Mental Models Underlying Tactical Thinking Skills

Karol G. Ross, Deborah Battaglia, Jennifer Phillips	Eric A. Domeshek
Klein Associates Inc.	Stottler Henke Associates, Inc.
Fairborn, OH	Arlington, MA
karol@decisionmaking.com debbie@decisionmaking.com jenni@decisionmaking.com	domeshek@stottlerhenke.com
James W. Lussier	
U. S. Army Research Institute	
Fort Knox, KY	
James.Lussier@knox.army.mil	

ABSTRACT

Recent research has shown that mental models are constructs for understanding tactical thinking that can also guide the development of training and training evaluation (Ross, McHugh, Harris & Pliske, 2003). In the context of developing an Intelligent Tutoring System (ITS) for teaching tactical thinking skills, we examined themes underlying tactical expertise developed in earlier research (Deckert, Entin, Entin, MacMillan, & Serfaty, 1994; Lussier, 1998). They are (1) Keep a Focus on the Mission and Higher Headquarters' Intent; (2) Model a Thinking Enemy; (3) Consider Effects of Terrain; (4) Know and Use All Assets Available; (5) Consider Timing; (6) See the Big Picture; (7) Consider Contingencies and Remain Flexible; and, (8) Visualize the Battlefield. During the ITS development, we observed 24 instructional sessions in which expert tacticians provided one-on-one tutoring to novices during scenario-based training. One of our research goals was to refine our understanding of how the themes are developed and used. In our analysis of the tutorial session transcripts, we documented developmental stages within each theme, and described the interactions between themes, i.e., the sequence in which the themes are acquired and used as expertise develops. In a subsequent project, we developed concepts of training measurement within the framework of macrocognition. For one measure, we used the themes to guide our development of cognitively based Behaviorally Anchored Rating Scale (BARS) that could assess mental models. As we developed the BARS, we concluded that some of the themes represent mental models and some represent how mental models are used in the performance of tactical thinking. Future research will focus on validation of the macrocognition functions and processes and their measurement.

ABOUT THE AUTHORS

Dr. Karol G. Ross is a Senior Research Associate at Klein Associates Inc. She is currently pursuing research and development on cognitive models of performance in natural environments to support training, systems development and performance evaluation. Formerly, as a Research Psychologist for the U.S. Army Research Laboratory, she conducted research and training development for adaptive tactical thinking training at the Brigade level and development of PC-based simulation training for Field Artillery decision making. She also previously served as a Senior Researcher for BDM International studying battle staff performance and as a Research Psychologist for the Army Research Institute in Heidelberg, Germany working in the area of large-scale simulation training for echelons above Corps. She earned her doctoral degree from the University of Tennessee in Experimental Psychology in 1984.

Deborah Battaglia is a Research Associate at Klein Associates. Her research interests include: theories of leadership and organizational performance; the nature of expertise and skilled performance; and the development of training programs to support decision skills. Currently, Ms. Battaglia is the project leader for an effort sponsored by the Joint Advanced Distributed Learning Co-Laboratory to develop an online Vignette Development Tool to assist training developers in creating scenario-based online training. She also led an effort to develop classroom-based decision skills training for Navy pilots. She previously worked on an effort sponsored by the Army Research Institute to develop decision skills training in urban battle environments for the Army Rangers. In addition, she was a core researcher on an Air Force project to examine the training needs that military operations other than war impose on the service. Ms. Battaglia holds a B.A. in Psychology from the University of Dayton.

Jennifer Phillips is a Research Associate at Klein Associates. Her research interests include the nature and acquisition of expertise, and decision-centered training. Ms. Phillips served as project lead on an Army-sponsored effort to develop decision skills training for small unit leaders in military operations in urban terrain, and recently completed a similar effort to provide decision skills training to Air Force personnel for Operations Other Than War. Ms. Phillips has worked on several USMC-sponsored efforts to re-engineer existing command posts and design experimental combat operations centers. She is currently leading an Army-sponsored program of research to identify the process by which individuals make sense of situations as they unfold, and to develop training that will bolster sensemaking skills. She is experienced in using Cognitive Task Analysis methodologies to capture components of expertise in a range of domains, and has used Cognitive Task Analysis to identify training requirements and for purposes of knowledge management. Ms. Phillips received a B.A. in Psychology from Kenyon College in 1995.

Dr. Eric A. Domeshek is an Artificial Intelligence (AI) Project Manager at Stottler Henke Associates, Inc. He received his Ph.D. in Computer Science from Yale University, where his work focused on cognitive modeling and technology, most especially on development of Case Based Reasoning (CBR). While working as Research Faculty at the Georgia Institute of Technology, he helped launch the EduTech Institute, and became involved in educational applications of AI and CBR. He continued to work on educational and training technology while on faculty at Northwestern University's Institute for the Learning Sciences. For the last three years, Dr. Domeshek has conceived and managed a variety of Intelligent Tutoring System (ITS) projects at Stottler Henke.

Dr. James Lussier has worked as a psychologist at the U.S. Army Research Institute since 1984, and currently works at the Fort Knox Field Unit. Research interests include command and control training, group planning and problem solving, and battlefield thinking skills. He received an A.B. degree in Psychology from Columbia University and a Ph.D. in Experimental Psychology at Fordham University. Lussier served with the US Army as an interrogator with the XVIII Airborne Corps. He holds the title of expert with the United States Chess Federation.

Mental Models Underlying Tactical Thinking Skills

Karol G. Ross, Deborah Battaglia, Jennifer Phillips	Eric A. Domeshek
Klein Associates Inc.	Stottler Henke Associates, Inc.
Fairborn, OH	Arlington, MA
karol@decisionmaking.com debbie@decisionmaking.com jenni@decisionmaking.com	domeshek@stottlerhenke.com
James W. Lussier	
U. S. Army Research Institute	
Fort Knox, KY	
James.Lussier@knox.army.mil	

INTRODUCTION

Recent research has shown that mental models are constructs for understanding tactical thinking that can also guide the development of training and training evaluation. This paper begins a brief discussion of the concept of mental models to situate the subsequent research study that is the focus of this paper. We then describe our observations of mental models in use during scenario-based tactical thinking exercises, and discuss how training can support the development of tactical expertise. We close with a discussion of how this understanding is being used to develop assessments of the impact of training on tactical thinking.

Mental models are internal representations of the external world that describe the dynamics of a particular domain—how things work. These pre-indexed, abstract "packets of knowledge" have been developed over an individual's range of experience. Mental models, or relevant fragments of them, are retrieved and applied for making sense of new situations, understanding how to monitor situations, and deciding how to take action in situations. The depth, breadth, and accuracy of one's mental models comprise the chief distinguishing factors between experts and novices, since mental models are the basis from which other high-level cognitive activities operate.

Developing an expert's knowledge base is not just a simple process of memorizing large amounts of de-contextualized factual information, principles, knowledge, schemata, or of being exposed to a variety of circumstances. Mental models include both contextualized technical knowledge and cause and effect relationships that vary from domain to domain. Just simply knowing a lot of information or rules about situations will not meet the two conditions for a novice to gain expertise.
First, the novice must acquire information in a manner that mentally indexes and stores the knowledge to make it accessible later on. Indexing of information during experiences allows the expert to quickly see through large amounts of information and spot cues in new situations. This indexing and the retrieval of information to form unique, "just in time" mental models in response to a situation may involve the use of several mental models that the practitioner already brings to the situation.

Second, to develop mental models, the novice must practice recognizing cues, forming expectancies, goals, and concepts of action, and performing mental simulation in a variety of contexts under the pressure of real or realistic conditions. One cannot "learn about" mental models to increase expertise, as mental models are not verbally encoded sets of rules or information. In fact, they may not be easily recalled unless the stimulus of an environment or the memory of an experience is present. Therefore, when attempts are made to de-contextualize the model into abstract principles for training, for example, key elements of information and meaning are lost.

When experts confront a new situation, they are selecting relevant information and putting it together based on the goals they have brought to the situation and an initial, quick hypothesis of what is happening. They visualize the situation-specific hypothesis, or what we call a "frame," trying to understand how the "moving pieces" of that situation might work together over time. Experts use deep structures to represent what they are seeing (Larkin, McDermott, Simon, & Simon, 1980). Novices, in contrast, use hastily formed, concrete, and superficial problem representations. Experts create a deep understanding before they apply problem-solving activities.

The development of mental models is a crucial process that interacts with other processes and supports many other functions. When mental models are inadequate, macrocognitive processes and functions like planning, replanning, sensemaking and decision making (for a full description of macrocognition see Klein, Ross,

Moon, Hoffman, Klein & Hollnagel, 2003; Ross, Crandall & Battaglia 2003), all of which are key elements in tactical thinking, can break down in the following ways. (These breakdowns are characteristic of novice performance.)

- Critical cues are not recognized as such.
- Patterns of cues are not interpreted, or are not interpreted correctly.
- Mental simulation lacks an accurate basis on which judgment can occur.
- Relevant data are not noticed, or irrelevant data are deemed relevant.
- Data are misinterpreted.
- Leverage points are not recognized.
- Expectancies are not set, or the wrong expectancies are set.
- Action scripts are unavailable.

The remainder of this paper presents our research about how mental models are used during sessions where expert tacticians tutor novices in tactical training. We then present the implications of this research for assessing training performance. Our research was carried out with U. S. Army and U. S. Marine participants. Therefore, the applicability of these models may be most relevant for the tactician engaged in ground-based missions.

ANALYSIS OF MENTAL MODELS USED DURING TRAINING SESSIONS

Mental models have been identified as the foundation for achieving excellence in tactical thinking, an important skill for preparing officers for battle command (Ross, McHugh, Harris & Pliske, 2003). The tutorial sessions that were analyzed were part of a study for the purpose of building an intelligent tutoring system (ITS). The ITS was built on the Think Like a Commander (TLAC) research program (Lussier, 1998; Lussier, Shadrick, & Prevou, 2003), which provided 8 tactical thinking "themes" that expert tacticians are thought to use. These themes, which were based largely on interviews with numerous tactical experts (Deckert et al., 1994), would provide the instructional foundation for the ITS. The original themes guided analysis of 24 tutorial sessions whereby expert tacticians coached novices through tactical decision games (Schmitt, 1994). The themes and their definitions follow:

Keep a Focus on the Mission and Higher's Intent. This theme refers to the need for leaders to always stay aware of the higher purpose and results they are directed to achieve. Even when unusual and critical events may draw them in a different direction, it is essential to stay focused on the overall mission.

Model a Thinking Enemy. The focus of this theme is on the importance of remembering that the adversary is a reasoning human being who is intent on defeating friendly forces. Although it's tempting to simplify the battlefield by treating the enemy as static or simply reactive, this will harm the troops' ability to fight an effective battle.

Consider Effects of Terrain. This theme reflects the importance of not losing sight of the operational effects of the terrain on which they must fight. Every combination of terrain and weather has a significant effect on what can and should be done to accomplish the mission.

Know and Use All Assets Available. This theme refers to the necessity of leaders to maintain awareness of the synergistic effects of fighting their command as a combined arms team. This includes not only all assets under their command, but also those which higher headquarters might bring to bear to assist them.

Consider Timing. The focus of this theme is on the importance of being cognizant of the time available to get things done. A good sense of how much time it takes to accomplish various battlefield tasks and the proper use of that sense is a vital combat multiplier.

See the Big Picture. This theme refers to the importance of maintaining awareness of what is happening in the environment and how it might affect operations--what courses of action can affect others' operations. A narrow focus on one's own fight can get you blind-sided.

Consider Contingencies and Remain Flexible. Small unit leaders must never lose sight of the old maxim that "no plan survives the first shot." Flexible plans and well thought out contingencies result in rapid, effective responses under fire. Contingencies are characterized by thinking that begins with questions like "What if…?" or "How else can I...?"

Visualize the Battlefield. Leaders must be able to visualize a fluid and dynamic battlefield with some accuracy and use this visualization to their advantage. A leader who develops this difficult skill can reason proactively like no other.

The themes are somewhat arbitrary. Other themes could be used to describe tactical thinking. For example, Spiro, Feltovich, Coulson et al. (1992) used the themes of indirection, deception, balance, boldness, and alternative objectives in their research into cognitive flexibility in the military. These themes were drawn from the military strategy of the "indirect approach" derived from the thinking of Hart (1954).

Other domains like literature or medical diagnostics might address incorporate different themes. In reality, each expert probably has developed their own categorization of principles and mental models specific to their field. The TLAC themes were used because they were drawn from interviews with a number of experts; therefore, they summarized and integrated a general structure of tactical thinking expertise that was drawn from practice rather than imposed on practitioners.

We analyzed the tutorial sessions by each theme and expanded each definition so that there was an explicit stage model of the theme from novice to expert. The stages generally reflected a novice's narrow focus and static concept of the battlefield, the progression to initial abilities to link battlefield elements in a procedural manner, and finally the ability to model dynamic situations and make accurate predictions characteristic of expert performance (Ross, Battaglia & Hutton, 2002; Ross et al., 2003).

FINDINGS: EXPERT TACTICIANS' USE OF THEMES AND INSTRUCTIONAL STRATEGIES

Session transcripts and post- session interviews with the expert tacticians exposed a more sophisticated use of themes than first suspected. *Visualization* was observed as the penultimate skill to teach the novices, with the other themes as building blocks to reach this skill. We define *visualization* as the ability to integrate the use of the other themes in response to a particular situation through the activation of mental simulation. We observed that the 8 basic themes, the adaptation of the themes to understand novel situations, and the process of mentally simulating the themes into a holistic view of the battlefield, can all be tutored. The practice of using the themes in context creates deeper understanding for the student.

The instructors typically started a tutorial session by introducing discrete themes one at a time (e.g., a discussion about *Knowing and Using all Assets Available* in the context of developing a course of action). However, as the session progressed, themes were interwoven by asking the student to engage in mental simulation. The instructor often described his own mental simulation of the situation to model the thinking he desired from the student. To do so, the instructors often had to start with small pieces of a situation (e.g. I know that these air assets will take this amount of time to get on station and can fly for this amount of time before needing to refuel) and slowly building toward a more comprehensive visualization (e.g. the air assets will arrive at about the time we are ready to launch the offensive and the enemy will most likely avoid this choke point and will have taken the alternate route to the north). Some students could not follow even this slow build because they lacked basic aspects of the mental models (e.g. weapon capabilities or ranges, typical size of enemy units, formations or doctrine), and the instructor had to stop and provide help to the student by reviewing such basic facts.

Our observations indicated that constructing a dynamic model of friendly assets is the key mental model for the journeyman. With this ability, he or she is then able to progress towards modeling typical enemy behavior and courses of action. Other literature in the area of tactical thinking also suggests that the building block of the friendly model precedes that of the enemy model during the development of expertise (Strater, Endsley, Pleban, and Matthews, 2001). Strater et al found that at the platoon level in the U. S. Army, officers with greater experience attended more to information about enemy locations and strengths, while less experienced officers attended more to information concerning friendly strengths. The concentration on the friendly model before enemy model development and then the integration of the two is a general trend in the way the instructors in our study facilitated the development of tactical thinking and may hold as a general feature of expertise development in this domain. The expert tutors' focus on friendly assets may also reflect the tutor attempting to counter the novices' tendency in all domains of expertise to jump to solutions before gaining a sufficiently deep understanding of the situation.

The expert tutors then used contextual cues to invoke the themes of *mission focus and big picture*. Mission focus typically followed from an understanding of the student's knowledge of own assets and enemy picture, and was the key method the tutors used to direct student development. Each scenario was fashioned so that the explicit mission was overcome by events and out of sync with the higher commander's intent. The student was only able to realize this lesson if he or she first gained a sufficiently deep understanding of the commander's intent, friendly assets, and the enemy story through contextualized cues in the scenario. For the less sophisticated student, the tutor might then highlight other themes in a discrete fashion. In this case, the use of themes was an attention management device to get the student to focus on important situational elements and their meaning. For the more sophisticated student, additional themes were often added by the student as soon as he or she began weaving together the entire situation and visualizing a fluid battlefield. In these cases, the tutor could add an emphasis on terrain, timing, and potential contingencies to sharpen such visualization practice.

Contingency thinking seemed to be the theme least used in these sessions, perhaps because it is dependent

on having first built all the other skills for visualization to some degree. Many students did not get to that point. While "what if's" of contingency thinking can be introduced at anytime in scenario-based tactical training, we believe it will not be meaningful unless a student has developed a deep appreciation of the situation. And this was the method used in these tutorial sessions.

Almost all the students could be led through some visualization exercises starting with very elementary representations, such as concentrating on the meaning of one cue in the environment or doing structured exercises with the tutor. One such exercise was "What Do You Know and How Do You Know It?" This exercise was typically used to help a student who was struggling with gaining any depth in his understanding of the enemy story in the situation. In this exercise, the sketch map accompanying the scenario was mentally divided into four quadrants by the tutor who then helped the student examine each quadrant to see what could be inferred given the known assets available and the accompanying scenario narrative.

The structure of theme introduction that the tutors followed, the use of a scenario that required the recognition of a conflict between the stated mission and an implied mission to stay in line with the intent, and the methods for improving the visualization skill can all be used in training development to increase tactical thinking expertise. In addition, each of these areas has implications for measurement of student progress.

IMPLICATIONS: USING MENTAL MODELS TO ASSESS TRAINING IMPACT

We believed that our findings could be used to create a training assessment methodology. The following describes our rationale and the construction of this methodology. In another study focusing on the development of macrocognitive measurement in training of small group leaders (Ross et al, 2003), we reviewed the analysis described here and examined the themes as mental models. Our goal was to see if the themes and the data we had gathered in the ITS study could be used to develop a measure to assess gains in tactical expertise.

When an individual faces a situation on the battlefield, he or she calls forth elements of mental models that are applicable to that particular situation. He or she then tailors those FMMs to the situation in the form of a frame to make sense of the surrounding context and to take actions in light of goals brought into the context. The frame organizes information that the individual is facing and allows for interpretation of the situation by enabling the individual to associate the current circumstance with previous encounters. This orienting function of the frame allows the expert to know what to look for in a situation, i.e., to understand what is a cue and what it may mean in terms of a larger story in the situation. The following example may help the reader understand how an expert uses mental models when facing a new situation.

During a Marine Corps exercise, a reconnaissance team leader and his team were positioned overlooking a vast area of desert. The fire team leader, a young Sergeant, viewed the desert terrain carefully and observed an enemy tank move along a trail. The tank then took cover. He sent a situation report to his headquarters indicating that a tank had been spotted. A Brigadier General, experienced in desert-mechanized operations, had arranged to go into the field as an observer. He also spotted the enemy tank. But he knew that tanks tend not to operate alone. Therefore, based on the position of that one tank, he focused his eyes on likely over watch positions and found another tank. Based on the section's position and his understanding of the terrain, he focused his eyes on likely positions for another section and found a well-camouflaged second section. He repeated this process to locate the remaining elements of a tank company that was well camouflaged and blocking a key chokepoint in the desert. The size and position of the force suggested that there might be other higher and supporting elements in the area, and so he again focused his eyes on likely positions for command and logistics elements. He soon spotted the glint of one antenna in an otherwise superbly camouflaged command post. He eventually located a logistics site. In short, the Brigadier General was able to see and understand and make more sense of the situation than the young Sergeant. He had much more experience, and he was able to develop a fuller picture rather than record discrete events that he noticed. One cue, in light of existing mental models could be used to infer a possible situation and direct attention to look for other cues to confirm that expectation.

Cognitive Flexibility Theory (Spiro, Feltovich, Coulson et al., 1992; Spiro & Jehng, 1990) describes the development of expertise as "criss-crossing" the conceptual terrain of a domain. This is accomplished by interacting with a number of domain specific experiences, each from a variety of viewpoints to develop deep understanding. Without practice that includes use of data to solve problems, challenges to assumptions that have been constructed, and reflection on what was important in the situation and why, the learner may continue to develop shallow interpretations, fixate on early solutions, and develop the inaccurate or inadequate mental models of a novice (Bransford, Sherwood, Hasselbring, Kinzer, &

Williams, 1990; Brown, Collins, & Duguid, 1989; Spiro, Feltovich, Jacobson, & Coulson, 1992)

The role of mental models in expertise suggests that this concept is a fruitful area to work on assessment. However, it is also difficult to construct evaluation once we move out of the realm of declarative knowledge and into the application of higher-level cognition. Evaluation of higher-level cognitive skills and deeper levels of learning is undergoing a continuing revolution in the test and measurement community at large outside the military (Bennett & Ward, 1993). To address the limitations of the multiple-choice format and assessment that centers on declarative knowledge, educators have increasingly advocated the use of constructed-response tasks.

Constructed-response assessments encompass a wide range of evaluation methods. Baron (1991) describes constructed-responses as performance assessments in which the student is actively engaged in solving a realistic problem that demands more than simply recalling information. Performance can range from a time-limited response such as five minutes to an extended assessment over many days within a broad, loosely structured project. The use of constructed-response tasks for assessment has raised criticisms—not all agree that this is the best path to pursue. Fewer questions can be asked in a fixed testing period and less content covered, lack of standardization may result, and comparability may be adversely affected and, thus, the validity of the evaluations. However, many educators at this point acknowledge the weakness and limitations of assessing higher- level cognition through multiple-choice type items, and a move to bring constructed-response tasks into education has become firmly situated in our education system. Such constructed-response assessment is used in the Army at all levels of training, even if it does not go by that name. Therefore, it is a natural fit for assessing high-level cognitive challenges. The challenge for both the Army and the wider education and training community is how to include constructed-response methods in training evaluation more easily and with a greater understanding of the reliability and validity of the results.

We believe our findings about mental models can be used to address create useful constructed response assessments in higher-level military training. A type of measurement that could potentially help exploit the rich area of mental model assessment is the Behaviorally Anchored Rating Scale (BARS). Industrial-organizational psychologists have long recognized the strengths of using situation-based assessment tools for selection purposes. They have also advocated the use of assessment tools that are related to observable behaviors. The BARS is used by many organizations to evaluate the effectiveness of individuals who perform a wide variety of different tasks (Muchinsky, 2003). A scale is constructed for each performance that a rater wants to evaluate. Typically, the scale is a Likert-type scale with poor performance on one end and excellent performance on the other end. In the construction of the BARS, work is observed and/or incidents about work are gathered from subject-matter experts (SMEs). Each of the ratings (from poor to excellent and often several intermediate ratings) is anchored with a description of typical performance at that level based on the critical incidents observed or gathered. This provides the rater with a specific behavioral example of what is meant by performance that is poor, fair, etc. Raters using the BARS are less prone to common rater biases associated with the use of other rating scales, such as the halo effect and positive leniency (Muchinsky, 2003; Riggio, 2000). An additional benefit of using the BARS is that the traditional process for developing a BARS establishes the construct validity of the different performance dimensions and the reliability of the rating scales as part of the development process.

One may question the utility of developing *behaviorally* anchored scales to assess *cognitive* processes. However, cognitive processes cannot be directly observed so it is necessary to focus our assessment efforts on the observable behaviors or verbalizations that reflect the use of the critical underlying macrocognitive processes that have been trained in a particular training intervention. Although the development process for the BARS is time consuming and requires the input from a significant number of SMEs, the end product is a set of valid and reliable rating scales.

In light of the different environments in which training evaluators may be asked to assess changes in cognitive skills, we believe that the BARS can have a high level of utility. Consider the virtual environment setting, for example. BARS would be appropriate in such a setting on a couple of different levels. BARS could be used post-scenario to rate the sophistication of mental models as a researcher or training evaluator listens to the recordings of the radio communications. However, given the financial constraints that are often associated with obtaining these recordings, the BARS could serve another useful function. Researchers and training evaluators could use the BARS tool as a real-time and non-obtrusive assessment measure, assessing the cognitive skills of the small unit leaders as they progress through the scenario.

In field situations, the BARS is likely to be a highly promising assessment tool as well. In such situations, a paper-and-pencil version of the BARS is likely to be

appropriate for making real-time performance assessments while observing behavior and listening to the communication stream. In a similar vein, a BARS-type tool also holds significant promise for classroom training evaluation using a situation exercise.

In such assessment settings, the BARS would be less likely used as a real-time performance measure. Instead, the BARS could be used as a grading tool for performance on a situation-based exercise. Tactical scenarios could be administered at different times throughout a course and researchers could use the BARS measure to make some qualitative assessment of the student's development through the course.

Figure 2 below shows a resulting BARS for the theme being used as a mental model, *Keep a Focus on Mission and Higher's Intent.* The first step in our mental model BARS development was to review the transcripts from the tutoring sessions in which tactical thinking experts instructed students through scenario-based training. We selected a total of six transcripts that reflected rich interactions between student and mentor and various stages of mental model development and application on the part of the student. Each member of the project team first reviewed the transcripts individually and began annotating the various stages along the novice-expert scales with example behaviors or verbalizations that were reflected in the instructional session transcripts. Examples were extracted that reflected each point along the developmental scales that had been developed for each theme.

Theme: Keeping a Focus on Mission and Higher's Intent

Focus on Own Mission	Discriminate Intent and Explicit Mission	Model Effect of Own Mission on Higher's Intent	Make Accurate Predictions	Support Higher's Intent
1	2	3	4	5
Articulates an understanding of the mission without any consideration of higher's intent Neglects to keep headquarters informed of plans and situation. Neglects to request reinforcements when the plan requires it. Ignores or loses sight of higher's intent when distracted by unusual events.	Is able to differentiate mission from higher intent, yet does not apply these differences to understanding the current evolving situation. Understands both mission and intent, but does not consider whether mission will support that intent or whether it needs to be modified in any way to better support that intent.	Considers whether mission will support intent. Considers whether mission needs to be modified to better support intent. Considers ways to modify mission to better support intent. Mentally simulates what needs to be accomplished in order for higher intent to be achieved.	Mentally simulates how specific unit mission will contribute to achieving overall higher mission. Prioritizes what needs to happen in order for higher mission to be accomplished (e.g. "I need to do X instead of Y…")	Able to articulate how and/or why the specific unit mission or COA supports the commander's intent. Allows intent and current situation to guide COA development rather than the explicit mission.

Figure 2. BARS for assessing the mental model "Keeping a Focus on Mission and Higher's Intent."

CONCLUSIONS

As we constructed the BARS from the TLAC themes, we realized that four of the themes really represented mental models that were developed and sharpened during training and practice. The themes *Know and Use Own Assets, Model a Thinking Enemy, Focus on Mission and Higher's Intent, and Consider Effects of Terrain*, reflected a basic understanding of how the battlefield works. The other four TLAC themes are skills that are applied in the construction of a unique temporary model (frame) and in the elaboration of the frame via mental simulation when the practitioner is confronted with a specific situation. This understanding is shown in Figure 3 in which we integrated the themes and aspects of macrocognition. We also added the levels of Bloom's Taxonomy (Bloom, 1956) since we have found that this framework is often used in military training development. Figure 3 shows four themes as mental models that are developed over time (i.e., novice to expert development) and then used to perform visualization, which is used to support a number of macrocognitive processes and functions. The other four themes were seen as aspects of how mental simulation was carried out.

We believe that the exploration of problem spaces to construct one's own meaningful mental models is the most effective strategy for later transfer of training as opposed to the encouragement of a student to conform to a pre-determined model of expert performance that has been de-contextualized. Essentially, the student must learn to self-assess and to build his or her own variety of mental models of domain expertise. The learner must then practice how to manipulate and combine the mental models he or she has constructed through experience in order to construct a unique model for each situation encountered. This practice of constructing mental models in a variety of situations is the essence of real-world performance, and therefore must be the essence of training.

Refining our understanding of the development and use of mental models in tactical thinking will form the focus of our continued research. We will investigate the validity of the tactical thinking mental models and of the macrocognitive functions and processes of which they are a part, as we continue to develop training and training assessment based on our macrocognitive framework.

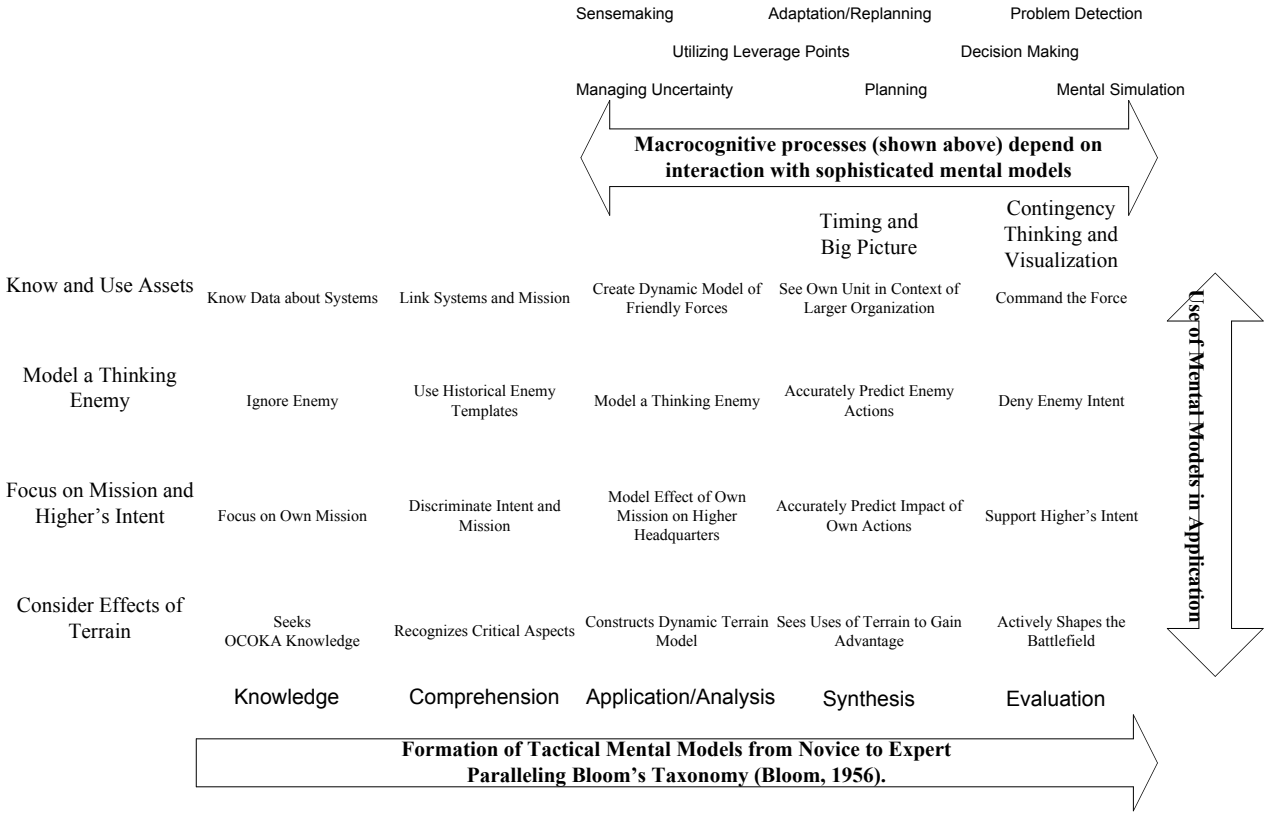

Figure 3. The development and use of mental models for tactical thinking.

ACKNOWLEDGEMENTS

The research was funded through Stottler Henke Associates' contract DASW01-01-C-0039 from the Army Research Institute, Fort Knox. This work grows out of the research by Dr. James Lussier and his "Think Like a Commander" training program at Fort Knox. The training assessment research was conducted under Contract DASW01-03-P-0185 for the Army Research Institute, Fort Benning.

REFERENCES

Baron, J. B. (1991). Performance assessment: Blurring the edges of assessment, curriculum, and instruction. In G. Kulm & S. Malcolm (Eds.), *Science assessment in the service of reform* (pp. 247-266). Washington, D.C.: American Association for the Advancement of Science.

Bennett, R. E., & Ward, W. C. (1993). *Construction versus choice in cognitive measurement: Issues in constructed response, performance testing, and portfolio assessment*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Bloom, B. C. (Ed.). (1956). *Taxonomy of educational objectives: Handbook I, cognitive domain*. New York; Toronto: Longmans, Green: David McKay Company, Inc.

Bransford, J. D., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K., & Williams, S. M. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), *Cognition, education and multimedia* (pp. 115-141). Mahwah, NJ: Lawrence Erlbaum Associates.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Deckert, J. C., Entin, E. B., Entin, E. E., MacMillan, J., & Serfaty, D. (1994). *Military decision-making expertise: Final report*. Fort Leavenworth, KS: Army Research Institute.

Hart, B. H. L. (1954). *Strategy*. London: Faber & Faber.

Klein, G., Ross, K. G., Moon, B. M., Hoffman, R. R., Klein, D. E., & Hollnagel, E. (2003). Macrocognition. *IEEE Intelligent Systems, 18*(3), 81-85.

Larkin, J., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Science, 20*, 1335-1342.

Lussier, J. W. (1998). *Developing expertise in battlefield thinking: Models of battlefield thinking* (Unpublished briefing). Ft. Leavenworth, KS: U. S. Army Research Institute.

Lussier, J. W., Shadrick, S. B., & Prevou, M. I. (2003). *Think like a commander prototype: Instructor's guide to adaptive thinking* (ARI Research Product 2003-01). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Muchinsky, P. M. (2003). *Psychology applied to work*. Melmont, CA: Wadsworth/Thomson Learning.

Riggio, R. E. (2000). *Introduction to industrial/organizational psychology*. Upper Saddle River, NJ: Prentice Hall.

Ross, K. G., Battaglia, D. A., Hutton, R. J. B., & Crandall, B. (2003). *Development of an instructional model for tutoring tactical thinking* (Final Technical Report for Subcontract No. SHAI-COMM-01; Prime Contract No. DASW01-01-C-0039 submitted to Stottler Henke Associates Inc., San Mateo, CA). Fairborn, OH: Klein Associates.

Ross, K. G., Crandall, B., & Battaglia, D. A. (2003). Complex cognition of battle command in the objective force unit of action (UA), *Proceedings of the 2003 CTA Symposium. Manuscript submitted February 2003.*

Ross, K. G., McHugh, A. P., Harris, D. S., & Pliske, R. M. (2003). *Assessment of Macrocognition in Small Unit Leader Training* (Final Technical Report for Contract #DASW01-03-P-0185 U.S. Army Research Institute, Ft. Benning, GA). Fairborn, OH: Klein Associates Inc.

Schmitt, J. F. (1994). *Mastering tactics*. Quantico, VA: Marine Corps Association.

Spiro, R. J., Feltovich, P. J., Coulson, R. L., Jacobson, M. J., Durgunoglu, A., Ravlin, S., & Jehng, J. (1992). *Knowledge acquisition for application: Cognitive flexibility theory and transfer of training in ill-structured domains* (AD-A250 147). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1992). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. Duffy & D. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 121-128). Mahwah, NJ: Lawrence Erlbaum Associates.

Spiro, R. J., & Jehng, J. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In D. Nix & R. J. Spiro (Eds.), *Cognition, education, and multimedia* (pp. 163-205). Mahwah, NJ: Lawrence Erlbaum Associates.

Strater, L. D., Endsley, M. R., Pleban, R. J., & Matthews, M. D. (2001). *Measures of platoon leader situation awareness in virtual decision-making exercises* (Research Report 1770; ADA 390238). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.