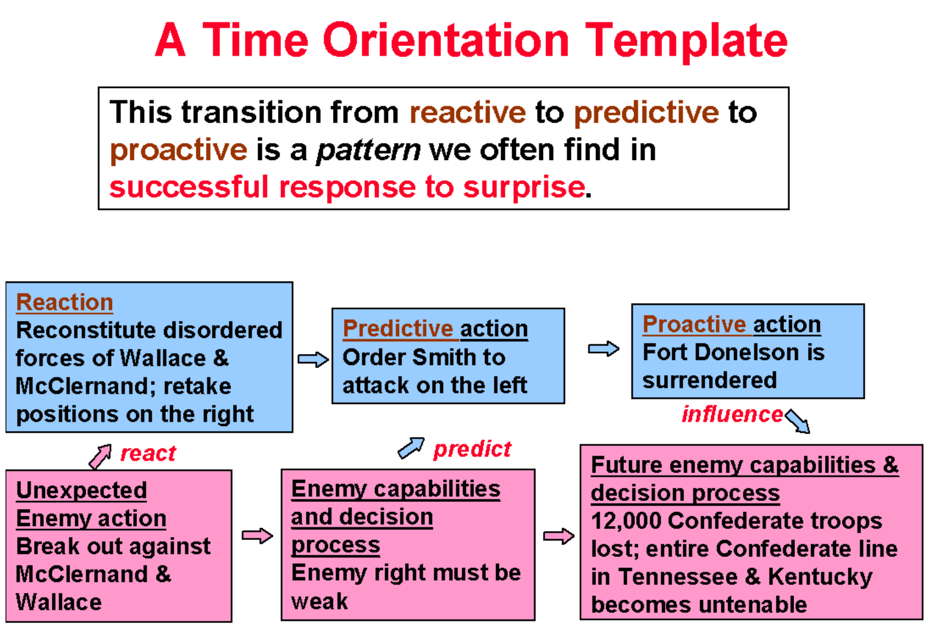

Figure 14. A time orientation template (reaction to prediction to proaction) illustrated by Grant's decision making at Fort Donelson.

A commander who wishes to concentrate forces and take the offensive (for proactive purposes) in one location, may have to rely on *predictions* regarding the weakness of enemy forces elsewhere. The training illustrates a third typical time orientation template that applies in such cases. Since there is no guarantee that the predictions will turn out to be correct, the commander may prepare contingencies for reaction in case of surprises. We illustrate this pattern in Figure 15 by the allied use of economy of force in the Ardennes in 1944, prior to the unexpected German offensive that led to the "Battle of the Bulge."

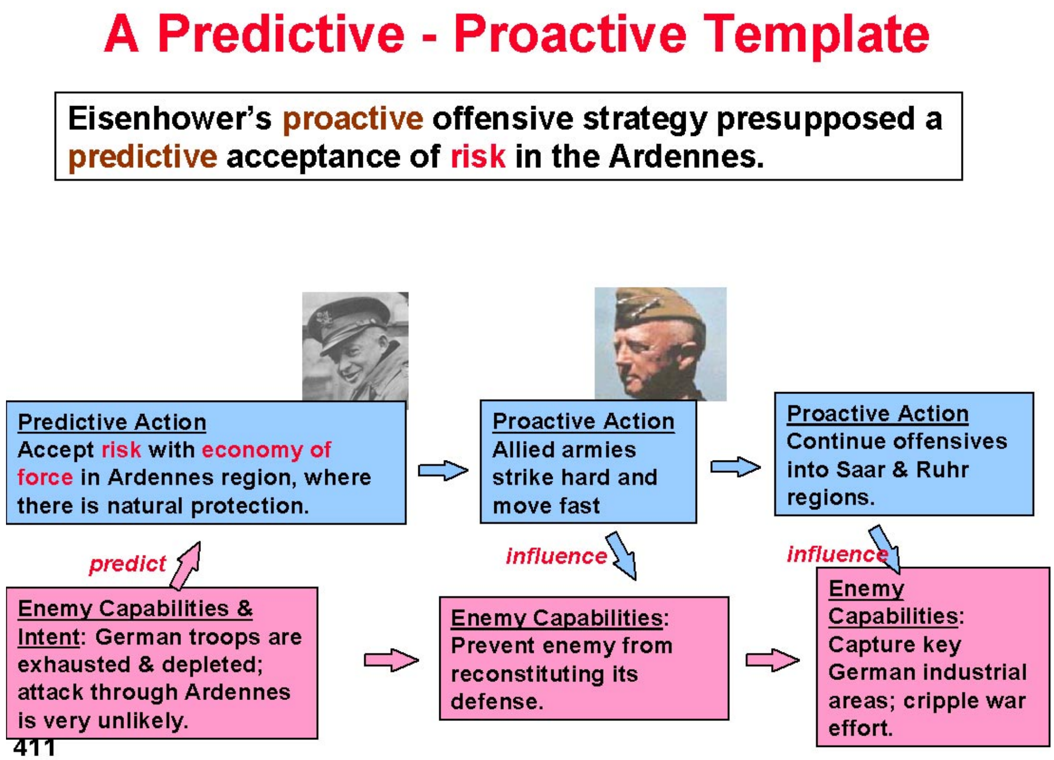

Figure 15. Another time orientation template illustrated by Eisenhower's decision to thin out forces in the Ardennes to enable offensives elsewhere.

Training Part 3: Maneuver Warfare

Critical thinking about mental models can be used in decisions that involve difficult tradeoffs between boldness and risk. Part 3 addresses the tradeoffs that are likely to arise in application of "maneuver" warfare principles and some thinking strategies for creating robust plans (Hooker, 1993; Lind, 1985; The United States Marine Corps, 1989; Leonhard, 1991, 1994).

Maneuver warfare theory starts with two observations: (i) winning by attrition, i.e., by destroying the enemy bit by bit; is very costly, and (ii) destroying or wearing down the enemy is not a prerequisite for victory. The only true requirement is that the enemy decide to stop fighting, and that result can be achieved more quickly and with fewer losses by directly influencing the enemy's decision making process. Maneuver warfare focuses on points of enemy weakness that produce disproportionate effects on the enemy's ability to carry on the fight. It wins by constantly seizing the initiative.

Mental Models of Maneuver and Attrition Warfare

Attrition and maneuver methods differ in how each of the three time orientations is used and in how they support one another, as shown in see Table 7.

Table 7. Differences between attrition and maneuver methods in terms of time orientation

	Attrition methods	**Maneuver methods**
Proactive:	Attrition destroys the enemy's *materiel and personnel* in order to gradually wear down its ability to fight and limit its future options in each successive battle.	Maneuver tries to win more quickly, by generating "moral" effects, like shock and panic. These reduce the enemy's *decision making ability*, and can lead to a sudden enemy collapse without destruction of its forces.
Predictive:	To accomplish this goal, attrition emphasizes predicting and attacking enemy *strength*,	To achieve this goal, maneuver emphasizes predicting and attacking enemy *weakness*
Reactive:	To destroy enemy strength, attrition emphasizes taking time to *prepare* reactions to different contingencies, in particular, planning how the battle will transition from one predictable stage to the next (e.g., from artillery preparation to infantry or armored attack) as enemy assets are destroyed.	To discover enemy weaknesses and exploit them before they disappear, maneuver emphasizes the ability of local commanders on the spot to react *quickly* and flexibly to opportunities. High tempo also increases the proactive effects on the enemy of shock and panic.

The training helps students use maneuver warfare methods by showing how to build an interdependent system of mutual supports among time orientations. A series of time orientation templates, representing typical combinations of methods, gives them the flavor of these relationships.

In a tactic called "recon pull" friendly forces probe in many locations for weaknesses (or "gaps") in enemy front lines, and react rapidly to any success by sending reserves through the gaps into the enemy rear. If this *reaction* is rapid enough, the enemy will be *predicted* to be unable to repair the breach in time to prevent the exploitation. Conversely, rapid reaction is facilitated by the predicted weakness itself. The tactics of surfaces and gaps thus involves mutual support between rapid reaction and prediction of enemy weakness: The weaker the enemy, the faster the breakthrough. The faster the breakthrough, the less likely the enemy can repair breach in time, hence, the weaker the enemy.

The enemy rear is a typical objective point in maneuver warfare because it combines predicted weakness with proactive effects on future warfighting capability. The enemy rear is *predicted* to be relatively lightly defended, and the rapidity of attack is *predicted* to prevent any redeployment of enemy forces for its defense. Such an attack is also *proactive*, because of the presence of high-leverage enemy vulnerabilities in the rear area, such as command and control or logistics, without which the enemy cannot continue to fight. (Figure 16). In addition, by attacking suddenly in an area thought to be safe, friendly forces can cause the enemy to panic. This panic will *proactively* degrade the enemy's ability to continue the fight as much as the actual loss of command and control or logistics. These proactive effects create new weaknesses that can be further exploited by future predictive actions. This exemplifies a proactive-predictive virtuous cycle: The more decision making is disrupted, the weaker the enemy. The weaker the enemy, the more panic, hence the more disruption in decision making.

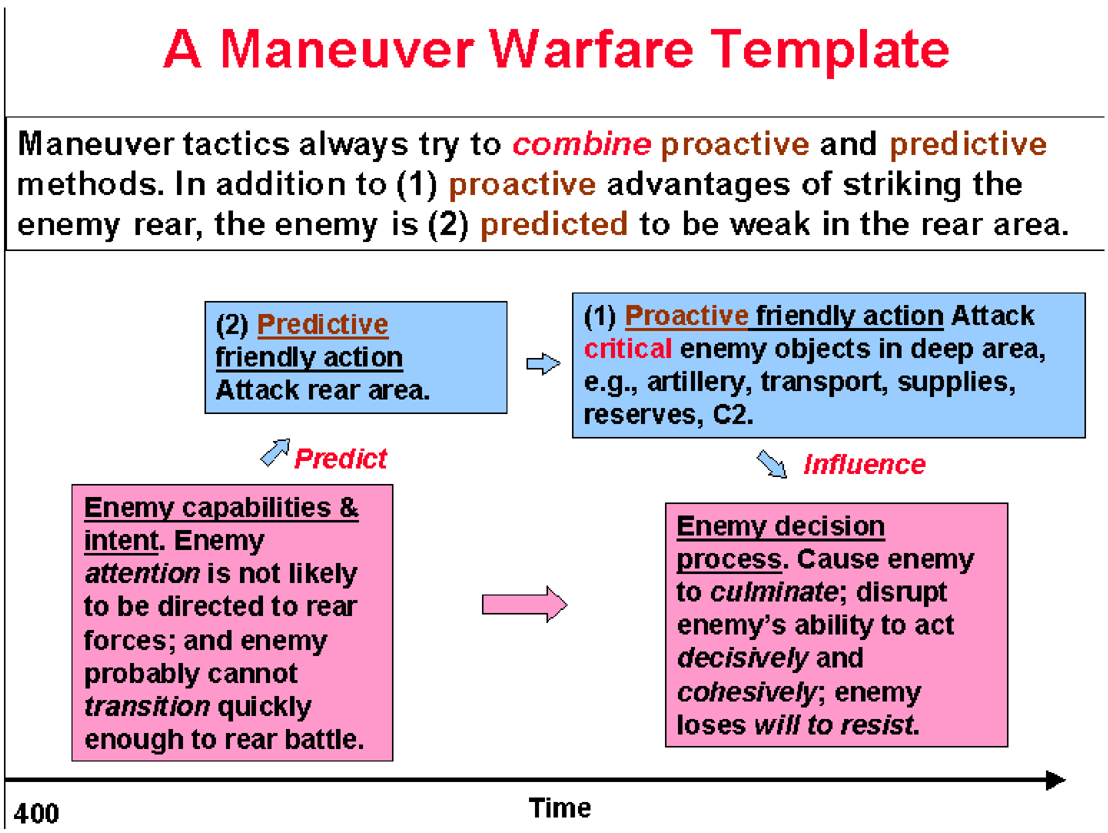

Figure 16. Predictive and proactive time orientations support one another in maneuver warfare.

The essence of maneuver warfare is the snowballing, positive feedback effects that it strives to create among the three time orientations. Autonomous decision making by low-level units is crucial for the required rapidity of response that gets the process going, as the basis for predicted inability of the enemy to redeploy in time, and for the sake of its pure shock effect. The purpose is to win as quickly as possible, at the least cost.

Critical Thinking about Maneuver Warfare

The next section in this segment explores critical thinking about maneuver warfare tactics more closely. It explores how each phase of the I.D.E.A.S. cycle can help address problems to which highly initiative-oriented maneuver tactics can lead. Specific problems in applying maneuver warfare tactics are addressed in detail.

Reactive and predictive orientations can conflict, for example, if speedy reactions leave units with unprotected flanks (Figure 17). This is an example of a more general problem with taking initiative in the absence of complete communication or advance coordination. Assumptions must be made about the actions taken, or the success realized, by other friendly units, and these risks must be weighed against the potential advantages of quick reaction.

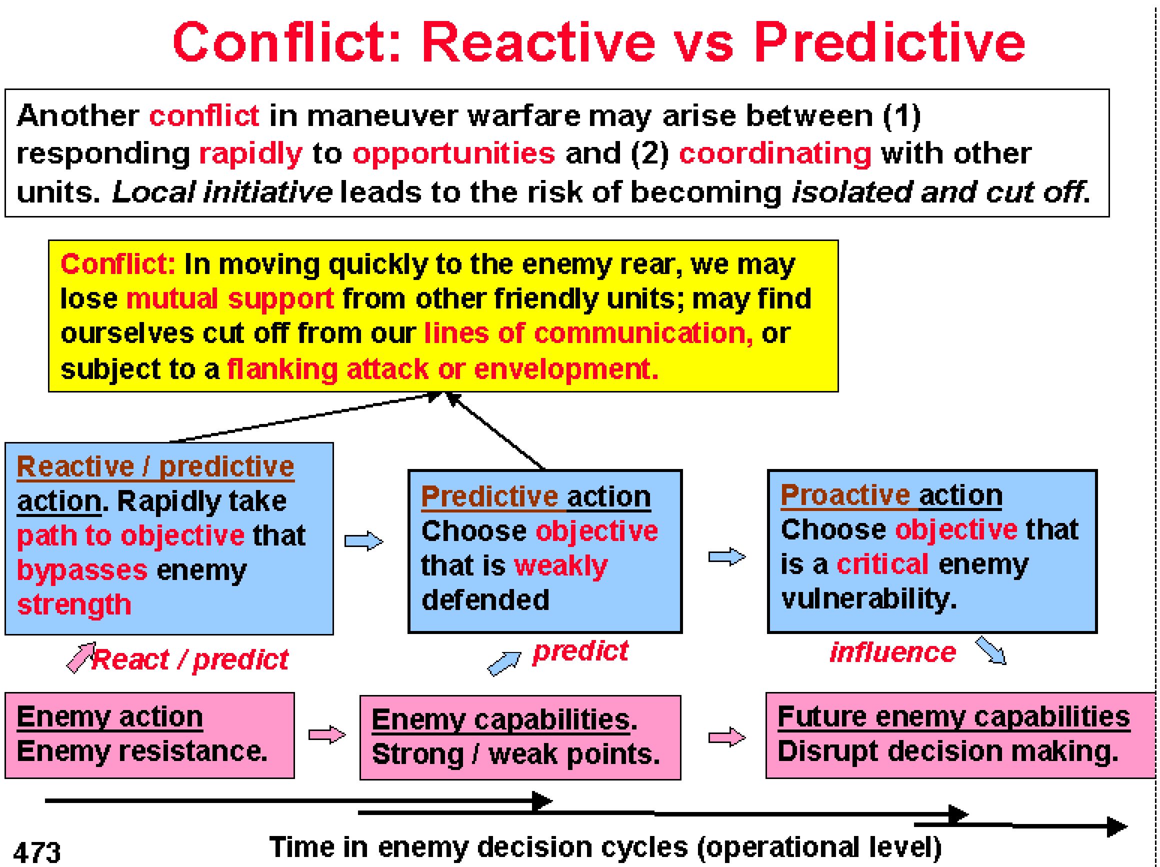

Figure 17. Risk of loss of coordination associated with rapid reaction.

Predictive and proactive orientations can conflict if normally high-leverage targets, such as command and control and logistics, are in fact not weakly defended. A greater emphasis on preparation and coordination rather than tempo and surprise may be required when this is the case.

Maneuver tactics choose speed of action over coordination among friendly units, and as a result incur certain risks. Maneuver tactics emphasize ways to use all three time orientations to compensate for the risk caused by lack of coordination: by rapidly reacting to signs of existing enemy weaknesses, by exploiting them before the enemy can respond, and by creating new enemy weaknesses through high tempo and surprise and by striking high-leverage targets. Success on all these fronts depends, however, on a number of assumptions: that rapid movement can be executed given the terrain, weather, equipment, and enemy resistance; that predictions about weakness are correct, e.g., that apparent gaps in enemy front lines are real rather than traps laid by the enemy to suck us in; that shock tactics will have the intended psychological effects on this particular foe, causing them to collapse rather than hunker down; and that the enemy really does depend critically on the targeted command and control and logistics capabilities. Failure of these assumptions can turn promising initiative into disaster. Students get practice making these kinds of tradeoffs in exercises in which high levels of initiative involve a cost in communication and coordination (Figure 18).

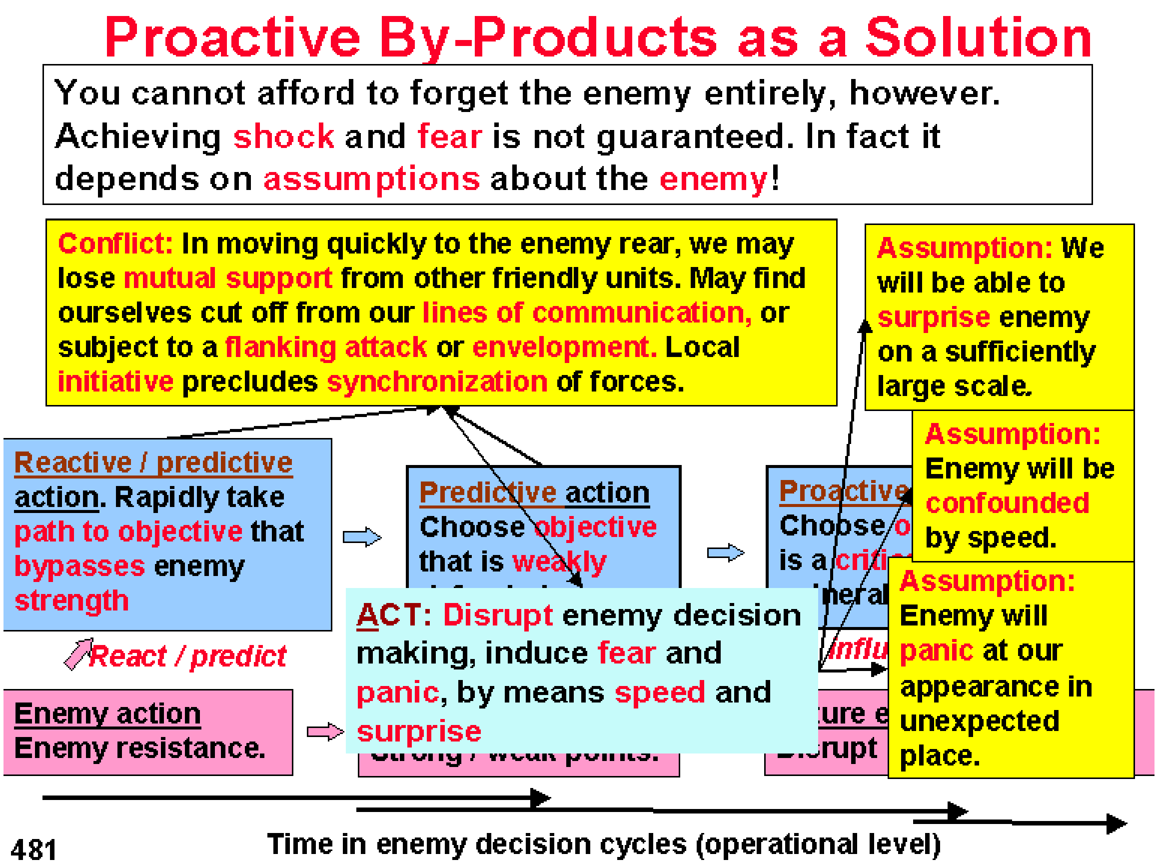

Figure 18. A possible answer for the problem of Figure 24 (see the yellow *conflict* box) is shown in the aquamarine *act* box. Some assumptions upon which its success depends are shown in yellow *assumption* boxes at right.

CHAPTER 8
SOFTWARE DESIGN, PRODUCTS, AND PROTOTYPES

The Challenge

The Army, in common with many large organizations, has a strong need for distance learning technologies. In order to maximize the effect of learning, we have focused on domain specific training of critical thinking skills. We developed a body of training materials that were successfully deployed within the context of a class at the CGSC. In addition, we designed and developed several advanced technology prototypes to enhance the efficacy of distance learning, including interactive exercises, collaborative learning, and adaptive feedback as well as a system to facilitate authoring of content and exercises.

During the performance of this project the Internet, and our understanding of it, has evolved rapidly. This has resulted in a number of changes as we account for the influence of new technology and radically increased connectivity on viable designs for distance learning systems. In particular, the designs have evolved from a focus on stand-alone products running on the users desktop to server-enabled distributed learning systems.

Server-based systems provide a richer context for distributed learning. They can support the more mundane, but necessary, course management. However they also enable new levels of interactive learning and create the potential for collaborative learning, asynchronous learning, and adaptive feedback from centralized "intelligent" servers. (The adaptive feedback system is described in section IV.)

The explosive growth in high-speed / low cost connectivity, the evolution in dynamic HTML, the capacity of the web browser to support dynamic or interactive content, and the evolution of server-side scripting and programming environments (e.g., Java Servlet Engines) has transformed the environment deploying distributed interactive training. Finally, the emergence of XML and its associated technologies is again reshaping the technology playing field.

The technology basis for distributed learning systems has changed. During the first phase of this research the focus was on intelligence on the desktop as we examined mechanisms for human-computer interaction that would facilitate the rapid elicitation of mental models. The desktop perspective carried over into the second phase of the research, with a concern for distributing physical media (e.g., CD-ROMs) with training content. Interactive exercises were to be facilitated by custom desktop programs that both delivered content (like a web browser) and embedded additional logic to support interactive exercises. With only "sneaker-net" connectivity (i.e., carrying floppies by hand), collaboration was not facilitated directly by the technology and had to rely on the organizational structure by which the training materials were integrated into the classroom.

Over the last several years Java emerged as a player in the network aware applications and "applets" market. An applet is a Java program designed to run within a security model of a web browser. An application is a Java program does not run within the web browser, and which has fewer, if any, security constraints. Java applets are the clearly preferable technology for most users and developers, as they combined transparent use with an advanced and network aware programming language. When all goes "according to plan" the applet is a seamless part of the user's web experience. Only technology savvy users can distinguish the mixture of mechanisms that provide content and interactivity in a web page or web site.

Unfortunately there have been a number of difficulties with this vision for Java in network aware applets. Foremost has been the incompatibility challenge posed by Microsoft. Microsoft has been mandated by court order to rectify this situation (emerging from a breach of contract with Sun Microsystems, the manufacturer of the Java technology). Past damages to compatibility continue to complicate the development and deployment of Java enabled web technology. As the utility of client-side Java programming was proved (at least temporarily) deficient, the use of Java has blossomed on the server. However the client-side situation is now improving. Compatibility issues can be addressed by a mixture of organizational management of technology and intelligent server technology (e.g., using XML and XSL, as described below) to deploy different solutions dynamically depending on the user's software environment.

The increased intelligence of the web browsers (while not yet standardized across the major browsers) supports designs for distributed training with interactive exercises based on dynamic HTML. This minimizes the bandwidth constraints as the logic for the interaction can be encapsulated within the web page (as JavaScript and/or Java), minimizing the need for exchanging content with the web server. Further, advances in server-side programming support the ready development of mechanisms to facilitate collaboration among learners and to coordinate online learning with classroom materials.

XML has now arrived as a standard for expressing the interchange of structured data among computational systems. In this role it is finding universal acceptance as the glue to coordinate business-to-business (B2B) transactions. Associated standard for style sheets (XSL Transforms) and formatting provide a technology for encapsulating distinctions among web clients (the browser applications). This means that server-side applications can now be concerned with manipulation of structured information (representing, in this case, training system resources, interactive exercises, feedback, distributed classroom guidance, etc.).

The current technology environment for distributed learning systems is encouraging. Intelligent and robust web server applications are enormously easier to develop using Java Servlets and J2EE technology, with their integrated support for HTML and XML processing, database connectivity, and intelligent management of client and server resources. XML ready web browsers, such as Internet Explorer 5.0 ™ provide robust environments for highly interactive training content *and* for the development of course authoring and course management tools manipulating shared XML representations of training content.

Finally, another emerging standard, WebDAV, provides client-server support for Distributed Authoring and Versioning. The importance of WebDAV lies in its ability to permit users to remotely author and manage content on web servers using WebDAV aware tools on the desktop. WebDAV clients are spreading rapidly and currently include Microsoft Office ™ 2000 products (e.g., Word 2000) among others. WebDAV server implementations are also emerging, beginning with the public domain mod_dav implementation for the Apache web server.

Essentially, WebDAV permits users to treat files on a remote server as if they were stored on the local desktop. The remote server is called a "repository" or "document database." Web server administrators can configure their servers so as to make documents saved in the repository directly available via the web server. This permits users to directly author web content on remote servers. WebDAV implementations provide for suitable security models to insure that users only have access to certain parts of the repository and does not require the user to have any other access permissions on the web server.

WebDAV also supports *versioning resources* (any document or content in the repository is termed a "resource"), *collection management,* resource *locking,* and *activity* management. Together these provide an rich and versatile basis for teams of authors that need to coordinate and manage coherent collections of content (such as a training course or set of courses that are collaboratively created). For example, by versioning a *collection* of resources that comprises a training course, authors are able to prepare a new version of the course materials while the current version remains in place for use by students. Such versioning and collection management systems are general purpose document history archives. The WebDAV standard, and the existing client and server implementations of that standard, will dramatically reshape collaborative authoring, e.g., of distributed teams, and the ways in which web content is created and maintained.

In the remainder of this chapter we will review the specific applications, designs and prototypes that were developed during this research effort. We are currently exploring business models for commercialization several aspects of the technology, including server-side integration environments for interactive web experiences and intelligent servers for providing adaptive training in critical thinking in the context of information search on the web.

CGSC Evaluation System

In this section, we discuss the software system that was used in the CGSC evaluation described in Chapter 10 below. This training program was entitled *Training to think critically about the battlefield*, and was the mechanism by which the *training content* described in Chapter 7 was delivered to students. The training content may be accessed directly using Internet Explorer or Netscape (versions 4.0 and up), or by CD-ROM.

As a software system, the present training system is conceptually quite simple -- most of the effort leading up to the CGSC evaluation was devoted to developing the training content. The training system is a collection of GIF format slides which are interconnected by a hyperlinked table of contents, implemented with JavaScript. Additional links are provided for the ARISLE scenario and hyperlinked Army Military Decision Making Process (MDMP) documents.

The training system is structured into three browser frames, which are (1) a TOC (Table Of Contents), (2) a content view and (3) a navigation view. An image of the training system is provided below, as Figure 26, for easier reference. In that image, one can see that the TOC fills the left-hand side of the training display; the *content view* fills the bulk of the display, and lies to the right of the TOC; finally, the *navigation view* is at the bottom of the display. The current selection is always displayed in red, while all other active links are displayed in blue. In the printed image of the training system, the red is rendered as a less visible font. The current selections in that image are "Training to Think Critically on the Battlefield" (in the TOC) and "Training" and the "Long" version in the *navigation view*.

The student views the training content by either (a) choosing among the topics listed in the TOC view or (b) progressing sequentially through the training materials using the Forward and Backward arrow icons found in the right-hand side of the *navigation view*. Each "slide" in the content view belongs to some high-level topic in the TOC. In Figure 19, you can see that this copyright slide belongs to the first section of materials in the TOC. As a result, that section is expanded and displays the various sub-sections that lie within its scope. When a section can be further expanded, it is always marked by a small black triangle pointing to the right: ▸. If the section is already expanded, then the triangle points down instead: ▾.

We make three basic sets of content resources available to the student. Each of these is associated with a different TOC, and the student chooses which materials to navigate by making a selection in the navigation view. These are, with reference to the sample view of the training system:

- "Training" -- Critical thinking training for Army Battlefield command. These are materials have been developed by CTI under the present contract and include both training content and sample exercises. This is the section selected in the sample image, and we are seeing the copyright slide at the start of the training materials.
- "Practice Scenario" -- A detailed practice scenario, known as the ARISLE scenario -- this scenario provides the student with background materials which are used to motivate a number of the discussions in the training content and are used to develop exercises for the student.

  We have extended the scenarios (with LTC Hadfield at CGSC) to include a series of Quick Decision Exercises (QDXs) that are designed to test critical thinking skills in realistic and time-constrained environments.
- "Military Decision Making Process" -- A hyperlinked version of the MDMP materials (currently, Chapter 5 of *FM 101-5*). These are provided solely for ease of reference by the student.

In addition, the student is able to choose among three levels of detail for the critical thinking training materials. Labeled, "Short", "Medium", and "Long" in the *navigation view*, these three levels provide a progressively more in-depth approach the training content. The Short sequence is most suitable for a brief, high-level overview of the training materials. The Long sequence is intended for students actually working their way through the training materials. The Medium sequence might be used for a detailed review of the key concepts presented in the training.

The student viewing the training materials with a smaller screen has the option to hide the TOC in order to provide more room to display the central training content. In order to hide the display of the TOC, the student uses the icon. To cause the TOC to be displayed again, the student uses the icon.

A help system is also available. It has contents that explain the navigational mechanisms, including the table of contents, and the meaning of the different icons that are used in the training system. The help system is accessed through the  icon.

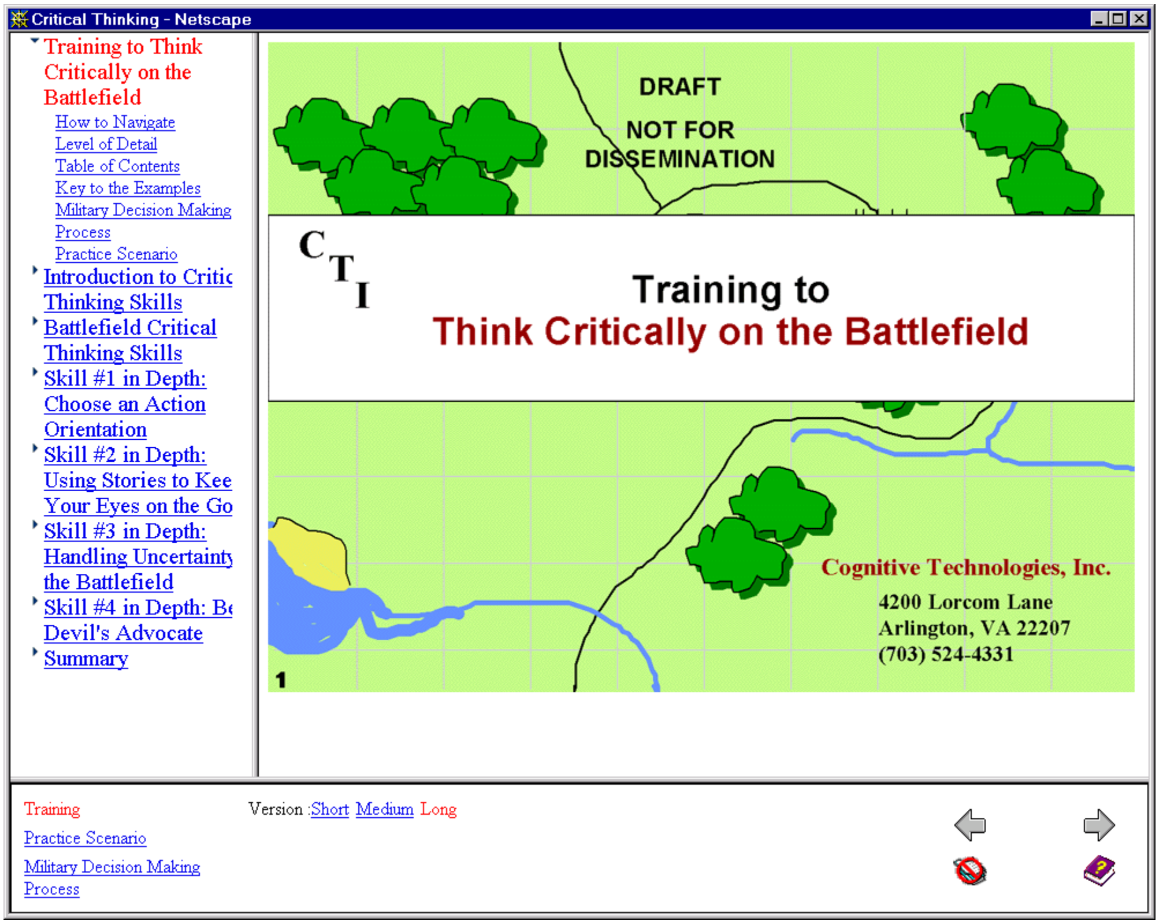

Figure 19. The initial screen of one version of the Training System. Table of contents is on left, and navigation bar at the bottom.

An Integrated Design for Distributed Training of Critical Thinking Skills

Introduction

This section will present a design for a system for the training of domain specific critical thinking skills. The architecture is intended to support distance learning with interactive content, intelligent feedback and coordination of online content with classroom instruction. Provisions have been made for authoring course materials and for collaborative as well as individual learning.

System Overview

Figure 27 provides a high level overview of the distributed training architecture. The training system connects users via the Internet to a web server that provides the enterprise specific business logic, here appropriately dubbed "training logic." The users connect to the training system using their standard Internet service provider and web browser (i.e., Netscape Communicator ™ or Internet Explorer ™). Requests to the training system are all routed through a Java Servlet Engine (or J2EE Enterprise Application Server). Internally all content is managed as XML or XHTML (HTML that conforms to legal XML syntax). The XSLT module is responsible for translating the XML representation into the dynamic HTML or XML content as determined by the capabilities of the user's client web browser.

Three classes of users are recognized by the training system: course authors; instructors; and training users. Separate training modules exist to facilitate and coordinate the activities of each kind of user. Additional software modules provide support for generic aspects of course structure (i.e., hierarchical course outlines) and collaboration of groups of users within the context of a common course. Finally the logic for adaptive feedback is encapsulated within another module that draws information from the activities of the individual training user and groups of users to recommend feedback on learning critical thinking strategies to the individual user.

A database is used to store all long term information about authors, instructors, courses, registration, user progress, etc. All training materials and content are stored within the database as well. Transient information concerning specific session with an author, instructor or training user is maintained by the Servlet Engine, for example, specific navigation details that locate a user within the training content.

Content Delivery

Training content deliver is via the Internet. The selection of content is controlled at several levels, including: the course author, who selects the raw materials and crafts a coherent body of instructional materials; the instructor, who may choose to provide guidance to training users by recommending or specifying specific aspects of the training to complement the progress of a classroom course; and the training user, who may exercise greater or lesser levels of self selection of training resources. Finally, the adaptive feedback system plays an active role in evaluating the development of critical thinking skills in training users and recommending materials and exercises to strengthen those skills.

Information flows in both directions between the user and the web server. Structured content flows from the web server to the user, while user actions and navigation behaviors are registered by the server (e.g., in the Author, Instructor and User Model modules). This reverse information flow is used to track user actions and, in the case of the User Model, to provide a basis for highly tailored adaptive feedback.

Modern browsers provide for caching logic that can greatly reduce bandwidth considerations *if* the web server has been intelligently designed. When streaming content from a database it is important to establish a logical mapping between media entities and URLs that that refer to those entities. Since the media entities are actually persisted in a database (and not a file system), the server logic must explicitly manage this relationship to minimize the re-loading of identical media objects by the remote web browser clients.

Dynamic Content

Dynamic content provides for a richer experience and is crucial to supporting interactive training exercises. The most modern browsers provide many mechanisms for dynamic content, including custom extensions, Java, JavaScript and dynamic HTML (browser specific HTML extensions that enable drag and drop behaviors, etc.). However it is a challenge to provide such interactivity in a broadly used distributed learning system. The emergence of XML and XSL (XML style sheet) Transformations (XSLT) provides a basis for concentrating the business logic (or, in this case, the training logic) within XML aware modules in the web server.

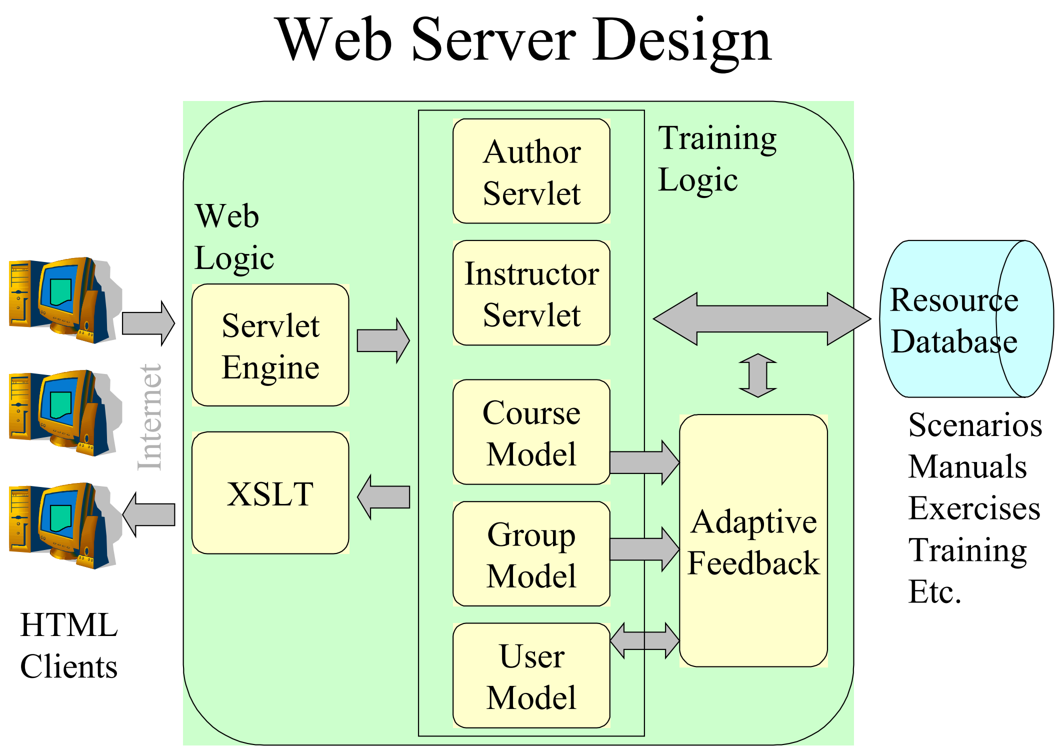

Figure 20. High level overview of the distributed training architecture.

The complexity of dealing with specific browsers and the relative ability (and inability) to support dynamic content is managed by XSL Transforms. Specific *kinds* of interactive content are modeled as XML structures (e.g., a table of contents for training materials or an arrangement of questions and answers that must be associated by the training user). Since these are managed as structured information (vs hard-coded HTML content), it is (for the system designer) easy to develop web-based tools to manipulate these representations (e.g., as the training author). Specific realizations of the interactive training content are implemented created by system programmers. Those *implementations* are realized as XSL Transforms that translate the XML representation of an interactive exercise into a specific combination of HTML, JavaScript and Java that is suited for the browser platform being used by a specific user.

XML and XSL Transforms have restored a critical separation between a data model (XML) and interactive views of that data (HTML + JavaScript + Java). The XML aware modules that implement the "training logic" provide a controller for the data. This model-view-controller paradigm greatly simplifies both system and content design.

The remainder of this chapter discusses several of the Training Logic Modules in the integrated design.

Author Module

The Author Module encapsulates the logic to support the creation of training content by course authors. When a training author is using the Author Module they use their web browser and navigate HTML pages. However, those pages are generated and designed so as to permit the training authors to create and modify training materials. Essentially, the navigation actions of training authors are translated into changes to XML representations of training structure that are stored in the database on the server. Content is created and modified using WebDAV enabled clients.

Training material is comprised of *structure* and *content*. Training s*tructure* is modeled as XML that expresses specific kinds of training relevant information. For example, the hierarchical outline of training materials is the *structure* that organizes a collection of *content* into a training course. (The table of contents in a book is the *structure* that organizes the book's *contents*. The index and glossary of the book are other *structures* that organize the books contents.) For training courses, the *content* includes documents, graphics, manuals, etc.

Interactive exercises are a hybrid -- they are *content* (in that they are organized by the overall training structure) that is represented as XML *structures*. This permits them to be easily authored as training authors interact with the Author Module. The XSL Translations are responsible for converting the interactive exercises into dynamic HTML content targeted for the browser currently in use by each training user.

This approach to interactive exercises has many strengths: it centralizes the interactive logic; separates the training content from the implementation of that content; and makes it possible for non-technical personnel to create interactive exercises. However, it means that a general template for a *kind* of interactive exercise must exist before an author can add interactive exercises of that nature to the training materials. In order to add a new kind of interactive exercise system, a XML representation must be identified, the Author Module must be extended to support authoring instances of that exercise, and the XSL Translations must be extended to provide translations of that kind of exercise for the different supported browser platforms. (Specific exercises that were developed for the CGSC training system are described above in Chapter 7.)

Instructor Module - Course Management

The instructor is, of necessity, concerned with managing the training materials so as to maximize the learning experience of the students. Also, of necessity, the instructor must manage enrollment and evaluation of student learning. The logic to support these functions is encapsulated within the Instructor Module. It includes components for:

- Enrollment management,
- Coordinating the classroom and distance learning, and
- Evaluation

Course Module

The Course Module is not directly expose to authors, instructors or students. It encapsulates the logic governing the XML representation training materials, courses, and participation by students. It is the responsibility of the system administrator and programmers to extend this module as the functional scope of the *kinds* of training structures and the *kinds* interactive exercises (for individuals and groups) is extended.

User Module

The actions of each *training user* are mediated by the User Module. This module is responsible for integrating the XML structure of the training materials (created by the course author) with the user's navigation history. The resulting XML representation is passed to the XSL Translation and on to the training user's web browser. The navigation history (including responses to the interactive exercises) of the training user is passed onto the Adaptive Feedback module. Feedback generated by that module is also represented as XML data. That data is also integrated by the User Module, resulting in individual feedback to the user. Such feedback might, for example, recommend sections of the training materials that are design to strengthen particular critical thinking skills.

Group Module

The focus of the group module is to coordinate collaborative exercises, e.g., among training users enrolled in the same training course. It will support learning Communities and asynchronous collaboration.

Adaptive Feedback Module

The Adaptive Feedback Module provides individualized analysis of training user performance on tasks designed to test critical thinking skills in domain specific contexts. The intelligence in this module is based on the reflexive / reflective reasoner and the Shruti architecture described in Part IV below. It supports monitoring of user activities and adaptive feedback mechanisms for critical thinking skills.

Shruti Implementation

The present Shruti implementation is a C program that has been ported to a variety of Unix ™ environments. In order to simplify the development of intelligent client applications, CTI and ICSI collaborated to develop a Java package, org.icsi.shruti.proxy, that provides an object encapsulation of the Shruti simulation in terms of rules, predicates and facts. Two high level classes, *ShrutiProxy*, and *SimClient* abstract all communicates with the Shruti simulation engine.

The *ShrutiProxy* class provides a *proxy* representation of a the Shruti simulation engine, which may run on the same machine or on a remote host accessed across the Internet. The Java client communicates with the *ShrutiProxy*, which maintains a local representation of the Shruti network state in terms of Java objects. These objects may be directly accessed from the Java client. The second class, *SimClient*, manages the socket based communications with the Shruti engine. All network simulations are executed by the Shruti simulation engine. Java clients register using an event model to receive notifications when specific activation values change in the network.

A socket based server interface was implemented for the Shruti simulation engine. This interface communicates with the Java client via the *SimClient* and *ShrutiProxy* classes. The server interface provides a restricted access to the Shruti simulation in order to maintain network security for the host machine.

CHAPTER 9
INTERIM EVALUATION OF PROTOTYPE SYSTEM

In this chapter and the next, we review our efforts to evaluate the Critical Thinking training system. The initial evaluation process, described in this chapter, was informal, on-going, and interview-oriented. Evaluations were held at a variety of Army posts periodically during the training development process. At these evaluations, officers viewed the training material on a computer screen in the presence of the experimenter. Both before and after exposure to the training, they worked on a military scenario, discussed their solutions to the scenario, and responded to queries from the experimenter. In the next chapter, we describe a more formal evaluation of the prototype automated training system with students at the Command and General Staff College, Leavenworth, Kansas.

Method

The Method section is divided into three sections. The first section provides a brief background description of the participants. The second section briefly describes the Arisle scenario that participants were asked to solve prior to working with the prototype training system. And the third section briefly describes the data collection and analysis procedures.

Participants

Seventeen active duty Army officers (rank of major or lieutenant colonel) at four different posts (Ft. Bragg, Ft. Riley, Ft. Carson, and Ft. Stewart) individually reviewed and critiqued prototype versions of the training system between March and September of 1998 in an effort to incorporate the opinions of senior-level personnel. All participants had completed their course work at CGSC, been on battalion and/or division staffs, and had combat experience and/or experience in a number of military training exercises. So, they clearly had the expertise to do the Arisle scenario and critique prototype versions of the training system.

Scenario

Prior to working with the prototype, the officers were asked to solve the Arisle Scenario developed by Dr. Rex Michel of the Army Research Institute (ARI). The scenario required the participants to recommend a course of action (COA) for regaining control of an island from an enemy force.

The scenario begins with participants being told that they are the new G-3 of the 105th Air Assault Division, and it's the morning of 22 March. The Division is engaging in OPERATION POST HASTE in support of the island of Arisle, which has been invaded by forces from the neighboring island of Mainlandia. The United States (US) was caught somewhat off-guard by the invasion, and contingency planning had not been completed for such an event.

The participants are given a briefing package containing the following information:

(1) The Road to War: a summary of the events that led up to the present situation.

(2) Mission Description – OPERATION POST HASTE: Summary of the execution order from the JCS to the Commander of the operation, Vice Admiral Coaler.

(3) Intelligence: A G-2 summary of the situation as of 0630 this morning.

(4) Status of Forces: G1/G4 summary of the friendly forces and equipment available.

(5) Commander's Estimate of the Situation (partially complete)

(6) Description of Arisle: A G-2 report covering topography, hydrography, vegetation, climate, infrastructure, demography, government, and economy.

In addition, participants had access to a large wall map of Arisle containing available information about the disposition and composition of enemy forces, including hostage sites. The participant's task was, as the Division G-3, to complete the estimate of the situation by developing and wargaming course(s) of action (COAs) for the invasion of Arisle by the ground forces. In particular, the Division Commander expects a recommended COA as well as justification for it.

A detailed description of the scenario, and a copy of the materials given to the participants that are listed above, can be found in the Appendix. Here we present some of the key points from the Execution Order, a brief description of the island, and key points from the Commander's Estimate of the Situation.

The first paragraph of the Execution Order reads as follows:

> The President of the United States directs that you proceed with all reasonable haste to retake the island of Arisle from the Mainlandia forces now in control of the island. It is vital to the interest of the United States and its allies that the freedom of Arisle be restored before the government of Mainlandia can gain sufficient international backing to make the restoration of full independence probable. The CJCS had also ordered that the island be under US forces control by 2400 25 March (bold for emphasis here). The CJCS had further stated that it is unlikely that any significant additional combat elements could be brought to bear within this timeframe—we will have to work with the forces available. H-Hour is 0300 24 March; consequently, there are 45 hours to complete the mission

A schematic of the island is presented in Figure 21. The capital city is Beauqua, which is located in the south near the American Compound, the Oregonium mine, and airport. The other major city is Mar Blanche, located in the north near the pineapple plantation in Nipponia, and the thick teak forest. The central ridgeline connecting three mountain peaks divides the island in two. The ridgeline is heavily defended, particularly with enemy artillery, because of its excellent field of fire and observation. The majority of the enemy's ground forces, which are out-numbered by the US force and its overwhelming combat power, are spread around the perimeter of the island patrolling the shoreline.

144 foreign nationals being held as hostages by a paramilitary force called the Noclas. They are being held in groups of six to eight at locations important to the Mainlandia retention of the island. It is impossible to attack their air defense or artillery positions, the airfield, port facility, or water and power sources by indirect fire without almost certain hostage causalities. The fanaticism of the Noclas works to their advantage in this situation as well as the fact that the military command on Arisle does not control

them. It is almost certain that the Noclas would kill the hostages even if the military capitulated. A 40 person Navy SEAL platoon is on Arisle providing intelligence information; they have located all hostages and have been tasked with freeing them prior to H-Hour.

There is no way that Mainlandia could have hoped to hold out for long against superior air, naval, and ground forces which the US could quickly buildup in the area. It is believed that their intent all along was to use the hostages to avert any large-scale counterattack until they could convince the other FOCOP nations to intervene economically, or even militarily, on their behalf. Their well-planned diplomatic offensive is apparently meeting with more success than we thought possible. Intelligence sources within FOCOP claim that the organization will most likely take actions to support Mainlandia within the next two days. Given these likely actions, the most probable intent of Mainlandia is to keep the US from gaining control of Arisle until a diplomatic success is assured. Their best bet for doing this is the threat of the lost of the hostages and of high US causalities in retaking Arisle.

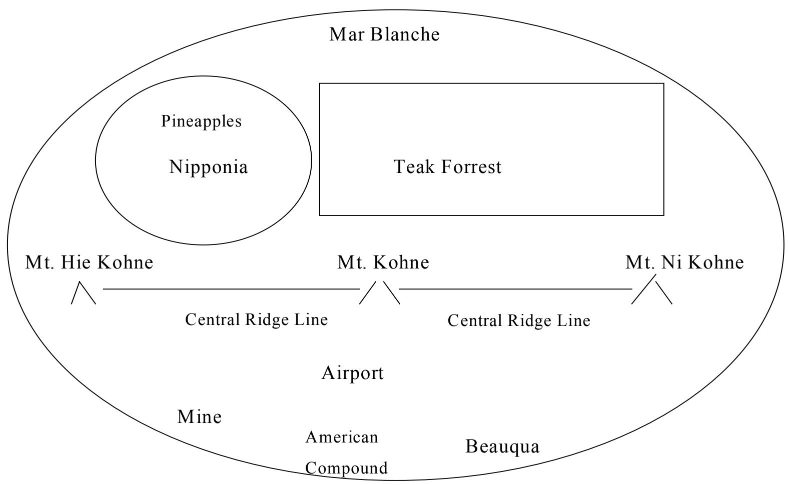

Figure 21: A schematic of Arisle.

Procedures

Participants had a maximum of three hours to recommend their COA and the justification for it, although many completed the task within two hours. The sessions were tape-recorded. Time and resources permitted us to transcribe and analyze the sessions for nine participants. These participants were coded as follows:

P#1 = Participant #3 from Ft. Riley (20 May 1998)

P#2 = Participant #1 from Ft. Carson (7 July 1998)

P#3 = Participant #2 from Ft. Carson (8 July 1998)

P#4 = Participant #3 from Ft. Carson (9 July 1998)

P#5 = Participant #1 from Ft. Stewart (8 September 1998)

P#6 = Participant #2 from Ft. Stewart (9 September 1998)

P#7 = Participant #4 from Ft. Stewart (11 September 1998)

P#8 = Participant #4 from Ft. Bragg (26 March 1998)

P#9 = Participant #5 from Ft. Bragg (27 March 1998)

The transcripts for the first seven participants (who received a similar version of the training system) were analyzed to identify the possible effects of training, i.e., changes in situation understanding or planning that occurred during use of the training system, compared to the initial course of action developed before receiving the training. Additional analyses were conducted to explore the situation understanding and decision making processes of the participants in more depth. In particular, we analyzed similarities and differences in how the nine participants (1) understood their mission, and especially, whether they drew on reasoning about high level *purpose* in framing the Arisle scenario, and (2) their recommended Course of Action (COA) and how this was effected by their understanding of the mission and purpose. In addition, the transcripts for the first seven participants were analyzed to identify similarities and differences in how they answered questions posed by the prototype system to address critical thinking skills. (The two participants from Ft. Bragg were not included in the latter analysis because it was based on questions that were modified considerably after the Ft. Bragg interviews.) These analyses are summarized in the Results section below.

Results

Insights Induced by Training System

Six of the seven participants who worked with the same prototype training system (i.e., P#1 – P#7) had significant insights about how they performed the Arisle scenario while working with that training system. Three of the participants (P#1, P#3, and P#4) actually modified their recommended COA to address the identified deficiencies. This section documents the new insights achieved by P#1 through P#6 during the training. In the absence of proper controls, there is, of course, no way to prove that these insights were brought about by use of the training system rather than, for example, by spending more time on the problem. However, each of the insights described below occurred in conjunction with use of the *specific* training module that was designed to elicit precisely the type of insight that occurred. This strongly suggests that, at a minimum, the training played a role in eliciting insights that might (or might not) have occurred anyway.

The systematic evaluation of his assumptions caused P#1 to modify his recommended COA. Specifically, P#1 said his biggest assumption was that the special operations forces could get the hostages off of the island. When asked if this assumption was important, he replied, "My goals are little collateral damage, get the hostages out safe, and destroy his forces. I won't get the hostages out safe if I lead with gun ships, which my plan does, and the hostages are there. I won't accomplish my goals." At this point, he said that he would change his recommended COA in two ways. First, he'd create "no fire areas" around certain key sites containing hostages to enhance their safety until he knew that the SEALs freed them. Second, he'd look at the MEU's special operations capabilities. (His COA already had the Rangers as a reserve to help free the hostages, and had focused on disrupting and destroying the enemy's command, control, and communications.)

The use of the crystal ball technique caused P#2 and P#5 to gain insights about one of their most important assumptions, which was that they would be able to suppress the enemy's air defense artillery (ADA) effectively. We consider each participant in turn.

> P#2 said that this assumption was critical to accomplishing his goals, which were to eliminate the enemy's ability to influence friendly forces and, thereby, secure the island. For, as he pointed out, if you lose aircraft carrying troops, the mission may become unattainable. Yet, when we started the crystal ball technique, P#2 was convinced that failure to suppress the enemy's air defense could only be due to two reasons: bad intelligence or that the enemy was very effectively dug in. When we finished, he had added bad weather and "… equipment failure or tactics, which would include the weapon systems and munitions that we employed against their systems. Okay, I guess I didn't consider that."
>
> P#5 was absolutely convinced that the US force could destroy the enemy's air defense assets. At the beginning of the Crystal Ball technique, he could think of only two ways that a majority of the enemy's ADA could survive the initial attacks on it. First, bad intelligence regarding its location; second, that the enemy was simply better than we thought and consequently, we were having trouble killing individual pieces of equipment. When the researcher said, "The crystal ball says it's not either of those two reasons," P#5 didn't know how to respond and said, "Everything I can think of would tie into one of these two." However, when the crystal ball exercise concluded about 15 minutes later, P#5 had identified five additional reasons why a majority of the enemy's ADA could survive. During the evaluation session, P#5 said, "The crystal ball is one of the sections I'd push the most because that's certainly one of the things I've seen, which is the ability to do good war gaming, [that] is truly limited."
>
> P#3 identified a number of important information gaps in his thinking about the Arisle scenario when reviewing that module of the prototype. In particular, he pointed out to the researcher that he had not explicitly considered the media, weather, tides, the rules of engagement, or the enemy's most dangerous COA when developing his COA. He was particularly upset about not considering the media. "I should have considered [it] because it's critical to achieving my goal!" He said that he'd now fill this gap by systematically interacting with the task force's Public Affairs officer.
>
> P#4 became increasingly concerned about his "Phase 1" plan for preparing the battlefield, which involved destroying the enemy's air defense assets and his artillery, particularly along the central ridgeline, as the training progressed. When asked the reasons against his COA he answered, "If Phase 1 is not successful, then the entire mission might not be successful." Yet, he had no contingency for it; he had just assumed that Phase 1 would be successful. However, later in the Story module, he began talking about how he might use the attack helicopters to help do Phase 1. Later during the "Identify Gaps" module, he realized that he didn't know (and may be could never know) where all the enemy's shoulder-fired

ADA were located. This greatly concerned him because, "I'm relying on the Rangers to jump in [at night on to the central ridge to destroy the enemy's fire support], and if one of those shoulder-fired missiles shot [down] a C-130, I'd lose an entire company." Finally, after the Crystal Ball technique, P#4 actually changed his COA to include a ground-based contingency. Specifically, in addition to now having the attack helicopters ready to support Phase 1, he'd tell the air assault brigade to be prepared to send one company to attack 1 to 3 artillery batteries if the Rangers were unable to take them out; for example, because they were shot down.

P#6 improved his communication of how he was linking higher- and lower-level goals during the Story module. Specifically, when he was asked what his goals were early in the Story module, he focused only on lower-level, tactical goals, such as eliminating or suppressing the enemy's air defense, and removing the enemy's ability to communicate. By the time that discussion of the Story module ended, P#6 was specifically describing how these lower-level goals were linked to his top-level goals of securing the island, removing the enemy's legitimacy for being in Arisle, and, hopefully, getting the enemy force to surrender with minimal fighting. This description made it much easier to see how his recommended COA, which focused only on controlling the southern portion of the island, was connected to his goals.

<u>Findings Regarding Purpose, Time, and Mission Interpretation</u>

Consider the literal wording of the mission, as articulated by the immediately higher headquarters:

> The CJCS had also ordered that *the island be under US forces control* by 2400 25 March. [italics added]

This statement specifies the mission as (i) placing the island under US forces control (ii) within a specific time limit.

Participants differed in how they interpreted the mission, i.e., in how they defined what "control of the island" meant. In particular, five of the nine participants (P#1, P#5, P#7, P#8, and P#9) defined "control of the island" as regaining military control of the entire island and destroying the entire enemy force (above a certain size, e.g., platoon). The other four participants (P#2, P#3, P#4, and P#6) defined "control of the island" as controlling the southern portion of the island, where the capital, American compound, airport, Oregonium mine, and port were located. All participants emphasized destroying the enemy force along the central ridgeline and in the south (since enemy anti-air and artillery on the ridge line also threatened any action in the south). We will consider these two groups in turn.

Control entire island. Participants in this group differed in how they arrived at their interpretation of the mission. For a few participants, there appears to have been little or no ambiguity in the mission statement. They felt that they were following its literal, direct meaning. For example:

> Participant #7: Destroy the enemy and *regain control of the entire island* as quickly as possible…. Being objective-oriented by going after the enemy and reducing his ability to continue combat operations… The

mission analysis was pretty clear; destroy the enemy and regain control of the island.

Participant #8: To *seize Arisle* by deadline

Participant #9 *Seize Arisle* no later than 2403 March to *deny Mainlandian forces opportunity to gain international backing*. ("Seize" means control of island & destruction of enemy force, or their withdrawal or surrender.)

These participants appear not to have considered the higher-level purpose or context of the mission – or, if they did consider it (e.g., the reference to international backing by participant #9), it had no discernable influence on their interpretation of the mission.

One participant, however, not only considered the higher-level purpose of the mission, but used it to justify aiming for military control of the entire island and destruction of the enemy force:

Participant #1: The American center of gravity is not just the mine, but *the whole perspective of how could Mainlandia have the audacity to do this*. Given that, we want to *take the entire island.*

Control southern part of island. Another group of participants departed from the literal interpretation of the mission statement, and defined control of the island more narrowly, as seizing the southern part only. Two of these participants were motivated in their redefinition of the mission by consideration of the higher-level political context and purpose:

Participant #4: seize the *political center of gravity*, which is the capital and airport.

Participant #6: Enemy's center of gravity is "a show of strength" in capital near the American Compound. It gives him legitimacy, and I want to remove that legitimacy. That's why I consider that area, capital, airport, and compound as main effort.… Since they'll have no reasons for being there, they'll surrender.

A crucial additional motivation for the narrower interpretation of the mission was an assessment that securing the entire island within the specified deadline was not feasible. All four participants who chose a narrow interpretation of the mission (i.e., controlling the southern part of the island only) argued in some form that the limited objective was the most expeditious way to achieve the overall purpose of the mission:

Participant #2: We are eliminating the enemy's ability to influence our actions, isolating him, and killing him… [so, avoiding prolonged fight]

Participant #3: Once south is controlled, including communications, it's just a matter of time before they surrender.

Participant #4: Avoids the enemy's strength in north to avoid an attrition battle [which may be prolonged]

Participant #6: Exploit their weaknesses and avoid their strengths… [to avoid getting bogged down]

One participant (#5) was intermediate between the two groups. He interpreted the mission as seeking to control both northern and southern parts of the island, but did not take the enemy force in the northern forest as his objective:

> Participant #5: First center of gravity, and most important goal, is to *control island* within 48 hours… [including] urban centers in the north and south … By getting into the airport, the mine, and urban centers, I was proactive with respect to preventing their destruction, and with respect to the media and my diplomatic goals…. My COA enables us to do that with minimal cost or troops being bogged down in field.

Thus, participants who interpreted the mission as controlling the southern part of the island (or, at least, as not requiring a direct attack on enemy ground forces in the northern forest) typically did so as a result of a critical thinking process in which they considered (i) the political context, and (b) the difficulty of clearing out the entire island within the 48 hour time limit.

Findings Regarding Courses of Action

There were significant differences in the participants' COAs, and these were influenced how they *interpreted the mission.* All participants who defined "control" as control of the entire island sent forces to either secure or seize Mar Blanche, the northern city of Arisle. None of the participants who defined "control" as control of the southern part of the island did so.

In addition, 3 of the 4 participants who defined "control" as control of the southern part only (i.e., P#2, P#4, and P#6), sent ground forces to seize the central and/or western mountains along the ridgeline as part of the initial attack. None of the five participants who defined "control" as regaining the entire island did so. This is probably because the former needed to remove the threat to southern mobility posed by forces on the ridgeline. The latter group all sent forces against Mar Blanche, and in two cases against enemy forces in the pineapple plantation of Nipponia (northwest part of island), as part of the initial attack instead.

Table 8 shows the correlation between mission interpretation and key elements of the course of action. In particular, most participants were both proactive and predictive to some degree and in certain respects, but differed in what those respects were. Participants who defined the mission as controlling the southern part of island tended to be highly proactive; they sought to induce the enemy to surrender by influencing the enemy's motivation or reason for staying on the island. They were predictive in the sense that they sought to avoid enemy strength and attack enemy weakness (in order to achieve the mission in the required time, and to minimize casualties). On the other hand, participants who sought to control the entire island were proactive in a more limited sense: eliminating the enemy's ability to resist by destroying its forces. Prediction also influenced their course of action, but in the opposite way: They sought to attack rather than avoid enemy strength.

Table 8. Relationship between course of action and mission interpretation.

Participant #	Mission Interpretation Control of entire island =1; control of critical points in south = 2	COA Time Orientation Proactive Destroy enemy troops = 1; induce enemy to surrender = 2	 Predictive Attack enemy forces in north = 1; Avoid enemy forces in north = 2
1	1	1	
5	1	2	1
7	1	1	1
8	1	1	
9	1	1	1
2	2		
3	2	2	2
4	2	2	2
6	2	2	2

Although the way that the participants framed the problem significantly affected their recommended COA, there was still significant COA differences among participants who framed the mission the same way. For example, P#2 and P#3 defined "control of the island" as control of the southern part of the island. Yet P#2 sent ground forces against enemy troops on the mountains; P#3 didn't. Also, P#2 did not seize the airport, which is what P#3 did. And although both had the MEU landing in the south, P#2 had them landing at the small beach below the American compound to secure it and the capital. In contrast, P#3 had the MEU landing at the beach below the mine to secure the mine; he let the air assault BNs secure the capital. The point is that although both officers framed the mission the same way, had the same goals, focused on the same situation features, and tried to connect their COA to all of this, they still recommended different COAs. Since we have no way of knowing whether one COA is better than another, we simply assume that *they represent different, yet comparable ways of achieving the same goals.*

Only 4 of the 9 participants (i.e., P#1, P#3, P#7, and P#9) generated and evaluated 2 COAs. One of the four (P#7) refused to say which one he'd select; he said he'd send both of them to the Plans shop for further development. The other three participants selected the second COA that they developed as their "recommended COA." Three of these four participants (i.e., P#1, P#7, and P#9) defined "control" as regaining control of the entire island. One of them (P#3) defined it as regaining control of the southern part only.

Participants were reasonably consistent in how they defined their "situation goals" in answer to our questions about the Arisle scenario later in the session. There were three secondary goals to the mission in addition to the primary goal of "controlling the island:"

- Safely freeing the hostages;
- Minimizing casualties; and
- Minimizing collateral damage.

All nine participants mentioned "freeing the hostages" as a concern. The other two secondary goals were not discussed explicitly by many of the participants. Five of the 9 participants explicitly discussed minimizing casualties at length; four explicitly discussed minimizing collateral damage at length.

<u>Time Orientation and Consensus on Courses of Action</u>

Participants also specified key "situation features" in answer to questions about the scenario. All participants agreed that the following were key situation features during their mission analysis:

- Enemy force spread out across island;
- Enemy's fire support (i.e., artillery) on the high ground;
- Enemy air defense assets;
- Enemy's command, control and communications; and
- The hostages

There was considerable agreement among the participants' COAs with respect to how they dealt with the above situation features, except for the hostage situation. For example, all participants tried to

- Move quickly and decisively by using simultaneous attacks (or near simultaneity in one case) against the spread-out enemy force;
- Eliminate a considerable portion of the enemy's fire support before (and shortly thereafter) inserting ground forces;
- Eliminate the enemy's ADA before inserting ground forces; and
- Eliminate (or use) the enemy's command and control.

As Table 9 shows, the almost uniform response to these key situation features was adoption of *proactive tactics to influence the enemy's ability to make use of an associated capability*. For example, dispersed attacks would keep the enemy from concentrating; air strikes and naval gunfire would eliminate enemy fire support and anti-air before it could be used; and enemy command and control would be knocked out to prevent the enemy from fighting in a coordinated fashion. The most remarkable thing about these proactive tactics (plus the plan to act at night) is the high level of agreement among participants.

Table 9. Number of participants planning specific proactive actions.

	Proactive					
	Simultaneous attacks to keep enemy from *concentrating*	**Destroy *arty & ADA* with air strikes &/or naval gunfire**	**Destroy or use enemy *C2* to prevent coordination**	**Act at *night* to influence enemy**	**Destroy enemy *reserve***	**Control *mine* to reduce enemy motivation**
# participants	9	9	9	9	6	4

As shown in Table 10, on the other hand, there was much more disagreement with respect to actions based on *predictions* of enemy intent, as opposed to the *proactive* efforts to influence enemy intent. Information gaps, e.g., predictions of enemy intent, were only addressed if the participant considered them to be a weakness in his COA. For example, P#1 repeatedly mentioned that "knowing enemy intent" was an information gap. But he later admitted that he really didn't care that much about it because he was going to hit the enemy with air strikes and simultaneous attacks to overwhelm him, regardless of his intent. In contrast, extraction of the hostages (and the assumption that the SEALs can free them) was a gap he kept trying to fill, because it was an important precondition for his ability to carry out the mission without delay.

All nine participants mentioned "freeing the hostages" as a concern, as mentioned above. Moreover, all participants resolved goal conflict – between primary mission accomplishment and freeing the hostages – in favor of primary mission accomplishment. On the other hand, participants differed dramatically in their predictions of whether this would be accomplished, and in what they planned to do about it. Only five of them (P#1, P#2, P#5, P#7 and P#9) seemed to have explicitly stated tasks for helping the SEALs rescue the hostages. Note that four of these 5 participants had defined "control" as regaining control of the entire island, so this may simply reflect a tendency to literal interpretation of the mission and thoroughness (or lack of true prioritization) in addressing every detail. In this respect, it is interesting to note that P#1, P#7, and P#9 seemed to emphasize all three secondary goals, as well as the primary mission. And P#5 emphasized two of them: freeing the hostages and minimizing casualties. All four of these participants (P#1, P#5, P#7 and P#9) defined "control" as regaining control of the entire island. (We realize that our sample size is small, but we thought this was interesting nonetheless.)

Table 10. Number of participants planning specific predictive and predictive-reactive (i.e., contingent) actions.

	Predictive			**Predictive-Reactive**
	Take advantage of fact that enemy is spread out & *divided by terrain.*	***Civilians* will be in cities, so don't attack there first.**	**Take account of prediction that enemy will move forces into the *forest* after attacks begin.**	**Adjust plan if *SEALs* fail.**
# Participants	7	4	3	5

Self-Identified Time Orientation

In response to questions from the researcher, participants identified, on average, 4.4 proactive actions as being in their recommended COA, 3.1 predictive actions, and 2.1 reactive actions, for a mean total of 9.7 actions. A repeated measures t-test found the difference between the mean number of proactive and reactive actions to be significant at the $p < 0.01$ level for a two-tailed test [$t(6) = 4.39$]. None of the other differences was significant at the $p \leq 0.05$ level.

The above analysis simply adds the number actions identified by each of the participants. For example, if one simply adds the number of proactive actions, then the participants identified a total of 31 proactive actions (i.e., 7 x 4.4). However, two (or more) participants identified the same 20 (of 31) proactive actions (i.e., 65%). This means there were only 11 distinctly different proactive actions. Through a similar analysis, we identified that there were 15 distinctly different predictive actions and 10 distinctly different reactive actions.

The results shown in Table 11 confirm the observation made in the previous section that there was more consensus among participants with regard to proactive tactics designed to influence enemy actions or capabilities, than with regard to predictive tactics based on expectations of enemy action or strength. Table 13 lists the number of distinctly different proactive, predictive, and reactive actions identified by three or more participants, by two participants, and by only one participant. Examination of this table shows that three or more participants identified 5 of the 11 distinctly different proactive actions (i.e., 45%). In contrast, three or more participants only identified 1 of the 15 different predictive actions (7%), and only 1 of the 10 reactive actions (10%). Even more strikingly, two or more participants identified 9 of the 11 proactive actions (i.e., 82%). In contrast, two or more participants identified only 5 of the 15 distinctly different predictive actions (i.e., 33%) and only 3 of the 10 different reactive actions (i.e., 30%).

A chi square test was performed on the data in Table 11 to assess if the degree of similarity for the proactive actions was significantly different than that for the predictive and reactive actions. The results of that test were statistically significant ($\chi_4^2 = 10.03$, $p < 0.05$), providing some statistical support for the position that the participants agreed more on the types of proactive than predictive or reactive actions they identified as being inherent in their recommended COAs.

Table 11. Degree of similarity in participant-identified proactive, predictive, and reactive actions.

Time Orientation	**Actions Identified by ≥ 3 Participants**	**Actions Identified by 2 Participants**	**Actions Identified by 1 Participant**	**Total Number of Different Actions**
Proactive	5	4	2	11
Predictive	1	4	10	15
Reactive	1	2	7	10
Total	7	10	19	36

The 5 proactive actions, 1 predictive action, and 1 reactive action for which 3 (or more) participants agreed, are listed below.

Proactive Actions

- Keeping enemy divided so that he can't mass his forces, including the inability to reposition his reserves. [P#1, P#2, P#4, P#5, P#6, and P#7]
- Focusing on the enemy's artillery and air defense assets and, more generally, taking away the high ground. [P#2, P#4, P#5, P#6, and P#7]
- Going after the enemy's communications to disrupt his command and control. [P#2, P#3, P#5, and P#6]
- The attack itself was considered proactive by three participants [P#1, P#2, and P#3]
- Seizing the urban areas (specifically the capital, which was Beaqua, and Mar Blanche) and the airport [P#3, P#5, and P#6]

Predictive Action for which 3 participants agreed:

- Predicted that enemy would move forces into the forest. [P#1, P#5, and P#6]

Reactive Action for which 3 participants agreed:

- We'd have to readjust significantly if the SEALs fail. [P#2, P#4, and P#5.] Note: P#6 explicitly said he would not adjust if the SEALs fail.

It is noted here that a separate analysis was performed to determine if participants who defined the Arisle scenario similarly tended to agree more on their proactive, predictive, and reactive actions than those who defined it differently. [The two definitions were control of the entire island (P#1, P#5, and P#7) or control of only the southern part (P#2, P#3, P#4, and P#6).] However, we failed to find a systematic relationship. For example, P#1 and P#2 agreed on four proactive actions, as did P#5 and P#6. In both cases, the members of the pair had defined "control" differently.

Stories and IDEAS Modules

This section summarizes the analysis for the seven participants' answers to the questions about their solutions asked in the Story and IDEAS modules of the prototype training system.

Story module.

The Story module asked participants to indicate whether or not they had used different types of stories when developing their COA. As can be seen below, *most of the participants used most of the different types of stories.*

1. Friendly Intent Story? (N = 7)
2. Enemy Intent Story? (N = 4)

    P#4 and P#7 - Enemy is trying to delay Americans from quickly regaining control of Arisle and, thereby, gain a diplomatic victory.

    P#5 - Enemy is going to kill the hostages and use the media to exploit it.

    P#6 - Enemy's legitimacy is controlling the capital and American Compound.

3. Mission Analysis Story? (N = 7)
4. Correlation of Forces Story? (N = 7)
5. Rate of Movement Story? (N = 4: P#2, P#4, P#6, P#7)
6. Principles of War? (N = 7)
7. Action Execution Story? (N = 7)
8. Evidence Interpretation Story? (N = 4: P#1, P#4, P#6, P#7)

Identifying gaps module.

All seven participants indicated that they wanted information about the status of the SEALs and hostages. In addition, five of the seven participants indicated that they wanted information about some aspect of the enemy force. In most other cases, the participants identified gaps unique to that person.

In most cases, participants indicated that they would try to fill the gap by some aspect of standard operating procedures (SOP). SOP ranged from coordination activities, such as a liaison with the Special Operations Force (SOF) to learn the status of the SEALS and hostages, or various intelligence requirements to learn about the enemy.

Deconflict module.

None of the seven participants identified the conflicting information in the written materials regarding the sophistication of the enemy's air defense assets (ADA). The researcher did not always tell the participant about the conflict. In two cases, however, the researcher did and the participants said it would not matter how sophisticated the enemy's ADA was because our air forces would still overwhelm it.

Six of the seven participants noticed the conflict between the goal of controlling the island quickly and freeing the hostages safely. P#1 was the only participant who did not notice the conflict because he thought we could accomplish both goals.

Evaluate assumptions module.

The two big assumptions were that the air and/or naval forces could suppress the enemy's fire support (i.e., artillery) and air defense artillery (ADA) assets, and that the SEALs could free the hostages. Other assumptions were unique to participants.

Act module.

This section lists the three most commonly identified actions that the participants indicated they would take to fill information gaps or deal with conflicts. *Most of the actions represent activities that are part of a task force's standard operating procedure*.

1. Stay in contact with the SEALs (N = 7)
2. Be proactive. Instead of trying to predict (or react to) enemy intent, hit the enemy with air strikes and simultaneous attacks to overwhelm them (N = 7)
3. Use various intelligence collection capabilities to obtain information about the enemy, such as human intelligence (HUMINT) from the SEALs or guys on the ground and photo imagery (N = 5: P#1, P#2, P#3, P#4, P#7).

Stop module.

This module had a number of questions. Unfortunately, all the participants did not answer all the questions, probably because this module came late in the interview session and time was running out in some cases. (P#6 did not answer any of the questions.) Therefore, only the questions answered by at least half the participants, and only the most frequently provided answers to each question, are presented below. As can be seen, *the participants tended to agree in their responses*.

1. How much time would you take if this were a real situation? (Note: P#5 and P#6 did not answer this question.) Four of the remaining five participants said that they though they could do the division-level planning within 8 hours with a staff.
2. Costs of delaying the mission? (Note: P#5, P#6, and P#7 did not answer the question.) All four remaining participants said that a delay would give the enemy time to improve his battle positions.
3. Unresolved uncertainties when start mission? (Note: P#6 and P#7 did not answer.) Four of the five remaining participants answered, "Whether SEALs have control of the hostages or even where they are." Two participants responded, "Not knowing where all the enemy's ADA is located."
4. Potential costs of not resolving uncertainties? (Note: P#1 and P#6 did not answer.) Three of the remaining five participants said, "Loose aircraft carrying troops, and take severe casualties."

Devil's Advocate (i.e., Crystal Ball) module.

Three participants (P#2, P#3, and P#5) identified "failure to suppress the enemy's ADA" as the problem they considered. The only reasons given that were common to the three participants were "bad intelligence" or that the enemy was better (in some way) that was thought previously. There were a number of reasons that were only generated by one of the three participants. As we noted earlier, none of the seven participants identified the conflicting information in the written materials regarding the sophistication of the enemy's air defense assets (ADA).

CHAPTER 10
CGSC CLASSROOM EVALUATION

This chapter describes a quasi-experimental evaluation of the automated training system with students at the Army Command and General Staff College (CGSC), Leavenworth, Kansas. We examined the effect of critical thinking training on both thinking process measures and on decisions that officers made in battlefield scenarios.

Method

The description of the Method includes five main sections: Participants, Test Scenarios Design, Hypotheses and Measures, and Procedures.

Participants

A total of 78 students at CGSC participated in the study. All students had the rank of Major, and were enrolled in the spring quarter of an advanced tactics course entitled, *Initiative-based Fighting*, taught by LTC William Hadfield. The participants' average length of Army service was 12.7 years, of which an average of approximately two years involved command staff experience. Slightly less than half (45%) of the participants belonged to a maneuver branch (infantry or armor), while others belonged to aviation or artillery branches. Over half of the participants (66%) had experience in a combat or peacekeeping mission. The officers had participated in an average of 10 major exercises.

Test Scenarios

Participants were asked to respond to a different tactical scenario before and after the training (or control) treatment. For this purpose, two brief tactical scenarios were adapted with permission from the *Marine Corps Gazette*, in which a "Tactical Decision Game" appears as a monthly feature. The test scenarios provide opportunities for students to exercise the critical thinking skills targeted by the training. Specifically, they offer:

- Opportunity for proactive planning, in which the enemy is drawn into a course of action that is relatively advantageous to own troops;
- Opportunity to respond to surprise or uncertainty by stepping beyond the immediate objectives of the unit under the officer's command to achieve the purpose of the larger unit of which the officer's command is a part;
- High levels of uncertainty that allow for the identification of information gaps, conflicts, and assumptions.

The following is the text of the two test scenarios:

Sanna's Post (Scenario B)[7].

[7] MacIntyre, Capt Douglas J. "Tactical Decision Game #97-4: Battle of Sanna's Post." *Marine Corps Gazette*. April 1997. Quoted with permission by Steve M. Crittenden, Managing Editor, *Marine Corps Gazette*, Box 1775, Quantico, VA 22134, 4 Feb 99.

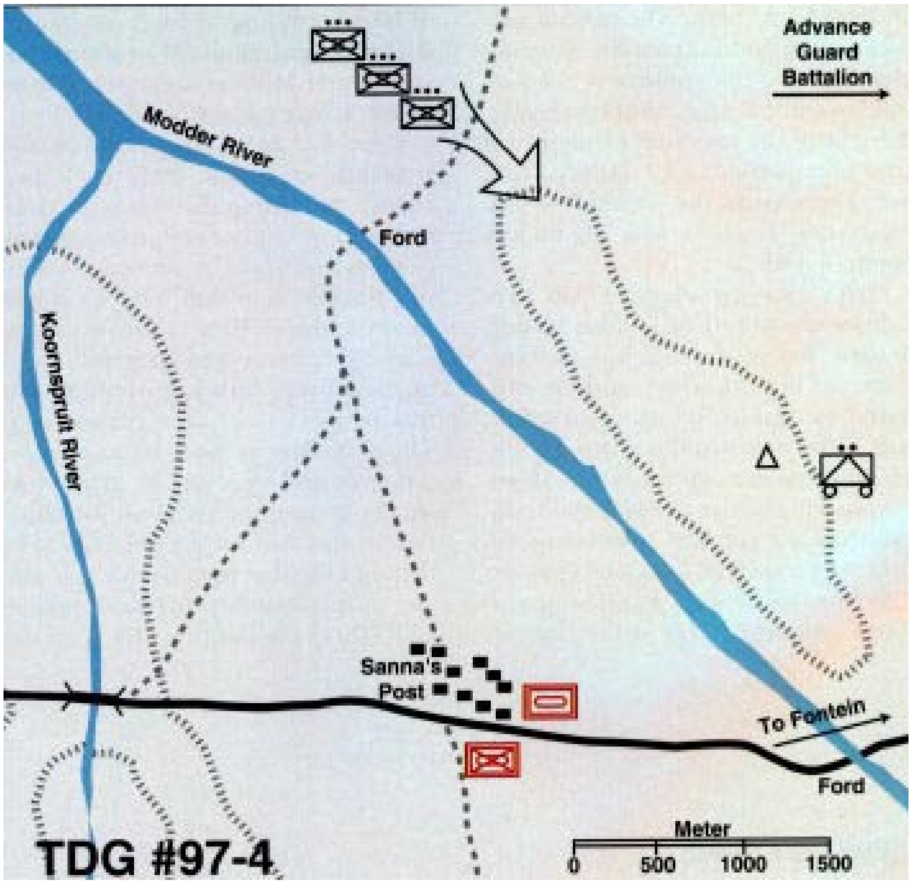

Figure 22. Sanna's Post scenario map.

You are the commanding officer of a rifle company with an assault amphibious vehicle (AAV) platoon and a combined antiarmor team (CAAT) made up of three TOW HMMWVs and two heavy machinegun (HMG) HMMWVs. The battalion is currently moving south-southeast as 2d Marines' advance guard. The regimental landing team (RLT) is pushing hard to engage enemy mechanized forces moving east before they can consolidate near the port city of Fontein. Your company's mission is to provide flank security on the right of the battalion's movement to contact and to be prepared to assume the lead element as directed.

The terrain in the area is a flat, rocky desert, with sparse vegetation. Two rivers, flanked by steep banks, run through the area and are swollen by recent rains; they are fordable at only a few points. Elsewhere trafficability for wheeled and tracked vehicles is good. It is 0100, partly cloudy with good visibility. You are currently moving 10-15 kilometers per hour south, approximately 34 kilometers west of your battalion.

The CAAT team, currently moving in advance of the company, has sent scouts along the high ground to observe the Modder River area, including Sanna's Post, a small village to the west, and the road running perpendicular to your route. The CAAT leader reports "Enemy sighted, vicinity of Sanna's Post, 2,000m west of Modder River Ford. Looks like a logistics site with two T-72s, a BTR-60 platoon, and many fuel trucks and supply vehicles. They are stationary near several small buildings. Will maintain observation and move vehicles into firing positions. I don't think they have seen us. Please advise."

As you digest that information, battalion reports "lead companies heavily engaged with elements of motorized rifle battalion and tank force... Regiment will attempt flanking maneuver with its follow-on forces as we fix the enemy... I am counting on your company to prevent enemy reinforcement from the west..."

What is your plan, Captain?

Platoon Ambush (Scenario A)[8].

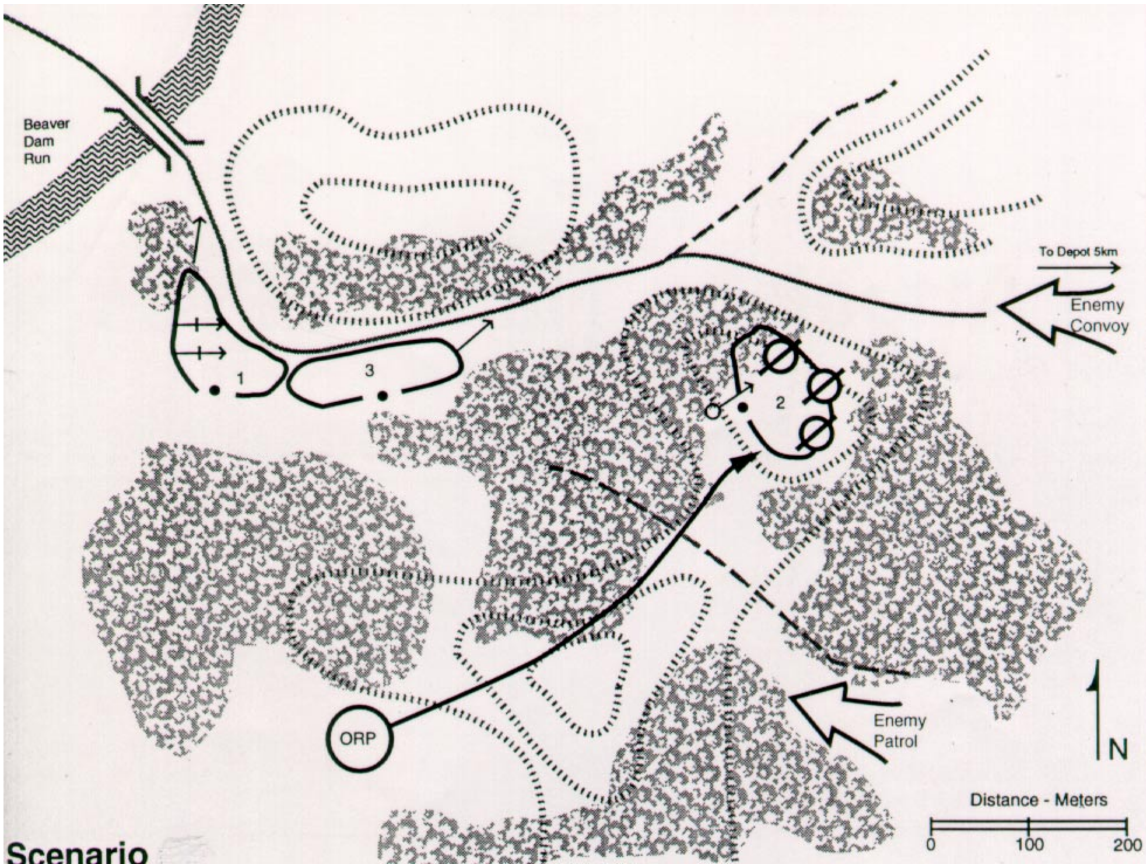

Figure 23. Map for Platoon Ambush scenario.

You are the second squad leader of 1st Platoon, Company A, 1st Battalion, 1st Marines. You have been fighting enemy infantry forces in wooded rolling terrain, Your platoon commander tells you that the platoon has been given the mission to conduct a patrol behind enemy lines to establish an ambush along a main supply route frequently used by enemy supply convoys to move supplies forward (west) from Depot, which is located about 5 kilometers east of the ambush site. The convoys usually consist of a machinegun jeep in front followed by a half-dozen or so covered trucks. There is a strong enemy garrison of motorized forces at Depot. The lieutenant plans to set in an L-shaped ambush with two squads at a bend in the road just east of Beaver Dam Run. “It’ll be like shooting fish in a barrel,” he says. He plans to blow the log bridge to the west, detonating it when he springs the ambush. Your squad, with one 60mm mortar team attached, will protect the other flank of the ambush from a position on the high ground to the east of the

[8] Quoted with permission by Steve M. Crittenden, Managing Editor, *Marine Corps Gazette*, Box 1775, Quantico, VA 22134, 4 Feb 99.

ambush site. You will be linked to the ambush by landline. In his patrol order under “Tasks,” the lieutenant gives you the following instructions:

"When you get to the ORP (objective rallying point), you will move out first to your position to provide security for the rest of the platoon while it sets in the ambush. The platoon will move out 30 minutes later. You’ll take a phone and LCpl Cooley (the platoon runner) with you. He’ll run the wire from your position back to the ambush site. Find a position that gives you a good view of the road toward Depot so you can provide early warning and information of the convoy’s approach. When you get in position, stay concealed and stay put. Once the ambush is sprung you will isolate the objective area by engaging any enemy forces trying to get in or out. You will provide protection for the platoon as it withdraws to the ORP. It’s especially important that you delay any react forces coming from the Depot garrison. A green-start cluster is the signal that you can withdraw back to the ORP. Surprise is essential, so it’s imperative, under all circumstances, that you stay concealed and to open fire until the ambush has been sprung, got it?"

Before departing on the patrol you draw one AT4 per fire team. In addition, each of your squad members is carrying one 60mm mortar round.

Everything goes as planned to the ORP. From the ORP you move out to your position. En route you cross a narrow animal track not on your map. You reach your destination and find a good position from which you can cover the Depot Road. You set in the mortar to cover the road to the east by direct lay. You hook up the landline, but the connection is bad; neither party can understand what the other is saying. Meanwhile, something attracts your attention the southeast. Movement of some kind? You send 1st fire Team to check it out, and return to supervising the defense preparations.

Fifteen minutes later, 1st Fire Team returns, out of breath.

“What have got, Cpl Turner?” you ask.

“An enemy foot patrol, 20-25 men, moving west through the woods about 200 yards south, auto weapons and light machineguns,” he replies.

“Did they see you?”

“Hell no,” he says with a grin. “Who do you think you’re talking to?”

You try to get through to the platoon on the landline, but the connection is very bad.

“Roger, I copy that the convoy’s on the way,” comes the reply. “We’re ready for ‘em. Remember, don’t engage until after the ambush goes.”

“Negative,” you say. As you try to repeat your message, Cpl Turner taps you on the arm and points down the road to the east. The convoy approaches around a bend, about 300-400 yards away: two machinegun jeeps, followed by at least seven trucks, and more coming into view, moving about 15-25 miles per hour.

In a couple of minutes, things are going to get interesting.

What do you do?

Experimental Design

Our intent was to evaluate the training using a pretest/posttest, controlled design. Specifically, half the subjects would receive critical thinking training and half would not. All subjects would receive a pretest scenario and a posttest in which they were asked to plan and evaluate a course of action in a brief tactical scenario. Two test scenarios were to be counterbalanced between pretest and posttest, for both trained and control subjects. Thus, a 2 x 2 factorial design was planned, with two between-subjects conditions crossed between participants: treatment level (trained vs no training), and test scenario order (scenario A on the pretest and scenario B on the posttest, versus scenario B on the pretest and scenario A on the posttest). It was intended that each of the four conditions would be presented to one or, if possible, two sections of the CGSC course, with each section containing approximately 20 students. The design was quasi-experimental in the sense that subjects were not randomly assigned as individuals to treatment groups, but received different conditions depending on the section of the course they belonged to.

Unfortunately, test booklets were not distributed as planned, so that the actual design deviated from the intent. Most significantly, all participants who performed the two scenarios in one order (B on the pretest, A on the posttest) were in the control group (i.e., none of these received the training), while all participants who performed the two scenarios in the opposite order (A on the pretest, B on the posttest) did receive the training (i.e., none of them served as controls). In addition, some students who completed the pretest did not complete the posttest, and several other students received the same scenario on both pretest and posttest.

Table 12 shows the breakdown of conditions that the CGSC participants actually received, and the number of students in each condition[9]:

Table 12. Experimental conditions, both planned and unplanned, and the number of participants who actually received each condition.

Condition	**No Training Group**	**Trained Group**
AB (planned)	0	19
BA (planned)	8	0
AA	6	1
BB	0	4
A_	9	0
B_	25	0

A = Platoon Ambush scenario

B = Sanna's Post scenario

AB = Platoon Ambush in pretest, Sanna's Post in posttest. (Similarly, for BA, AA, BB)

A_ or B_ means the posttest was not completed.

[9] Six students who did the posttest but not the pretest (i.e., _A and _B) are not included in this table, since we cannot determine whether or not they received any training before performing the posttest scenario.

The original design (treatment x scenario order) included only the upper four cells, with an approximately equal number of subjects planned for each cell. The distribution of booklets, however, resulted in a situation where only scenario B (Sanna's Post) could be used to assess the effect of training, and only scenario A (Platoon Ambush) could be used to control for time spent in the tactics course. In order to proceed, therefore, the following complementary analyses were conducted:

(1) An analysis of the effects of training on Scenario B was performed. This involved a comparison of performance by subjects who had B on the pretest with subjects who had B on the posttest after receiving training. 52 subjects for this analysis consisted of:

- Pretest, Not trained on B: 8 Ss in the BA Control group + 25 Ss in the B_ group.
- Posttest, Trained on B: 19 Ss in the AB training group

as shown by the shaded cells in Table 13.

Table 13.Conditions used in the analysis of Sanna's Post scenario.

Condition	**No Training Group**	**Trained Group**
AB (planned)	0	19
BA (planned)	8	0
AA	6	1
BB	0	4[10]
A_	9	0
B_	25	0

(2) The first analysis confounds the effects of training with time spent in the advanced tactics course. Mitigating this to some degree is the fact that many of the specific skills that were trained and measured were not addressed in regular coursework. To control further for the effect of regular coursework, a separate analysis was performed on changes in performance in Scenario A over time without the benefit of training. This analysis compared:

- Pretest: the 19 AB participants who had Scenario A on the pretest
- Posttest: the 8 BA participants who had Scenario A on the posttest.

as shown by the shaded cells in Table 14:

[10] We did not use the posttest results from the trained BB group because these four subjects were performing Scenario B for the second time on the posttest.

Table 14. Conditions used in analysis of Platoon Ambush scenario.

Condition	No Training Group	Trained Group
AB (planned)	0	19
BA (planned)	8	0
AA	6[11]	1
BB	0	4
A_	9[5]	0
B_	25	0

None of these subjects received critical thinking training. Thus, any improvements observed would be due to regularly assigned coursework or the passage of time.

This second analysis, of course, does not completely resolve the problem of confounding. The two scenarios are very different, and were selected in part for that very reason. Thus, there could be a tendency to learn more from the regular coursework (or, alternatively, from critical thinking training) about one scenario than about the other. Nevertheless, there is value in comparing results for the two scenarios, since explaining away performance improvements in terms of scenario differences is probably less compelling than explaining them away in terms of coursework. In addition, the likely significance of scenario differences can be assessed as we consider each of the dependent measures.

Procedures

The treatment was self-administered as a computer-based individual homework assignment. Training was distributed in the form of software on a compact disk, entitled "Introduction to Battlefield Critical Thinking." Class discussion, led by section instructors, was encouraged following each training assignment.[12] The control treatment involved regular participation in the advanced tactics class, with the omission of the critical thinking training homework assignment and the section discussions concerning it.

Test scenarios were also executed by participants individually on their own time, as homework assignments. In order to limit variance in the conditions of these tests, officers were asked to work from the front of the test booklet to the back, and not look ahead; to complete the test in a fixed amount of time in a single sitting (45 minutes); and to record their starting and stopping time on the test. They were also asked not to discuss the tactical exercises with others.

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[11] Pretest results for the AA and A_ groups were not analyzed because there was already a far larger number of subjects with Scenario A on the pretest (AB) than with Scenario A on the posttest (BA). Posttest results for the untrained AA group were not used because these subjects were working that scenario for the second time.

[12] The presentation of the training and scenario tests as homework was dictated by the shortage of classroom time. Discussions of the training witnessed by the experimenters were quite brief.

Participants' task on each test was to read a brief, tactical scenario, and then to develop op orders, explain those orders, describe alternative plans, list the strengths and weaknesses of all plans, give reasons for choosing the preferred plan, and indicate how weaknesses in the preferred plan are addressed. In addition, participants rated their confidence in each plan. Specifically, they received a test booklet with the following questions:

1. Write your op orders for scenario problem. Mark up the attached map to reflect your orders.

2. Explain your decisions. Be sure to address the following:

    a. Alternative possible plans that you considered

    b. Strong and weak points of each

    c. Why you ultimately chose your plan

    d. How you addressed any weak points in your plan

3. List your plan and any alternate plans you considered here. Rate your confidence in each plan using this scale:

- 1 -- Extremely low confidence
- 7 -- Extremely high confidence

<u>Hypotheses and Dependent Measures</u>

As noted earlier, the critical thinking skills targeted by the training were based on the Recognition / Metacognition model, together with research on real-world battlefield decision making, and an investigation of student needs at CGSC. Based on these sources, and on results of testing critical thinking training in other contexts, the following hypotheses were tested:

- *Purpose :* Training will increase the likelihood that officers refer to higher-level, longer-range purposes.
- *Time Orientation:* Training will increase the likelihood that officers' engage in effective proactive, predictive, and predictive-reactive planning.
- *Gaps:* Training will increase the likelihood that critical information will be used.
- *Conflict:* Training will increase the amount of conflicting information and goals that officers detect.
- *Assumptions:* Training will increase the number of assumptions officers detect.
- *Confidence in action:* Training will increase officers' confidence in their plans.
- *Improved plans:* Training will change and improve officers' planned courses of action.

These hypotheses were operationalized in terms of specific concrete measures that could be consistently applied to participants' responses to test questions. The basis for this operationalization was a cognitive task analysis of sample responses to the scenarios. First, sample solutions published in the *Marine Corps Gazette* were analyzed and an initial set of measures for each hypothesis was identified. For example, a set of responses that counted as proactive was identified, another set that counted as predictive was identified, and so on. Then a sample of participants' test booklets were also analyzed and scored in the same way. The initial set of measures for each hypothesis was enlarged as more sample responses were analyzed, until it appeared to stabilize. Two graders reached agreement on how statements in the sample solutions and in the participants' answers should be classified in terms of the hypotheses. It was very rarely necessary to add additional measures after the original set was developed in this way.

The resulting dependent measures are described in Table 15, along with the test questions used to score them, and the hypotheses that they address. Note that measures based on different questions are free to vary independently. Further elucidation of the measures will be found in the Results section.

Table 15. Dependent measures for each scenario, classified in terms of relevant critical thinking skills.

Hypothesis	**Measure**	**Sanna's Post**	**Platoon Ambush**
Course of action description (questions 1 and 2c)			
Consider higher-level purpose	Percent Ss who reference longer-range purpose of mission in description of their course of action	Maintaining contact with battalion and being prepared to move with battalion	(1) Accomplish ambush of convoy (2) Ensure platoon safety

Use time orientation effectively	Percent Ss who provide a proactive rationale for their course of action. Overall measure of proactive action elements, plus breakdown by short-range frame of reference versus longer range frame of reference.	<u>Overall</u> = sum of the following two categories <u>Short range: Company relation to enemy in sector</u> *Use of Arty:* Use fire to drive enemy out of SP. Use arty to take out tanks at SP before ground attack. *Ground attack:* Prevent withdrawal from SP; confuse enemy by attacking from multiple directions; confuse enemy by speed and surprise. *Guard fords:* Use high ground to conceal movement. <u>Long-range: Company relation to battalion</u> Prevent use of SP as logistics for attack against battalion; guard Koornspruit bridge against reinforcements against battalion; block northern Modder R. ford; attack SP to keep enemy away from Modder R. fords; force enemy to attack west by approaching from east; prevent use of armor at SP against battalion; prevent enemy ability to attack in battalion rear; block Koornspruit R. against enemy withdrawal to west from battalion fight.	<u>Overall</u>= sum of the following two categories <u>Short-range: Squad relation to enemy in sector</u> *Patrol:* Prevent patrol from interfering with ambush; prevent patrol from discovering platoon main body. *Convoy:* Prevent convoy from being alerted to ambush. <u>Long-range: Squad relation to platoon main body</u> *Withdraw*: Shift rally point, recommend platoon withdraw, recommend platoon abort ambush. *Reverse roles:* Squad takes over ambush of convoy; recommend platoon main body attack patrol.

	Percent of Ss who provide a predictive rationale for their course of action. Overall measure of predictive action elements, plus breakdown by short-range frame of reference versus longer range frame of reference.	Overall Short-range: Company relation to enemy in sector *Ground attack:* Logistics site is soft target; do not have combat power to take SP (need fire support, need close air support); crossing Modder is dangerous (need smoke, LAVs); will (or will not) lose men or time; good defensive position at S.P. against enemy from west. *Guard fords:* Good defensive position on high ground or at fords; good observation from high ground; mass forces at decisive time & place. Long-range: Company relation to battalion Taking SP provides battalion more room to maneuver plus additional capability (this company).	Overall Short-range: Squad relation to enemy in sector Rejoin platoon main body to increase combat power; withdraw without attacking patrol or convoy. Long-range: Squad relation to platoon main body Determine convoy plus patrol cannot be handled by platoon; determine squad has better chance against convoy; determine squad is in better position to fight patrol

	Percent of Ss who provide a predictive-reactive course of action. Overall measure of contingency plans or branches, plus breakdown by short-range frame of reference versus longer range frame of reference.	Overall Short-range: Company relation to enemy in sector *Fires + guard fords*: Defend Modder R. crossing if fires do not destroy SP. *Ground attack + fires*: Launch ground attack only if tanks are destroyed by fires. *Ground attack + guard fords*: Prepare to take blocking position at Modder R. fords after successful attack on SP; prepare to secure Koornspruit bridge after successful attack on SP; reserve prepares to help at SP; reserve or attack unit prepares to defend Modder R. crossing; all units prepare to shift position or mission after accomplishing main task. *Guard fords:* Use screening force to detect enemy as it approaches Modder R. Long-range: Company relation to battalion Company prepares to take over battalion main effort.	Overall Short-range: Squad relation to enemy in sector Strike patrol after convoy is near ambush point. Long-range: Squad relation to platoon main body: Rejoin platoon main body after attacking patrol; rejoin platoon main body after engaging convoy; rejoin platoon main body at alternate rally point, then engage enemy.
	Average number of time orientations adopted by each subject	From minimum of 0 to maximum of 3: Proactive, predictive, predictive-reactive	From minimum of 0 to maximum of 3: Proactive, predictive, predictive-reactive

Critiquing and correcting Intent Mental Model (Questions 2a, 2b, and 2d)			
Detect and fill gaps in Intent Mental Model	Percent of Ss who refer to all 2 of the 3 top-level concepts associated with Intent Mental Model	Purpose, opportunity, capability	Purpose, opportunity, capability
	Number of Intent Mental Model concepts referred to	Purpose, opportunity, capability	Purpose, opportunity, capability
	1.Percent of Ss who refer to purposes or principles underlying of course of action	*Purpose*: Need to guard battalion flank, keep moving with battalion, keep contact with battalion. *Key principles:* Avoid casualties and collateral damage; maximize control and maintain the initiative.	*Purpose*: Support platoon ambush of convoy. *Key principles:* Avoid casualties; maximize options / control, maintain the initiative.

	2. Percent of Ss who refer to opportunity (specific conjunction of time, terrain, and information that is conducive or non-conducive to action)	*Terrain and Time:* Enemy will (or may not) use highway to attack battalion; enemy may break contact with battalion & attack west; enemy does (or may not) need logistics site; ground attack may take time / prevent moving with battalion; not attacking will leave viable enemy in battalion rear. *Information:* Attack will reveal my presence / increase difficulty of guarding fords. There is risk of fratricide while maneuvering near battalion and enemy at night. Not attacking will allow enemy to take initiative, control events.	*Time and place:* There is (or may not be) time to link with platoon main body before enemy attacks; runner will (or will not) be able to warn platoon in time; squad can reach position to ambush patrol before platoon main body can; convoy will (or may not) be in kill zone before patrol is within squad weapons range; patrol will (or may not) continue northwest toward platoon main body; there is risk of squad being caught between two enemy forces. *Information*: Convoy may (or may not) detect squad if it attempts to rejoin platoon now; squad's attack on patrol will alert convoy to platoon's presence; platoon main body will be surprised by patrol unless we attack; squad's attack on convoy will draw patrol away from platoon main body; surprise is on our side in attacking patrol or attacking convoy; multiple attacks will produce enemy confusion.

	3. Percent of Ss who refer to capability (enemy vs. friendly force correlations and expected outcomes)	Fires will (or may not) destroy all tanks; ground attack may bog down; enemy strength is (or may be stronger than) observed; logistics site is associated with low readiness; ground attack will cause casualties; ground attack will split combat power; use of fires allows enemy withdrawal-regrouping-counterattack.	Squad can (or cannot) protect platoon's flank from both patrol and convoy; squad has (or lacks) combat power to ambush convoy; squad has (or lacks) combat power to ambush patrol; patrol could destroy platoon main body given advantage of surprise; platoon has (or lacks) combat power to fight larger than expected force; failure to mass platoon combat power creates risk; squad's ambush of patrol may lead to decisive engagement; all mortar rounds are (or may not be) available to squad; squad may take casualties from patrol and/or convoy
Find conflict & assumptions	Number of specific problems identified (conflicts plus assumptions)		
	Conflicts identified		
	Assumptions identified		
	Number of alternative options considered		
Quick Test and Action (Question 3)			
Judge when to commit to action	Confidence in favored option		
	Difference in confidence between favored and next best		

Improved decisions (Question 1)			
Effects on decisions	Percent of Ss who ignore unexpected situation	Do nothing about Sanna's Post (no fires, no ground attack - either conditional or unconditional - and no provision to observe)	Do nothing about patrol (do not block or attack, and do not indicate that main body of platoon will handle)
	Percent of Ss who use specific tactical elements	Use at least part of company to defend Modder R. fords from high ground	Use at least part of squad to isolate the objective area after ambush of convoy by main body of platoon
		Bold: Fires on Sanna's Post	Recommend that platoon abort ambush of convoy (revise mission)
		Aggressive: Ground attack on Sanna's Post	Aggressive: Squad takes over ambush of convoy
	Percent of Ss who use combined tactics	fire on SP + defense of Modder R. fords	handle patrol + recommend new rally point
		fire on SP + ground attack on SP	recommend abort ambush + recommend new rally point
		ground attack on SP + defense of Modder R. fords	handle patrol + recommend abort ambush
		fire on SP + ground attack on SP + defense of Modder R. fords (company does it all)	handle patrol + recommend abort ambush + recommend new rally point
	Average number of the above tactical elements used	(from minimum of 0 to maximum of 3)	(from minimum of 0 to maximum of 3)

Measures based on the same questions in the scenario booklet may be logically related or redundant to varying degrees. For example, measures of high-level purpose and measures of time orientation are each based on questions 1 and 2c. However, they can vary independently since they specify completely different aspects of participants' responses. On the other hand, the measure of the average number of time orientations used is logically related to the frequency of use of each of the specific time orientations, and they cannot be regarded as independent tests of the effects of training. Similarly, measures of intent mental model components and measures of conflicts and assumptions are each based on questions 2a, 2b, and 2d. These may also vary independently since they specify different aspects of the responses. But the measures of number of intent mental model components used is not independent of the specific components. Finally, measures of time orientation and of intent mental model components are based on separate questions, and provide completely independent tests of the effects of training.

Results

We will review the results for each of these measures below. An overview of the results, in the form of a network showing the links among training and selected dependent variables, is given in Figure 36. This diagram was derived by Pathfinder from correlation data (Schvaneveldt, 1990), and will be discussed in more detail later.

Focus on Longer-Range, Higher-Level Purpose

In each of the two scenarios, it is necessary to deal with an unexpected event, i.e., the observation of enemy vehicles at Sanna's Post, and the observation of an enemy patrol threatening the platoon ambush, respectively. In each case, it is plausible to argue that the mission requires offensive action against the unexpected enemy element. Attacking Sanna's Post helps further the mission of guarding the Battalion's flank. Attacking the enemy patrol protects the ambush of the convoy by the main body of the platoon. However, in each case, the impact of these actions on the achievement of purposes over the *longer-term* is less clear, and needs to be critically considered. In the Sanna's Post scenario, the main purpose – guarding the flank of the battalion – implies, over a longer period of time, readiness to move when the battalion moves. Becoming bogged down in a fight at Sanna's Post may make this difficult, and cause the battalion's flank to be exposed in the *future*.[13] In the Platoon Ambush scenario, attacking the patrol may spoil the ambush of the convoy by eliminating the element of surprise. It may also jeopardize the safety of the squad and/or the platoon main body by leading to a confrontation with superior forces.

The question here is whether training encourages officers to consider the impact of actions on purposes over this longer term. As shown in Table 16, references to the longer-range or higher-level purpose of the mission increased significantly for the Sanna's Post scenario after training. In the pretest only 3% of the participants mentioned the importance of maintaining contact with the battalion as it moved, whereas 26.3% did so after training. In the Platoon Ambush scenario, two separate measures of higher-level purpose were looked at. There was no change in attention to high level purpose as defined by either measure. First, there was no difference in the likelihood that the officers would rethink and revise the platoon's plan for ambushing the convoy, based on the necessity of dealing with the enemy patrol. This frequency was quite high (88.9%) early

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[13] A broader definition of higher-level purpose could have been used, for example, to include blocking or destroying enemy reinforcements for the battalion fight. We chose this narrow definition of higher-level purpose (being ready to move with the battalion) in part because it refers explicitly to a longer time-line, and to events occurring beyond the current tactical situation. A second reason for adopting the narrow definition was to keep this measure logically distinct from the dependent measures of time orientation. A desire to support the battalion fight by destroying tanks at Sanna's post counted as proactive, and so for purposes of this analysis was not counted as a reference to higher-level purpose. The significant increase in use of the proactive time orientation (Table 17) is thus an independent result.

in the course, and remained high later (87.5%). There was also no change in the frequency with which officers revised the plan for withdrawal by the squad and/or the platoon main body, e.g., by changing the time or place of withdrawal.

Table 16. Results regarding high-level purpose.

Reference to higher-level purpose	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
	Maintain contact with battalion: $F(1,50) = 7.024$ $p = 0.011$ ** 3.0% 26.3%	Revise ambush plan: $F(1,24) = 0.010$ $p = 0.922$ 88.9% 87.5% Revise plan for withdrawal: $F(1,24) = 0.020$ $p = 0.889$ 27.8% 25.0%

Use Time Orientation Effectively

Proactive.

The proactive time orientation involves taking action to influence the intent of another agent, by shaping that agent's opportunities or capabilities, or by affecting its decision processes. A proactive time orientation can be adopted at any level of planning. For example, in the Sanna's Post scenario, longer-term proactive considerations might justify the decision to attack Sanna's Post in terms of the larger battalion fight. These considerations might include: attack Sanna's Post to destroy the ability to use enemy tanks presently positioned there against the battalion; destroy Sanna's Post to reduce the enemy's logistical support for the fight against the battalion; attack east to force the enemy to orient west, away from the battalion; attack Sanna's Post to keep the enemy further away from the fords to the east. ON the other hand, *given* that Sanna's Post will be attacked, relatively short-term proactive tactics might be adopted for doing so. These tactics might include: taking out the tanks early with artillery to prevent their use in ground fight; using surprise and speed to create confusion; forcing the enemy to react in multiple directions at once; and guarding the bridge to the west of Sanna's Post to prevent reinforcements.

Training significantly increased the proportion of officers who used proactive elements of both kinds in their favored course of action (Table 17). A breakdown in terms of short-term versus long-term proactive elements reveals that by far the largest effect of training was on *longer-term* proactive planning. The difference between the short-term and long-term effects of training was itself significant (Figure 24).

Table 17. Results regarding proactive time orientation.

Proactive time orientation	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Overall	F(1,50)= 5.016 p =0.030 * 42.4% 73.7%	n/a 100.0% 100.0%
Short term	F(1,50)= 0.164 p =0.687 45.5% 52.6%	F(1,24)= 1.477 p =0.236 83.3% 100.0%
Long term	F(1,50)= 9.584 p= 0.003 ** 27.3% 68.4%	F(1,24)= 0.692 p =0.414 27.8% 12.5%
Interaction	Interaction: F(1,50)=3.990 p = 0.051 *	Interaction: F(1,24)= 1.198 p = 0.285

By contrast, there was no effect of coursework at any level on the frequency of proactive elements in the Platoon Ambush scenario. At the short-term level, proactive elements were common both early and late in the course, including, for example, delaying the patrol until the ambush of the convoy was completed. Longer-term proactive elements included influencing the intent of the superior unit (the platoon) in the conduct of the ambush or the plans for withdrawal. These began relatively low and remained low in the posttest (decreasing non-significantly).

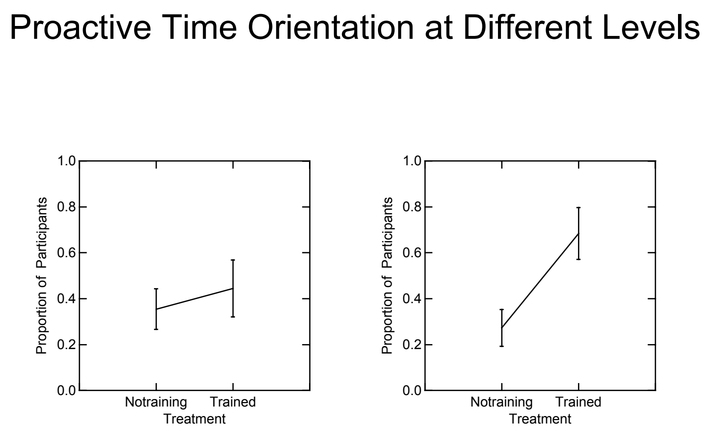

Figure 24. Effect of training on proactive time orientation at low level planning (on left) and high level planning (on right).

Predictive.

A predictive time orientation implies action based on expectations of how another agent (friend or enemy) will act, and the weaknesses or strengths associated with those actions. Predictive time orientations may exploit enemy weaknesses and avoid enemy strengths, or try to anticipate and support vulnerabilities of other friendly units. Unlike the proactive time orientation, the other agent's action is not specifically influenced by one's own actions.

There was no change in the use of predictive time orientations either in the trained (Sanna's Post) condition or in the untrained (Platoon Ambush) condition Table 18). Overall, there was a greater use of the predictive orientation in the Platoon Ambush scenario, probably because of the critical importance of timing issues in that scenario.

Table 18. Results regarding predictive time orientation.

Predictive time orientation	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Overall	F(1,50)= 0.590 p =0.446 36.4% 47.4%	F(1,24)= 2.534 p = 0.124 (T) 88.9% 62.5%
Short-term	F(1,50)= 2.037 p= 0.295 30.3% 47.4%	n/a 88.9% 62.5%
Long-term	F(1,50)= 0.328 p= 0.570 6.1% 10.5%	n/a 0.0% 0.0%
Interaction	F(1,50)=0.426 p = 0.517	n/a

Predictive-reactive.

Actions undertaken with the predictive time orientation may fail if predictions are wrong. The proactive time orientation is one way to deal with this uncertainty, by attempting to influence rather than simply predict future actions by the enemy (or friend). The predictive-reactive time orientation is another crucial tool in handling uncertainty. It involves anticipation of a range of alternative possible situations, and preparation to react appropriately when and if they occur. Branches help decision makers deal with assumptions, by preparing ahead for situations in which assumptions may fail. They help decision makers deal with conflicting evidence or goals by enabling them to postpone an action until the conflict is resolved.

Training significantly increased the proportion of officers who incorporated branches or contingencies into their plans (Table 19). Use of the predictive-reactive time orientation increased significantly for short-term planning and for the combination of short-term and long-term planning. In the absence of training, there was no effect on contingency planning in the Platoon Ambush scenario.

Table 19. Results regarding predictive-reactive time orientation.

Predictive-reactive time orientation	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Overall	F(1,50)= 5.058 p =0.029 * 27.3% 57.9%	F(1,24)=0.782 p =0.385 11.1% 25.0%
Short-term	F(1,50)= 4.446 p= 0.040 * 6.1% 26.3%	F(1,24)= 0.516 p =0.385 5.6% 0.0%
Long-term	F(1,50)= 1.799 p = 0.186 24.2% 42.1%	F(1,24)= 2.065 p =0.165 5.6% 25.0%
Interaction	F(1,50)= 0.022 p= 0.882	F(1,24)= 2.374 p = 0.136 (T)

Predictive-Reactive Time Orientation at Different Levels

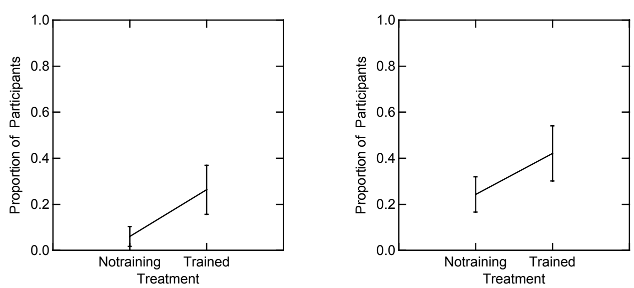

Figure 25. Effect of training on predictive-reactive time orientation at low level (on left) and high level (on right).

Combinations of time orientations.

An important part of critical thinking is to combine multiple time orientations within a plan, so that weaknesses of one are counterbalanced by strengths of others. Since training increased the use of specific time orientations (especially high-level proactive and low-level predictive-reactive), training might also be expected to increase the use of *combinations* of time orientations by individual participants. This is not necessarily the case, however. Training might increase the use of some time orientation for each participant; but it might hardly ever lead to an increase in more than one orientation for the same person (perhaps due to limits on attention or learning rate). In this case, combinations of time orientations would increase less than expected from the assumption of independent effects of training on each time orientation for each individual. In addition to this, two other possibilities exist: Training might have an independent effect on each time orientation for each individual, in which case combinations would increase as the individual time orientations increased; or training might have a synergistic effect for each individual, e.g., if learning one time orientation made learning a second or third easier. In the latter case, combinations would occur *more* frequently than expected from independent effects of training.

It is seen in Figure 26 and Table 20 that training did significantly increase the average number of different time orientations used by individuals in the Sanna's Post scenario. The increase was significant both overall (combined long and short term), and for long-term planning. By contrast, there was virtually no change in the average number of time orientations used for the Platoon Ambush scenario, in the absence of training.

Table 20. Results regarding number of time orientations.

Number of time orientations adopted	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Overall	F(1,50)=5.615 p =0.022 * 1.06 1.79	F(1,24)=0.029 p = 0.866 0.33 0.383
Short-term	F(1,50)= 2.037 p= 0.160 0.82 1.26	F(1,24)= 0.444 p =0.512 1.78 1.63
Long-term	F(1,50)= 6.898 p= 0.011 ** 0.58 1.21	F(1,24)= 0.029 p =0.866 0.33 0.38
Interaction	F(1,50)= 0.297 p = 0.588	F(1,24)= 0.360 p = 0.554

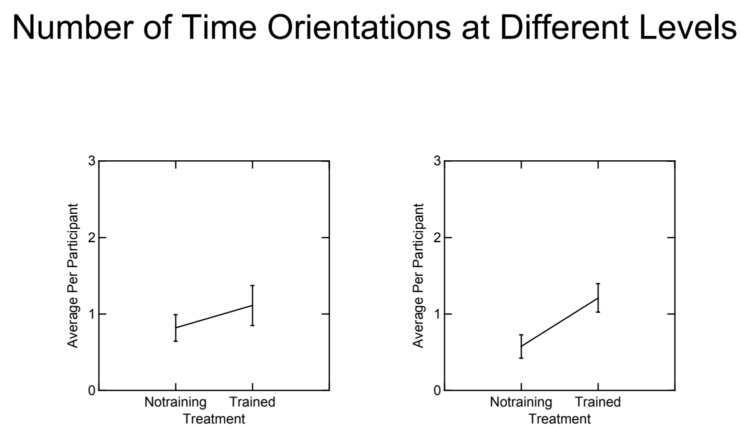

Figure 26. Effect of training on number of time orientations at low level (on left) and high level (on right).

Was this increase due to independent effects of training on individual time orientations for each participant? To address this question, we focused on the two specific time orientations for which training had the largest individual effects: high level proactive and low level predictive reactive. Figure 27 compares the observed number of combinations with the number that would be expected based on independent effects. There were slightly (and non-significantly) more combinations of these two time orientations than expected in both the trained and no training conditions; but the difference between the expected and the observed number of combinations was not affected by training. In other words, the effects of training on the different time orientations were independent.

Hi-level Proactive + Lo-level Predictive-Reactive

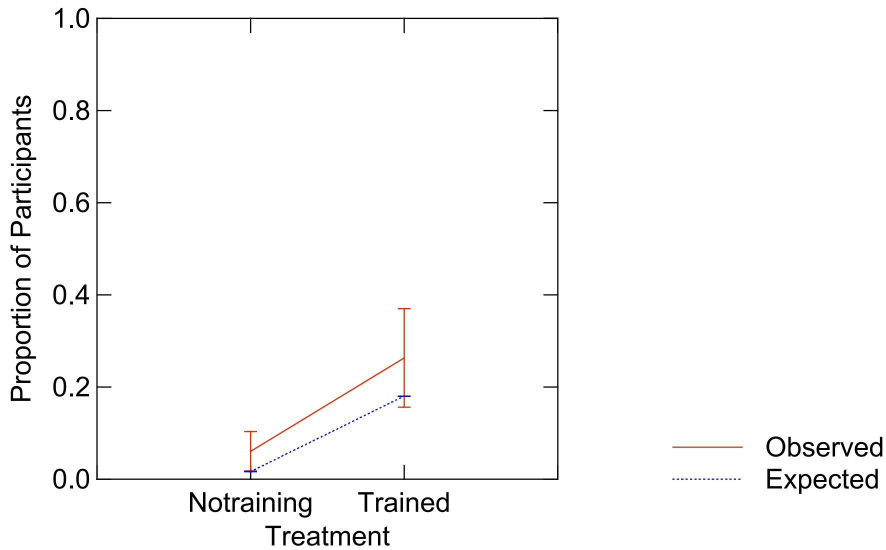

Figure 27. Effect of training on proportion of participants using both proactive high level and predictive-reactive low level time orientations, compared to expected proportion based on the assumption of independent effects.

<u>Critical Thinking about Mental Models</u>

<u>Detect and fill gaps in intent mental models.</u>

All the measures discussed above pertain to filling gaps in *mental models*:, i.e., organized structures of concepts that enable officers to evaluate their own mission and situation in terms of high-level purposes, and to identify and exploit proactive, predictive, and predictive-reactive opportunities. A particularly common cluster of co-occurring concepts concerns *intent* (friendly or enemy), and includes elements representing both causes (or reasons) and effects of a particular intent. At a broad level, the causes of an intent can be categorized into (1) the mission, purposes, or principles motivating the action, (2) opportunities, i.e., factors of terrain, time, and information that provide a window for action, and (3) capabilities, or relative strengths and weaknesses of friendly and enemy forces. The effects of an intent include whatever actions would be taken to implement it.

There was a consistent, but non-significant increase after training in the frequency with which participants referred to each of the three causal components of intent mental models – purpose, opportunity, and capability (Table 21, Figure 28). There was a non-significant trend for training to increase the average number of causal components referred to by each participant; in addition, the number of participants referring to at least two out of three of the components increased non-significantly from 15% to 32%. In the non-trained group (Platoon Ambush), increases were less consistent across the three components and much smaller in each one. It should be noted, however, that absolute values were consistently higher in the Platoon Ambush scenario than in the Sanna's Post scenario, and that the failure to see consistent increases may reflect ceiling effects.

Table 21. Results concerning use of intent mental model concepts.

Intent Mental Model Concepts	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Number of concepts referred to	F(1,50)=2.387 p =0.129 (T) .52 .95	F(1,24)=0.009 p =0.924 2.7 2.8
Motivation (Purpose, mission, principles) (% Ss)	F(1,50)=8.546 p =0.169 15.2% 31.6%	F(1,24)=0.434 p =0.516 94.4% 100.0%
Opportunity (terrain, time, information) (% Ss)	F(1,50)=1.687 p =0.200 12.1% 26.3%	F(1,24)=0.231 p =0.635 83.3% 75.0%
Capability (enemy and friendly forces) (% Ss)	F(1,50)= 0.913 p =0.344 24.2% 36.8%	F(1,24)=0.434 p =.516 94.4% 100.0%

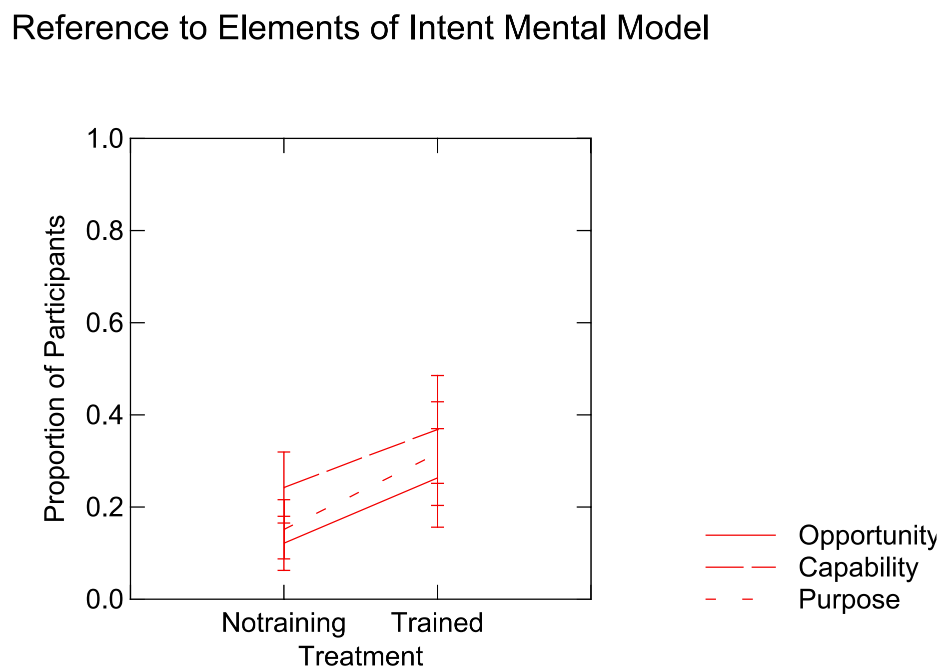

Figure 28. Effect of training on use of components of intent mental model.

Although training had little effect on the use of intent mental model components, these data provide some confirmation for the mental model construct. Earlier findings suggested that these components (purpose, opportunity, and capability) tended to be correlated with one another. Figure 29 shows that in these data as well references to opportunity and capability both increase sharply when a participant referred to purpose. All three components of intent were highly significantly correlated with one another, and the degree of association was not affected by training. The Figure 29 provides further confirmation by showing that the intent mental model components are more highly correlated with one another than they are with other characteristics of situation understanding and planning.

Association among Intent Components

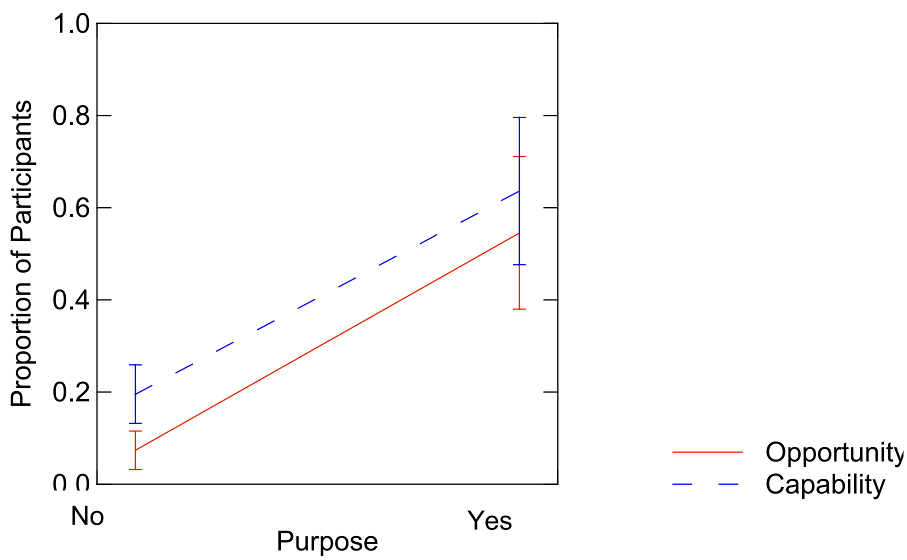

Figure 29. Association between reference to purpose and reference to opportunity and capability.

Identify conflict and unreliable assumptions.

In addition to filling gaps in mental models, trained decision makers should learn to identify conflicts in evidence or goals, and to ferret out critical assumptions in their situation understanding or plans. More over, one effective decision making strategy addressed in the training is to explain conflicting evidence or resolve conflicting goals by means of assumptions (if data are not available), and then to step back and evaluate the assumptions.

There were no significant effects of training on the total number of problems identified or on the number of conflicts identified. However, there was a trend for training to increase the number of assumptions that officers found (Table 22). Trained participants found almost twice as many assumptions as untrained participants, while the number of conflicts they described decreased slightly. The interaction between training and type of problem (conflict vs. assumptions) was non-significant, but reflects a possible trend Figure 30). By contrast, there were no effects or trends in the Platoon Ambush scenario either on conflicts or assumptions, or on their interaction.

Table 22. Results in regard to number and types of problems detected.

Number of problems identified	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Overall	F(1,50)=0.689 p =0.410 1.03 1.42	F(1,24)=0.004 p =0.951 8.61 8.50
Conflicts	F(1,50)= .063 p = .802 .55 .47	F(1,24)=0.015 p =0.903 3.50 3.38
Assumptions	F(1,50)= 2.425 p =0.126 (T) .49 .95	F(1,24)=0.000 p =0.990 5.11 5.13
Interaction: Treatment x Type of problem	F(1,50)=2.437 p =0.125 (T)	F(1,24)=0.004 p =0.951
Number of alternative options considered	F(1,50)=3.951 p =0.052 (T) 2.5 1.9	F(1,24)=0.219 p =0.644 3.1 2.9

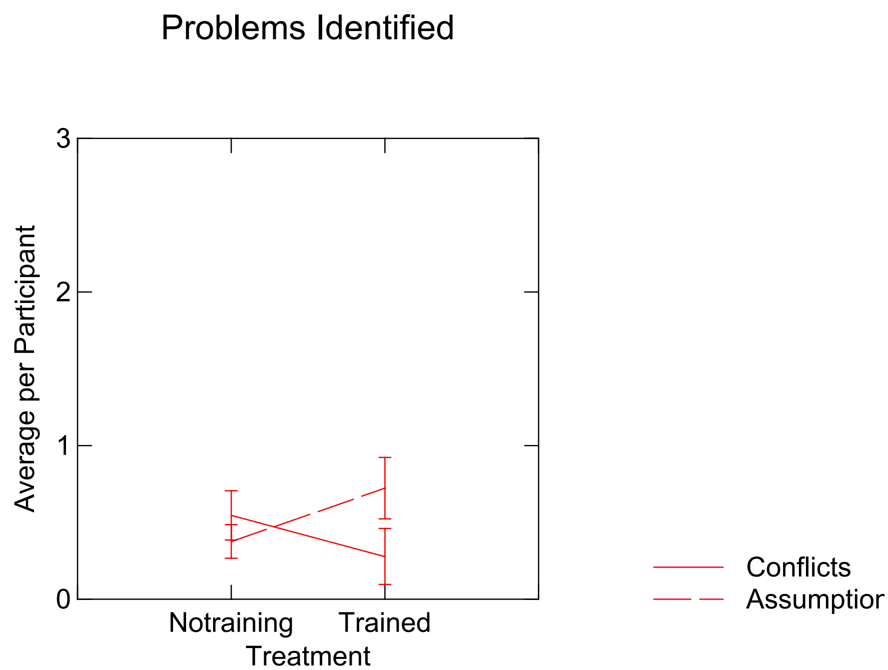

Figure 30. Effects of training on number of conflicts and number of assumptions detected.

When assumptions are found to be implausible, and further data are not presently available, decision makers may (i) modify the existing plan to mitigate the effect of the assumptions, or (ii) generate and consider alternative options. The latter strategy was not used. On the contrary, training actually decreased the number of alternative options that officers considered, and this decrease approached statistical significance (Table 24). In the Platoon Ambush scenario, there was a very slight, non-significant decrease in the number of alternatives considered.

Instead of generating and considering alternative options, the trained participants worked to improve the options that they did consider. One way of making plans more robust is to incorporate contingencies or branches, and we saw earlier that use of the predictive-reactive time orientation increased significantly after trained. Another, related strategy is to adopt multi-faceted plans, in which different components balance weaknesses in other components. We have already seen that trained participants tended to combine time orientations more than untrained participants. In a subsequent section, we look at the effects of training on the specific tactical options that were adopted.

Decide when to act: Confidence.

Our expectation (based on previous experimental results) was that critical thinking training would not decrease confidence in officer's final decisions. In this study, however, there was a marginally significant decrease in confidence in the Sanna's Post scenario after training (Table 23). It is unclear what the role of training was in this decline, since there was a small (and non-significant) decline in confidence among non-trained participants in the Platoon Ambush scenario as well. It is also unclear what the decrease in assessed confidence actually means. Another plausible measure of confidence, the *difference* between assessed confidence in the favored option and assessed confidence in the second-favored option, did not change (Figure 31).

Table 23. Results regarding confidence.

Confidence	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Favored option	F(1,50)=3.736 p =0.059 (T) 53% 39%	F(1,24)=1.875 p =0.184 56% 50%
Difference between favored and next best	F(1,50)= .080 p =0.778 (NS) 19% 18%	F(1,24)=0.500 p =0.486 24% 19%

Figure 31. Effect of training on confidence in the favored option and on the second-favored option. Difference between the curves remained unchanged.

Effects on Decisions and Tactics

Perhaps the most important questions about the effect of training concern its effects on planning outcomes: Did training influence the decisions that officers made? And if so, did it do so by influencing the cognitive processes to which training was addressed?

We focused first on whether or not officers dealt with the uncertain event in each scenario. That is, in the Sanna's Post scenario, did officers adopt any action at all with respect to Sanna's Post (including a possible decision merely to keep an eye on it)? In the Platoon Ambush scenario, did they adopt any action at all with respect to the patrol (including a possible decision to stand aside and let the platoon main body would handle the patrol)? There was a highly significant increase in attention to the unexpected presence of enemy at Sanna's Post after training (Table 26). On the other hand, there was no significant improvement in attention to the enemy patrol in Platoon Ambush, although the latter failure may again be due to ceiling effects.

We then took a more detailed look at the effects of training on the tactics that participants selected. We categorized the plans adopted by participants in the Sanna's Post scenario along the following, non-mutually exclusive dimensions: whether or not they used artillery (fires) against Sanna's Post, whether or not they employed a ground attack (either contingent or non-contingent) against Sanna's Post, and whether or not they defended one or both of the Modder River fords from positions on the nearby high ground. Each of these three tactical elements shows a highly significant increase in frequency after training (Table 24, Figure 32).

Table 24. Results with respect to tactical elements in decisions.

Decisions	Pre-training vs Post-training: Sanna's Post	Pre-control vs Post-Control: Platoon Ambush
Ignore unexpected situation	F(1,50)=18.041 p =0.000 *** 63.6% 10.5%	F(1,24)=2.374 p =.136 (T) 0.0% 12.5%
Specific Tactical Elements	Defend fords: F(1,50)= 8.546 p =0.005 ** 39.4% 78.9%	Squad handles patrol: F(1,24)=0.923 p =0.346 88.9% 100.0%
	Fires on Sanna's Post: F(1,50)= 6.969 p =0.011 ** 15.2% 47.4%	Recommend abort of ambush F(1,24)=0.010 p =0.922 11.1% 12.5%
	Ground attack on Sanna's Post: F(1,50)= 6.386 p =0.015 ** 24.2% 57.9%	Take over ambush of convoy: F(1,24)=.434 p =.516 5.6% 0.0% Recommend new rally point: F(1,24)=.231 p =.635 16.7% 25.0%

We categorized the plans officers adopted in the Platoon Ambush scenario along the following dimensions: whether or not the squad chose to handle the enemy patrol on its own (rather than ignoring it, allowing the platoon main body to decide what to do, or recommending that the main body handle the patrol itself); whether or not the squad recommended to the platoon main body that the convoy ambush be aborted; whether or not the squad chose to take over the ambush of the convoy from the platoon main body; and whether or not the squad recommended a change in the rally point for rejoining the platoon main body (in order to avoid the patrol). These dimensions are not mutually exclusive, with one exception: If the squad recommended that the ambush be aborted, it could not then chose to take over the ambush itself. There was no effect of coursework or time on any of these tactical elements. In other words, the actions adopted by officers in the Platoon Ambush scenario remained essentially unchanged in the absence of training. Moreover, ceiling effects cannot account for at least three out of the four tactical elements.

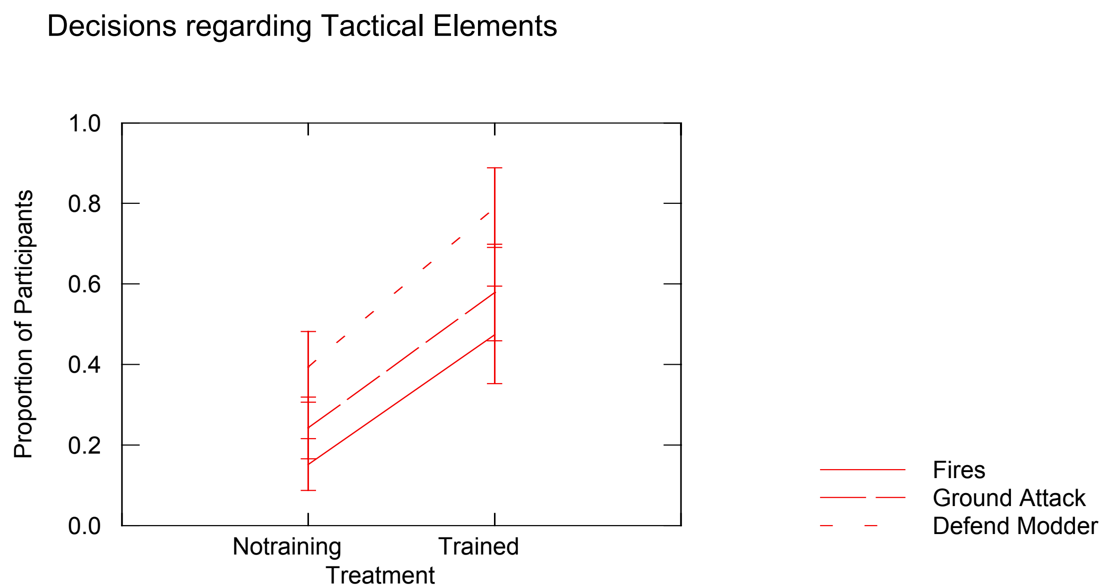

Figure 32. Effect of training on tactical elements.

It is not necessarily the case that increases in the use of individual tactics would lead to increases in combinations of tactics by individual participants. For one thing, some of the tactics may work against one another (for example, attacking Sanna's Post with fires gives away the presence of the company and may make defense of the fords less effective). It may even be judged impossible to implement both tactics simultaneously with the available resources (e.g., a ground attack against Sanna's Post and effective defense of the fords). In addition, even when tactics are compatible, the use of combined tactics would not increase if the attention of each participant were focused by training on a single tactical element. On the other hand, there may be value in combining tactics in order to deal proactively with assumptions, e.g., using fires to take out tanks before a ground attack; or using fires to fix forces in Sanna's Post while guarding the fords.

In fact, training was associated with increases in the use of combined tactics (Table 25). For example, there was a significant increase in the "combined arms" tactic of applying fires in conjunction with a ground attack on Sanna's Post. There was also a trend to combine fires on Sanna's Post and defense of the Modder fords. Finally, the combination of using fries on Sanna's Post and defending the fords also increased, but non-significantly. In each case, the increase in use of a tactical combination was approximately equal to what would be expected based on the independent effects of training on each individual tactic (Figure 33, Figure 34, Figure 35). Finally, there was a highly significant increase in the average number of tactical elements used by each participant (Table 24).

By contrast, in the Platoon Ambush scenario, there were no significant changes in the absence of training. However, there were two trends: to combine handling the patrol and recommending a changed rally point, and to combine those two tactics with recommending an abort of the convoy ambush. There was, however, no effect on the average number of tactical elements used per participant.

Table 25. Results regarding combined tactics.

Decisions	**Pre-training vs Post-training: Sanna's Post**	**Pre-control vs Post-Control: Platoon Ambush**
Combined tactics	fire + defense F(1,50)=1.949 p =0.169 15.2% 31.6%	patrol + rally F(1,24)=.231 p =.635 16.7% 25.0%
	fire + ground F(1,50)=4.446 p =0.040 * 6.1% 26.3%	abort + rally F(1,24)=2.374 p =.136 (T) 0.0% 12.5%
	ground + defense F(1,50)=3.274 p =0.076 (T) 15.2% 36.0%	patrol + abort F(1,24)=.352 p =.558 5.6% 12.5%
	fire + ground + defense F(1,50)=0.328 p =0.570 6.1% 10.5%	patrol + abort + rally F(1,24)=2.374 p =.136 (T) 0.0% 12.5%
Number of tactics used	F(1,50)=18.591 p = 0.000 *** .79 1.84	F(1,24)=0.780 p =0.386 2.06 2.25

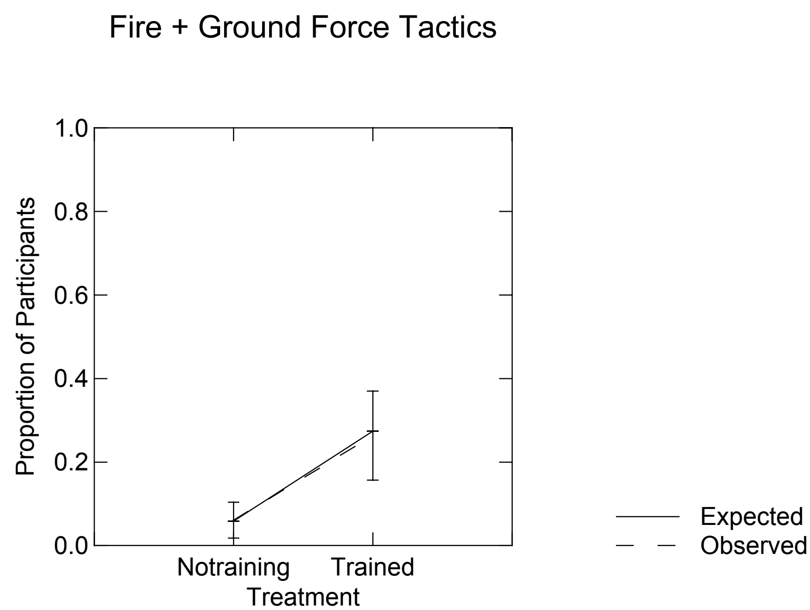

Figure 33. Effect of training on combined use of fire and ground forces on Sanna's Post, compared to expectation based on independent effects.

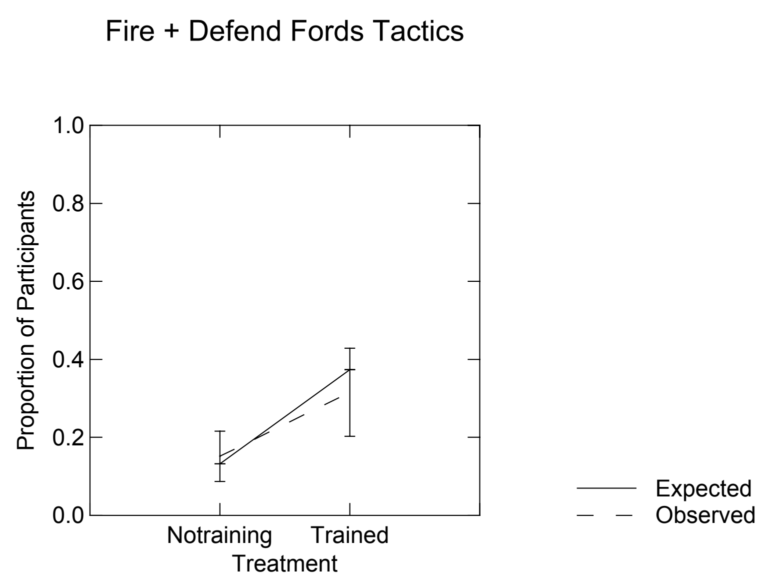

Figure 34. Effect of training on combined use of fires on Sanna's Post and defense of fords from high ground, compared to expectation based on independent effects.

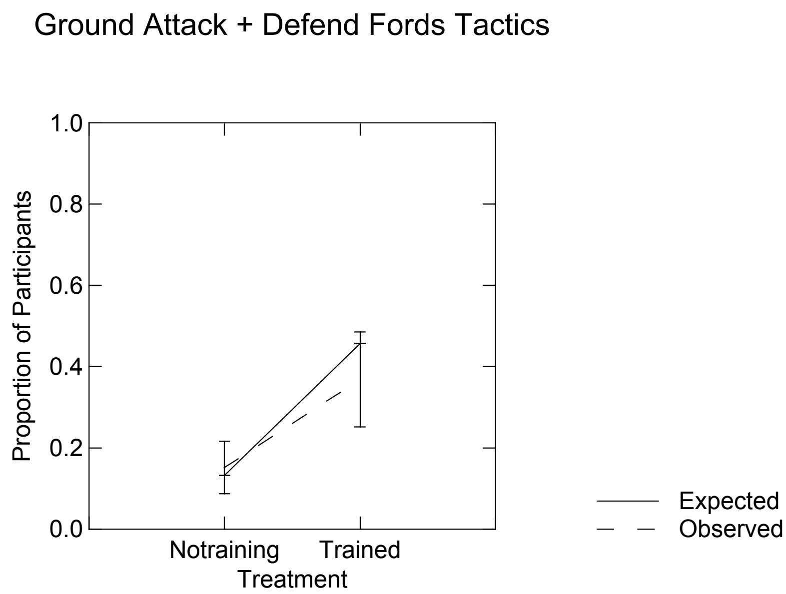

Figure 35. Effect of training on combined use of ground forces on Sanna's Post and defense of fords from high ground, compared to expectation based on independent effects.

Summary and Conclusion

Training had a significant effect on both (1) variables related to critical thinking processes and (2) participants' decisions in the Sanna's Post scenario. With respect to critical thinking processes, training increased the frequency with which participants used the proactive time orientation at a high (i.e., battalion) level, used the predictive-reactive time orientation at a lower (i.e., enemy in sector) level, and made reference to higher-level purpose (regarding support for the battalion fight). Training was associated with a trend to more frequent use of intent mental model components, and also with a trend toward identifying more assumptions in plans. The effect on decisions was dramatic. Participants significantly increased their use of three key tactical elements after training, and also increased their use of combinations of those tactical elements.

Surprisingly, training decreased confidence in the chosen alternative, although the difference between the first and second favored alternatives was the same before and after training. Training also decreased the number of alternatives that participants considered. The latter may be due of offsetting increase in the use of contingencies or branches (the predictive-reactive time orientation).

How Did Training Change Decisions?

Given that training influenced decisions in the Sanna's Post scenario, how did it do so? What is the relationship among the critical thinking variables, training, and changes in plans? To address this question, albeit in a highly provisional manner, we constructed a Pathfinder network (Schvaneveldt, 1990). The inputs to the Pathfinder software were correlations among selected variables, transformed to reflect distances rather than similarities. The software extracts patterns in these correlational data, by finding what can plausibly be considered the most basic set of relationships among the variables. Other relationships are hypothesized to be more parsimoniously explained in terms of the basic set.[14]

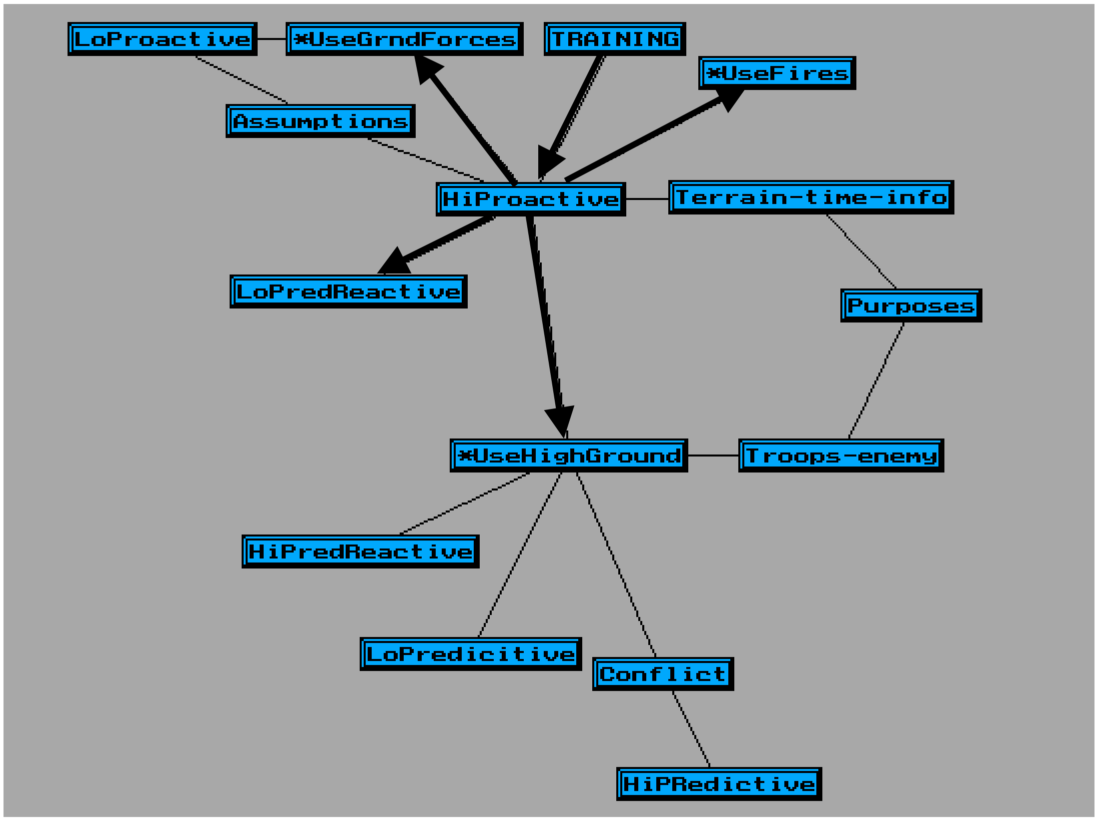

Figure 36. Pathfinder network representing relationships among training, decision elements, and critical thinking variables.

As inputs to the network we selected experimental variables in three categories: (1) the independent variable (training), (2) the three tactical decision elements (fires on Sanna's Post, ground attack on Sanna's Post, and using high ground to defend the fords), and (3) other dependent variables that were found to be correlated with at least one of the tactical decision elements at or below the p=.20 level. The latter group of variables included all three time orientations (proactive, predictive, predictive-reactive) at both the high (i.e., battalion) and the low (i.e., company) levels, the number of assumptions and

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[14] Constructing a Pathfinder network involves eliminating any direct link between nodes A and B whenever that link is not the shortest distance between A and B. Weights on the surviving links are simply the original distance inputs, and are reflected as nearly as possible in the link lengths. In deciding whether to eliminate a link, the weight on that link (i.e., its distance) is compared to the distances of all other paths between the two nodes. The distance of a path is measured as a Minkowski r-metric sum of the weights on its component links. In this application, r was set to infinity, thus equating the distance of a path to the maximum distance of any link within that path (an approach which is suitable for ordinal measurement). Paths of all lengths were considered (q = n-1), to maximize sparsity of the resulting graph. As a result of these parameters, a direct link between nodes A and B was deleted whenever the distance from A to B on that direct link was greater than the length of the longest link in some other path between A and B.

the number of conflicts identified, and the three components of the intent mental model (purpose, opportunity, and capability.[15]

The resulting network is shown in Figure 41. All the links in the graph represent highly significant correlations. The absence of a link, however, does not imply the absence of a significant correlation, since other correlations are explained in terms of the correlation that are represented by links. In particular, according to this network, the effect of training on the use of ground forces is mediated by the effect of training on the high-level proactive time orientation. Effects of training on the other two tactical variables (use of fires and defense from the high ground) are also mediated by the effects of training on the high-level proactive time orientation. Finally, the effect of training on the use of contingencies or branches (the predictive-reactive time orientation) is also mediated by the effect of training on the high-level proactive time orientation.

Pathfinder does not identify the *direction* of causality between nodes. The directions of the arrows in Figure 41 were inferred by taking Pathfinder as a starting point, and using a plausible heuristic (Pearl, 1989; Glymour, Scheines, Spirtes, & Kelly, 1987).[16] Applying this method to the original Pathfinder graph resulted in the causal

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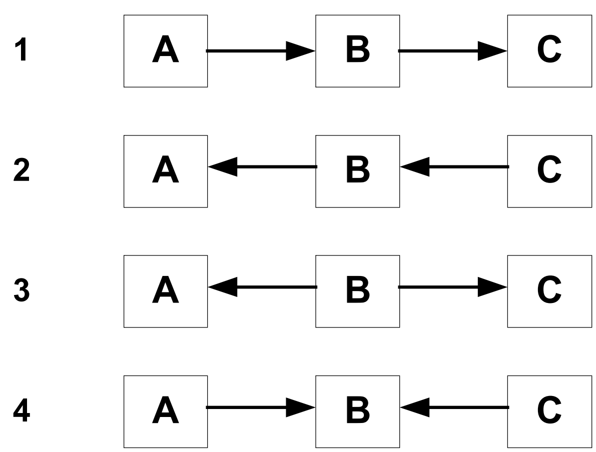
[15] We also required that there be no built-in logical relationships or redundancies among the selected variables, which might artifactually distort the resulting graph. This precluded, for example, variables representing combined tactics, number of time orientations, or use of two out of three mental model components. It also excluded high-level purpose, since this was one element in the purposes component of the intent mental model.

[16] Suppose we know, from a non-directed Pathfinder graph, that variable A is linked to B, and B is linked to C, and that there are no other paths connecting A and C other than the one through B. The figure in this note shows all the possible ways the two links (A-B and B-C) could be directed: Causality may run (1) from A to B to C, (2) from C to B to A, (3) from C both to A and to B, or (4) from both A and B to C. Therefore, if A is already known to cause B, and if A and C are correlated, only case (1) fits; and B must cause C. (Symmetrically, if C is known to cause B, and A and C are correlated, only case (2) fits, and B must cause A.). It is also plausible to assume that training can be a cause of other variables but may not serve as an effect, based on the quasi-random assignment of participants to treatment groups in this study. The assumption allows us to infer the direction of causality between training and the high level proactive time orientation. We can then infer the direction of causality from the proactive high level time orientation to the other variables by reference to case (1) in the figure.



The four possible directions of causality among three variables.

relationships represented by the heavy lines and directional arrows in Figure 36. The network in Figure 36 thus represents a tentative hypothesis about the causal mechanisms underlying the effectiveness of training. Although this model should be regarded as highly provisional, it suggests that the primary impact of training was to influence participants to think more about shaping enemy actions and capabilities in order to serve the purpose of the operation in a larger spatial and temporal context.

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