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for the Behavioral and Social Sciences**

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**Computerized Training in Critical Thinking (CT)²:
A Skill-Based Program for Army Personnel**

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June 2008

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We are very grateful for having had the opportunity to study critical thinking over the past seven years. The main product of this research, a web-based program to train eight critical thinking skills, could not have been developed without the support of the U.S. Army Research Institute Fort Leavenworth Research Unit. Several employees of Anacapa Sciences, Inc. contributed to the development of the training system, Computerized Training in Critical Thinking (CT)². Bill Campsey, in particular, was instrumental in shaping the approach we took to training critical thinking. His ideas and words can be found on nearly every page of the training. Even his voice can be heard in the audio portions as we learned that he had significant theatrical talent. Having served in the Army for many years and retired, Bill also served as our subject matter expert and kept the training relevant, interesting, and engaging. He is largely responsible for creating almost all of the scenarios contained in (CT)² and authored major components of several modules. The training system could not have been created as such without his contributions.

We are also grateful to Dr. Eric Holder and Dr. Patricia Mautone, who contributed greatly to the creation of several of the modules. Eric's industry and creativity produced a large amount of material that was incorporated into the training. He seemed to always be able to find the right graphics and put the package together, even under time constraints. Similarly, we are grateful to Tricia for authoring one of the skills. More than that, though, we are deeply indebted to her for her careful review of all the material and her expertise in multi-media presentation. She is largely responsible for setting standards for the pretests.

Finally, we would like to express our gratitude for the contributions of Anacapa's colleague, Jim Kornell, who authored several of the training components. His ability to see the core of a critical thinking skill and derive its components was instrumental to our approach and to the product. His ideas and words can also be found throughout the training components.

COMPUTERIZED TRAINING IN CRITICAL THINKING (CT)²: A SKILL-BASED PROGRAM FOR ARMY PERSONNEL

EXECUTIVE SUMMARY

Research Requirement:

This report describes the development and assessment of distance training in critical thinking (CT) for Army personnel. The United States military has served a leadership role in promoting thinking skills for good reason. Today's military situations demand novel, yet insightful, solutions, which can only be derived from sharply honed thinking skills. Traditional methods of training tactical decision-making offer a prescriptive model that corresponds to doctrine and focuses on the products of decision-making. The procedural nature of the doctrinal methods may actually discourage the application or development of thinking skills, inhibiting the creation of novel solutions that might be the result of CT (Fallesen, Michel, Lussier, & Pounds; 1996).

Procedure:

The primary product of this research program was easily distributed and accessed training in CT skills, **Computerized Training in Critical Thinking (CT)²**. The development of the training was supported by research that was conducted over three broad phases. An overview of this research program is given in Fischer, Spiker and Riedel (2008a). The third phase of the research, which is the focus of the present report, was devoted to developing and evaluating a complete Internet-based training package that provides training and assessment for eight CT skills. Two versions of the training were developed: a standard version for each of the eight CT skills, and a longer version for each of four skills. A user-centered design process was used to ensure that the resulting training and assessment products were usable, useful, and well accepted by potential training populations. Consistent with the user-centered design philosophy, four formative evaluations were conducted. Feedback obtained from the formative evaluations was used to inform and make modifications to the training system. The effectiveness of the resulting training system was evaluated in two additional evaluations. Samples of potential users were asked to complete portions of the training. Their abilities were tested before and after the training to determine if the training had improved their critical thinking skills. One of the evaluations also assessed whether the extended version of the training provided any greater learning benefit than the shorter standard version.

Findings:

(CT)² is a modular training system that is accessed from the Internet and can be self-administered. It comprises a number of training and assessment components including pretests, training modules, and posttests for each of eight CT skills. The pretests and training modules are highly interactive, include multiple exercises with corresponding feedback, and utilize multi-media presentations. All of the components are designed not only to improve critical thinking skills, but also to increase self-awareness of one's thinking. (CT)² is based on a model of CT which was developed during the research effort and which has received initial empirical support

(Fisher, Spiker & Riedel; 2008b). (CT)² was designed using well-founded pedagogical principles. The particular CT skills on which the training system focuses were empirically identified in the first phase of the research as important and problematic to Army battle command. The (CT)² software itself is SCORM compliant and ready for implementation with any learning management system (LMS).

The formative evaluations conducted during (CT)² development found that the training was generally well designed although many specific improvements were needed. The results of both summative evaluations indicated that the training increased participants' skills on the two critical thinking skills evaluated. These findings suggest that the training program is effective at improving critical thinking. Because the training and testing components of each of the eight skills follow a similar pedagogy and presentation format, it is expected that each training module would produce a similar learning effect. The results of the second summative evaluation suggest that the shorter standard training is as effective as the extended training in teaching critical thinking skills. Given the limited time often available for extra training, these results suggest that the standard version is sufficient to produce a desired learning effect. The extended version could be used if a student wanted more explanation or needed some question resolved. The extended version could serve as supplemental material, which could be made available for those trainees who desire additional training.

Utilization and Dissemination of Findings:

(CT)² is available for use by any Army organization. Army units seeking to improve the critical thinking skills that are important and problematic in battle command will find it particularly useful. It is accessible on the Internet and is suitable for use as stand-alone self development training. It can also be inserted into a school house course in critical thinking, either using selected modules or in its entirety.

The results of this multi-year research program bring two important resources to the field of critical thinking that were previously unavailable to researchers. The first is a testable model of CT that can guide future research efforts on the construct. The second is (CT)², which provides an off-the-shelf training package and a model on which future training development efforts can be launched and which provides a vehicle for research on critical thinking.

COMPUTERIZED TRAINING IN CRITICAL THINKING (CT)²: A SKILL-BASED PROGRAM FOR ARMY PERSONNEL

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COMPUTERIZED TRAINING IN CRITICAL THINKING (CT)²: A SKILL-BASED PROGRAM FOR ARMY PERSONNEL

INTRODUCTION

The United States military has served a leadership role in promoting thinking skills for good reason. Military leaders have always had to make tactical decisions in complex and stressful situations where knowledge is incomplete and uncertain, and when sound thinking can make the difference between success and failure. But today's asymmetrical warfare is very unlike the warfare that Army personnel have previously experienced or studied, and therefore requires innovative thinking. Today's situations demand novel, yet insightful, solutions, which can only be derived from sharply honed thinking skills.

Officers and enlisted personnel are thoroughly educated in the practice and art of warfare. Traditional methods of training tactical decision-making offer a prescriptive model that corresponds to doctrine and focuses on the products of decision-making. The application of doctrinal procedures may actually discourage the application or development of thinking skills, inhibiting the creation of novel solutions that might be the result of CT (Fallesen, Michel, Lussier, & Pounds, 1996).

Without explicit training, whatever thinking skills a Soldier possesses are gained through on-the-job experience, fortuitous experiences in training exercises, individual disposition, or other idiosyncratic means such as self-study. Establishing an integrated training program to address the development of thinking skills is preferable to hoping that these skills will somehow develop on their own. Therefore, the primary purpose of this research program was to provide easily distributed and accessed training in CT skills. The development of the training was supported by research that was conducted over three broad phases. In the next section, these three phases will be briefly reviewed in order to provide a context to the present report.

This report describes the main product of a multi-year research and development program to create distance training in critical thinking for Army personnel. The training that was developed, **Computerized Training in Critical Thinking (CT)²** is a modular, interactive training system that is accessed from the Internet and can be self-administered. It comprises a number of training and assessment components including pretests, training modules, and posttests for each of eight CT skills. Four of the CT skills have an extended training version in addition to the standard shorter version. The pretests and training modules are interactive, include multiple exercises with feedback, and utilize multi-media presentations. All of the components are designed to not only improve critical thinking skills, but also to increase self-awareness of one's thinking. (CT)² is based on a model of CT, developed during this research effort, which has undergone initial empirical testing (Fischer, Spiker & Riedel; 2008b). (CT)² was developed using well-founded pedagogical principles. The particular CT skills on which the system focuses were empirically identified in the first phase of the research as important in the battle command domain and whose execution was problematic (Fischer, Spiker, & Riedel, 2008c). Here battle command applies to "the leadership element of combat power... Commanders visualize the operation, describe it in terms of intent and guidance, and direct the actions of subordinates within their intent. They

directly influence operations by personal presence...” (Department of the Army, 2001, Section 5-1).

The next section of this report gives a brief overview of the multi-year research program in critical thinking that provides the foundation for (CT)². Succeeding sections describe the curriculum, the training components, and the formative and summative evaluations of (CT)². Finally, suggestions for future research are presented.

OVERVIEW OF THE RESEARCH PROGRAM

In the first phase in the development of (CT)², which constituted preparatory research, the CT literature was reviewed, CT was investigated in a military context, and pedagogical techniques used to teach CT were surveyed. In the second phase, a prototype CT training program was developed for two CT skills. The final phase, which is the focus of the present report, was devoted to developing a complete Internet-based training package that provides training and assessment for eight CT skills. The preparatory research and development of the prototype (CT)² are discussed below.

Preparatory Research

The preparatory phase conducted the necessary preliminary research that would support development of (CT)². The major tasks in this first phase were to (1) review the literature on CT, (2) develop and validate a model of CT, (3) inventory CT skills identified in the literature, (4) specify the role of CT within the Army, (5) select a set of CT skills for which to develop training, (6) establish lessons learned from the literature on training CT and from efforts to teach CT to Army officers, and (7) establish functional requirements for the to-be-developed instructional material. A more detailed description of this research is contained in Fischer, Spiker, and Riedel (2008b).

The review of the literature on CT concluded that the field is highly fragmented and lacks consensus (Fischer, et al., 2008b). A lack of empirical investigation of CT as a psychological process and/or individual difference variable is a major problem with this field and may be one reason for its lack of coherence. The review showed that the literature on CT did not contain a model of CT that grounded the construct in objectively observable behavior. The literature review also produced an inventory of CT skills and provided input to development of a testable model of CT (Fischer, et al., 2008b), which was one of the most important products of the preparatory research.

An empirically testable model was developed and two studies were conducted to provide an initial validation of the model. The model incorporates many ideas about CT offered by leading thinkers in philosophy and education and embodies many of the CT skills and predisposing attitudes discussed in the CT literature. It also specifies the relationships among a variety of variables including the influence of experience and knowledge, and the relationship of CT to cognitive tasks (e.g., judgment and problem solving). The model also provides a framework in which CT can be empirically investigated as a cognitive process. Figure 1 shows the model. A description and discussion of the model is contained in Appendix A.

A validation experiment tested four of the model's predictions involving the effects of situation (type of material to be processed), type of task, predisposing individual differences, and experience level on CT (Fischer, et al., 2008b). It also examined the model's proposition that CT can have negative affective consequences. The model's predictions concerning the type of material to be processed were generally supported. High substance material took longer and was

more effortful to process than low substance material. Response times were longer for degraded substance material than non-degraded substance material.

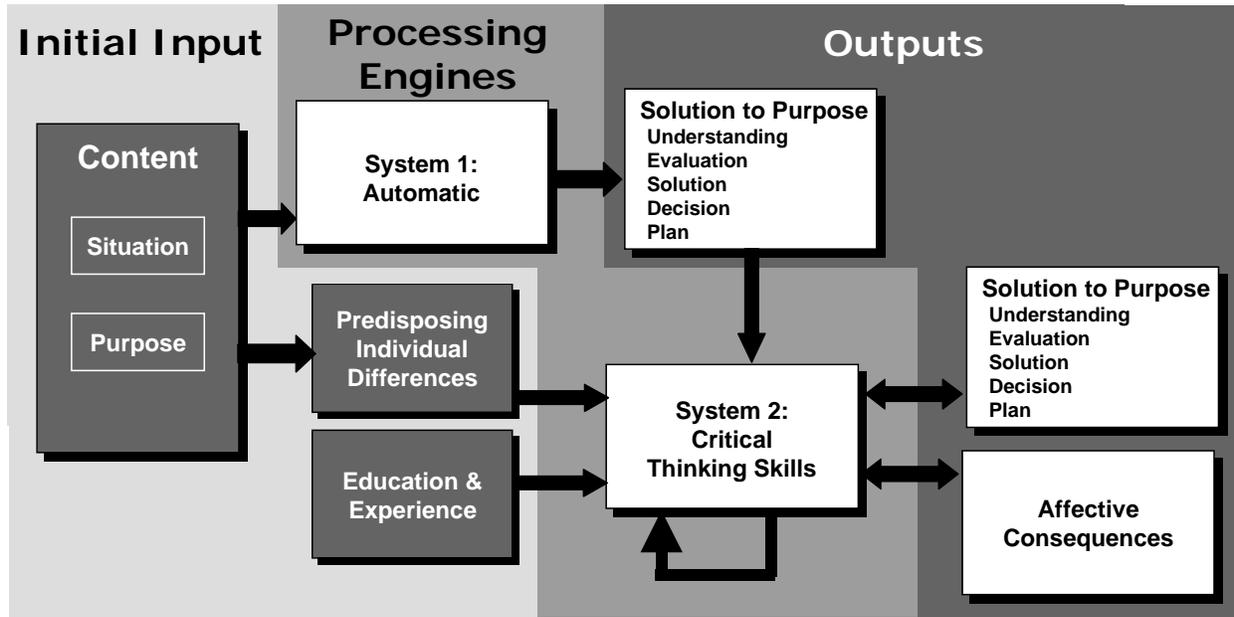


Figure 1. Model of critical thinking (Fischer, et al., 2008b).

The results of this investigation failed to support the hypothesis that predisposing individual difference factors affect the tendency to engage in CT skills. A “Need for Cognition” (NFC) scale failed to correlate with any measure of CT. However, potential restriction of range problems on the NFC scale may have produced this null effect.

The investigation further found that experience level does affect the application of CT skills. The investigation also found that negative affect was not a simple, direct outcome of CT in this investigation. Instead, it appears that other factors such as type of task and type of material determined the type of affect experienced by participants.

In summary, the model of CT generated a number of predictions that had not been previously empirically tested. The model was sufficiently specified to permit falsification of many of its assertions. The validation experiment tested five of its central predictions, three of which were supported.

The preparatory research also examined the role of CT within the Army and identified either high impact critical thinking skills to train. (Fischer, Spiker, & Riedel, 2008b). Eighteen Army officers at Ft. Hood, Texas, completed a survey that assessed their opinions and experiences concerning CT skills, and predisposing attitudes and situational conditions within the battle command related to CT. The officers were asked to rate how important each of thirteen broad categories of CT skills were to battle command, where battle command applies “to the leadership element of combat power...Commanders visualize the operation, describe it in terms of intent and guidance, and direct the actions of subordinates within their intent. They directly influence

operations by personal presence, supported by their command and control (C2) system.” (Department of the Army, 2001, p. 89). They were also asked to indicate if, in their experience, they had observed problems in the execution of each broad skill category. The survey results were then used to select several categories of skills that are key to effective battle command. Selecting a subset of key CT skills from the set of 13 skill categories evaluated by the officers was accomplished by applying two criteria to the Fort Hood survey data: the mean importance rating and the reported incidence of problems in executing the CT skills. By jointly considering the two criteria in the selection process, eight CT skills were selected and became the target skills to be trained in (CT)². The results also indicated that the CT model largely captures the skills, situational conditions, and predisposing factors significant to Army leadership.

Before developing the prototype for (CT)² however, lessons learned were gathered from (1) the civilian research literature on training CT and (2) current efforts to teach CT to Army officers. The literature review (Fischer, et al., 2008b) found that educators have used a wide variety of methods to teach CT. These were inventoried in Fischer, et al., 2008b. However, only a small proportion of those methods have been empirically validated. Lessons learned from educators at the Command General Staff College (CGSC) at Fort Leavenworth, Kansas State University, and the Army War College revealed a number of issues (Fischer, et al., 2008b). Respondents reported that the biggest difficulty instructors experienced came from the Army itself. Specifically, Army culture tends to discourage thinking to some extent. Because of the Army’s hierarchical organization and the requirement for unit cohesiveness, thinking “out of the box” is often discouraged by leaders and by doctrine. For this reason, courses in CT that are electives typically have low enrollments, and students sometimes balk at the content in CT courses.

A final effort of the preparatory research was to integrate the information that had been gathered to establish functional requirements for (CT)². The research concluded that a CT training system would need to be (1) practically integrated with current Army training methods, (2) administered at multiple levels of training, and (3) readily accessible by instructors and students in a variety of settings such as the schoolhouse or field unit. With these functional requirements in mind, the second phase of the research program was initiated. A complete discussion of the research and results conducted in the preparatory phase can be found in Fischer Spiker, and Riedel (2008a, 2008b, 2008c).

Prototype Development and Evaluation

Prototype Training System for Two Skills

The CT model provided the basis on which to design and develop a prototype training system. The prototype system targeted two of the eight CT skills previously identified. The two skills were “Frame the Message” and “Recognize Gist in Material”. Because the model proposes that CT is a deliberate, systematic awareness of the process and products of one’s own thinking, the prototype training focused on increasing self-awareness. It also targeted common, and potentially serious, errors that people make when they fail to apply the two CT skills. The prototype training program highlighted awareness of common errors and taught specific techniques that can be used to overcome them. It presented the student with real-world situations

and asked them to complete numerous thinking exercises that require the practice and application of CT skills in a variety of realistic settings.

Evaluation of Prototype Training

To evaluate the effectiveness, usability, and student acceptance of the prototype training system, an empirical evaluation was conducted during the second phase of the research program (Fischer, Spiker, & Riedel, 2008c). The central objective of the evaluation was to determine whether the prototype CT training system effectively increases measurable indicators of CT compared to two other learning conditions. The investigation also assessed participating students' attitudes and subjective evaluations of the training as indicators of acceptance and usability. The effectiveness of the prototype system was evaluated in an investigation in which participants from the 85th Reserve Training Division worked through parts of the training. The results of this investigation indicated that military students found the training highly acceptable. Although the sample of participants who used the training was small, it was uniformly positively rated. Users found it interesting and well worth their time. The prototype training also appeared to be generally effective at encouraging critical thinking, at least about messages Army personnel must evaluate. The investigation showed that the web-based prototype enhanced memory for messages, possibly because it encourages greater depth of processing.

The evaluation also showed that the training inhibited the production of (potentially incorrect) inferences that go well beyond what is explicitly given in the message. Participants who took the training made far fewer unjustified inferences than participants assigned to the other two training conditions. Examination of the responses reveals that training participants did make inferences; however, they justified them by pointing out explicit information given in the message that supported their inferences. Therefore, the prototype system appeared to encourage discrimination of what is "known" or "given" from what might be added (i.e., inferred) by the perceiver.

Development and Evaluation of (CT)²

The final phase of the research program, which is the focus of the present report, was devoted to developing a complete Internet-based training package that provides training and assessment components for eight CT skills. The training component contains an extended training version for four of the eight skills.

A user-centered design process was used to ensure that the resulting training and assessment products were usable, useful, and well accepted by potential training populations. Early in the development of (CT)², a panel of Army training experts was convened to review early conceptions of its design. A systematic design process was also used, starting with the development of functional specifications for each training component, proceeding to storyboarding and content development, and then moving to implementing the content on the web. Consistent with the user-centered design philosophy, four formative evaluations were also conducted. In each investigation, Army Soldiers or reservists worked through and evaluated one or more of the training or assessment components. The resulting curriculum is described in the next section.

OVERVIEW OF (CT)² CURRICULUM

We begin with a brief description of the purpose of the training as well as the student population to which this training is targeted. We then outline the specific critical thinking skills that the training addresses. The next section provides a detailed account of the five-step development process that was used and includes technical specifications, content review, storyboarding, software development, and formative evaluations. The section concludes with a description of the products that comprise the training, including pretests, posttests, and the training modules themselves.

Purpose of Critical Thinking Training

The overarching purpose of (CT)² is to provide students and their instructors with a framework for acquiring knowledge of eight key critical thinking skills, learning the basic concepts underlying their application, and receiving interactive practice in exercising these skills in the context of realistic decision-making scenarios using actual battle command materials. (CT)² is intended to raise students' awareness of the need for CT and of their own use of CT. Pretests were developed for each skill and posttests were provided as a means to gauge that students had achieved the enabling and terminal objectives upon exiting the training module.

Intended Population

(CT)² was originally designed for Army captains and majors (O-3 and O-4). However, as content development proceeded, and iterative usability testing with uniformed personnel was performed, it became clear that many of the foundational principles of critical thinking would be equally applicable to Army personnel of lower ranks, including Lieutenants and Non-Commissioned Officers (NCOs). Thus (CT)² was designed for a broad target audience, with few prerequisites needed. Scenarios and vignettes were developed that require only modest exposure to the principles of command and control, the military decision making process (MDMP), basic Army symbology, operations orders, and reporting formats.

This broader target population now includes advanced undergraduates in the ROTC program, West Point cadets, National Guard and Reservists, as well as the more senior captains, majors, and even lieutenant colonels and colonels (O-5, O-6). The original intent was to restrict our training to officers, but usability reviews and interviews with recently returning Operation Iraqi Freedom (OIF) veterans (see formative evaluations later in this report) showed that NCOs are also an appropriate group. In today's military, NCO's have important command responsibilities, and must utilize critical thinking skills on a daily basis, just like their officer counterparts. Hence, the overall target audience for (CT)² is now any Army personnel who will be required to review, comprehend, and respond to battle command materials. At the very least, that would be any Soldier who would be assigned to a tactical operations center (TOC) at the battalion, brigade, division, or corps echelon.

Critical Thinking Skills Trained in (CT)²

The (CT)² approach to training critical thinking is both data-driven and model-based. Empirical data were collected to determine which critical thinking skills were most important and most in need of training. This entailed conducting in-depth interviews with 19 Army officers at Fort Hood (Fischer, et al., 2008b). The results of this survey revealed the types of errors that are most often made during battle command tasks, and thus guided the content of our training. The model of critical thinking, described in Appendix A, was then used to determine how to train the most important of these high-payoff skills. Because the model of critical thinking—and its emphasis upon two systems of information processing—is unique, the approach to training critical thinking is unique as well. As discussed in later sections, we emphasize thinking by doing, where the learner is led to make typical thinking errors. Critical thinking skills are then taught to help identify those errors, correct them, and thus avoid them in the future.

(CT)² is not intended to promote perfect, error-free performance. Rather, the techniques are intended to help Army personnel catch thinking errors that do occur, and correct them, before performance degrades. The ability to recognize one's own thinking errors is the hallmark of a good critical thinker.

The eight high-payoff CT skills trained in (CT)² are summarized in Table 1. The left-hand column gives the name of the skill, while the second column offers a working definition of the skill in practical terms. The third column describes the battle command tasks most directly supported by the skill, with the right-most column specifying the errors and problems most frequently reported with that task. The skills are listed in no particular order. The (CT)² User's Manual (Fischer, Spiker, Harris, & McPeters, 2004), describes how the trainer might wish to organize the sequence of skills in order to maximize training effectiveness.

Table 1. Overview of Eight High-Payoff Critical Thinking Skills

Skill	Definition	Primary Battle Command Task	Battle Command Errors and Deficiencies
1. Frame the Message	The ability to identify the essential elements of a message, understand their relationships, and describe a high fidelity representation of the message.	Clarify the intent of the commanders 1 and 2 levels up	Difficulty in establishing clear and accurate understanding of commander’s intent Difficulty in conveying clear commander’s intent
2. Recognize Gist in Material	The ability to sort through the details in a message (written, graphical, visual, auditory, and/or tabular) and extract the gist therein.	Restate mission objectives provided by upper echelon to write own mission statement	Too much detail in operations orders (OPORDs) that must be filtered to establish gist that supports writing of own mission statement Too little time at lower echelons to accurately extract essence of mission
3. Develop an Explanation that Ties Information Elements Together in a Plausible Way	The ability to: <ul style="list-style-type: none"> • Arrange evidence logically • Highlight the gaps in knowledge. • Develop an explanation or multiple explanations based on evidence • Evaluate explanation(s) for plausibility 	Interpret reports of recent enemy activities in area of interest to estimate enemy intent and predict enemy actions	Overlook seemingly unrelated facts Fail to assess the quality of information Difficulty in filtering excessive information Tendency to embellish enemy activity reports—over-reports of enemy contact and movement Tendency to discount initial reports
4. Generalize from Specific Instances to Broader Classes	The ability to recognize and then classify specific facts/incidents/events as part of a general category.	Interpret reports of enemy disposition	Fail to accurately induce patterns of overall movement based on report instances Tendency to disregard reports that do not match expectations Tendency to inflate information in reports
5. Use Mental Imagery	The ability to accurately create mental images in one’s mind of how resources will be applied and events will unfold within a situation.	Develop scheme of maneuver War game courses of action (COAs)	Fail to visualize events Fail to include sufficient detail in COAs Fail to consider contingencies Fail to consider how plans could go wrong Generate only one COA Fail to consider combat multipliers Difficulty in keeping track of mobile forces
6. Challenge One’s Bias	The ability to consistently reevaluate one’s current view of the situation for prejudice or bias as new information is received.	Change own-unit plans based on new tactical input	Tendency to “fight the plan” General reluctance to change plans
7. Examine Other Peoples’ Perspectives	The ability to view and interpret a set of circumstances from the perspectives of different individuals, different cultures/religions, and different timeframes (historical perspective).	Interpret reports of recent enemy activities in area of interest	Failure to accurately estimate enemy intent
8. Decide When to Seek Information Based on its Value and Cost	The ability to evaluate the need for new information in terms of its cost in: time, resources, risk	Assess current situation	Tendency to spend too much time planning and gathering information Tendency to make quick decisions without gathering more information

DESCRIPTION OF TRAINING

(CT)² is modularized into several components for the eight separate, but complementary, skills. The training modules and associated tests can be selected individually from a learning management system. Figure 2 shows that a pretest, training module and posttest are available for each of the eight skills. An extended training module is available for Skills 1, 2, 3 and 4. These extended modules provide more exercises and more detailed explanations. They each take about 12 hours to complete as opposed to two hours each for the standard modules.

<u>Introduction to Critical Thinking.</u>	
<u>Critical Thinking Use Manual.</u>	
<p>Skill One: Frame the Message</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p> <p>Extended Training Module</p> <p><u>Introduction</u></p> <p><u>Element 1</u></p> <p><u>Element 2</u></p> <p><u>Element 3</u></p> <p><u>Element 4</u></p> <p><u>Element 5</u></p>	<p>Skill Two: Recognize Gist in Material</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p> <p>Extended Training Module</p> <p><u>Introduction</u></p> <p><u>Element 1</u></p> <p><u>Element 2</u></p>
<p>Skill Three: Develop an Explanation</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p> <p>Extended Training Module</p> <p><u>Introduction</u></p> <p><u>Element 1</u></p> <p><u>Element 2</u></p> <p><u>Element 3</u></p> <p><u>Element 4</u></p>	<p>Skill Four: Generalize from Specific Instances</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p> <p>Extended Training Module</p> <p><u>Introduction</u></p> <p><u>Element 1</u></p> <p><u>Element 2</u></p> <p><u>Element 3</u></p> <p><u>Element 4</u></p>
<p>Skill Five: Use Mental Imagery</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p>	<p>Skill Six: Challenge One's Bias</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p>
<p>Skill Seven: Examine Other Perspectives</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p>	<p>Skill Eight: Decide When to Seek Information</p> <p><u>Pretest</u></p> <p><u>Standard Training Module</u></p> <p><u>Posttest</u></p>

Figure 2. Course modules of (CT)².

Pretests

A pretest is provided for each skill for the purposes of 1) enabling student self-assessment of proficiency in application of the skill, 2) increasing student sensitivity to the errors and deficiencies associated with lack of or inappropriate skill application, 3) increasing student self awareness of CT capability, and 4) presenting feedback to initiate the process of learning skill application. While the pretest for each skill requires about the same amount of time (20 minutes or so), pretests differ somewhat in the format employed to meet pretest objectives. Brief descriptions of the pretests for Skill 2 (*Frame the Message*) and Skill 4 (*Generalize from Specific Instances to Broader Classes*) are provided here to illustrate the types of formats employed for the pretests.

The Skill 2 pretest is organized around three short passages that represent the kinds of messages typically encountered by an Army officer, such as intent statements or operational plans. Following each passage, students are required to make four types of responses designed to assess their ability to recognize the gist of a message: 1) writing a one sentence summary to capture the gist of the passage, 2) selecting, from a list, the points that should be included to capture the gist, 3) selecting from a list the statement that best captures the gist, and 4) ranking a set of statements on how closely each is related to the gist of the passage. After the test is completed, feedback is provided on the student's ability to capture the gist of a message.

The Skill 4 pretest is organized around three scenes or scenarios, each involving some type of stability and support operation. Two scenarios are described via photographs in which features and situations must be viewed for a limited time by the student and then classified by responding to questions. The third scenario, described in a situation report, is classified by answering a set of questions. In each case, after the scenes or scenarios are removed from sight, the student is asked to 1) make a classification based on memory of the defining features that were present, 2) report whether certain critical features or elements were present, and 3) identify the critical features that might alter the classification if they were known by the student to be present or absent. After the test is completed, feedback is provided, in the form of a test score, on the student's ability to generalize from specific instances to broader classes.

Posttests

A posttest for each training module is provided for use in assessing student comprehension of the critical thinking concepts presented in the module and for evaluating student capability for applying the skills learned. Posttests vary in format from module to module, depending on what testing techniques were considered most effective in meeting the assessment objectives for the module. Training administrators may employ posttests to evaluate student progress and to identify training weaknesses. Students may employ posttests for self-evaluation of their progress and to identify weaknesses in their critical thinking knowledge and skills.

The eight posttests employ a variety of testing techniques. Multiple-choice questions are used extensively for testing knowledge acquisition and, combined with other techniques, for testing skill application. Many posttests require the application of critical thinking skills to

operational scenarios and sample materials such as messages and photographs. Formats for student responses include classification, matching, ranking and rating by means of dragging-and-dropping items. Analytical responses are also made by selecting items from lists by checking boxes, selecting YES or NO, or selecting TRUE or FALSE.

Standard Training Modules

A standard training module is provided for each of the eight critical thinking skills (see Table 1). The modules were developed to meet Army training needs and to adhere to the four themes and 18 pedagogical principles (Fischer et al., 2008c). Each module requires approximately two hours to complete; however, individual differences among students have been shown to result in a sizable distribution of times around this two-hour target.

Extended Training Modules

Extended training modules are provided for the skills considered most fundamental to critical thinking: Skill 1 (*Frame the Message*), Skill 2 (*Recognize Gist in Material*), Skill 3 (*Develop an Explanation*) and Skill 4 (*Generalize from Specific Instances to Broader Classes*). Each extended training module consists of an introduction and from two to five training elements. The organization of each extended module is illustrated here with a description of the Skill 1 module, which consists of an introduction and five elements. The other extended training modules follow essentially the same approach and format.

The introductory tutorial provides answers to the following questions: What is framing? What is a frame? How does framing help you think? What are the benefits of framing a message? What does a message frame look like? What is the plan for training this skill?

In Element 1 the student learns about structured messages and their frames, and practices identifying correct frames for messages of different structures and matching parts of structured messages to parts of the frame.

Element 2 provides instruction and practice in analyzing unstructured messages. A categorization system is introduced and employed to categorize message components. Practice is then provided in applying the system to messages and, also, in identifying the relationships that exist among message components.

The objective of Element 3 is to teach the student how to identify weak spots in a message. The student is instructed in the six different ways that a message might contain weak spots. He or she is then given practice in identifying these weak spots in sample messages. The student is also instructed and given practice in distinguishing between message components that are weak because they are unclear and components that are weak because the information is uncertain.

Element 4 addresses the resolution of weak spots in a message. The student is instructed in and given practice in procedures that are effective in resolving message weaknesses due to lack of clarity and uncertainty. The student is also instructed and given practice in gauging the

strength of inferences that may be required for resolving weak spots in messages. The final element, Element 5, provides instruction in the difference between evidence and inference, and provides practice in evaluating inferences.

Flexible Use and Progression of Course Elements

The time required to work through all of the training modules in the (CT)² program may exceed the training time available for a group of students. On average, it will take approximately two hours to work through each of the eight CT skills, for a total of 16 hours. If a unit has only 8 hours available for CT training, which 4 modules should be selected? If only 4 hours can be spared for training, which 2 should be selected?

As discussed below, we recommend two possible courses of action for selecting modules/skills for training when time is limited. On the one hand, one can examine the types of errors that each training module is designed to address, and compare those to known or conjectured areas of weakness within one's operational or training unit. Alternatively, one can arrange the skills in order of difficulty, and concentrate on those CT skills that match the unit's present CT skill level.

Because the training materials for each skill were developed as standalone items, none of the training modules are prerequisites for any other. Consequently, either method is valid for selecting a subset of modules for conducting CT training. We next briefly describe how each method could be employed.

Recommended Use - Matching CT Skills to Errors

To use this CT skill selection strategy, the analyst or trainer would first construct a list of the most troublesome or vexing errors/breakdowns in the battle command domain observed in his/her unit. Then, depending on the time available for training, pick the CT skills whose targeted errors best match the ones that have been occurring in the field. Since the listing of battle command errors in Table 1 is only partial, the analyst will have to use his/her judgment to find the best matches. In Table 2, we provide a set of decision rules that could be used to guide selection.

Recommended Progression – Matching CT Skills to Difficulty Level

Another way to select the CT skills to be trained is based on estimated difficulty level. Table 3 categorizes the eight CT skills based on an estimated level of challenge. For simplicity, the skills are grouped into low, medium, or high difficulty level. Please note that these are only estimates, as empirical data concerning relative skill difficulty have yet to be collected. However, this listing provides a reasonable starting point for making a skill selection decision when training time is limited.

Table 2. Decision Rules to Guide Selection of Training Modules

If the unit is having problems understanding, translating, or writing commander’s intent statements or following commander guidance	THEN	Use CT Skill 1: Frame the Message
If the unit is having trouble reading through complex OPORDs, is taking too long in writing their own mission statements, or not able to filter out irrelevant information from mission objectives	THEN	Use CT Skill 2: Recognize Gist in Material
If the unit is having trouble interpreting reports of enemy intent, does a poor job in assessing the quality of information, or is inconsistent in reporting enemy contact and movement	THEN	Use CT Skill 3: Development Explanation that Ties Information Together
If the unit is having trouble extracting patterns of movement based on individual reports or is not able to interpret reports of projected movements accurately	THEN	Use CT Skill 4: Generalize from Specific Instances to Broader Classes
If the unit is failing to consider contingencies, include sufficient detail in COAs, or anticipate how time and place affect how the world looks	THEN	Use CT Skill 5: Use Mental Imagery
If the unit is showing a general reluctance to change a failing plan (i.e., fighting the plan)	THEN	Use CT Skill 6: Challenge One’s Bias
If the unit is failing to accurately estimate enemy intent or is unable to appreciate the other side’s point of view	THEN	Use CT Skill 7: Examine other People’s Perspectives
If the unit is spending too much time planning and gathering information and is unable to make quick decisions without the need to gather more information, or if they tend to make quick decisions without enough information	THEN	Use CT Skill 8: Decide When to Seek Information Based on its Value and Cost

Table 3. Eight Critical Thinking Skills Listed in Ascending Order of Difficulty

Critical Thinking Skill	Estimated Difficulty Level
CT Skill 2: Recognize Gist in Material	Low
CT Skill 4: Generalize from Specific Instances to Broader Classes	Low
CT Skill 1: Frame the Message	Low to Medium
CT Skill 3: Development Explanation that Ties Information Together	Medium
CT Skill 8: Decide When to Seek Information Based on its Value and Cost	Medium
CT Skill 7: Examine other People’s Perspectives	High
CT Skill 5: Use Mental Imagery	High
CT Skill 6: Challenge One’s Bias	High

DEVELOPMENT PROCESS

Figure 3 depicts the five-step process that was used to develop and validate the training materials for (CT)². We began by creating an outline of the functional specifications for each skill. These outlines were then delineated further, amplified with examples, and presented to a panel of subject matter experts (SMEs) as part of a comprehensive content review. The SMEs were instructional developers who had extensive experience in developing training and educational systems for the Army. The feedback loop in the figure represents the modifications to proposed content that occurred as a result of this review. The modified content was then rendered in storyboard form, which included instructional scripts, animation, graphics, and video. The storyboards were then given to the software developer who coded each skill as a series of integrated html pages that were linked to a server-resident database. The pages were subsequently hosted on a web site, and representative portions of the training were given to Army personnel during a series of four usability studies. The feedback loop to Step 3 indicates that comments from the usability studies were instrumental in modifying both the storyboards (conceptual flow) and the actual training materials themselves. Below, we describe each step in more detail.

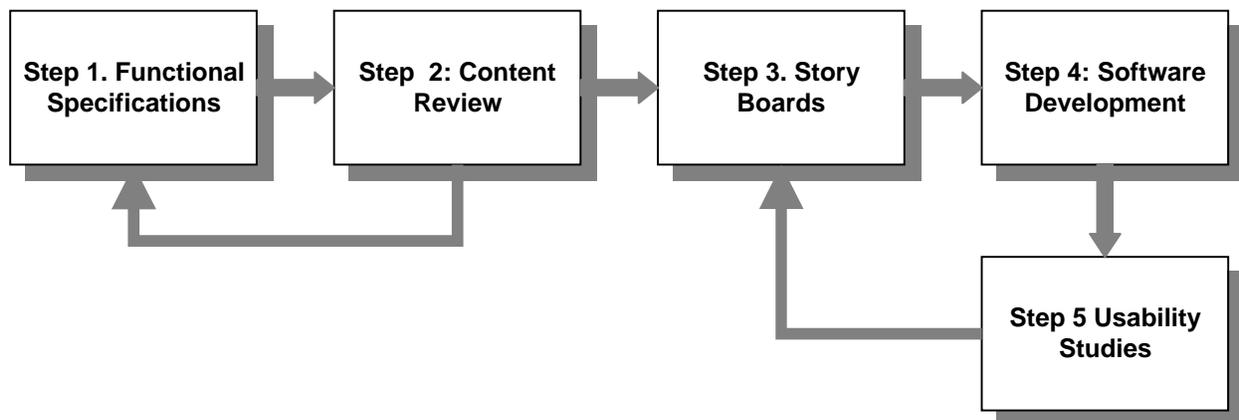


Figure 3. Overview of the five-step development process.

Functional Specifications

We began (CT)² development by creating a detailed outline of the functional specifications for each skill. Figure 4 provides the major organizational elements of those outlines, and some example content, for one of the skills, *Recognize Gist in Material* (Skill 2). Appendix B presents the completed functional specification outlines for all eight skills. For each skill, a template was used by a project training-analyst to begin the process of creating the functional specifications. The organizational elements of the template included the definition of the skill, a description of the cognitive processes underlying the skill, battle command tasks that require that skill, types of errors associated with performing the skill in the field, the terminal and enabling learning objectives for the training of the skill, the other (CT)² skills most closely associated with the skill (i.e., the skill boundaries), the flow of training events that should be used, and the types of training exercises that should be created to achieve the aforementioned learning objectives.

Skill Definition

This critical thinking skill is the ability to sort through the details in a message (written, graphical, visual, auditory, and/or tabular) and extract the gist therein.

Description of Skill

This skill involves the ability to sort through the details of a message and distinguish essential from non-essential information. It involves the ability to generate a clear, concise statement that summarizes the gist or main point of a complex message.

Recognizing and extracting the gist of a message is a useful skill because: . . .

Furthermore, the process of extracting the gist is a useful skill because: . . .

Subcomponents of the skill are: 1) considering context; 2) weighing info, 3) combining & rephrasing info, 4) generating gist statement, 5) reviewing gist statement

Battle Command Task Associated with Skill

The target battle command task for which this skill is required is restating mission objectives provided by upper echelons in order to write one's own mission statements. However, this skill also facilitates: Better memory for and focus on relevant tasks, Better communication, plus others.

Types of Errors that commonly occur when executing this skill: 1) Failure to distinguish relevant from irrelevant information, 2) Failure to eliminate less important details from central meaning of message, etc.

Learning Objectives for this Skill

This training module will focus on a set of learning objectives that constitute aspects or components of this CT skill. These are: 1) Recognizing good and poor quality gist statements, 2) Identifying errors in extracting the gist, 3) Understanding the importance of context, etc.

Skill Boundaries

The most closely related skill is CTS 1, Framing the Message. CTS 2 also contains elements relating to CTS 6, *Challenge One's Bias*.

Flow of Training

1. The training will begin with an interactive experience that shows the student how extracting the gist of a message is in essential to communication and decision making.
2. The second section will review the qualities of a good gist statement, and common errors people make in extracting the gist
3. The third section will review a 5-step technique to systematically and accurately extract the gist from complex messages. This section will walk the user through a series of brief exercises designed to focus attention on the meaning and purpose of each step.
4. Then, there will be a series of exercises that provide an opportunity for the student to apply the technique they just learned to a variety of military-themed messages.
5. Exercises on applying the technique to non-text messages, such as graphics and tables.
6. Summary of what students are expected to get out of the module, and where it might be applicable.
7. The module will end with a Post test.

Training Exercises

The training will include the following exercises, broadly described.

1. Beginning scenario
2. Training Set 1: Recognizing a good gist statement
 - a. given a non-military example, classify several potential "gist statements" by the type of error
 - b. given a military message example, classify several potential "gist statements" by the type of error
3. Training Set 2: Applying a 5-step technique for extracting the gist from complex messages
 - a. given a non-military example, walk through each of the five steps of the 12-8-4 Technique (read message, reduce message, revise key words, rewrite message, review)
 - b. Apply the technique to a commander's intent statement, military briefing, and enemy message
4. Training Set 3: Applying the 12-8-4 Technique to non-text messages (graphic and table)

Figure 4. Partial example of a functional specification for CT Skill 2.

Because the skills were developed in a staggered fashion, the functional specifications for CT Skills 1-4 were used as concrete templates for the later ones. In addition, the training analyst responsible for a given skill consulted with the project director and other analysts on a frequent basis during creation of the specifications. These consultations provided skill development with a fresh perspective, and expedited the creation of technical content within a standardized, yet creative, format. Moreover, as the project unfolded, the functional specifications were reviewed and refined to ensure that there was no overlap in content coverage, or any incompatibility in training flow or exercises.

Content Review

To ensure that the training materials were technically consistent with Army doctrine and tactics, and the strategy compatible with the Army's long-term objectives, a panel of SMEs was formed to serve as a formal review board. This user panel consisted of four retired Army officers presently serving as educational specialists for a government-contracting firm under contract to the Army at Fort Leavenworth to develop training curricula for the Command and General Staff College (CGSC). All panel members were well-versed in instructional design, had extensive experience in developing training curriculum at CGSC, and were knowledgeable of the goals of critical thinking training and its potential value for the Army.

Although the overall review was very positive, the panel also offered a number of useful suggestions for modifying our materials and approach. Because the training modules adhered to a common format, theme, and approach, the panel's comments on Skills 3-4 are also applicable to the other six skills. Some of their suggestions for improving the training are given below.

- Consider using the training modules in the context of classroom assignments in addition to using a distance learning approach.
- Use current examples and vignettes to the extent possible. Although historical examples are effective for making certain points, the bulk of the material should be based on current doctrine and tactics.
- Make the language simple and direct, using graphics and pictorial representations whenever possible.
- Target the training for ROTC students or junior officers so that Army personnel of all levels of experience can benefit from critical thinking training.
- Deliver the training in the context of simulated exercises whenever possible.
- Incorporate expert opinion from the areas of learning and human information processing into the review in addition to the Army perspective.

Storyboarding

Using the functional specifications as the basis, an extended narrative description of the instructional content was created. This was done for each skill. These descriptions were then

rendered in a multi-media storyboard. The storyboard, which contained true multi-media capabilities (video, sound, animation), was then rendered within a web-based environment using Flash, dynamic HTML, and JavaScript. The steps involved in developing the system software are described later.

From the beginning, (CT)² was envisioned as individual, knowledge-focused on-line instruction. The training analysts expanded each section of a given skill's functional specifications so that key concepts were illustrated, examples sketched out, and the rudiments of training exercises were constructed. To support this expansion for each module, Word files were created that contained narrative descriptions and explanations, supporting graphics, hyperlinks to roll-over (supplemental) concepts, and practical examples. With the modular Word files as the basis, a multi-media storyboard was then created for each skill. This storyboard was intended to provide a very concrete, explicit framework that would then be used by the software developer to create the web-based content that would serve as the delivered training content.

The storyboard slides did a number of things to increase student interest and make the training content appropriate for an Army audience. First, the extensive text descriptions were replaced with audio voice-over that drastically decreased the amount of reading required of the user. Second, the training flow was revised so that the detailed academic points were simplified and users were given the barebones theoretical information necessary to appreciate the importance and significance of CT concepts. Third, extensive use was made of Army graphics and military examples in order to "draw the user in" to the importance of critical thinking for performing critical battle command tasks. Graphics included maps, tactical sketches, satellite images, photos, and other pictorial information. In creating the narrative voice-over, we were mindful of the beneficial effects on learning that comes from a judicious integration of audio narration with graphic illustration (Mayer, 2001). When completed, the PowerPoint files were quite large (>10MB), owing to the liberal use of graphics, audio, and video. The files were then sent to an ftp site, which the software developer then used as the basis for his Flash/JavaScript/dynamic HTML programming.

In creating the storyboards, significant effort went to transforming the theoretical principles of critical thinking into practical skills. Content was rendered in a PowerPoint form that exploited the learning benefits of audio narration, drag-and-drop interactivity, visual effects (transitions, fade-ins, pop-ups), and high-resolution graphics. Practice was then embedded in the training in a scenario-based, interactive multimedia interface. This interactive environment compels the user to make practical judgments in a credible environment. After the user sees the sensible use of the Skill, the web-based training presents enough of the theoretical underpinnings to cement the principles behind the learning.

Software Development

Due to the ease with which relatively complex user interactions can be developed using the browser-based technologies of HTML, CSS (cascading style sheets), and JavaScript manipulation of the DOM (document object model), these three technologies have collectively come to be known as dynamic HTML (DHTML), and constitute the software for the training.

In addition to DHTML, a variety of other software tools were used to craft the (CT)² training environment. These included: (1) Macromedia Flash™ for creating animations and synchronizing audio; (2) Adobe Photoshop™ for manipulating and compressing graphic files; (3) Macromedia Dreamweaver™ for creating HTML source code; (4) IBServer (a Sourceforge project distributed under the GPL license) as a Windows™-based testing; and (5) Sapien’s PrimalScript™ integrated development environment for Windows™ scripting languages.

From a user interface standpoint, a host of functional capabilities and visual formats were created to support the functional specifications required for the eight skills. In some cases, the capabilities were developed using the services offered by DHTML and supported by the Internet Explorer browser. Other times, new tools and display formats were designed. To illustrate the strategy used for user interface design, Figure 5 depicts a display screen from one of the practical exercises in Skill 1, *Frame the Message*. The “look and feel” of this screen, and the associated functionality, is fairly typical of the instructional content and exercises that populate our training system.

Practice Exercise #1

You are the executive officer of a military intelligence battalion. It is Friday morning and you are arriving at your office. Last night you received a phone call from your HHQ company commander. She told you that one of her soldiers - Terry Jensen - was involved in a domestic abuse incident in military quarters. A sworn statement from the soldier in question, gathered by the military police who responded to the incident is on your desk when you arrive:

Click on WORKSPACE to begin working. WORKSPACE

In the table below, analyze the message by classifying each of its components into the categories of who, what, why, when, where and how. If you drag your mouse over the message, you'll see that some of its components become highlighted. Drag each component to the appropriate place in the table below. Each row of the table should represent a single idea, *usually* a sentence, but not always.

If you want to move a component once you have dragged it to a slot, highlight it then click the "DELETE WORD" button. When you are done with one relationship section, click the "PUT IN RELATIONSHIP TABLE" button to receive feedback and move on to the next relationship.

Our company was deployed until today to support a Division Exercise. We weren't supposed to return until next week. I came home last night and discovered my spouse with someone else in my bedroom. They were both half dressed. I was angry enough that I don't remember everything. But I do remember screaming and throwing whatever I could find in their general direction. I can remember the stranger running past me to leave and I can remember that one of the objects I grabbed and threw hit Pat, my spouse, on the face. When I saw what I had done, I stopped throwing stuff. However, I was still very, very angry. I left the house and went to a bar. I was having a beer when the MPs picked me up.

Relationship 1 of 14

Who	What	Why	When	Where	How

DELETE WORD PUT IN RELATIONSHIP TABLE

Figure 5. Example of the user interface of (CT)².

As can be seen, the text in the upper part of the screen presents the student with a “scenario” that is intended to structure his/her critical thinking in the exercise. The scenario usually indicates the role the student is to play (Executive Officer in a military intelligence battalion), along with contextual and background information that sets the scene (receiving a phone call

from the Commanding Officer (CO) about a domestic abuse incident). Below that is presented some instructions for interacting with the instructional material that is about to follow.

A message then appears that the student must classify using various drag-and-drop tools. Mousing over the text will select it, where drag-and-drop functionality is invoked for moving words and phrases into a relationship table. Buttons at the bottom of the screen let the student operate on the information at a more macro level. The interplay between message analysis, classification, and selection/deletion lies at the heart of our practical, hands-on approach to critical thinking. While other exercises have other tools (e.g., selecting symbols on a map, moving cells in a table), the same basic philosophy applies. As shown by the usability studies described in the next section, this graphics-oriented, interactive-focused approach to training was well received by learners.

FORMATIVE EVALUATIONS: USABILITY INVESTIGATIONS

Due to scheduling constraints, it was not possible to subject all eight CT skills to a comprehensive usability review. Consequently, formative evaluations were conducted on a sample of training components. Nevertheless, we believe this was a legitimate strategy since the pretest, training module, and posttest share many features across skills, including user interface, format, framework, logic, and functionality. Accordingly, user reaction to, and comments on, any subset of pretest/training modules/posttest will apply to the entire set. The results of the usability tests on these samples were then used to inform the other tests and modules.

During April – September 2005, four usability tests were conducted. The sites were Fort Riley, KS; Fort Hood, TX; Fort Lewis, WA; and the 63rd Regional Readiness Command (RRC) Los Alamitos, CA. Table 4 provides an overview of the four usability tests. As can be seen, the usability tests covered the pretests for Skills 1-4 as well as the training modules associated with Skills 2 and 4. A total of 19 Army personnel served as subjects, ranging in rank from lieutenant to major. In addition, one participant was an ROTC cadet.

Table 4. Descriptive Overview of the Four Usability Tests

Location	Date	Participants	Materials Assessed
Fort Hood	26-29 April 05	6/ 2 majors (Artillery), 2 lieutenants (Finance), 2 lieutenants (Medical corps)	Pretest, Skill 3 (<i>Develop Explanation</i>); Pretest, Skill 4 (<i>Generalize from Specific</i>); Training Module Skill 4
Fort Riley	6-10 June 05	5/ 1 majors (Signal Corps), 1 captains (Chemical Corps), 3 lieutenants (Ordnance, Signal, Chemical Corps)	Pretest, Skill 1 (<i>Frame Message</i>); Pretest, Skill 2 (<i>Recognize Gist</i>)
Fort Lewis	26-28 July 05	5/ 2 captains (Armor, Artillery), 2 lieutenants (Signal Corps, Arty), 1 cadet	Training Module Skill 4 (<i>Generalize from Specific</i>)
Los Alamitos Army Reserve Base	10-11 Sept 05	3/ 2 lieutenants (Medical), 1 captain (Engineer)	Training Module Skill 2 (<i>Recognize Gist</i>)

A detailed description of each usability evaluation is available in the technical memoranda published on each investigation (Mautone, 2005; Holder & Fischer, 2005; Holder, Campsey, & Fischer, 2005a; Holder, Campsey, & Fischer, 2005b). Though different training materials were reviewed in the four studies, a common method and procedure was used, as described below.

General Method

All personnel participated as part of a research support request scheduled either during a reserve training weekend or as part of the Army’s Umbrella Week program. All were told their participation was voluntary. For each investigation, the training module and/or pretest/posttest

was programmed in an HTML presentational format and was run via an Internet Explorer web-browser from a laptop computer. The evaluation focused on three main areas:

- (1) *Overall usability*: Were users able to easily navigate the training program? Were the mechanics of the exercises (e.g., the drag-and-drop procedure) clear and easy to use? Did they have any comments or suggestions regarding the format and layout of the module?
- 2) *Instructional methods*: Was the wording easy to follow? Were the lessons, examples, and exercises engaging? Did they feel like they learned something? Was the module worthwhile? Could they see others, perhaps those less experienced, gaining useful knowledge and skills from the training module?
- 3) *Content*: Did the military examples and exercises seem realistic and engaging? Did users understand and agree with the feedback? Did the scenarios require too much specialized knowledge? Was the terminology unclear – either for the users or perhaps for others who have less experience?

Each investigation utilized an assortment of assessment techniques, including questionnaires, observation, a think-aloud protocol, and interviews. The variety of data collection methods afforded gathering subjective opinion of the materials as well as objective observations of the training materials' usability.

Two questionnaires were administered using a laptop computer. Examples of each are shown in Appendix C. The first was a demographic instrument that asked about participants' military experience, educational background, Internet usage, and experience with and attitudes toward web-based training. The second questionnaire asked participants to rate and comment on general components of the training module – such as the usability, clarity, logic, usefulness, and length of the training program as a whole. Participants were also asked to answer questions about specific components, such as the usefulness and clarity of the training exercises, feedback, lessons, and introductory sections. Most of the questions used five-point Likert scale ratings (1=strongly disagree, 5=strongly agree) were used.

The experimenter directly observed participant interaction with the materials and took notes on their behaviors, comments, and questions. Participants' on-screen activities were recorded at 6-second intervals using Win-Spy Software 8.3 Pro screen-capturing software. User comments were also tape-recorded.

Participants were instructed to verbalize their thoughts, or “think-aloud,” as they completed each training item. This technique has been shown to be highly effective for uncovering the purpose behind participants' actions, as well as identifying confusing language and issues with navigation (Cordingley, 1989; Kirwan & Ainsworth, 1992). The “think-aloud” data was recorded on audiotape and was supplemented with the experimenter's notes.

The experimenter also used free-form interviews to obtain further data and to clarify issues observed during task performance. Interview procedures depended on the specific issue in question. Questions that did not interfere with participants' natural performance were asked as they worked through the material. Other interview questions were noted and asked after participants had completed their review of the material being evaluated. As needed for

clarification, the experimenter redisplayed particular content to participants or provided paper copies of the material. Issues discovered with the first few participants of each investigation were broached with subsequent participants to solicit a variety of opinions.

General Results

Specific results for each training component are reported in the technical memoranda cited previously. Below, we present examples of the general findings that characterized most or all of the formative evaluation studies. To facilitate presentation, the general findings are organized according to general usability, instructional methods, appropriate user population, and technical content.

Overall Usability

Navigation and Usability. While all participants were generally able to navigate through the program with ease, several expressed a desire for a page counter or progress bar to indicate the amount of material remaining. One participant suggested building a navigation window that provides an outline of the module, allowing users to go back and forth between pages previously visited. To address this issue, a “past pages” link was incorporated into each training module, which allows users to revisit previously seen pages as well see a listing of all pages in the module.

Various minor navigational issues were identified that were specific to each component tested, e.g., confusion about which button to press, inability to find a link, etc. Hence, these navigational issues were corrected in the final version of the program, and those corrections were transferred to all standard training modules. For example, the CT logo designed for the training was removed from every training module page except the first page of each because some reviewers thought it was a link. Based on participants’ comments, additional changes were made to the formatting (e.g., bolding, color, italics) of the text in the training components evaluated to direct users’ attention to appropriate navigational cues, and these changes were made throughout all training components. Participants also requested the ability to cut and paste their own typed-in text to reduce typing effort. This capability was provided in all modules in their final versions.

Understandability. The reading level required for each training component was evaluated with standard word processing tools. Changes were made to any text that exceeded a ninth grade reading level, and such modifications were made prior to usability testing. Thus, materials presented to participants in the usability evaluation were at a ninth grade reading level and users generally thought that they were understandable. However, there were elements of each training component that was evaluated that confused particular participants; modifications were made to the final versions to address those confusing elements.

Length. All participants thought the pretests and posttests lengths were “just about right.” Evaluators of the Skill 2 training module thought that this module was a little too long and repetitive. The length of this module was reduced in the final version, although it remains the longest module incorporated in (CT)².

Graphics. Skill 4 (*Generalize from specific instances*) tests and training made extensive use of photographic stimuli for presenting examples and illustrating principles. Several participants expressed a desire to zoom in and out of the pictures to permit detailed aspects of the picture to be more closely scrutinized. For some graphics, then, a zoom function was added. However, rather than providing a zoom function for all graphics, some graphics were enlarged to address this issue. All participants responded that the viewing time for graphics was just about right.

In addition, participants made a variety of suggestions to enhance usability. The most frequently occurring suggestion was to shorten the lengths of some of the pages. Thus, page length and amount of required reading was kept to a minimum in each training module. Also, participants found a number of typos, missing words, misspellings, overly long sentences and paragraphs, awkward phrasing, and ambiguous words. These deficiencies were corrected as discovered, and the modifications were incorporated into the next formative evaluation investigation.

Instructional Methods

As noted previously, participants favored web pages in training modules that minimized the amount of required reading. Thus, an instructional method was adopted that utilized the presentation of informational material in audio form in lieu of text that had to be read. Each of the final versions of the standard training modules presents audio files that are linked to relevant graphics presented on the screen. In some cases, the student is presented with both textual material and audio files if the information requires referral or is complex.

Participants also had difficulty following training exercises that included multiple steps, i.e., were complex. Thus, many of the exercises that can be found in the final versions of the standard training modules are simpler than they were originally designed. To simplify the exercises, the number of steps required for their completion was reduced.

All exercises incorporated feedback after each user response. However, participants had varying opinions about the amount and kind of feedback they favored. For example, in Skill 2 (*Recognize Gist*), some participants liked having multiple perspectives pointed out in the feedback section. On the other hand, other participants found this kind of feedback problematic because there was no “right answer” and differing opinions are vague and difficult to comprehend. While the majority of participants indicated that the feedback was informative and clear, an effort was made to limit the use of multiple perspectives (multiple right answers) in feedback. In some standard training modules this kind of feedback is still used because the nature of the exercise itself does not lend itself to a single clear answer. In these cases, the exercise experience was given a higher priority than the feedback.

Although (CT)² was designed to be individual training, the investigations were conducted with groups. Several participants noted the training value of reviewing the material as part of group, where student discussion and instructor feedback clearly facilitated the students’ learning of key concepts. Consequently, group learning should be considered as a potentially valuable educational tool for future implementations of (CT)².

Appropriate Student Population

Most users thought that the training could be effectively provided to students with less experience than captains and majors. It was believed possible and desirable to deliver the training to third and fourth year West Point cadets and ROTC students. Most participants understood the concepts, principles, and illustrations of the CT skills that were presented. They took this to mean that the material could also be presented to student populations that had less experience than themselves.

Technical Army Content

One of the most highly rated aspects of the system concerned the Army contexts and scenarios. Participants thought that setting the exercises in realistic Army scenarios gave credibility to the training. Indeed, participants uniformly endorsed the concrete military examples. However, several users indicated that they would prefer to see such examples right in the beginning of the training, to help users see the relevance of the topic. Hence, the final versions of the standard training modules utilize Army contexts and scenarios early in the training. In short, the Army contexts and scenarios were seen as an asset, and participants found the technical language easy to understand. All modules, pretests, and posttests incorporate realistic Army scenarios.

While there were some comments critical of the particular wording of terms, there was little disagreement regarding the technical veracity of the information being presented. However, a few participants made comments about certain phrases and/or individual pictures. The technical memos (Mautone, 2005; Holder & Fischer, 2005; Holder, et al., 2005a; Holder, et al., 2005b) for each usability evaluation give detailed descriptions of feedback provided by users. For each investigation, user comments were distilled into a three-column table corresponding to item, issue, and suggested improvement. An example of such a table, taken from the evaluation of Skill 4 at Fort Lewis (Holder et al., 2005b) is shown in Table 5. Due to space constraints, this table is only a partial representation of the entire data set collected at this site.

Conclusions

Taken together, the results of the four usability evaluations found that (CT)² was generally well designed, although many specific improvements were needed. Using the data illustrated in Table 5, the desired changes were presented to the system programmer immediately following each usability evaluation. The suggested improvement column (column 3 in Table 5) was the means by which the changes required were communicated. The formative evaluations proved to be a very effective and efficient means for improving the overall quality and relevance of the computer-based training system.

Table 5. Example of the Data Collected from the Usability Evaluations

Skill 4 Generalize from Specific Instances		
Item	Issue	Suggested Improvement
Overall	Pictures have a menu bar when your mouse is over it that covers up important features	Disable the menu bar
Gut Check ex. 1	Participants did not realize they were under time pressure and lost valuable time	Put the timing statement in bold and then flash an in-between screen that tells them they only have 30 seconds
Gut Check Ex 1	Timer counts up	Make timer count down
Gut Check Ex. 1: 2nd response box	Some participants needed a reminder definition of the feature types, especially contextual features	Include roll-overs for the feature column heads with a definition or example
Gut Check Ex. 1: 2nd response box	Order of the feature types is inconsistent with later exercises	Switch order to physical, contextual, then psychological
Gut Check Ex. 1: 2nd response box	When the page scrolls it cuts off the picture although it does not have to	Fix placement of automatic scroll
Gut Check Ex. 1: Photo	Several participants focused on the prominence of black clothing possibly as a sign of mourning.	Consider further for inclusion in the feedback
Gut check Ex. 1: Comparison page	Participants did not notice the compare statement	Make the comparison statement larger and in bold to grab attention
Devil in the Details Ex. 2	Participants could not find the 6 th kidnapper unless you assume it is a driver	Change feedback to say at least 5 and likely 6 with the driver
Illustrative scenario	The word palpable was not known	Change to “strong”
Defining Features page	Under the tank comparison text add some pictures of tanks	Add pictures and words asking which of these are tanks, BMPs, Russian T-55, T-80, Panzer, then Stryker, BTR, consider if they need to actively check yes or no to make it interactive. We can then can have the terrorist paragraph under the screen break to divide the reading (see above)

HARDWARE AND SOFTWARE DESCRIPTION AND REQUIREMENTS

Hardware Requirements

All (CT)² software was developed assuming that the training would be portrayed on mid-range desktop or laptop computers. In particular, the hardware requirements include (1) broadband connection to the Internet in which Internet Explorer (IE) version 6.0 or greater is installed; (2) a video card capable of 16-bit color at a minimum resolution of 1024 X 768 pixels; (3) 17-inch color monitor (15-inch on a laptop); (4) hard disk with 20 – 30 MB of free space; and (5) sound capability.

Software

(CT)² is a SCORM compliant web-based training package. The content structure is primarily made up of HTML pages. However, other media types used in the training include:

- Javascript files (.js)
- CSS Style files (.css)
- Adobe Flash files (.swf)
- image files (.jpg and .gif)
- audio files, (.wav and .mp3)
- video files (.mpeg)
- PDF files (.pdf)

All programming, SCORM and otherwise, is handled on the client side via Javascript. No server side programming (e.g. ASP, PHP, CGI) is used in the training to ensure compatibility with a wide variety of server configurations. All database capabilities of (CT)² are handled through SCORM; therefore, no specific database vendor is required for its use.

At the SCORM level, (CT)² comprises eight skill directories (e.g. Skill 1, Skill 2), as well as directories containing global reference files that are used by all Sharable Content Objects (SCOs) during runtime. Each skill directory is in turn broken down into individual SCOs, housed in separate folders. All SCORM manifest files are included in the root level of the SCOs. As a rule, initiation of each SCO is handled by the index page of its directory.

Consistent with SCORM compliancy standards, the training package is designed to run on an LMS. (CT)² is currently being tested on Moodle, which is an open source LMS. However, any 2004 SCORM compliant LMS should be compatible with each of the training and assessment components of (CT)².

All administrative features of the training can be accessed through an LMS. The following features can be tracked through the LMS database:

- SCO initiation
- SCO page to page movement
- SCO test scores
- SCO time on test

SUMMATIVE EVALUATIONS

To evaluate whether (CT)² increases CT skill, two summative evaluations were conducted. The first evaluation was designed to assess the learning achieved through one training module compared to a control group. This investigation was conducted at Fort Riley, Kansas. The second investigation assessed whether the extended version of the training provides additional learning over and beyond the gains in skill achieved through the standard training module. This investigation was conducted with volunteer ROTC students from the University of California, Santa Barbara.

Investigation 1

The central objective of this investigation was to determine the learning effect of training provided by (CT)² on a particular CT skill. A comparison was made between Soldiers that received (CT)² training and a control group that did not receive (CT)² training. The training component of one CT skill, Skill 8: *Decide When to Seek Information Based on Its Value and Cost*, was used in the investigation. The central hypothesis tested was that participants who complete (CT)² training on one particular CT skill will display superior performance on that skill. Post and pre training assessments were taken on both the experimental and control groups to control for potential variation in pre-training ability.

Method

Participants. Twenty-one male Soldiers participated in the evaluation. Their ranks included 1st lieutenant (n = 5), 2nd lieutenant (n = 4), captain (n = 11), and major (n = 1). Eleven participants were randomly assigned to the no-training condition and 10 were randomly assigned to the training condition. Participants were originally tasked to attend the session as part of a scheduled data collection activity at Fort Riley, Kansas. Upon arrival participants were informed that their participation was voluntary. All participants provided informed consent.

Materials. The materials used in this investigation were a subset of the (CT)² training materials. Specifically, the materials were taken from the training module for Skill 8: *Decide When to Seek Information Based on Its Value and Cost*. Participants were first given a pretest to assess their ability on this skill. This pretest, which was developed specifically for this evaluation, was essentially a parallel version of the post-test component of the module. Participants assigned to the experimental condition then completed the training module for Skill 8. Finally, all participants were given the posttest for the module, assessing the participants' ability to decide when to seek information based on its value and cost. A brief demographic questionnaire was also used. The training items were programmed in an HTML to allow for the intended web-based delivery. The materials were run via an Internet Explorer web-browser from a laptop computer.

Procedure. Upon arrival, participants were greeted, and were asked to select a card that randomly assigned them to the training or no-training group. Then, they were given a brief overview of the project, its purpose, a description of the data collection procedures, and a discussion of how the data would be used. Next, the participants read and completed the consent

form and a demographic questionnaire. After all questions were answered, all 21 participants completed the Skill 8 pretest. After completing the pretest, participants assigned to the no-training group took a 15-minute break, and then completed the Skill 8 posttest. After completing the Skill 8 pretest, the experimental group completed the Skill training module, followed by the Skill 8 posttest. They then completed a posttest questionnaire soliciting their opinions about the training. The experimental group was allowed to take breaks, as desired, while completing the training.

Results

Participants' posttest scores were subjected to a One-Way Analysis of Covariance (ANCOVA) that examined differences in post-test scores between the training and no-training groups, using participants' pretest scores as a covariate to control for baseline skill. The training group performed significantly better than the no training group on the posttest $F(1, 18) = 10.121$, $p < .01 = 59.922$. The pretest and posttest means (unadjusted and adjusted for pretest) are listed in Table 6.

Table 6. Pretest and Posttest Means and Standard Deviations by Group for Investigation 1

Group	Pretest Mean (SD)	Posttest Mean (SD) (unadjusted)	Posttest Mean (SD) (adjusted)
Training (N=10)	50.5 (11.2)	64.0 (8.4)	61.4 (8.4)
No Training (N=11)	42.3 (13.8)	47.7 (12.3)	50.1 (12.3)

Discussion

The results indicate that completing the Skill 8 training module increased a participant's skill at deciding when to seek information based on its value and cost. These findings suggest that (CT)² is effective at increasing learning on this particular skill. Because the training and testing components of each of the eight skills follow a similar pedagogy and presentation format, one might expect that each training module would produce a similar learning effect. However, further research would be necessary to test that assumption.

Investigation 2

The central objective of the second summative evaluation was to determine if an extended training module provides greater learning than the standard training for a particular CT skill. The extended version, of course, requires a greater time commitment than does the standard version. Previous studies had shown that the extended versions took around 10 to 13 hours to complete; whereas the standard training modules were designed to take no more than 2 hours. Hence, the investigation sought to determine if the greater time cost was worth the investment, i.e., paid off in greater learning. This investigation was accomplished with the assistance of the University of California-Santa Barbara (UCSB), Military Sciences Department ROTC Surfriider Battalion. Cadets and cadre from the ROTC department volunteered to participate in the investigation. The central hypothesis tested was that participants who complete an extended training version of a particular CT skill will display superior performance on that skill compared to participants who

complete the standard training module. The research also evaluated participant's subjective preferences between the two versions of the training.

Method

Participants. Twenty-one participants completed the experiment. Eight completed the extended version of the training and 13 completed the standard version. Of these participants, 5 were cadre (instructors) and 16 were cadets (students). Eighteen males and 3 females comprised the participant sample. All participants provided informed consent. For each participant who completed the standard version of the training, a contribution of \$25 was made to the UCSB ROTC Surfrider Battalion's Morale and Welfare fund. For each participant who completed the extended version of the training, \$75 was contributed to the fund.

Facilities and Equipment. The experiment was conducted at the UCSB's Military Science computer laboratory. Six laboratory computers and 3 laptops were used to display the training and other materials in the experiment.

Training Materials. Four components of the Skill 4 (*Generalize from Specific Instances to Broader Classes*) training module were used as materials in this investigation. The pretest component of Skill 4 was used to assess the participants' pre-training ability regarding this CT skill. The extended training version and the standard training version of the Skill 4 module were also used. Following completion of either the extended or standard training version, participants were also asked to complete the posttest component of Skill 4 as a post training assessment of their skill level. The training items were programmed in HTML to allow for the intended web-based delivery. The materials were run via an Internet Explorer web-browser from a laptop computer.

Procedure. Prior to the investigation, visits were made to the UCSB Military Science department to brief the cadre and cadet participants on the purpose of the investigation. Interested parties were invited to sign up to participate in the investigation. Volunteers were randomly assigned to either the standard training condition or the extended training condition. Participants were then assigned time slots to complete their assessment and training obligations.

Upon arrival, participants were greeted and seated at a computer terminal. Participants were then given a brief overview of the project, data collection and use of the data. Then, they were given a brief overview of the project, its purpose, a description of the data collection procedures, and a discussion of how the data would be used. After preliminary questions were answered, participants completed the Skill 4 pretest. After completing the pretest, participants randomly assigned to the extended training condition completed their training, followed by the Skill 4 posttest and a post training questionnaire. The participants who had been assigned to the standard training version followed the same procedure, except they completed the standard training module. After completing the training and questionnaire, both training groups received a short email inquiry once a day for the next 10 work days, asking them to note instances of how the training concepts they learned applied to their everyday affairs. The participants' responses were submitted via email.

Results

Participants' posttest scores were subjected to a One-Way Analysis of Covariance (ANCOVA) that examined differences in post-test scores between the extended and standard training groups, using participants' pretest scores as a covariate to control for baseline skill. There was no significant difference found between the post test performances of the two groups $F(1, 18) = 0.00, p > .05$. The pretest and posttest means (unadjusted and adjusted for pretest) are listed in Table 7. The two groups' averages were almost identical indicating that the extended version did not produce a learning advantage over the 2-hour version as measure by Skill 4 posttest performance.

Table 7. Pretest and Posttest Means and Standard Deviations by Group for Investigation 2

Group	Pretest Mean (SD)	Posttest Mean (SD) (unadjusted)	Posttest Mean (SD) (adjusted)
Extended (N=8)	120.2 (12.3)	174.5 (34.6)	174.4 (34.6)
Standard (N=13)	120.2 (10.3)	174.5 (29.1)	174.5 (29.1)

Participants' subjective ratings of the overall training were analyzed by using an ANOVA comparing the average rating of the extended version to the average rating of the standard version. The ANOVA showed no significant difference in the average ratings of the two groups ($M = 1.84$ for standard version; $M = 1.75$ for extended version. $F(1, 18) = .168, p > .05$). All of the participants, except one in the 2-hour version (who rated the training as 3–neutral), rated the training as either very good (1) or good (2), reflecting positively on the training.

Discussion

The results suggest that the standard training was as effective as the extended training in teaching the skill of generalizing from specific instances to broader classes. Given the limited time often available for extra training, these results suggest that the standard version is sufficient to produce a learning effect. The extended version, then, could be used if a student wanted greater explanation or needed some question resolved. The extended version could serve as supplemental material which could be made available for those trainees who desire additional training or used by instructors for homework or for additional instructional material.

FUTURE RESEARCH

This multi-year research program brings to researchers in the field of critical thinking two important resources that were previously unavailable to researchers. The first is a testable model of CT that can guide future research efforts on the construct. The second is (CT)², which provides an off-the-shelf training package as a vehicle to conduct the research. There are many possibilities for future CT research. Below, we discuss several interesting potential topics.

One of the requirements for (CT)² was that the training be maximally accessible by Soldiers anywhere in the world. Hence, early in its design, the design decision was made that it would be delivered via the Internet. (CT)² was to be a web-based program that would provide distance training, perhaps stand alone, on CT skills important to Army concerns. Informational content is truly unlimited with web-based delivery, and computers possess an exceptional capability to create opportunities for practice. However, distance training, and its web-based instantiation, impose constraints on the content and training experiences that can be delivered to students. We found that the greatest limitation of current web-based training is that it provides only limited capability to deliver feedback to students' responses. For a skill like critical thinking, limitation on the quality and amount of feedback might severely hamper learning. While several evaluations have shown that (CT)² does produce learning and increases CT skill, it is likely that feedback tailored to students' thinking would be more effective. The classic pedagogy that appears to be maximally effective at generating clear thinking is the Socratic method, in which a tutor points out the weaknesses of a student's thinking by asking repeated and pointed questions. The technology to emulate the Socratic method on a computer is available in the form of intelligent tutors. In recent years, largely due to research efforts funded by the United States military, intelligent tutoring technology has reached impressive capabilities. It is now theoretically possible to create computer-based CT training that might meet this high standard of feedback. Future research should explore the possibility of creating a true Socratic training system designed to increase CT skills.

(CT)² rests on the assumption that increasing self-awareness of one's own CT will recursively improve the same. Indeed, the most widely used textbooks on CT (e.g., Paul & Elder; 2001) solely use exercises that increase self-awareness of one's thinking. Yet, the effectiveness of increasing self-awareness on improving thinking skills has not been empirically shown. More research is needed to further investigate the relationship between meta-cognition concerning CT and the effective use of CT.

(CT)² was developed to improve CT in individuals. Yet, an emergent property of team behavior may be its composite ability to critically think. It is not clear whether the most effective teams are composed of members who are all good critical thinkers, or have only one or two members with this skill. The effect of the distribution of CT skills across a team likely interacts with communication capability, level of cooperation and other team characteristics. Team composition and the distribution of critical thinking skills across the team is a new, potentially important, area of study that should be pursued. Further, since critical thinking in the Army is most often conducted as a team activity and in team settings, the examination of the process of team critical thinking and methods to train team critical thinking would be relevant and valuable

research. Preliminary work in this area has been conducted by Cohen and his colleagues (Cohen, et al., 2006).

The relationship between intelligence, ethics and CT has been pursued since Watson and Glaser (1980) first conceptualized CT in the early 1940s. Having progressive political attitudes, these early researchers hypothesized that liberal viewpoints were related to high levels of CT. Since then, others with conservative political perspectives have also maintained that conservatism is an indicator of CT. While the bias is obvious in these positions, the fact remains that we know little about the relationships among intelligence, ethics, and CT. We can create good theories of CT only by knowing, via empirical demonstration, what it is not. The construct validity of CT should be pursued in future research, or the field will continue to follow the fragmented path that has been its course since the 1940s.

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APPENDIX A: MODEL OF CRITICAL THINKING

Critical thinking was first investigated in the early 1940's by two psychologists, Goodwin Watson and Edward Glaser. Watson and Glaser also developed the first test of CT, the Watson-Glaser Critical Thinking Appraisal (WGCTA) (Watson & Glaser, 1980), which is still widely used. Since then, almost all of the thinking and theoretical development of CT has been conducted by educators and philosophers. It is unclear why psychologists have played a small role in this work; however, see Halpern (1996) and Baron & Sternberg (1986) for notable exceptions. Because most of the work on CT has been conducted by educators and philosophers, the construct has not endured the kind of empirical inspection typically bestowed upon constructs developed by psychologists. Its relationship to other, well-established psychological constructs such as IQ, working memory, and reasoning, for example, has rarely been studied. It is the authors' admittedly subjective opinion that the lack of empirical investigation of CT and its relationship to other individual difference dimensions has produced a fractionated view of the construct. Without the grounding of data, theorists have been free to postulate divergent concepts of CT. An effort in philosophy to reach a consensus definition of CT in 1993 had little effect on unifying the field (American Philosophical Association, 1990).

To fill this gap, Fischer, Spiker, and Riedel (2008a) developed a model¹ of CT that is sufficiently specified to permit empirical testing and falsification. The model identifies CT's role within the related fields of reasoning and judgment, which have been empirically studied since the 1950s and are better understood. The model incorporates many ideas about CT offered by leading thinkers (e.g., Paul & Elder, 2001) in philosophy and education. It also embodies many of the relevant variables discussed in the CT literature (e.g., predisposing attitudes, experience, knowledge, and skills) and specifies the relationships among them. The model can, and has been, used to make testable predictions about the factors that influence CT and about CT's psychological consequences (Fischer, et al., 2008b). The model also offers practical guidance to the development of CT training. In this Appendix we briefly review current literature about reasoning and judgment, on which the model is based, and describe the model's main features.

Dual System Theory of Reasoning and Judgment

Prior to the 1950's, the dominant theories held that people made judgments by calculating (1) the probability and (2) the utility of competing options. Although this *rational choice* model took on a variety of forms, all versions posited a rational actor who made calculations of probability and/or utility, and selected the option that had the highest value. In the 1950's, however, researchers began to notice that the model failed to predict *actual* behavior (Meehl, 1954; Simon, 1957). Evidence that falsified the rational choice theory accumulated over the following decade.

In the early 1970s, an alternative theory proposed that people use heuristics, as opposed to the rational weighing of relevant factors, to make judgments. The "new" theory was, and continues to be, supported by empirical investigation. The heuristic theory states that many judgments are based on intuition or rules of thumb. It does not propose that *all* judgments are

made intuitively, just that there is a tendency to use such processes to make many judgments. The most recent versions of heuristic theory, in fact, propose that *two* cognitive systems are used to make judgments (Kahneman, 2003). The first system, *intuition*, is a quick, automatic, implicit process that uses associational strengths to arrive at solutions. The other, *reasoning*, is effortful, conscious, and deliberately controlled.

Since the 1970's, multiple and similar two-process theories have been proposed to explain judgment. To accommodate the multiple theories, many researchers now refer to the implicit associational type of process as *System 1*, and the conscious deliberate process, as *System 2*. The following example, taken from Kahneman and Frederick (2002), shows how these two processes may lead to different judgments.

Suppose a bat and a ball cost \$1.10 in total. The bat costs \$1 more than the ball. How much does the ball cost?

Most people's immediate judgment is that the ball costs 10 cents. This is a response derived from *intuition or System 1*, which again, is quick, automatic, and relies on associations. The strong mathematical association between \$1.10, \$1, and 10 cents leads to this quick, *but wrong*, judgment. The ball can't cost 10 cents because then the bat would have to be \$1, which would make it only 90 cents more than the ball. The more effortful deliberately controlled *reasoning, or System 2*, process usually produces a different, and correct, answer. When people spend the time and effort to think about the problem, they usually realize the ball must cost 5 cents and the bat must cost \$1.05. Hence, in this example, the two systems produce different judgments. It would be a mistake to conclude that System 1 *always* produces different judgments than System 2, however. Nor does System 1 always produce an incorrect answer, nor one that is poorer than one produced by System 2.

In fact, researchers have shown that expert performance in any field, which is commonly the gold standard, is often driven by intuition derived from extensive experience (e.g., Klein, 1999). That said, expert performance is not without fault, and studies have shown that even experts make errors in judgment when well-learned associations lead them astray. The associational processes used in System 1 that make expert performance so quick and powerful are the same processes that are responsible for systematic errors that experts sometimes make. Additional weaknesses of System 1 are that it depends on the quality and amount of experience an individual possesses, and it can't be used effectively in novel situations. System 2 reasoning also has its strengths and weaknesses. While it is highly useful in novel situations and problems, it is also slow and effortful. It usually cannot be utilized concurrently with other tasks and, like System 1, it can also produce wrong judgments.

Most researchers posit that judgments can be made using either system. Some models posit that System 1 is the preferred system because it demands fewer resources and is less effortful to apply. Most recent theories, however, believe that Systems 1 and 2 *run in parallel* and *work together*, capitalizing on each other's strengths and compensating for weaknesses. For example, many researchers believe that one function of the controlled deliberate process is to monitor the products of the automatic process. System 2 is thought to endorse, make adjustments to, correct, or block the judgment of System 1. However, if no intuitive response is accessible, System 2 may be the primary processing system used to arrive at judgment. Sloman (2002) states that the

systems work hand in hand as “two experts who are working cooperatively to compute sensible answers.”

The similarities between descriptions of CT and System 2 are striking. The words “effortful, controlled, deliberate, purposeful, and conscious” are frequently used to describe both. In the next section we will see that the Fischer, et al.’s (2008a) model proposes that CT’s primary function is to monitor and control the judgments produced by System 1 association reasoning. It further proposes that System 2 is the engine that powers CT skills. It follows that errors in reasoning can occur when CT has failed to serve its monitoring and correcting function.

Overview of CT Model

System 1 and 2 Engines. As shown in Figure 1, the CT model assumes that CT skills are executed by System 2.² CT skills serve to monitor, evaluate, and control the judgments produced by the System 1 associational process. Hence, Figure 1 shows that System 1 solutions provide input to CT skills. The two processes are thought to *run in parallel* and *interact* to produce judgments. Because System 1 is truly an automatic and uncontrolled process it cannot be initiated or stopped. For this reason, CT monitors only the *products*, and not the *process*, of System 1. Because System 1 is quick, it often comes to judgment before System 2. However, CT skills executed by System 2 may override, or confirm, that judgment. Therefore, System 2 has the potential for controlling judgment, although it may not always utilize that potential.

CT skills can provide *thorough examination* of the problem at hand. While System 1 typically derives only one solution (Klein, 1999), CT skills can provide multiple potential solutions. System 1 works to narrow possible action paths, which is often highly effective when the task must be accomplished quickly and when the problem space is limited. However, when the problem space is novel or complex or when solutions must be innovative, CT skills are more

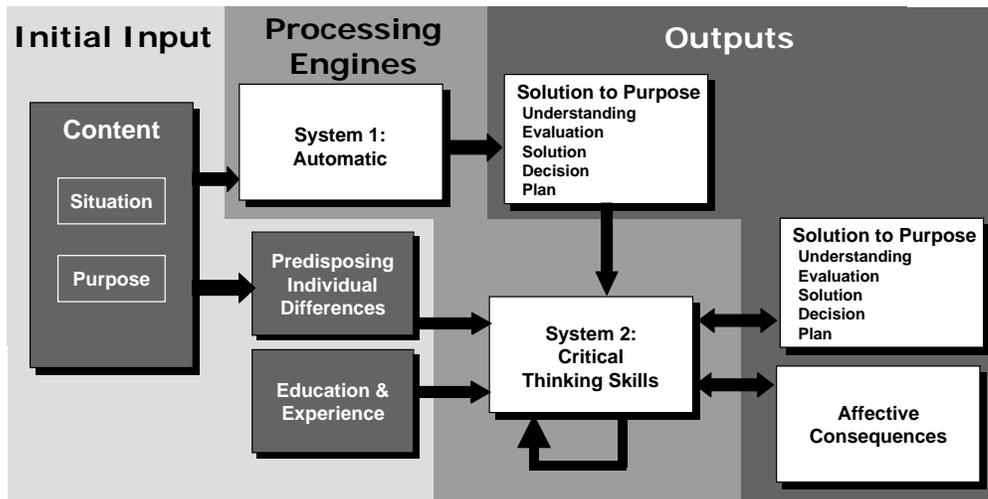


Figure 1. Model of critical thinking (Fischer, et al., 2008b).

We do *not* claim that all processing executed in System 2 involves CT skills, but that all critical thinking requires the kind of analytic, rational processing that only System 2 can provide. For example, System 2 may drive other deliberate processes such as controlled visualization. However, controlled visualization is not considered a CT skill.

powerful. CT skills have the meta-cognitive capability to monitor the progress of their own processing. In this sense, CT is *recursive*, as represented by the arrows leading out and back into the “System 2: CT Skills” processor in Figure 1.

Figure 1 also shows how the processing engines of CT and System 1 interact with environmental and individual factors. Both systems receive initial input from the environment in the form of information about a situation or problem that requires judgment. Part of that input is a meta-task that defines the general *purpose* of judgment. The other part of the input is information about the situation. System 1 immediately and automatically begins processing of the input by searching through its associational network for potential solutions that will satisfy the purpose. CT skills, motored by the System 2 processing engine, receive the same input, filtered through predisposing individual difference factors, which are discussed in greater detail below. CT skills may, or may not, also begin processing at that time. If CT skills are engaged, they will begin to evaluate solutions offered by System 1 or they will apply deliberate reasoning to the problem.

Whether or not CT skills are utilized depends on a variety of factors, including individual predisposition and situational variables. The sum value of these factors provide the impetus to engage in effortful CT skills, but that motivation must exceed some threshold value for CT to be initiated. Let’s examine each component of the model in more detail.

The Context: Situation and Meta-Task. As noted above, the opportunities for judgment are set in motion by contextual factors, which include (1) the situation and (2) purpose (meta-tasks). While the automatic System 1 will engage in all conditions, two characteristics of the situation *must* be present to elicit CT activity. First, stimulus material *must* contain substantive information. Second, there must be sufficient time available to engage in an appropriate CT skill. Other characteristics of the situation make it more likely that CT will be initiated. For example, the presence of conflicting information, disordered or unorganized material, uncertain information, and complex material all make it more likely that CT will be engaged.

CT is not an end in itself, but serves other objectives specified by purpose (meta-tasks). The purpose also dictates the specific response that will be required to successfully end the execution of a CT skill. For example, the situation may include a meta-task to *understand, make an evaluation, make a decision, or solve a complex problem*. Whether final judgment is based on CT or System 1 processing, System 2 determines when the requirements of the purpose have been met. Hence, successful completion of the meta-tasks as determined by System 2 can also provide input that terminates a CT episode, as depicted in the bidirectional arrow in Figure 1.

Predisposing Factors. Predisposing factors influence the likelihood of a person using, or persisting in using, a CT skill. Like features of the situation, they serve as input conditions to CT skill, and as a filter through which the situation and purpose are evaluated. Some may be key factors that strongly affect an individual’s use of a CT skill. Other factors may have a weaker relationship to CT, perhaps increasing the likelihood of engaging in CT by a marginal amount. In summary, predispositions are *measurable* ways in which people differ, whether *fixed* or *modifiable*, that influence the *use* or *persistence of use* of a CT skill.

Moderating Variables, Education, and experience Moderating variables are individual variables that influence how, and how well, CT skills are performed. For example, domain expertise, recent experience, and education influence the quality of the reasoning produced by CT. They do not, however, influence whether one executes a CT skill, as do predisposing factors.

Negative Experiential Consequences. There is a general consensus in the literature that individuals are reluctant to engage in CT. This is based on widespread observation of incoherent reasoning, nonsensical beliefs, lack of respect for evidence, poor CT test scores, and unsupported decision-making in various American populations. Indeed, much of the CT literature is devoted to a movement to increase the application of CT in various populations. One of the central topics has been the question of why the public seems disinclined to use CT. Some theorists posit that individual characteristics, such as intellectual laziness, arrogance and cowardice (which are represented in the model as predisposing individual differences), are the reasons why CT is avoided. The model of CT discussed here, however, also posits that negative affective consequences associated with the application of CT are inhibitory sources.

The model posits that individuals who engage in CT for any substantive length of time are likely to experience negative affective reactions. For example, CT can produce mental fatigue, increased effort, increased anxiety, cognitive dissonance, and decreased self-esteem. Negative affect experienced during a CT episode might be countered by positive affect that is the result of a positive outcome (e.g., solving a difficult problem) that, in turn, is a direct result of CT. Therefore, the application of CT may be positively rewarded and hence, increases in its use may be realized. Some individuals, then, may not experience negative affect associated with CT. But at the very least, by definition, CT requires more effort than System 1 processing, and is therefore a less desirable means to achieve judgment in that limited sense.

Figure 1 shows that affective experiential consequences serve as both a byproduct of CT and as input to the decision to maintain a CT episode, as depicted by the bidirectional arrow in Figure 1. When the affective consequences of applying a CT skill become too negative, the motivation to maintain the episode is decreased. If the negative consequences are sufficiently strong, they may result in a cessation of the episode. It is important to note that research conducted in our lab has indicated that engagement in CT does not always produce corresponding negative affect (Fischer & Spiker, 2004a).

System 1 and 2 Products. As shown in Figure 1, Systems 1 and 2 have the capacity to generate products in the form of judgments. The double arrow leading to and away from System 2 solutions indicates that this deliberate process is capable of evaluating its own products. In contrast, the single arrow leading from System 1 to its judgment product shows that this associational process does not have that same meta-cognitive capability. Note also that the System 1 judgments also serve as input to System 2.

The Quality of Judgment. The *task* posed by a particular situation should not be confused with the system that is used to solve it. For example, one may have the task of understanding a commander's intent statement that could be achieved using associational processes of System 1 or controlled CT skills powered by System 2. Therefore, an individual who is trying to understand an intent statement may or may not be using a CT skill to do so. Even more

important, the application of CT skills driven by System 2 *does not always* produce the best solution to a task. It would be a mistake to encourage consistent use of CT because that strategy would deny the power and effectiveness of System 1. Similarly, it is not advisable to only develop associational processes because controlled deliberate reasoning can (1) produce superior solutions, and (2) provide necessary checks on the products of System 1. Moreover, the issue of which system is most effective is practically irrelevant because most theorists believe that both are almost always used in conjunction to produce a solution. Hence, the real issue that determines the quality of a solution is probably *how well the two systems interact*.

The quality of a solution produced by the application of a CT skill may also be affected by how well the skill is executed. Decrements in performance may be produced by *failing to apply* a component of the CT skill (e.g., failing to clarify ambiguous information in a message or failing to consider alternative explanations for a pattern of data), *failing to accurately perform* a component of the skill, or by *lacking sufficient knowledge* that can be processed by the CT skill. Therefore, one could apply a CT skill and still produce inferior solutions to a task. Moreover, it is not possible to determine whether System 1 or System 2 was applied to derive a solution based on the solution alone. The quality of a solution may also be affected by moderating variables such as educational level and experience. These issues are important to the design of training that seeks to improve CT skills. The model of CT presented here was used to identify a pedagogical approach and principles of training CT. This approach was then used to design (CT)²

APPENDIX B: FUNCTIONAL SPECIFICATIONS

CT SKILL 1: FRAME THE MESSAGE

WHAT THIS SKILL IS ABOUT

Skill Definition

This skill is the ability to identify the essential elements of a message, understand their relationships, and describe a high fidelity representation of the message.

Description of Skill

First, let's consider what is meant by a "message". In this training, "message" refers to any stimulus material that is relevant to a task that must be performed by an Army officer. It may be written on a computer screen, a piece of paper, or in the sand. It might also be an audio transmission, recorded or live. A message does not necessary use language to communicate; it could use graphics. Thus, a message might be a commander's intent statement, a situation map, a decision support template, a radio transmission, and so forth.

Frame the Message is a core skill that critical thinkers use to:

- identify key information elements in a message,
- discern the meaning of all message components, and
- identify what is known and unknown given the message, and
- identify inferences that can be easily derived from the message vs. inferences that can only be derived if certain assumptions (based on uncertain information) are applied

Next, let's consider what is meant by "frame". The frame is not an exact replica of the message. Rather it is a structure that can hold all of the message's components. It is an abstract representation of the message. Just as a carpenter builds a house by first creating the framing or supporting structure - the foundation, the two by four's, the rebar, and so forth - so too, the critical thinker begins his/her analysis of a message by framing its content. The frame of a house provides support for the details it will later enjoy, such as windows, doors, a roof, panels, etc. In a similar fashion, the frame of a message supports the content the message contains. But just as the frame of a house determines many of the structure's features (e.g., size, shape, facilities and functions), the frame a person adopts for a message will determine how that message is understood.

The frame of a message can be regarded as the foundational structure of the information. As a foundation, the frame will:

- indicate the information boundaries, or topics, contained within the message
- represent information given in the message
- highlight the weak or questionable items
- denote how message content elements are related
- indicate content that may be missing from the message
- indicate content that may be incorrect in the message

A Frame is a mental structure that helps us interpret information. Frames provide the scaffolding on which information can "hang". Frames have powerful effects on peoples' understanding of situations, information, and the world around.

Battle Command Tasks Associated with Skill

The target battle command task for which this skill is required is "clarify the intent of the commanders 1 and 2 levels up". However, this skill also facilitates many other military tasks that involve interpreting messages including, but not limited to:

1. Review a mission statement
2. Determine own unit's area of responsibility
3. Determine constraints/restraints placed on mission by higher command
4. Indeed, this skill can be applied to any battle command task that involves the reception and interpretation of a message, whether that message is delivered in print, graphic, or auditory (e.g., radio transmission) form.

Types of Errors

A variety of errors are common when executing this skill:

1. Select wrong frame for message
2. Fail to place information in frame slot
3. Place wrong information in slot
4. Fail to place ALL information in slot
5. Fail to identify or recognize weak spots in message
6. Fail to resolve weak spot in message
7. Make unjustified inferences:
8. Substitute what a message should say for what it does say
9. Interpret content of message to fit preconceived notions
10. Believe that own inferences are given as evidence in message
11. Fail to recognize probability that inferences developed in framing the message is correct or incorrect

Learning Objectives for this Skill

This training module will focus on a set of learning objectives that constitute aspects or components of this CT skill. Upon successful completion of the training, the student will be able to:

1. Identify an unstructured message's components
2. Understand and identify six different reasons why a message may contain weak spots
3. Distinguish between weak messages based on unclear information and those based on uncertain information
4. Understand the steps involved in resolving six types of weak spots
5. Distinguish actual evidence from inferred assumptions
6. Gauge the strength of the inference made in framing the message

Skill Boundaries

The most closely related skill is CTS 2, *Recognize Gist in Material*. The two skills differ, however, in their goals and end products. The goal of *Frame the Message* is to thoroughly examine a message and to represent each of its components, whether they are key or incidental. In contrast, the goal of *Recognize Gist in Material* is to extract and represent only the key components of a message. The ideal end product of *Frame the Message* is a restatement of the message, with each component analyzed and understood to the degree possible. The ideal end product of *Recognize Gist in Material* is a summarization of the message that captures its most important meaning.

CTS 1 is also related to other CT skills and often forms a first step because CT is often based on messages crafted by other individuals. In particular, CTS 1 is related to CTS 6 *Challenge One's Bias*, and CTS 7 *Examine Other Peoples' Perspectives*.

A central challenge in CTS 6 is to recognize and correct confirmation bias, which can also influence how one *Frames a Message*. Confirmation bias, however, can be applied not only to messages, but also situations, explanations, predictions, etc. CTS 1 is limited to understanding messages, whether they are in text, auditory, or some other form.

Examining another person's perspective (CTS 7) can be applied to framing a message crafted by another person. Both skills focus on other people's thinking or products. However, CTS 7 requires and guides extensive inferencing, while CTS 1 attempts to recognize and limit inferences. The goal of CTS 1 is to stick to what is given in the

message, and recognize information that is not given that might be related to inferences that might be made. The goal of CTS 7 is to open one's mind to another person's goals, and to NOT limit one's understanding of another person. By its nature CTS 7 demands careful inference. CTS 1 demands limitations be placed on inferences.

Flow of Training

1. The training will begin with an interactive experience that shows the student how frames are important how they influence thinking. Students will be exposed to messages for which a frame cannot be applied without additional information. The message will be uninterpretable until the frame is given.
2. Then, students will be given a series of exercises designed to promote thorough examination of every component of the message. The exercises will ask students to place each of the message components into a category of agent, object, etc.
3. Going deeper into analyzing the message, students will next be given a set of exercises designed to sensitive them to weak spots (messages components whose meaning cannot be easily accessed from the message alone) in a message. The exercises will ask students to identify if weak spots are present and then decide why they are weak spots.
4. The weak spot exercises will be followed with several exercises designed to train students in the resolution of weak spots.
5. Then, students will be asked to examine inferences that might be made about weak spots.
6. A post test will conclude the training.

Training Exercises

The training will include the following exercises, broadly described.

Training Exercise Set 1: Agent--Object

Training Exercise Set 2: Weak Spots

Training Exercise Set 3: Resolution of Weak Spots

Training Exercise Set 4: Inference Making

CT SKILL 2: RECOGNIZE GIST IN MATERIAL

WHAT THIS SKILL IS ABOUT

Skill Definition

This critical thinking skill is the ability to sort through the details in a message (written, graphical, visual, auditory, and/or tabular) and extract the gist therein.

Description of Skill

This skill involves the ability to sort through the details of a message and distinguish essential from non-essential information. It involves the ability to generate a clear, concise statement that summarizes the gist or main point of a complex message.

Recognizing and extracting the gist of a message is a useful skill because:

- ♦ the gist serves as a convenient shorthand to help communicate
- ♦ the gist is more easily remembered
- ♦ the gist helps one keep focused on the most important issues at hand

Furthermore, the process of extracting the gist is a useful skill because:

- ♦ it requires deeper processing of the message
- ♦ it highlights where clarification is needed
- ♦ it helps one evaluate how parts of the message fit together

Extracting the gist of a message is often an automatic process; people rarely remember a message verbatim, instead they remember the parts that seem relevant to them. This is often referred to as the “take home message.” This process generally works well if the original message is simple and the main points are stated clearly and unambiguously. However, messages have varying degrees of complexity. Some are created for a wide audience, and it is up to the recipients to extract the gist that is most relevant for their purposes. Other messages are wordy or poorly written and the recipient must sift through the details to determine what is and isn’t important.

When extracting the gist, the recipient often attempts to make sense of the message by dropping things that are unfamiliar and by using their prior knowledge to fill in any gaps. This is related to Bartlett’s schema theory, which examined the processes people engage in when remembering and recounting information. Bartlett found that when people retold stories, the stories changed in systematic ways. Specifically, details such as names and places, as well as themes that are unfamiliar to the reader tend to be dropped, while other details, especially vivid ones, tend to be elaborated upon. Another common change is the addition of explanations or rationalizations that are consistent with the readers’ expectations, and which help them make sense of the story.

These systematic changes are normal and expected, but they can also lead to misunderstandings and the distortion of messages, particularly when the gist of the message is passed on from person to person. Other common problems that people have when extracting the gist are being too vague, focusing on supporting details rather than on the main point, focusing on irrelevant details, or missing the main point altogether. Thus, an important part of extracting the gist of a message involves creating a deliberate awareness of how one is evaluating what is and is not important, and requires one to be cognizant of the ways in which messages can be altered or distorted.

Subcomponents of the skill are:

- 1) considering context – why is the author sending the message and what is the recipient’s role?
- 2) weighing the relative relevance of specific bits of information
- 3) combining and rephrasing information to make it more concise
- 4) generating a compact gist statement that is relevant, accurate, and meaningful.
- 5) reviewing the gist statement to make sure that anything that was left out or added does not alter the intended meaning of the message, or lead to possible misinterpretations later on.

Battle Command Task Associated with Skill

The target battle command task for which this skill is required is restating mission objectives provided by upper echelons in order to write one's own mission statements. However, this skill also facilitates:

1. Better memory for and focus on relevant tasks
2. Better communication
3. Opportunity for clarification of the intended purpose of the message
4. Developing solutions and making decisions about what is relevant to one's unit
5. Prioritization

Types of Errors

A variety of errors are common when executing this skill, including:

1. Failure to distinguish relevant from irrelevant information
2. Failure to eliminate less important details from the central meaning of message
3. Writing or presenting overly detailed OPORDS or failure to provide the bottom line up front (BLUF)
4. Failure to accurately extract the essence of a mission
5. Inserting unsupported rationalizations or exaggerating details
6. Leaving out potentially important information merely because it is unfamiliar
7. Being too vague in recounting the gist

Learning Objectives for this Skill

This training module will focus on a set of learning objectives that constitute aspects or components of this CT skill.

These are:

1. Recognizing good and poor quality gist statements
2. Identifying errors in extracting the gist
3. Understanding the importance of context
4. Applying techniques to select and extract central themes and most important points from a message
5. Combining information and revising to make it more concise
6. representing the essential points of a message in a clear, concise manner
7. Checking for unsupported inferences and distortions of the original message
8. recognizing how the process of distilling the main idea encourages deeper processing and can lead to increased ability to remember, evaluate, and use the information

Skill Boundaries

The most closely related skill is CTS 1, Framing the Message. CTS 1 develops the ability to parse messages and examine specific details so that any flaws or weak spots in the message – such as inconsistencies, missing information, ambiguous information, questionable information – can be detected. CTS 2, in contrast, is concerned with filtering out extraneous details and focusing on the most important main point of the message.

CTS 2 also contains elements relating to CTS 6, *Challenge One's Bias*. When restating a message, it is common for personal biases to influence what we remember and what we believe to be important; thus, we may ignore details that don't fit our pre-existing ideas of what the message should say. Likewise, we may exaggerate some details or provide rationalizations that were not in the original message in order to make it fit with our expectations.

Flow of Training

1. The training will begin with an interactive experience that shows the student how extracting the gist of a message is in essential to communication and decision making.
2. The second section will review the qualities of a good gist statement, and common errors people make in extracting the gist
3. The third section will review a 5-step technique to systematically and accurately extract the gist from complex messages. This section will walk the user through a series of brief exercises designed to focus attention on the meaning and purpose of each step.
4. Then, there will be a series of exercises that provide an opportunity for the student to apply the technique they just learned to a variety of military-themed messages.

5. Finally, we'll provide exercises on applying the technique to non-text messages, such as graphics and tables.
6. Training will end with summary of what they were expected to get out of the module, and where it might be applicable.
7. The module will end with a Post test.

Training Exercises

The training will include the following exercises, broadly described.

1. Beginning scenario
2. Training Set 1: Recognizing a good gist statement
3. Training Set 2: Applying a 5-step technique for extracting the gist from complex messages
4. Training Set 3: Applying the 12-8-4 Technique to non-text messages

CT SKILL 3: DEVELOP AN EXPLANATION THAT TIES INFORMATION ELEMENTS TOGETHER IN A PLAUSIBLE WAY

WHAT THIS SKILL IS ABOUT

Skill Definition

This skill is the sum of the abilities to:

- Arrange facts logically.
- Highlight gaps in knowledge.
- Develop an explanation or multiple explanations of the event/phenomenon in question
- Evaluate the explanation(s) for plausibility.

Description of Skill

The essence of the skill is the ability to look at evidence from multiple perspectives, assess its credibility and meaning, and develop one or more explanations that account for the evidence and make sense for the current mission or task. The product of applying the skill is generation of useful evidence-based explanations.

Battle Command Task Associated with Skill

The target battle command task for this skill is to interpret reports of recent enemy activities in the area of interest to estimate enemy intent and predict enemy actions.

Types of Errors

Errors commonly made when executing this skill fall into one of two general categories, prejudicial treatment of evidence and failure to look broadly enough at plausible explanations.

Some typical evidential errors are:

- Ignoring evidence that doesn't fit a preconceived story or preferred conclusion
- Failure to identify important relationships within the evidence
- Failure to distinguish between causal and associative evidence
- Failure to incorporate all evidence into explanation

Examples of explanatory errors include:

- Selecting only explanations that fit a preconceived story
- Constructing causal chains based on prejudice or preference, without evidential justification
- Failure to build more than one explanation, a priori selecting the preferred one or the worst-case
- Judging explanations based on preferred outcome instead of objective standards

Learning Objectives for this Skill

The terminal learning objective for this skill is the ability to see multiple possible explanations in a body of evidence and select, without over-commitment, those that best fit the available evidence.

Upon successful completion of the training, the student will be able to:

1. quickly generate multiple explanations
2. quickly organize evidence, and to be aware of gaps
3. see relationships among elements of evidence, both reinforcing and disconfirming
4. connect evidence to explanations without distortion
5. select explanations based on dispassionate assessment of fit with evidence

Skill Boundaries

Because comprehension of the situation is central to so many battle command tasks, this skill overlaps with other skills. Frame the Message, Generalize, Recognize Your Biases, Decide When to Seek highly related to Examining Other People's Perspectives as they will inform alternative explanations.

Flow of Training

1. The training will begin with exercises that give students the opportunity to generate multiple explanations.

2. Then, students will be taught principles of gathering and organizing evidence.
3. Going deeper into the validity and quality of the evidence students will be given exercises in critically examining evidence.
4. Students will then be taught how to select a working explanation.
5. A post test will conclude the training.

Training Exercises

The training will include the following exercises, broadly described.

Training Exercise Set 1: Generate at least one explanation from these perspectives: first thought, describe the facts, describe the motivation, describe from “their” perspective, describe from my perspective.

Training Exercise Set 2: Create a table of evidence you and don’t have.

Training Exercise Set 3: Check evidence for internal contradiction.

Training Exercise Set 4: Compare explanations using method of triangulation.

CT SKILL 4: GENERALIZE FROM SPECIFIC INSTANCES TO BROADER CLASSES

WHAT THIS SKILL IS ABOUT

Skill Definition

This skill is the ability to recognize and then classify specific observations, facts, incidents, or events into a broader class. This skill is successfully executed when there is: an accurate observation and description of the individual instance, identification of multiple classes to which the instance might be generalized, an assessment of how well the instance fits the different classes, and an indication of how that instance might change over time to fit another class.

Description of Skill

The essence of this skill is the ability to make three types of generalization rapidly and accurately. The three types of generalization are:

- Categorization—putting an instance into a larger bin. Is a fleeing vehicle an enemy BMP?
- Trending—determining whether something is growing, shrinking, or expanding. Is a crowd of potentially hostile local citizens growing or staying steady?
- Reconstitution—determining whether a partially masked or degraded observation is an object of importance. Is a small roadside object with protruding wires an IED?

Battle Command Tasks Associated with Skill

The target battle command task for use with this skill is interpreting reports of enemy disposition based on the availability of only partial information. Other battle command tasks that are aided by this skill include:

- If 2 local citizens are seen on the street, does that mean a (potentially hostile) crowd is forming?
- If a roadside mine is detected, does that mean a mine field is nearby?
- If we see a partially cloaked individual with some characteristics of a terrorist, does that mean he is one?
- If we see some elements of a motorized rifle regiment, does that mean the rest of the unit is nearby?
- If we see a partial glimpse of a low, fast flyer, is it an enemy or neutral aircraft?

Types of Errors

A variety of errors are common when executing this skill:

1. fail to accurately induce patterns of overall movement based on report instances
2. tendency to disregard reports that do not match expectations
3. tendency to inflate information on reports

Learning Objectives for this Skill

The terminal training objective is the ability to make rapid, accurate categorizations, trend assessments, and generalizations based on complete descriptions of observed instances.

There are four enabling objectives:

1. Accurately describe observed instances without missing any important features in an unbiased manner.
2. Comprehensively identifying alternative classes in which the instance might fit by considering counter-evidence that would indicate a non-fit.
3. Evaluating how well the observed instance fits into alternative classes by considering the most relevant features.
4. Evaluating how the categorization decision might change over time by considering the relative permanence of the distinguishing features.

Skill Boundaries

The most closely related skill is CT Skill 3, “Generate a Plausible Explanation.” That skill also involves the application of a generalization process, but in that case the focus is on telling a “story” based on tying events together. A major subgoal of that generalization is usually to make some sort of causal inference.

For CT Skill 4, though, the thrust is to generalize from a specific fact, observation, or other “piece of data” to a broader class. In CT Skill 3, the observed instances may be perfectly clear individually, i.e., not degraded or masked,

but there is still a need to tie them together where the story is used to derive a causal inference. But in CT Skill 4, we are focused on isolated instances from which we make a more limited (non-causal) generalization.

So, the type of generalizations that are not addressed in this skill include generalizing in order to:

- make a causal inference
- infer intent
- create a narrative story
- derive some type of an explanation

Flow of Training

The training flow will follow four elements, which include:

1. Describe the observation or instance. This involves describing the observed instance in terms of its relevant features and details.
2. Identify multiple classes that the observation might be an instance of. This involves coming up with alternative categories to which the instance might be generalized.
3. Evaluate fit to multiple classes. This involves comparing the features and details of the observed instance to each of the possible classes and determining which one fits the best.
4. Identify how instance could change over time to fit another class. Once an observation is classified, a determination is made concerning how that classification might change over time.

Training Exercises

A variety of exercises will be utilized in the training module.

1. GUT CHECK is a technique that will require the student to compare his or her intuitions against a more systematic feature check. The technique is designed to show that while one can certainly use their instincts to make an observation and classification quickly, such judgments will result in missing key features and focusing on salient (i.e., noticeable) dimensions at the expense of more subtle, but possibly more important dimensions.
2. DEVIL'S IN THE DETAILS is a technique to teach students how to tell if all the critical features in an observed instance have been examined. It is designed to help make one's observations as complete as possible, by forcing students to list as many features as possible, even ones that do not seem to be important.
3. LOOK BOTH WAYS is a technique that is designed to overcome priming effects and other attention-getting properties of stimuli that tend to "capture" one's focus and make us pick the first classification that comes to mind rather than consider other categories that could be even better candidates.
4. WHAT ELSE COULD IT BE is a technique to train the student how to view likely candidate classes. It is designed to create that "little voice in your head" that is asking what other class the observed instance might be a member of
5. WHERE'S WALDO? is a technique to compare an observed instance with many other classes. It is based on the popular children's book series, where the difficulty of finding Waldo depends on how similar to Waldo are all the other non-Waldo distracters. The more similar they are, i.e., the more features they have in common with Waldo, the more difficult the comparison is since more features have to be reviewed before ruling out alternative candidate classes.
6. IF IT DOESN'T FIT YOU MUST ACQUIT is a technique for teaching students to know how and when to stop checking that the observed instance fits as a member of one or more target classes. The emphasis in this training will be to instill the notion that sometimes there is not enough evidence—i.e., not enough features are associated with the observed instance—to make any type of classification with confidence.
7. DO YOU FEEL LUCKY? is a technique designed to teach students how to assess the confidence level they place in their original classification. It is specifically intended to instill in students the need to recheck their classification whenever their confidence level is low.
8. THERE'S NO FREE LUNCH is a technique that shows that it can be costly not to recheck one's original classification at some later point in time. The training is oriented around a speeded presentation of material, in which there is a cost (in terms of limited time available) associated with stopping the process and rechecking one's original classification.

CT SKILL 5: MONITOR AND CONTROL VISUALIZATION AND EVALUATE ITS PRODUCTS

WHAT THIS SKILL IS ABOUT

Skill Definition

This critical thinking skill is not visualization¹ per se. Rather, it is the ability to monitor and control the visualization process, and evaluate the mental images produced by the visualization process.

Description of Skill

Before consideration of this CT skill, it is important to understand the process of visualization, its purpose, how it benefits the individuals who use it, and its weaknesses. Visualization is used in the military planning process, such as in the Military Decision Making Process (MDMP) and during operations. It involves the ability to use mental images to “see” past, present, and future military situations, and also to predict how situations may evolve. Thus, visualization involves both the creation of static mental images as well as the ability to mentally animate these images over some internally consistent timeline. It allows military personnel to anticipate potential conflicts or problems, allocate resources where they are most needed, and form expectations of future events. Visualization is an individual phenomenon, but through communication, its products may be shared among team members to develop a shared visualization of a situation.

The mental images created by the visualization process are produced automatically without conscious control or deliberation. They are created from past experiences and knowledge about the world. Extensive past experience tends to develop rich, varied, and accurate visualizations. However, extensive past experience can unduly limit and constrain visualization, producing stereotypic visualizations, especially for novel situations. Past experience can also set up expectations and assumptions that are inaccurate when applied to novel situations, or even situations that are only slightly different from those experienced in the past. In other words, past experience is highly beneficial to visualization; but, it can be misleading. This training will provide skills to maximize the value of experience while minimizing the risk.

This CT skill serves the purpose of monitoring and controlling the visualization process. It serves as a meta-cognitive check on the visualization process but It is not about creating the visualizations per se. If, for example, the visualization process focuses on irrelevant details of the situation, the ability to reflect on one’s visualization and then consciously redirect it is one aspect of this CT skill. Or, if the visualized expectations are inaccurate, this CT skill provides a check that may serve to eliminate or modify those expectations. In this way, this CT skill serves the purpose of evaluating the mental images produced by the visualization process. In summary, CTS 5 is the ability to monitor, control, and evaluate the process and products of visualization.

Battle Command Tasks Associated with Skill

The target battle command tasks for which this skill is required are (1) develop scheme of maneuver (2) develop COAs, and (3) war game COAs. However, this skill also facilitates many other military tasks including, but not limited to:

1. The development of contingency plans, alternative actions that might be taken if certain events transpire.
2. One’s actions during the mission by increasing the speed of response, helping to select appropriate responses, and helping to problem solve when unforeseen events or situations occur.
3. Sensitization to relevant cues in the environment related to danger or other factors that may affect the mission.
4. Understanding of the situation.
5. Communication among the staff or team members in the planning stage as well as the execution stage. In the planning stage, people attempt to sync their visualizations of the situation, their actions as a team, their vision of the desired end state, their expectations of what might happen, and their concerns about events that may interfere with successful completion of the mission. In the execution stage, the team can capitalize

Definition of Visualization: *Visualization is the process of creating a static or dynamic mental image that has pictorial qualities in one’s mind of a past, current or future situation.*

on the fact that they share a visualization because it allows them to interpret events in the same way so as to better respond as a team, i.e. supporting each other's efforts, anticipating each other's actions, etc. Importantly, this can be done even when they are geographically separated. It is a process that supports shared understanding among team members.

6. Updating of a strawman model of the situation as the situation unfolds. This updating function is essential to communication to other team units and to command so as to "paint the picture" for the commander

Types of Errors

A variety of errors commonly occur when executing the critical thinking skill of monitoring and controlling visualization and evaluating its products:

1. Failure to visualize key variables during an on-going situation; and instead visualize those that are salient or more accessible
2. Failure to check that the implications of their visualizations are consistent with the actual situation at hand.
3. Intrusion of past experience dominates the visualization, which establishes over confidence and results in a failure to identify important ways in which the new situation differs from past situations.
4. Failure to consider the second and third order effect of actions.

Learning Objectives for this Skill

The training purposely will not cover visualization per se, i.e., the process of creating visualization, but will cover aspects of visualization products related to CT. The focus for the training on this skill is on two components of visualization:

1. The student shall gain skill in checking expectations and assumptions concerning visualized images of past, present, and future experience, and
2. The student shall gain skill in monitoring his/her visualizing of second and third order (indirect) effects.

Enabling objectives include:

1. The student shall gain an understanding of the tendency to base mental images on previous experience and knowledge, and how the resulting mental images may be inaccurate.
2. The student shall increase his/her sensitivity to, and recognition of, their own tendency to base mental images on previous experience and knowledge.
3. The student shall gain skill in checking expectations and assumptions that may underlie his/her mental images.
4. The student shall gain skill in checking the accuracy of his/her mental images.
5. The student shall gain an understanding of the tendency to avoid visualizing second and third order effects.
6. The student shall gain skill in visualizing second and third order effects.

Skill Boundaries

The most closely related skill is CTS 4, Generalize from specific instances to broader classes. CTS 4 develops the ability to (in real time) recognize and then classify specific observations, facts, incidents, or events into a broader class. The stimulus material for CTS 4 is often pictorial. CTS 5, in contrast, considers images that are produced mentally, where the originating stimuli might not necessarily have been external pictorial stimuli.

Flow of Training

1. The training will begin with an interactive experience that shows the student how his/her expectations of how something looks (images of past, present, or future experiences) may be inaccurate. Integral to the training is the notion that the inaccuracy will be due to an over reliance on previous experience and (1) the failure to realize and acknowledge that an expected image may be wrong, and (2) the failure to make checks and seek additional information about how that image may be wrong. Hence, the first experience contained in the first few pages will involve looking at a set of pictures (training set), visualizing scenes related to this first set, viewing a set of "test" pictures and selecting those that they believe are of the training set. This first experience will be made intentionally extremely difficult so that the student will make errors; the point of which is to increase the student's awareness of the tendency to make this error.

A micro-process detail describing the task and kinds of errors we expect people would make follows. First, we expect people to look at a set of pictures at time t and then create an image of what happens at time $t+Y$? Errors might occur because (1) the pictures cannot be a complete representation of the environment, (2) they may lead students to believe one thing (e.g., movement in a certain direction), when in fact there's evidence in the picture set that (e.g., a barrier at the top of the hill) that movement must occur in a different direction, and (3) the training set will not include all militarily important information contained in the situation. Note that you one could invoke a visualization from non-pictorial stimuli, such as a spot report. For example, the subject's task could be to visualize what the enemy will be doing at some time later based on a spot report.

2. Then, there will be a series of exercises that provide an opportunity for the student to make similar predictions about how something will look. These exercises will be easier and will allow students, if they do the appropriate checking on their initial images (whatever that checking may amount to) will do better than if they do not. We'll want maybe 3 exercises of this sort, if time allows.
3. Then we'll transition to the second and third order effects section. The ability to recognize and predict second and third order effects depends on the ability covered in the first section of the training. If a person's images are based on experience and they go unchecked, they will be unable to accurately predict second and third order effects.
4. Then we'll provide exercises on predicting second and third order effects, focusing on the images generated.
5. Training will end with summary of what they might have gotten out of it and where it might be applicable.
6. Post test.

Training Exercises

The training will include the following exercises, broadly described.

Training Exercise Set 1: Check on Images—Downside of Experience

Present students with a set of 5 to 10 pictures of a city, family, OR type of structure. The pictures should be consistent with one another with not much variability. Students will then be instructed to visualize other scenes from the city, which may be cued by specific verbally delivered instructions, or may be generally instructed. Then, students are presented with a test set of pictures, 5 to 7 of them. Some of the pictures would be from the same category of pictures in the study set, some from a different category. The ones from different category would be similar but would have something that indicated they weren't from the same category. The student's job will be to pick which of the pictures best matches their visualization.

Training Exercise Set 2: Indirect Effects

Present student with a historical example, one that is not all that well known, in which a decision was made and as a result of that decision, there were a set of direct effects (1st order). Then, those direct effects in turn caused a set of additional outcomes that are known (2nd order). Those second order effects in turn caused a set of third order effects that history documents.

1. Students are first asked to visualize as many 2nd order effects as they can. THEN, students are given a set of outcomes that MAY have been the direct result of the direct effects (2nd order). Student's task is to select the ones that best match their visualized second order effects. We could then give them feedback about their choices (tell them which actually were 2nd order effects and which were not). There will be no question about the accuracy of the "correct" answers because history would document the facts. The exercise will generate awareness of how many different kinds of things can happen as a result of the effects of actions, and the effects of effects.
2. An additional, related, exercise will be used after the first. It will present the set of second order effects *before* describing the direct first order effects, but after the brief description of the situation and action. Student's job would then be to identify which second order effects were the direct result of a set of first order effects, which would be displayed. This is the Jeopardy version of the first exercise because you get the answer before the question, or in this case, the effect before the cause.

CT SKILL 6: CHALLENGE ONE'S BIAS

WHAT THIS SKILL IS ABOUT

Skill Definition

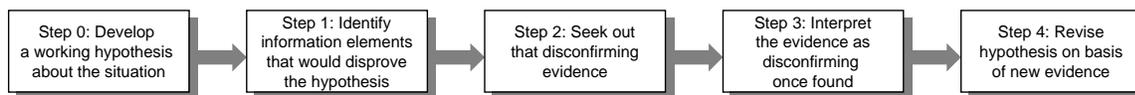
This critical thinking skill is the ability to consistently reevaluate one's current view of the situation for prejudice or bias as new information is received. Specifically, it is the ability to overcome a built-in cognitive bias that all people have—the tendency to collect and attend to information that confirms a hypothesis or belief that we have, at the expense of potentially disconfirming, negative evidence.

Description of Skill

Before considering this CT skill in detail, it is important to understand the erroneous tendency it is designed to overcome, confirmation bias. This bias comes about as a natural result of forming hypotheses or beliefs concerning upcoming events. Our hypotheses help guide us in the search for new information so that our perceptions are not random. However, the price we pay is that our senses are tuned or primed to look for those aspects in the surrounding environment that would confirm the validity of our hypothesis. This tendency, which everyone has, can result in “cognitive tunnel vision,” wherein we either fail to detect any conflicting information, or if we do notice it, we “explain it away” as not being relevant to, or cause for, changing our current beliefs.

A classic example of confirmation bias is found in the 1988 incident onboard the USS Vincennes, which had tragic consequences. During a prologue to the 1990 Iraqi Gulf War, our ships were routinely patrolling in the Persian Gulf waters. The captain of the Vincennes had formed a hypothesis that an approaching aircraft was hostile. Even though some on his crew were uneasy with that rapid assessment, the captain failed to consider alternative hypotheses (e.g., that the aircraft was an Iraqi commercial airliner). As a result, personnel in the ship's Combat Information Center (1) failed to recognize that the aircraft's altitude was increasing, indicating non-hostile intentions; instead it was assumed that its approach profile was descending; (2) incorrectly perceived the airliner's IFF transponder was set to Mode II (military) when it in fact was set on Mode III (commercial); and (3) failed to realize that commercial traffic patterns in their area were such that a prior takeoff in that time period would put an aircraft in a position consistent with the approaching aircraft. Thinking the radar screen contact was a fighter-sized aircraft, they launched a missile attack killing everyone on Flight 655. The captain's tunnel vision, reflecting a confirmation bias, caused him to both (1) fail to look for any evidence that might disconfirm his belief (that the approaching aircraft was hostile) and (2) interpret all new information as consistent with his hypothesis. The results were catastrophic.

We can identify the logical, mental steps that one must go through to properly form and test one's hypothesis about some aspect of the world. These five steps are shown below.



We start by developing a working hypothesis about something in the world that has not happened yet, but might (Step 0). This hypothesis will then guide us in the types of information we look for so that our environment does not seem random. We cover this step in other skills so we will not address it here. Instead, CTS 6 will assume that this step has already been formed. In Step 1, it is important to identify, in advance, the types of information that, if found, would provide disconfirming evidence against our hypothesis. The Captain of the Vincennes failed to perform this step. Had he done so, he would have focused on cues like changes in altitude, IFF mode settings, and the like. In Step 2, the critical thinker must put in place actions that will help ensure that potentially conflicting information is collected if it arrives. In this current example, this would mean having people posted in the CIC whose duty includes continually watching for signs that the prevailing hypothesis might be wrong. It would mean monitoring items such as altitude, IFF mode settings, commercial air traffic so that if counter-evidence is available, it isn't missed.

Once counter-evidence is found, it should be reviewed fairly and not “explained away” (Step 3). In the present example, this would mean that if the CIC had been monitoring the aircraft's altitude and spotted the increase, it would be interpreted clearly (i.e., as something that means no harm), as opposed to some conjecture like: “he's increasing altitude to ensure that he's outside his 'frag' envelope once he releases his bombs.” The final step (Step

4) involves actually revising one's hypothesis once disconfirming evidence has been specified, collected, and interpreted. This will typically involve weighing evidence from multiple sources, not just one, and making the most objective assessment possible given time and resource constraints.

The skill we are describing here is not easy, since everyone is tuned to look for evidence that confirms rather than disconfirms our beliefs. This bias is a known problem in a number of professions, not just the military, where evidence must be collected and interpreted. Thus, we see confirmation bias crop up in areas such as medical diagnosis, weather forecasting, and legal analysis. To compound the problem further, our "cognitive tunnel vision" tends to get even narrower—we miss even more disconfirming evidence—when we are stressed, overloaded, and under time pressure. The techniques we provide under this skill are designed to "widen" one's cognitive vision so that important disconfirming information is identified, collected, and interpreted properly.

Battle Command Tasks Associated with Skill

The target battle command task for which this skill is required is changing own-unit plans based on new tactical input. However, this skill also facilitates:

1. Development of the commander's critical information request (CCIR), in which information "tripwires" are identified to help the commander know, as soon as possible, if conditions on the battlefield (e.g., enemy location, visibility, dispersal of friendly tactical assets) have changed.
2. Tracking the battlefield, where the ability to objectively identify new information, even if it is at odds with what was expected, is needed to determine if a tactical force needs to be reconstituted or the mission objectives need to be modified.
3. Assessing the situation, where planners and analysts need to know which new information will confirm or disconfirm prior assessments, and have the means to collect such information.
4. Inferring status of enemy forces, where a clear, unbiased assessment of enemy intent is needed in order to determine the most effective countermeasures.
5. Developing a common operating picture (COP). The commander and staff must view all new information, even unexpected and "conflicting" (with some currently held belief) information, with a "clear eye" so they may arrive at an assessment that can be synched with commanders of other units who may not be holding the same pre-operational opinions. A COP can only arise if all commands view new, incoming information with an unbiased mindset.

Types of Errors that commonly occur when executing this skill:

1. Failure to identify the evidence that would be needed to disconfirm a currently held view or belief.
2. Failure to identify, when available, evidence that runs counter to one's current beliefs or hypothesis about a given situation.
3. Failure to actively seek out information that would disconfirm a currently held view or belief.
4. Failure to identify how potentially conflicting information could be obtained.
5. Failure to interpret conflicting information as in fact conflicting, but instead interpreting it as consistent with the originally held belief or hypothesis.
6. Failure to integrate conflicting information into the currently held hypothesis and revise one's beliefs accordingly.

Learning Objectives for this Skill

This training module will focus on two terminal learning objectives that constitute aspects or components of this CT skill. Upon completing this training module the student shall gain skill in:

1. Identifying information that will either confirm or disconfirm a presently held belief or hypothesis, and
2. Collecting and interpreting information that can be used to disconfirm a presently held belief or hypothesis.

Enabling objectives include:

1. The student shall gain an understanding of the tendency or bias to ignore information that is inconsistent with a currently held belief or hypothesis.
2. The student shall gain an understanding of the tendency or bias to seek out information that is consistent with a currently held belief or hypothesis.

3. The student shall gain an understanding of the tendency or bias to interpret neutral or irrelevant information as being consistent with a currently held belief or hypothesis.
4. The student shall gain skill in correctly interpreting new information as either consistent with or inconsistent with a currently held belief or hypothesis.
5. The student shall gain skill in revising a currently held belief or hypothesis so that it is consistent with the information that is available.

Skill Boundaries

There are two closely related skills to this skill. CTS 4, Generalize from Specific Instances to a Broader Class, develops the skill to recognize (in real-time) information items as they arrive and then classify them into useful categories. Some of the categories discussed in that skill will serve as working hypotheses (or beliefs) for this skill. CTS 3, Develop Explanation that ties the Evidence together, is a skill that underlies Step 0—Develop a Working Hypothesis—in this skill. Consequently, the first step in the present skill will receive little coverage as it is already addressed in CTS 5.

Flow of Training

1. The training will begin with an example of how confirmation bias can operate insidiously. We'll use the example where the user sees the numbers 2, 4, 6 and we ask them to guess what's next. The underlying rule is "the numbers increase." However, because the pattern looks so mathematically precise, most people tend to focus on rules like "it goes up by two." They then interpret each next number, which might be a 7, or 9, as suggestive of some other, increasingly more complex rule. This exercise will engage the student in an experience of how confirmation bias can put "cognitive blinders" on someone to the point that they fail to objectively review new evidence.
2. As an optional link, we will provide a multi-media illustration of how confirmation bias has caused disasters in military settings. We'll use as our example a fratricide case history that occurred subsequent to the first Gulf War. This involved a breakdown in coordination between Air Force and Army airborne units while patrolling the skies over Iraq (Operation Provide Comfort) in which a two-ship of F-15s ignored available counter-evidence and shot down an Army Blackhawk helicopter. Specific details from that case history will be amplified and shown to link directly to problems with confirmation bias.
3. We'll then go into the first set of exercises, which will collectively address the problems associated with Step 1, Identifying Potentially Conflicting Information. An introductory exercise will expose students to the different forms that a decision-making bias might take, to increase their self awareness. Then the main exercises will require students to reflect on, then list, the type of evidence they would need to change their hypothesis about a situation. The hypothesis they will be forming will vary, from a simple assumption about enemy intent or avenue of approach, to more elaborate battle plans. The exercises would be presented in the form of a what-if game. Part of the skill training will involve listing a series of information elements and asking the student to state whether they confirm or disconfirm that hypothesis. This could be done by dragging individual pieces of evidence into the confirm box or disconfirm box. As a supplemental exercise, we'll have students attempt to "widen their cognitive tunnel" by selecting information they would want (to confirm or disconfirm) from a lengthy list of possibilities. Once again, the "hypothesis" being tested might start off being a simple piece of evidence (e.g., a CCIR) and then become more elaborate, such as a set of (logically, empirically) inter-related assumptions or even a full-blown plan.
4. Then we'll transition into the second set of exercises, which will collectively address the problems associated with Step 2, Collecting Disconfirming Evidence. These exercises will have students actively select each piece of new evidence as it comes in rather than passively observe all evidence. Emphasis will be placed on adopting an active, controlling orientation toward all features in the evidence, including negative (i.e., the absence of confirming evidence). In some cases, students will be instructed to take an "outside view" when they collect the evidence, by addressing the role and influence of contextual information directly. They will learn to view context as part of the stimulus environment they are addressing.
5. We will then administer the third set of exercises, which collectively address problems associated with interpreting potentially disconfirming evidence (Step 3) and revising one's hypothesis based on the new evidence (Step 4). The exercises will all have students operate a "doubt meter," in which they state their current confidence in their hypothesis and update that confidence statement as each new piece of evidence

arrives. On occasional trials, we'll have the student "sift through trash," by reviewing evidence that they had previously "explained away." They'll use this review to recalibrate their doubt meter.

6. Training will end with a summary of what they might have gotten out of it and where it might be applicable.
7. Post test.

Training Exercises

The training will be organized around 3 classes of techniques, each class designed to counteract our tendency to focus on confirming evidence to the exclusion of potentially disconfirming evidence. These techniques will be assembled into a set of exercises that address one of the four steps (excluding Step 0) in the sequence depicted above.

Training Exercise Set 1: Identifying Potentially Disconfirming Information

Introductory Exercise: Self Awareness. Provide several compelling examples of decision making biases, using simple real-world example stimuli, to increase students' self-awareness of the presence of confirmation bias in all that we do. Other related biases (overconfidence, positive testing) will be illustrated as well.

Main Exercise Thread: What-if Game. Students will start with a particular hypothesis as a given. The hypothesis will at first be a single-item hypothesis, and then progress into complex, multi-item hypotheses. For each trial, students will be asked to play a what-if game by considering different pieces of evidence so that IF they appeared, would they confirm or disconfirm their hypothesis. They will drag these what-if items into either a confirm or a disconfirm box. Scores will be posted and times provided as feedback.

Exercise Supplement: Widen your Cognitive Tunnel. On some of the exercises, students will attempt to broaden their perspective (widen their cognitive tunnel) by considering a larger than normal range of information items. They will do this by reviewing a lengthy list of potential pieces of evidence for a given hypothesis. This widening will be designed to help them form, and then consider, alternative hypotheses to their original hypothesis.

Training Exercise Set 2: Actively Collect Potentially Disconfirming Information

Main Exercise Thread: Seeking Evidence. Students will be given some hypothesis and then asked to actively seek out individual pieces of information to confirm their hypothesis. The focus will be on active selection of information as a conscious choice, where they will be required to reflect on why they are choosing to seek out certain pieces of information. Cues and hints will be embedded in the search materials to instill in students the importance of seeking out disconfirming evidence as well as confirming evidence.

Exercise Supplement: Outside Viewing. During some of the search trials students will be shown examples where they are either looking at the information from the "inside," in which contextual information is not considered, or looking at it from an "outside view," where contextual information is considered. These exercise supplements will help students see that contextual information surrounding an event *is* part of the stimulus array and should often be considered just like any other information.

Training Exercise Set 3: Interpreting Disconfirming Information

Main Exercise Thread: Doubt Meter. Students will be given a hypothesis and asked to collect information to test it. As they collect the information, they will be required to state their current confidence level in their hypothesis, where this confidence level will be updated after each new piece of information comes in. The metaphor to be used will be a "doubt meter," expressed as a yardstick whose length the student can manipulate to indicate their current level of confidence. The complexity of the hypothesis will increase progressively over the course of the exercise, starting with simple single-item hypotheses (CCIR present/absent) to multi-item hypotheses (enemy approaches via Avenue A then changes their intent from neutral to hostile) to a full-blown battle plan.

Exercise Supplement: Sifting through Trash. On occasional exercises, as students review individually-presented pieces of information, they will be asked to open the trash to look at previous interpretations that they had discarded (or "explained away"). The training is designed to sensitize students to the dangers of discounting potentially conflicting evidence prematurely. They will recalibrate their "doubt meters" accordingly after each review.

CT SKILL 7: EXAMINE OTHER PEOPLE'S PERSPECTIVES

WHAT THIS SKILL IS ABOUT

Skill Definition

The ability to examine other people's perspectives is the ability to view and interpret a set of circumstances from the perspectives of different individuals, different cultures/religions, and different timeframes (historical perspective).

Description of Skill

The ability to understand other people's perspectives takes conscious and deliberate cognitive effort. Our natural tendency is to interpret and predict others' behavior based on our own goals, intentions, values, assumptions, beliefs, roles and preferences. For this reason, it is very common to misunderstand another's perspective, especially when the other person comes from a different culture or background than one's own. It is almost an automatic response to ascribe meaning to others' actions based on what we ourselves would mean by those actions. There is also a strong automatic tendency to attribute another person's behavior to personal qualities, rather than the circumstances that surrounded the person.

This CT skill involves placing checks on automatic attributions about another person to carefully and consciously examine his or her perspective. Individuals who possess high levels of this skill are able to impede the automatic response, and focus deliberate thought on the examination of other's perspectives. As a result, they demonstrate a better understanding of the other person's goals and intentions and can better predict their future behavior. Individuals who perform poorly in this skill assume that their immediate interpretations of other's perspectives are correct. As a result, their attributions are frequently incorrect.

In both cooperative and adversarial relationships, understanding others' desires and goals is of critical importance. In a cooperative relationship, understanding the perspectives of colleagues, superiors, and those who work at your direction are critical to harmonizing effort for maximum effect. Understanding an adversary's perspective is critical to predicting future behavior. In cooperative and adversarial relationships, there are several major sources from which the future behavior can be predicted. For example, past behavior, the physical capacities and constraints the other faces, the situation, and the other's goals are sources of information that can be used to predict future behavior.

One may understand another person's perspective at the strategic and tactical level. At the strategic level, the task involves understanding another person's (team member or enemy) goals, the history from which they emerge, and the preferred means of pursuing them. At the tactical level, this skill is central to rapidly adapting to evolving events and correctly anticipating what the other is most likely to do next.

Battle Command Task Associated with Skill

The most salient battle command tasks that demand competence in this skill are interpreting reports of recent enemy activities in an area of interest and determining enemy intent. Other battle command tasks that involve this skill include: infer status of enemy forces, interpret reports of enemy disposition, read the battlefield, and track the battlefield, and assess the situation.

This skill is also important to unit effectiveness. Even though any given Army unit shares the general goal or mission, the distribution of responsibilities nearly always means that individual team members will have different perspectives, sub goals, information needs, etc. The ability to accurately understand other team members' perspectives greatly enhances team cohesion and effectiveness.

Types of Errors

The training for this skill will target four general and common types of error in applying this skill:

1. Failure to attribute another's actions or motivation to situational factors.
2. Failure to understand and integrate the assumptions and expectations that underlie or follow from the goals
3. Misunderstanding the costs the other is willing to bear, or to impose, to achieve a goal
4. Inaccurate or inadequate assessment of the uncertainty of each of the three issues above

Learning Objectives for this Skill

The training for this skill targets two learning objectives:

1. Dispassionately understand others' goals, motivations, assumptions, expectations, and the costs they are willing to bear
2. Calibrate the uncertainty in your assessment

Enabling objectives include:

1. Recognizing that understanding others' perspectives is important and difficult.
2. Recognizing that the adversary may have meaningfully different values, assumptions, and expectations than oneself.
3. Recognizing that superficial assessments and failure to learn increases risk and decreases chances of success.

Skill Boundaries

The most closely related skills are CTS 3, 'Develop an explanation that ties evidence together in a plausible way', and CTS 6, 'Challenge one's bias'. Developing an explanation might require seeing things from another person's perspective. Therefore, there is some overlap between CTS 3 and CTS 7. The situation for which an explanation is developed, however, might not involve any other person. Moreover, developing an explanation involves other elements such as tying various elements of a situation together, integrating the circumstantial, material, and personal elements, and making testable predictions. Hence, the two skills can be distinguished.

Challenging one's bias overlaps with examining another's perspective because the bias one needs to challenge may be about another person. CTS 6, however, focuses on the ability to reduce confirmation bias, which is the tendency to seek confirming and avoid disconfirming evidence. Hence, CTS 6 may be used in conjunction with CTS 7 when attempting to avoid confirmation bias about another's perspective. However, the two skills are based in avoiding different types of errors and require different processes.

Flow of Training

1. The student is presented with an opening example that demonstrates that there are alternative ways to interpret others' behaviors and perspectives, and that some ways are better than others. They are given a series of exercises in which they evaluate various reasons why an individual would take a certain action.
2. They are then presented with a series of exercises in which they are required to evaluate a particular scenario from a variety of different individual's perspectives.
3. This is followed by the delivery of information about the fundamental attribution error, in which people commonly make the mistake of attributing dispositional causes to others' behavior but situational causes to their own behavior. This is also called the person-situation bias in this training.
4. They are then given several exercises that require students to identify indicators that they might not be understanding others' perspectives.
5. A series of exercises follows instruction in the PMESII method used by the military, which can be used to better understand others' perspectives.

Training Exercises

The training will include the following exercises, broadly described.

Training exercise Set 1: What does it look like from someone else's viewpoint?

Training Exercise Set 2: Identify "we're not on the same page" indicators.

CT SKILL 8: DECIDE WHEN TO SEEK INFORMATION BASED ON ITS VALUE AND COST

WHAT THIS SKILL IS ABOUT

Skill Definition

This skill involves the ability to evaluate the need for new information in terms of its value relative to its potential costs in time, resources and/or risk. It encompasses the ability to overcome the tendency to spend too much time gathering unnecessary information, as well as the tendency to act too quickly without gathering and analyzing sufficient information.

Description of Skill

Is sufficient information at hand to make an informed judgment, to make a decision with sufficient certainty, or to develop an adequate plan? How does one know? What human limitations must be overcome in acquiring and employing additional information that is appropriate to the task? What is the relationship between the acquisition of additional information, the accuracy of ensuing plans and decisions, and the levels of confidence one has in these plans and decisions? What types of additional information lead to increased accuracy in judgments and what types do not? These questions suggest the challenges involved in developing skills needed for deciding when to seek information based on its anticipated value versus its cost of acquisition.

A substantial body of research has revealed the principal challenges entailed in seeking the appropriate information. Moreover, research conducted with experts in fields as diverse as military operations, weather forecasting, medical diagnosis, stock market analysis and horserace handicapping have shown that the same challenges are encountered consistently. Consequently, a critical component of this skill is the capability to understand and to meet successfully these challenges that will certainly be encountered.

The first principal challenge is that of knowing when one has the minimum information needed to make an informed judgment, because this is the point at which further information seeking should stop. Additional information obtained after this point typically does not improve the correctness of decisions or the accuracy of estimates. Worse, the additional information typically results in unwarranted increased confidence in the resulting decision or estimate.

The second principal challenge is that of understanding just what information is actually being employed in the planning-decision process. Even experienced planners can be unaware of what information they actually use during this process. Research results have shown that most do not realize that their judgments are determined by a relatively few dominant factors rather than by the systematic integration of all available information—that is, most use much less of the available information than they think they do.

A simple investigation illustrates these two challenges; it was conducted a number of years ago by decision researcher Paul Slovic with experienced horserace handicappers. He first asked each handicapper to select, from a list of variables employed in handicapping, the most important 5, 10, 20 and 40 items of information used to handicap a horse race—that is, which he would want to use if limited to only 5 items of information per horse, and similarly if limited to 10, 20, and 40 items. He then gave each handicapper true data on horses from 40 past races and asked him to predict the results of the race four times, using the 5, 10, 20, and 40 items of information for each horse for each race—thus predicting each race four times. Each handicapper also indicated his degree of confidence in his predictions. The handicapper's predictions were as accurate with 5 items of information as they were with 10, 20 or 40; accuracy did not increase as information was added. Even so, the handicappers expressed steadily increasing confidence in their predictions as the amount of information available increased.

But what about the type of information that is added beyond the minimum required? Would not some types of additional information contribute potentially more than others to the accuracy of judgments? There are two types of additional information that are not likely to contribute to the efficacy of the process—additional detail about information items already available and additional information items beyond the minimum required. The main effect of providing supplementary detail about and consistent with information already available and addressed in the process is to increase the confidence in but not the accuracy of the results. And, as discussed above and illustrated

with the horse race example, additional variables are also most likely to increase the confidence in but not the accuracy of the results. Judgments are inevitably based on a relatively few critical variables rather than on the entire spectrum of evidence.

There are two types of additional information that are likely to increase the efficacy of the planning-decision process. The first type is information that corrects or otherwise changes the nature or value of information already available—such as new information that the insurgency group that had been identified and located is twice as large as previously estimated. The second type is information that relates to the relative importance of known variables and how these variables relate to each other. As suggested earlier, the mental models that we use in our planning and decision-making are necessarily simple due to limitations in our information processing capabilities. Thus, in reality, we are limited to employing models that can handle a relatively small number of variables (between 5 and 9), making it important to select the most critical variables. Additional information, then, that helps identify which variables are most important and how they relate to each other adds significant value to the process.

Within the context of the cognitive challenges and considerations described above, cost-value tradeoffs must be made in support of decisions to either act now or collect and analyze additional information. If the decision is to seek additional information, further cost-value comparisons will be required in which different types of information will require different expenditures in terms of time and effort, and in the potential risks of delays in taking action. The principal skill to be developed, then, will be that of assessing alternatives in the face these of planning-decision challenges and selecting courses of action that will be most likely to lead to desired results.

Battle Command Tasks Associated with Skill

The principal battle command task for which this skill is required is that of assessing the current situation. The specific task elements include:

1. Identification of what specific information is lacking or not sufficiently reliable
2. Determination of whether or not sufficient information is available to make informed judgments
3. Identification and verification of specific information that is unusual, unexpected or out of the normal range
4. Assessment of the relative importance to the plan-decision objective of known variables and how these variables relate to each other
5. Assessment of the tradeoff between the potential cost of developing additional information (time, people, material, risk, etc.) and the value of the information
6. Determination of when to stop seeking information when not found/developed

Types of Errors

A variety of errors are common when executing this skill:

1. Failure to determine that needed information is missing
2. Failure to determine that available information is insufficiently reliable
3. Fixation on specific missing information to the exclusion of other possibilities
4. Gathering additional types of information that are not likely to result in increased judgment accuracy
5. Unwarranted increases in confidence related to the collection of additional, unneeded information
6. Failure to identify and verify questionable information
7. Failure to trade off the potential value of information with the cost of obtaining the information
8. Failure to balance time and cost of developing additional information against their possible effects on the mission
9. Failure to terminate the search for information on the basis of value/cost/risk tradeoffs
10. Failure to develop and apply criteria for terminating the search for additional information

Learning Objectives for this Skill

This training module will focus on a set of learning objectives that constitute aspects or components of this skill. Upon successful completion of the training, the student will be able to:

1. Develop an understanding of the two principal challenges related to seeking additional information—1) knowing when one already has the minimum information to make an informed judgment and 2) developing an awareness of the types of information one is actually using in the planning-decision process

2. Develop the capability to identify what specific information is missing or not sufficiently reliable to complete satisfactorily the planning-decision process
3. Develop sensitivity to and skill in the Identification of indicators of questionable information based on observed values of variables—information that is unusual, unexpected or out of the normal range—and seeking information that will serve in its verification or refutation
4. Develop understanding and skill in assessing the relative importance to the planning-decision process of known variables and how these variables relate to each other
5. Develop sensitivity to the costs (time, labor, material, risks) of acquiring additional information and skill in making value-cost tradeoffs when considering the acquisition of additional information.
6. Develop an appreciation of the consequences of continuing to seek additional information when it is not necessary for determining an appropriate course of action, and skill in developing and applying criteria for when to terminate the search for additional information.

Skill Boundaries

This skill is related, to a greater or lesser degree, to each of the other critical thinking skills since each involves some degree of information gathering and analysis. Clearly, time and effort spent to collect unneeded information will cut into that needed for the application of these other skills and also burden battle command tasks with irrelevant information. On the other hand, not taking the time and effort to identify and collect needed information will result in inadequate material upon which to apply these other skills. Thus, inadequacies in the application of this skill can reduce the effectiveness of framing the message, recognizing the gist in messages, developing explanations, generalizing from specific information, creating mental imagery, addressing biases, and examining the perspectives of others.

Flow of Training

1. Start the training with a simple game that requires the student to make tradeoffs between costs of playing and potential payoffs from the actions taken. The objective is to introduce the concept that actions have associated costs and that actions can have maximum payoff only if the associated costs are carefully considered. This initial game will not necessarily relate to military operations or information acquisition, but will be in a context that should be familiar to any student.
2. Introduce the topic of this training session—deciding when to seek information based on its value and cost. An example of a typical problem will be presented and discussed within a realistic or actual military context.
3. Describe and discuss the two principal cognitive challenges related to seeking additional information—1) knowing when one already has the minimum information to make an informed judgment and 2) developing an awareness of the types of information one is actually using in the planning-decision process.
4. Present a series of scenarios in which the student is required to 1) determine whether or not sufficient information is available to take action and 2) if sufficient information is determined to not be available, identify the information that is needed.
5. Present a series of scenarios in which the student is required to identify the five most important variables to be employed in deciding on a course of action. The variables are to be selected from a list that accompanies the scenario. The student then indicates for which variables there is sufficient information available from the scenario and for which variables additional information must be obtained.
6. Describe examples of questionable information based on observed values of variables—information that is unusual, unexpected or out of the normal range—and how seeking additional information will serve to verify or refute its validity.
7. Present a series of scenarios that may or may not have variables with out-of-the-normal range values. The task of the student is to identify these variables and, further, to evaluate the relative importance of each in terms of the effort that should be expended to verify or refute its validity. The assessment will be made employing a five-point rating scale graduated in terms of the amount of expenditure (person-hours) the student would be willing to make.
8. Present information and describe examples relative to the costs (time, labor, material, risks) of acquiring additional information and skill in making value-cost tradeoffs when considering the acquisition of additional information.

9. Present information and describe examples about the potential consequences of continuing to seek additional information when it is not necessary for determining an appropriate course of action. Present considerations and criteria for when to terminate the search for additional information.
10. Present exercises in which value-cost tradeoffs are required for seeking additional information relative to deciding on alternative courses of action. For each, a military scenario (containing the information available) is provided along with three alternative courses of action to be decided upon. The probability of success is degraded differentially for each course of action depending upon the time delay in executing it—time is of the essence. A look-up table provides the costs (person-hours) for acquiring various types of additional information associated with different variables potentially relevant to the action decision and its contribution to the probability of success of the associated action. The exercise is assessed in terms of the probability of success of the action ultimately selected. (Note that success does not depend on knowledge of military courses of action but on the ability to make trade-offs with knowledge about values and costs of additional information provided.)

Training Exercises

The training will include the following exercises briefly described.

Training Exercise Set 1: Out-of-the-normal range values. The task of the student is to identify out-of-range variables and, further, to evaluate the relative importance of each in terms of the effort that should be expended to verify or refute its validity.

Training Exercise Set 2: Sufficient information. The student is required to determine whether or not sufficient information is available to take action.

Training Exercise Set 3: Value-Cost tradeoffs. The student is required to make trade-off decisions about alternative courses of action.

APPENDIX C: FORMATIVE EVALUATION QUESTIONNAIRES

Demographic Questionnaire

Control Number

Rank Gender

Branch Estimate the number of months you have been in a combat zone.

Post Secondary Education Post Secondary Major

Age Dominant Hand

GPA last semester Internet Usage- Average per week

Which Internet Browsers have you used in the past year?

Internet Explorer? Mozilla Firefox?

Netscape Navigator? Other Browser

Which Internet Browser do you use most often?

Please indicate your willingness to use online/web-based distance education training courses in order to further your Army education?

What best describes your work-related experience with web-based training materials?

If you have taken web-based training courses, please rate on the 5-point scale below your experience with these courses?

Record: 1 of 1

Example Usability Questionnaire

Skill 4 Element 2

Control Number

1. Taking this test increased my awareness of the skill of objectively identifying features and classifying events Please elaborate

2. On the scales below, please rate the training on its ability to accomplish the following training objectives

I clearly understand the concepts of defining features, distinguishing features, prototypes and priming effects. Please elaborate

The training clearly explained how to use the available features to generate non-intuitive alternate candidate classifications Please elaborate

The training clearly explained the need to view one's initial, intuitive classification with skepticism, and continue the detective work needed to produce alternative, plausible classifications Please elaborate

I have an internal, refined sense of when sufficient feature review has taken place, so that the process of suggesting alternative classifications can stop Please elaborate

3. Please rate the length of the training materials Please elaborate

4. This aspect of critical thinking (objectively ID features and classifying events) is a skill I would use in my job. Please elaborate

5. The wording of the materials was easy to understand. If not, did it interfere with your ability to use the materials? (Please specify where if possible.)

6. Using the interface to navigate through the materials was easy: Please indicate which features, functions, or tasks were problematic

7. The Army contexts and scenarios increased my engagement in the material. Please elaborate

8. I would be interested in receiving training in other elements of this skill Please elaborate. What factors would increase your interest?

9. I would be interested in receiving training in other critical thinking skills Please elaborate. What factors would increase your interest?

10. The exercises were effective at reinforcing the training material Please elaborate, what did you like or not like about them?

11. Rate the overall quality of the training materials Please elaborate

12. Where in the Army curriculum or one's Army career would this training be most useful?

13. Any additional comments about the training materials

Record: of 2

