TEAM COGNITION IN INTELLIGENCE ANALYSIS TRAINING

A DISSERTATION

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ABSTRACT

Since the terrorist attacks of September 11, 2001, intelligence analysis has become the focus of much research. Given the technical nature of intelligence collection and the distributed nature of intelligence analysis, it is understandable that much of this research has focused on technology and representational aiding to support the analyst. There has, however, been a shortage of research in team cognition for analytical tasks and effective training strategies for analysis.

The study of team cognition in complex domains is typically hampered by two aspects – concurrent, distributed work and the complexities of domain-specific tasks. Researchers may overlook critical vulnerabilities due to unfamiliarity with the work prior to observation and are also unable to easily observe interactions and simultaneous processes across multiple areas. In this study, a group of observers used a unique variation on established ethnographic techniques to observe teams of intelligence analysts.

Findings from this study indicate a cognitive work balance dilemma exists between critical support functions for macrocognition. We note aspects of workspace design and use that support team cognition. Finally, our data suggests findings about analytical strategy that are important for those who educate and lead analysts.

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To my beautiful wife, Ronna. Without her encouragement and assistance, I would never have begun this journey.

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CHAPTER 1

INTRODUCTION

Since the terrorist attacks of September 11, 2001, intelligence analysis has become the focus of much research. Given the technical nature of intelligence collection and the distributed nature of intelligence analysis, it is understandable that much of this research has focused on technology and representational aiding to support the analyst. There has, however, been a shortage of research in team cognition for analytical tasks and effective training strategies for analysis.

Military intelligence is an excellent domain in which to study cognition in complex, time-constrained, high-risk situations. It also presents the opportunity to study established teams, rather than contrived, ad hoc or short-lived teams. Intelligence teams consist of individuals of various expertise; often being comprised mostly of novices or journeyman led by one or more experts (cf. Dreyfus, 1997). Furthermore, they struggle with open-ended, robust analytical problems that go beyond the scope of laboratory problem-solving situations. These analytical problems usually present situations of data overload and require context sensitive inferences about relationships of data.

The study of team cognition in complex domains is typically hampered by two aspects – concurrent, distributed work and the complexities of domain-specific tasks. Researchers may overlook critical vulnerabilities due to unfamiliarity with the work prior to observation and are also unable to easily observe interactions and simultaneous processes across multiple areas. In this study, a group of observers used a unique variation on established ethnographic techniques (i.e. Woods, 2003) to observe teams of intelligence analysts.

This study investigates the effectiveness of teams of analysts in a training exercise. As a training exercise involving periodic instructor intervention, it also presents the opportunity to discover ways to support the acquisition of expertise in intelligence analysis. While research on technologies to support analytical work is important, this study focuses on the cognitive challenges of teams with little or no software or automated support tools. The goal of this research is to determine persistent analytical strategies and study the interplay between the critical functions of macrocognition for teams of novice analysts.

In order to frame our research question, we begin with a review of literature related to macrocognition, teamwork, information analysis and adult educational strategies.

CHAPTER 2

LITERATURE REVIEW

Military Intelligence analysis is typical of decision making in other naturalistic settings as described by Orasanu & Connolly (1993) - ill-structured problems; uncertain dynamic environments; shifting, ill-defined, or competing goals; action/feedback loops; time stress; high Stakes; multiple players; and organizational goals and norms. Cannon-Bowers and colleagues (1996) have identified other characteristics – multiple goals, decision complexity and quantity of information that are also important in this domain. Given the context sensitive nature of the challenges experienced in this domain, it would be an over-simplification to focus on challenges to individuals or ad hoc groups in laboratory settings. Rather than focus on the microcognitive challenges that may mask larger issues, it is best to begin with an understanding of macrocognitive functions and their interdependencies.

Macrocognition

Leading cognitive systems researchers have noted that cognitive psychology continues to remain focused on individual cognition in laboratory contrived situations which emphasize experimental control (cf. Cacciabue and Hollnagel, 1995 and Klein, et al, 2003). In stripping the context from real world problems, these laboratory experiments often encourage cognitive processes that contrast with complex decision making that often relies on domain expertise in order to recognize patterns. Klein and colleagues (2003) have proposed a model of cognition that occurs in situated individuals and teams that includes six functions: Naturalistic Decision making, Sensemaking, Problem Detection, Planning, Adaptation, and Coordination. Relationships among these functions are still unclear as well as the effects of stress and other activity on these relationships. We will review the research related to each of these functions.

Naturalistic Decision Making

Naturalistic Decision Making is the process of arriving at decisions in natural settings. While research in NDM has spawned a broader understanding of other macrocognitive functions (which will be discussed in turn), this discussion will focus on Recognition-Primed Decision Making (RPD). From his study of firefighters, Gary Klein (1997) has developed the concept of RPD in order to describe the cognitive processes of expert decision makers. Experts rely on their ability to recognize domain-specific patterns in order to make rapid decisions that are "good enough" (Rasmussen, 1983; Klein, 1997). As options are generated, decision makers use mental simulations in order to evaluate feasibility before choosing a course of action. This strategy has three

variations: recognize situation and classify; experience uncertainty and collect information; and recognize initial misinterpretation. The last variation typically results in rechecking the initial explanation and/or building a story to explain the inconsistencies.

Mental simulations are essentially story construction or explanation based reasoning (Klein & Crandall, 1995). The need for mental simulations may be to generate plans, make predictions or evaluate existing plans. This cognitive strategy involves the decision maker selecting a small number of variables and manipulating them in their mind like a movie. It ends with a mental evaluation of the coherence or completeness of the story. We will discuss story construction as an analytical strategy in more detail later.

Sensemaking

Sensemaking is a "motivated, continuous effort" to understand information or a situation "in order to anticipate their trajectories and act effectively" (Klein et al., 2006a, p 71). As a cognitive process of creating and modifying mental models, it has no clear beginning or end point, and leads to situation awareness, diagnosis or adaptation. Carl Weick (1995) suggests that sensemaking is not done for its own sake, but rather in pursuit of goals, and he described seven characteristics of the process:

(1) Grounded in identity construction: driven by concern to confirm or reframe one's self-concept

(2) Retrospective: continual evaluation of past events to determine current or future states. However, people tend to consider only a handful of recent items or projects at once, and the process is subject to hindsight bias.

(3) Enactive of the environment: process is one of participating and exploring the world, not watching it

(4) Social: we are social beings and rely on those around us to partake in the world.

(5) Ongoing: it evolves over time

(6) Focused on cue extraction: all processed information is context sensitive

(7) Driven by plausibility: sufficiency and plausibility take precedence over accuracy.

Gary Klein and colleagues (2006b) have continued building on this earlier conceptualization. In framing the discussion for their model of sensemaking, they point out that sensemaking is more than just "connecting the dots". It is a context sensitive skill that requires identification of diagnostic data in order to infer relationships. They also indicate that complete openness does not necessarily aid in sensemaking. Decision makers and analysts must be sufficiently committed in order to test a hypothesis. Vagabonding, or shifting your analysis at every new piece of data results in an inability to make a decision. However, it is a balance for the analyst to resist becoming fixated or prematurely committed to their hypothesis.

There are two current competing models for sensemaking. The Data-Frame Model (Klein et al., 2006b) suggests a process of framing and reframing based on our pre-existing understanding of the world. It includes four functions: representing the situation as a frame; questioning the frame; elaborating on the frame; creating a new frame. As new available data is considered in light of our current understanding of the world, we evaluate that understanding. This evaluation causes us to either enhance or reframe our beliefs about the world.

Jensen and Brehmer (2005) have proposed an alternate model for sensemaking in military decision making. They distinguish sensemaking from situation assessment and awareness in order to emphasize the goal oriented nature of the process. Like Weick, their model suggests that sensemaking is never an individual effort. In military settings, it is the product of the interaction of the individual, the team or staff and the commander's sense of the world. Shared knowledge, team climate, and organization of work shape our interpretations of the real world. The goal of their study was to determine whether uncertainty affected the sensemaking process or the quality of the plan. Their findings indicated that the level of uncertainty did not affect either. This is likely due to the fact that they have confused data availability with certainty. That is to say that their independent variable was labeled uncertainty, but was measured by the number of enemy units that were identified for the participant teams. Other researchers have noted that this is poor indication of certainty or situational awareness (cf. Endsley, 1995 and Woods & Hollnagel, 2006). If we only consider the variable for what it was – amount of data available – the data in this study support other assertions that data fusion and availability do not aid in sensemaking (i.e. Klein et al., 2006a).

Weick (1993) in his analysis of the Mann Gulch fire found that sensemaking is affected by stress, fatigue and surprise. In this tragedy, which left 13 firefighters dead, sensemaking broke down due to poor communication and lack of trust in an ad hoc team and persistent incorrect hypotheses about their situation.

Problem detection

Problem detection or anomaly recognition is "noticing when events do not fit the current assessment or expectations" (Woods & Roessler, 2007) or identifying the need

to reframe (Klein, Pliske, Crandall & Woods, 1999). Cowen (1986) proposed a logical breakdown of problem recognition into a three stage process: Gestation – accumulating discrepancies; categorization stage – problem or not classification; and diagnosis – what type of problem is it. Empirical data suggest that this linear model of information processing is an oversimplification of what actually takes place (Klein et al., 1999).

As a form of sensemaking, problem detection is a function that is often overlooked in controlled laboratory settings because the participants are provided the problem and do not need to discover it. Cues, expertise, workload, fatigue, sensitivity and perspective contribute to the ability to detect problems (Klein, Feltovich, Bradshaw, and Woods, 2005). Cognitive fixations and knowledge shields (cf. Feltovich, Coulson, Spiro, and Adami, 1994) can degrade problem detection as we explain away initial symptoms and are less sensitive to the impact of new information.

Planning

A plan can serve a number of functions: Solve problem, shape thinking, generate expectancies, support adaptation, direct and coordinate team members (Klein & Miller, 1999). Although some refer to planning as a form of problem solving (i.e. Durfee, 2001), the two are clearly overlapping and will be treated similarly in this paper. Although prescriptive planning processes abound in military, scientific, and business literature, all planning is subject to multiple forcing functions (Klein & Miller, 1999). These forcing functions shape the plan and the planning process and include time, uncertainty, structure of task, resources and expertise. While many domains have sought decision support tools for planning tasks, research has indicated that these tools

can cause practitioners to focus on the automated solutions rather than consider other better solutions (Layton, Smith & McCoy, 1994).

Plans often degrade faster than the planning cycle of the organization (cf. Hayes, 1994 and Schmitt & Klein, 1999). Consequently, resilient organizations adopt flexible, low-investment plans that are easily reworked to fit changing situations. Expert practitioners in time constrained situations rarely adopt robust, methodical planning processes and rarely compare courses of action in parallel (Schmitt & Klein, 1999). Instead, they compare them in sequence and stop when they have a workable one. Furthermore, when experts arrive at a workable first solution, they typically move forward rather than delay to produce or evaluate additional alternatives.

Adaptation/ Replanning

Adaptation is making the appropriate responses to changing situations (Hollnagel & Woods, 2005). Since initial plans are inadequate to cope with surprise, adaptation and replanning allow for resilience in a system. Unfortunately, a common design philosophy involves reducing the practitioner's ability to adapt in favor of engineering in predictability in the system. By removing the primary source of resilience in the system – the human – the designer ensures that the system will be brittle, which leads to certain predictable forms of failure.

Woods and Shattuck (2000) have also noted that people are prone to either over or under adapting. Their ability to replan appropriately depends on their ability to see and track reverberations in the system based on plan modification (Woods & Roessler, 2007). Therefore, the following have been observed to aid in replanning: ability to

adopt teammates' perspectives; information integration; recognizing and accommodating the effects of multiple constraints (Smith, McCoy & Orasanu, 2001). As most work in natural settings takes place in teams, replanning and other macrocognitive functions become joint efforts.

Coordination and Team Cognition

A team is two or more individuals with defined roles or responsibilities working toward common goals (Orasanu and Salas, 1993). Coordination has been defined variably, but is essentially an attempt to act as a team. Team cognition and coordination have been understudied to date, with most studies focusing on ad hoc groups conducting relatively small problem solving tasks (e.g. Hinsz, 2004). Team cognition is difficult to study. Relevant variables of interest are hard to identify and measure, and team cognition is more than the sum of individual cognitions (Salas and Fiore, 2004). Because of the collaborative overhead inherent in team cognition, we will first discuss aspects relevant to collaboration in general.

Malone & Crowston (1990) noted four components of collaboration – goals, activities, actors and interdependencies. Cooperative goal interdependence, or the belief that your goals are being met by helping another achieve their goals, is important for successful team efforts (Salas & Fiore, 2004). There are also several principle problems for collaborations – effective division of labor, translation of goals into action, resource allocation, and information sharing (Malone & Crowston, 1990). A growing body of research on coordination has led Woods and Hollnagel (2006) to propose a set of laws that govern collaborative systems, three of which are important for our understanding of team cognition. First, collaboration is more than dividing tasks

between individuals. Second, collaboration requires appropriate inter-agent trust, and third, coordination requires continual investment. Effective collaboration entails multiple types of coordinating efforts, both implicit (shared mental models) and explicit (discussions). Breakdowns in both types have been linked to system failures (Salas, & Fiore, 2004).

Shared mental models as implicit forms of coordination are integral to team cognition. They are important for team training, efficient interaction, competent performance, team effectiveness, and for team situation awareness that is critical to rapidly changing environments (Salas & Fiore, 2004). Accurate mental models of teammates can also reduce intrateam conflict (Salas & Fiore, 2004).

Effective joint activity requires interpredictability, directability and common ground (Klein, Feltovich, Bradshaw & Woods, 2005). Interpredictability, or shared scripts and mutual perspectives, increases the ability of each member to anticipate actions of the other. Directability is the ability to direct each other in task or attention, and common ground is the process of repairing a continually degrading shared understanding of the world. Klein, et al. (2005) indicate that teams lose common ground because of:

- Inexperience in working together
- Access to different data
- Unclear rationale of leader
- Ignorance of competing priorities
- Loss of communication

Research has also indicated that open tools aid collaborative work in naval navigation (Hutchins, 1995). Open tools are artifacts or technologies that allow people to observe the cognitive work of others. Shared workspaces have been observed in

airport operations rooms (Suchman, 1996). These workspaces were defined not only by the interior design of the room, but also by the collaborations of the practitioners. Suchman observed a joint activity room which was void of internal walls or other barriers, but contained non-centrally oriented workstations for individuals. Shared workspaces such as these support the competing requirements of joint work and division of labor. More recent research has also indicated that collocated software developers demonstrate improved production (Teasley, Covi, Krishnan, & Olson, 2000).

Since this study focuses on the cognitive processes and analytical strategies of teams of analysts, the findings from one particular study are important to consider. Lehner and colleagues (1997) conducted an experiment with two man teams performing a command and control task. Their study indicated that as time stress increased, teams engaged in less effective cognitive processes than what they were trained to use. They concluded that "'Unnatural' decision making processes are unlikely to be used under time stress" (p. 698). Given the time-constrained nature of our participants' tasks, we now turn to examine processes and tendencies in information analysis.

Information Analysis

Information analysis has been studied in power generation, military intelligence, air traffic control, and firefighting with respect to anomaly response, problem detection and replanning. Technically, analysis is only the dissection of a topic into its component parts, whereas synthesis is the assembling of pieces into a coherent whole. However, most domains commonly refer to both of these functions as analysis, therefore, this paper treats them as the same and includes the challenges of both in any discussion on analysis.

As it has with work in all other domains, technology has changed analysis. It has provided greater access to data, while creating an over-reliance on flashy presentations. It has increased the tempo at which analysis is conducted – partially from increased capability and partially from expectations from customers and decision makers. Technology has also given more people access to data, so more people can be analysts (i.e. bloggers), and more people can conduct insufficiently rigorous analysis.

Elm and colleagues (2005) have characterized information analysis according to three support functions – Down Collect, Hypothesis Exploration, and Conflict and Corroboration. Their model of inferential analysis is a closed loop, iterative convergent process. Each of the three support functions consists of both broadening and narrowing functions that help the analyst periodically widen or revisit factors under consideration as they reduce the problem to an answer. The analyst faces a cognitive work dilemma as he or she attempts to balance the workload costs of broadening and the risk of prematurely settling on a favored hypothesis.

Patterson, Roth, Woods (2001)	Hutchins, Pirolli, Card (2007)	Trent, Patterson, Woods (2007)
Time pressure	Time pressure	Time pressure
Recognizing relevant data	Synthesizing data	Recognizing relevant data
Relying on default assumptions	Data overload	Mental set
Premature closure	Coordination issues	Fixation
	Inadequate tools	Trust under uncertainty
	High mental workload	Sustained attention
	Potential for error	Learning
	Complex judgments	Misperceiving expertise
	Coping with uncertainty	

Table 1 - Cognitive challenges for intelligence analysis

Recent research illustrates an array of challenges for information and intelligence analysis (see Table 1). Time pressure, difficulty with recognizing and synthesizing relevant data, and the challenges of reframing appear in all three of these studies. Two of the studies (i.e. Hutchins et al., 2007 & Trent et al., 2007) indicated that coordination between analysts and decision makers often affects the nature and quality of the analysis. These studies also indicated that analysts must cope with uncertainty.

Effects of uncertainty

"...we have to accept the fact of uncertainty and live with it." (Wohlstetter, 1962, p. 401)

Since uncertainty is an irremovable aspect of intelligence analysis, we should consider the effects of this uncertainty on analytical process. As suggested earlier, data relevant to making inferences about intent is often sparse. Hollnagel and Woods (2005) have identified some coping strategies that a controller might engage in when faced with sparse data:

- Extrapolation (stretching evidence to fit)
- Frequency gambling (frequency of past events used as basis for selection)
- Similarity matching (subjective similarity of past to present used as basis for selection)
- Trial and error (random selection)
- Laissez-faire (do what others do)

Any of these coping strategies are likely to result in poor inferences.

Lipshitz and Strauss (1996) reviewed earlier literature on uncertainty and elicited

stories of decision-making under uncertainty from military officers in the Israeli Defense

Forces Command and General Staff College. They identified three types of uncertainty -

inadequate understanding, incomplete information, undifferentiated alternatives.

Furthermore they classified the coping strategies related in these stories into five categories:

- Reduction (information search)
- Assumption-based reasoning (using knowledge base to go beyond the available data)
- Weighing pros and cons
- Forestalling (preemption or hedging)
- Suppressing uncertainty (denial, rationalization or gamble)

What is most interesting about their findings is that reduction and forestalling comprised approximately 48% of the self-reported strategies. The indecision that results from these two strategies would likely impact the effectiveness of intelligence analysis.

Analytical Strategies: Story construction and Hypothesis testing

Various prescriptions and descriptions about analytical strategies abound.

Depending on the source, they may be termed problem-solving, decision making or intelligence analysis processes or strategies. Some are compensatory, meaning that they seek to pit the strengths and weaknesses of options against each other. Others are non-compensatory. The rational choice strategy proposed by Soelberg (1965; in Klein, 1998) is a compensatory model. In this strategy, the analyst should:

- Identify set of options;
- Identify evaluation criteria;
- Assign weights for each evaluation criterion;
- Rate each option; and finally
- Select option with highest score

Janis and Mann (1977) have offered a similar prescriptive decision making strategy. Some non-compensatory strategies include the Mascot method, in which an option is selected that is best on the most important dimension (e.g. selecting a favored team based on mascot or uniform color). A face-off strategy could be used in which options are eliminated in a tournament style procedure of dyadic comparisons. Tversky (1972) proposed Elimination by aspects, in which a series of screening criteria are used as successive filters.

A compensatory strategy that has gained popularity within the intelligence community is Analysis by Competing Hypotheses (ACH) (cf. Heuer, 1999). An hypothesis is a general assertion about the state of the world. It can be tested by weighing the data that supports or conflicts with it. The focus in ACH is on item-by-item judgments of evidence as it becomes available. Table 2 outlines this iterative 8 step process.

Step 1	Identify the possible hypotheses to be considered.	Use a group of analysts with different perspectives to brainstorm the possibilities.
Step 2	Make a list of significant evidence and arguments for and against each hypothesis.	
Step 3	Prepare a matrix with hypotheses across the top and evidence down the side.	Analyze the "diagnosticity" of the evidence and arguments- that is, identify which items are most helpful in judging the relative likelihood of alternative hypotheses.
Step 4	Refine the matrix.	Reconsider the hypotheses and delete evidence and arguments that have no diagnostic value.
Step 5	Draw tentative conclusions about the relative likelihood of each hypothesis.	Proceed by trying to disprove hypotheses rather than prove them.
Step 6	Analyze how sensitive your conclusion is to a few critical items of evidence.	Consider the consequences for your analysis if that evidence were wrong, misleading, or subject to a different interpretation
Step 7	Report conclusions.	Discuss the relative likelihood of all the hypotheses, not just the most likely one.
Step 8	Identify milestones for future observation that may indicate events are taking a different course than expected.	

Table 2 - Analysis by Competing Hypotheses as described by R. Heuer (1999)

Heuer (1999, p 108) describes three key elements which distinguish ACH from what he terms "conventional intuitive analysis".

- Analysis starts with a full set of alternative possibilities, rather than with a most likely alternative for which the analyst seeks confirmation. This ensures that alternative hypotheses receive equal treatment and a fair shake.
- Analysis identifies and emphasizes the few items of evidence or assumptions that have the greatest diagnostic value in judging the relative likelihood of the alternative hypotheses. In conventional intuitive analysis, the fact that key evidence may also be consistent with alternative hypotheses is rarely considered explicitly and often ignored.
- Analysis of competing hypotheses involves seeking evidence to refute hypotheses. The most probable hypothesis is usually the one with the least evidence against it, not the one with the most evidence for it. Conventional analysis generally entails looking for evidence to confirm a favored hypothesis.

One of the goals of this research is to identify if and to what degree teams would adopt this analytical strategy. Soelberg's earlier study (as recounted in Klein, 1998) indicated that teams would not readily adopt such a strategy. Soelberg taught his students his rational choice strategy and then assigned them the task of selecting a job. He found that his students were inclined to make intuitive choices rather than use any semblance of his recommended analytical strategy. When they did compare courses of action it was not to test an alternative, but rather to justify their favored option. An alternative analytical strategy seems to persist in teams in another complex decision making domain.

Jurors have been found to use Story Construction or explanation based reasoning as a strategy for arriving at verdicts (Pennington & Hastie, 1992, 1993). They first construct a causal model (or story) to explain the available facts. They then construct alternative story representations, and evaluate their stories by best-fitting explicit or implicit verdict categories. Their decision and confidence in their decision is based on evaluating their story according to coverage, coherence, uniqueness and goodness-of-fit.

Certain aspects of jury decision making (Pennington & Hastie, 1993) are prevalent in intelligence analysis. These include a massive amount of information which is usually received over several days. The information is piecemeal and scrambled and often comes from a variety of sources with variable or unknown reliability. Additionally, the evidence is interdependent, or the meaning depends on related data. These commonalities suggest that story construction may be a common strategy for intelligence analysts, too.

So what is a story? Stories are frameworks for organizing events. A story has certain features - agents, predicament, intentions, actions, objects, causality, context and surprises (Klein, 1998). We elaborate on them as we learn more information, thus they are more flexible than hypotheses. This can pose a significant danger in relying on story construction as you can imagine away contradictory evidence. Others have described the process of story construction as mental simulation (Klein and Crandall, 1995). In analyzing a situation, we mentally represent a problem through a series of transitions like replaying a movie. This process can be helpful in making sense of the current situation or predicting future states given various courses of action. Mental simulations are quite basic and generally only rely on a few key variables. Figure 1 is a comparison of the story construction and mental simulation models.

Other researchers have suggested that inferential analysis is influenced by biased assimilation. Lord, Ross and Lepper (1979) studied college students with different views on capital punishment. They provided the students with information for or against the deterrent efficacy of the death penalty. They found that evidence was interpreted so as

to maintain initial beliefs, even to the point that completely inconsistent or even random data can maintain or even reinforce one's perceptions. McHoskey (1995) and Monroe and colleagues (2002) made similar findings in studies utilizing information on the John F. Kennedy assassination and evaluating presidential debates, respectively. These studies also indicated that the level of biased assimilation was correlated with attitude polarization in participants. Given the nature of these experiments, it is possible that similar cognitive strategies will arise among teams of intelligence analysts.

As social beings, we rely on story telling to transfer information. Narratives have the power to cause people to disregard real-world facts in favor of the created story. They can also help decision makers change beliefs and attitudes about the world in response to information in the story. Prior familiarity with story themes (e.g. having knowledge of similar occurrences or finding personal similarities with the characters) increases cognitive and emotional involvement for the recipient (Green, 2004). Furthermore, when presented with evidence in the form of a story people are more



confident in their decisions (Pennington & Hastie, 1993).

e Story Model for juror decision making adapted from Pennington & Hhastie, 1992.

Klein's Mental Simulation for explanations, adapted from Klein, 1

Figure 1 - Comparison of Pennington story model and Klein mental simulation model

Facilitating acquisition of expertise

Ericsson and Charness (1994) define expert performance as consistent superior performance on representative tasks in a domain. Experts must be able to perceive and encode relevant information as well as select appropriate actions for the situation. As such, expertise is very domain specific and can be context dependent. By anticipating future events, experts are able to circumvent the limits of basic serial reactions (Ericsson & Charness, 1994). Interestingly, Ericsson and Charness note that perceptions of expertise are often unsupported by measurably superior performance. This challenge has been reported in the intelligence analysis domain as well (Trent, Patterson, Woods, 2007). Knowledge and skill acquisition are much more relevant for expert performance than individual differences (Ericsson & Charness, 1994). Ericsson (2004) has observed that in domains requiring complex motor skills, acquisition of expertise is rarely achieved without years of practice and the aid of coaches. Although domains such as music have established instructional methods, the student ultimately has the responsibility for addressing their personal performance needs or deficiencies. This is usually done with focused attention and deliberate practice of the relevant tasks.

The study of experts provides insight into highly skilled, highly effective performance. As such, it provides us with an understanding of how things should be done. However, since most practitioners are inexpert, it is important to understand how novices perform and how to help facilitate their acquisition of expertise.

Training provides task specific skills, whereas education provides the basis for further skill acquisition. Because of the nature of intelligence analysis, the analyst must be able to perform analysis and create meaningful representations of his/her analysis. He/she must also be adaptable to emerging analytical problems. Therefore, it is likely that elements of both are critical for expertise acquisition. In this paper, we will discuss both in terms of instruction. We begin with a discussion of two philosophies of instruction summarized from the most recent book by Knowles, Holton and Swanson (2005).

Pedagogy vs. Andragogy

Various societies have provided us with a range of teaching methods. The Chinese and Hebrews developed the case method in which a situation or parable provides a story for exploring details and possible solutions. The Greeks gave us the Socratic dialogue, in which a mentor poses questions to the group and the group has to come together to find a solution. The Romans developed a challenge method that forces students to state positions and defend them. Typically these methods – or pedagogies - involve the teacher taking full responsibility for decisions relative to what, how, when and if learning will take place.

The pedagogical model has evolved to meet the cognitive needs of children. As such, it relies on four basic assumptions:

- Learners must only know/learn what the teacher teaches in order to pass
- Learners are dependent on teacher
- Learners have little relevant experience (teacher and provided material are only relevant sources)
- Learners are subject-oriented and motivated by external motivators

Since the 1950's, however, there have been improvements to our understanding of adult learning. Carl Rogers (1951), while elaborating on his Humanistic theory of personal psychology, proposed a student-centered approach to learning (in Knowles, Holton & Swanson, 2005). He noted that we cannot teach adults directly, but rather we can only facilitate their learning. Gessner (1956) suggested that only the humble become good teachers of adults (in Knowles, Holton & Swanson, 2005). He proposed that the student's experience counts as much as the teacher's knowledge. His proposals of shared authority and two-way learning were the basis for an andragogical model for adult learning that emerged in the 1970s.

In order to understand the differences between child and adult education (i.e. pedagogy and andragogy), we should understand what an adult actually is. Biological and social definitions aside, learning and education strategies rely on a psychological definition. Humanistic theories of psychology suggest that we are adults when we develop a self-concept of being responsible for our own lives. This is variable based on

individual and situational differences, but most of us reach this after we leave school,

and develop social obligations (i.e. career, marriage, family, etc.).

Andragogy has three dimensions (Knowles, Holton & Swanson, 2005) - goals for learning, individual and situational differences, and core adult learning principles. The core adult learning principles include:

- Adults must understand relevance prior to learning
- Adults are self-directing and autonomous (responsible for their own decisions and lives)
- Adults have a variety of relevant experiences
- Adults are ready to learn relevant things (life related or developmental)
- Adults are problem or task centered
- Adults are responsive to external motivators, but are more responsive to intrinsic motivators.

This model for education is important for naturalistic settings because the vast majority of practitioners fall into this category. Because instruction should be designed to suit the learner, any instruction related to developing expertise in complex domains would benefit from this adult education model.

Models and Methods for Instruction

At least four models for instruction have been proposed. The first is absorption. Absorption relies on lectures or videos for one-way transmission of information for assimilation by learners (Clark, 2006). This model is popular because it is easy to prepare, common teaching model, trainers lack understanding of other effective approaches.

The second model is behaviorism and relies on operant conditioning and observational learning. Behaviorist learning is the shaping of behavior by applying or removing consequences in response to desired behavior. This model evolved from turn of the century research on animals (i.e. Thorndike, 1911 as cited in McKeachie, 1974). Thorndike proposed Laws of Learning which were eventually the foundation for Skinner's principals of behavioral learning. Because of the emphasis on incremental improvement, this method often relies on drill and practice. Drill and practice involves repeated execution of individual tasks under increasingly difficult conditions. This linear, behaviorist approach is typical in manual task training. It is also used widely in the instruction of elementary mathematics

A third model for instruction is cognitivism (Clark, 2006). Cognitivism places the emphasis on promoting mental processes that encourage the construction of new knowledge. It relies on strategies that regulate the flow of information between the environment, working memory and long-term memory. Internal cognitive processes mediate learning, so maintenance and elaborative rehearsal are elements that become important. Cognitivism is concerned with helping learners organize and access frameworks for knowledge.

A fourth model is constructivism, which involves the learner participating in determining goals and directions for learning (Gagne, Wager, Golas, Keller, 2005). This model emphasizes motivation and the creation of socially observable products. The learner actively engages in experiences that are likely to result in building knowledge structures. An example would be to teach aerodynamics by having students build an airplane. In the construction of the product, they have to learn the underlying principles. Gagne and his colleagues (2005) suggest that this model of instruction might be more effective in collaborative environments which facilitate discourse about the problem.

Not all learning is equal. Gagne and his colleagues (2005) have proposed five kinds of learned capabilities.

- Motor skills
- Verbal information
- Attitudes
- Cognitive Strategies
- Intellectual Skills

The latter two learned capabilities have the most relevance for intelligence analysis training. Cognitive strategies include methods for learning further information and are domain specific. For example, an information analyst may use certain information search strategies that he/she finds useful at work. Alternatively, the military analyst uses certain heuristics and interim analytical products in order to discern the effects of terrain and weather. Since the end of World War II, the military has widely adopted scaffolding as a method for training cognitive strategies. Scaffolding involves decomposing lessons and tasks into components that can be put together to provide skills to perform the entire task.

Intellectual skills include problem solving, or higher order rule use and generation. Analytical strategies such as Lean Six Sigma (cf. George, 2003) and ACH would fall into this category. Gagne and colleagues (2005) describe two types of problem solving that are useful for developing intellectual skills. In discovery learning, a learner is given a problem and left on their own, whereas in guided discovery the teacher provides hints when they are needed. They assert that a cognitive apprenticeship facilitates this type of skill acquisition. In a cognitive apprenticeship, the learner works alongside a skilled practitioner and has the benefit of seeing the application of strategies and skills.

In order to facilitate the acquisition of problem solving skills, certain conditions should be set (Gagne, et al, 2005). Students should be presented with novel problems for which they have the composite rules to solve. This has also been called "situated

learning" (see Anderson, Reder & Simon, 1996) and has been used widely in higher education for medicine, business, architecture, law and social work under the name "Problem based learning" (Savery & Duffy, 1995). Students should be required to apply problem-solving strategies under the observation of an instructor who is prepared to intervene with guidance. This guided discovery should involve challenging, but manageable problems. Students should be encouraged to reflect on the learning process and their skill acquisition, and should be afforded opportunities to practice on multiple, similar problems to encourage positive transfer. Finally, Gagne and colleagues (2005) assert that collaborative group work which forces students to verbalize and share in their learning. Table 3 summarizes these attributes for instruction and highlights characteristics relevant to the training of intelligence analysts.

Models for Instruction	Learned Capabilities	Conditions for acquisition of problem-solving skills (Gagne, et al., 2005)	Adult learning principles (Knowles, et al., 2006)
Absorption	Motor Skills	Problem-based	Convey relevance prior
Behaviorism	Verbal	Guided discovery	to learning
Cognitivism	Information	Practice on similar problems	Problem centered
Constructivism	Attitudes	Collaborative group work	instruction
	Cognitive	Reflection on process	Pursue goal alignment in
	Strategies	Cognitive apprenticeship	order to harness intrinsic
	Intellectual		motivation
	<mark>skills</mark>		Afford self-direction and
			autonomy
			Leverage learners'
			relevant experiences

Table 3 - Models and methods of instruction relevant for training intelligence analysts
Summary and Implications of Literature Review

Research in cognitive systems engineering and educational psychology indicates several areas of interest for the present study. While multiple aspects of macrocognition have been identified, the relationship between the functions remains unclear. Given the nature of intelligence analysis, it is clear that sensemaking and coordination are critical for this study. It has been twelve years since it was observed that open tools and shared workspaces aid in collaboration, but it is not entirely clear how open workspaces might influence sensemaking, particularly for intelligence analysis.

Intelligence analysts experience significant difficulties recognizing relevant data in conditions of uncertainty and data overload. Due to the similarities of intelligence analysis and jury decision making, it is likely that these challenges will affect the analytical strategies that inexpert (or even expert) analysts prefer. Finally, problembased learning that is tailored to adult learners is most effective for knowledge acquisition, but there is a dearth of evidence for its effectiveness in shaping analytical strategy. With these issues in mind, we arrive at our research question - What will influence team cognition in novice intelligence analysts?

* * * *

Hypotheses:

- Teams using Open Workspaces are likely to be more successful.
- Teams will face a work balance dilemma with regard to the functions of macrocognition.

Teams will persist in Story Construction as an analytical strategy despite the instructional goals of the exercise, leadership changes in the teams, and instructor interventions.

CHAPTER 3

METHODS

The U.S. Army Intelligence Center at Fort Huachuca, Arizona trains all U.S. Army military intelligence analysts. Midway through a mandatory 20-week Military Intelligence Captains Career Course, recently promoted captains conducted a training exercise focused on stability and support operations. This exercise had two goals. The first was to teach the students about analytical problems that are encountered in intelligence support to counter-insurgency operations. The second was to allow the students the opportunity to apply Analysis by Competing Hypotheses (ACH) as an analytical strategy. Prior to this exercise, they studied case studies of other stability and support operations and received a class in ACH. Throughout this five-day exercise, which ran from 0830 to 1700 daily, teams received similar instructor interventions which had the purpose of illustrating analysis of insurgency behaviors and coaching them on ACH.

As military intelligence captains, the students are analysts and analyst supervisors with a bachelors degrees. Their ages ranged between 25 and 35. They had an average of four years of military service in either combat arms or military intelligence. As such, they had either used or conducted intelligence analysis in the past. Based on this experience, we assessed all of the participants to be journeymen (as described by Dreyfus, 1997) in the domain of tactical military intelligence. The class of 40 captains had been randomly divided into four squads at the beginning of the course. This presented the opportunity to study multiple teams which had been working together for several weeks. Under the supervision of the training cadre, all squads simultaneously executed the same scenario.

Prior to the exercise, all participants were provided an overview briefing by the cadre that described the general situation. Each squad was then assigned to separate rooms, which were equally equipped with dry erase boards, maps, overlay material and four computers with only standard desktop applications. All squads received a pile (literally) of information that was to replicate the remnants of information from their predecessor intelligence section, which had been recently destroyed by insurgents. They were also provided an intelligence summary from their simulated higher headquarters. Squads were given four hours to sort through their information, after which they were to brief their commander on their intelligence assessment.

Team leaders were assigned by the instructors at the beginning of the exercise. These leadership positions for all teams were changed twice throughout the exercise by the instructors in order to provide leadership opportunities for more students. It was up to the squads to determine how they would task organize and how they would arrange the physical layout of their rooms.

On subsequent days in the exercise, the squads received periodic situation reports and other items (e.g. paraphernalia collected by their patrols in search operations). As intelligence sections, the teams were responsible for creating and briefing daily assessments to an instructor acting as their commander.

This exercise included four types of events which served as embedded probes. These were the reports, instructor interventions, leadership changes and daily briefings. According to the scenario designers, the reports had normative interpretations and multiple other suboptimal interpretations. They were sources of new information which teams could share and, in the process, verbalize or change their assessments of the situation. Instructors held similar dialogues with all squads at approximately the same times in the scenario. These interventions had the purpose of teaching analytical techniques and encouraging teams to use ACH. Leadership changes served as opportunities for new leaders to change analytical strategy, layout, work distribution and hypotheses. Finally, the daily briefings to the instructors acting as commanders were common points for the crystallization and externalization of their thought process. Since all teams received the same probes at approximately the same time, they served as unique opportunities to observe simultaneous repeated measures between groups. Figure 2 provides a summary of all event probes.



Figure 2 - Event probe timeline

The instructors were another source for data. Having conducted this exercise multiple times for earlier classes, they were familiar with common areas of difficulty. Before and during the exercise, the instructors provided accurate predictions of team behavior at critical points in the scenario. More importantly, however, the instructors interacted with the teams based on their expert judgments of analytical performance. These instructor interventions generated discourse with the participants that externalized otherwise hidden team cognition. Furthermore, they provided feedback to the teams during the daily briefings and provided final judgments of whether the teams passed or failed on the last day of the exercise.

Scenario

This scenario is a fictional world based in 1940s Great Britain. The Germans have successfully invaded England and are now facing a growing insurgency during their occupation. The 19th Regiment is occupying an area in Northumberland between Morpeth and Berwick-upon-Tweed and has its headquarters in Alnwick Castle. In the past month, the headquarters was attacked by a car bomb. The students are brought in to replace the previous intelligence section, which was entirely destroyed in the attack. As the new intelligence section for the 19th Regiment, they are responsible for assembling the remnants of their predecessors' reporting logs. Fragments of a 13 page document of past reports are given to the participants and they must first assemble the fragments. (Once complete, the instructors provided them with a new printout version which was easier to read.)

In order to accurately infer the enemy's capabilities, limitations, goals and methods, the teams had to perform five primary analytical tasks. Terrain analysis was conducted in order to identify movement corridors, likely targets, cache sites and bases of operation. Operational methods analysis (or determining modus operandi) entailed capabilities and pattern analysis in order to determine how the enemy would conduct future operations (i.e. recruiting, resourcing, planning, attacking and coordinating). Geospatial and temporal pattern analysis used past activity in order to infer would when and where future attacks might occur. And finally, social network analysis based on an

existing personality database that was provided to them on Day 2 would identify key individuals, their relationships and roles, and their residences or work places.

This scenario is designed to include both garden path and emerging path problems. Garden path problems are a class of problem where revision is inherently difficult due to strong early cues followed by weak contradictory ones (Johnson, Moen & Thompson, 1988). Emerging path problems are simpler deductive reasoning tasks in which early cues are weak or non-existent and evidence is slowly amassed to support a new hypothesis.

The garden path problem in this scenario was that initial intelligence reports and descriptions of activity suggested that British Commandos were waging the insurgency. Later reports would slowly suggest that it was in fact a larger organization of militia or Home Guard. For the tactical military intelligence analyst, the difference between these two threats indicates significantly different capabilities and limitations, and thus different methods for reducing the threats would be warranted. For example, a Commando threat would include a small number of highly trained individuals that could operate out of austere locations and move long distances in order to conduct operations. Militia would be tied to population centers for support, incapable of some types of operations, but could include many more people, some of whom the Germans may be relying upon for labor and supplies.

The emerging path problem was that the intelligence section had to deduce when and where future attacks would likely be. Over the five days, teams received reports that slowly indicate a planned attack on Alnwick Castle – something fairly unexpected given the recency of the last attack on the castle which destroyed their predecessors. While this problem is related to the garden path problem mentioned

above, it could be deduced separately (and was by one participant team) given the information provided throughout the scenario.

The designers for this exercise developed an instructor's guide for reference within the team of instructors. Included in it were normative interpretations with respect to the information available with each successive report. This provided a useful frame of reference for comparing actual team performance to an envisioned "ideal path" of inferences. The inferences related to each of the two problems in this exercise are summarized in Tables 4 and 5.

Report	Day	Time	Normative Interpretation - Garden Path (Commandos)	Normative Interpretation - Emerging Path
				(Attack on Alnwick)
1: Initial activity log	1	0900	Insurgents are able to conduct attacks despite a strict currew; therefore locals are perpetrators. Given travel times by foot, period of darkness should yield operational radii. Operational radii should be plotted for all past and subsequent activity to determine cell areas of operation	Attack cycle is tied to 0% illumination, and that Day 1 is start of no moon; therefore next wave begins tonight.
			Inree macro-nypotneses: o Equipment/ expertise supplied via external source o Guerrillas are localized groups of UK citizens hitting targets of opportunity o Guerrillas are UK citizens trained and equipped prior to invasion for national level resistance	
2: <u>Attack</u> on Blackbrook Airfield	2	0830	Same aircraft components were damaged on all aircraft - indicates guerrillas have been trained. Aspects of modus operandi revealed: Use of silenced .22 Cal weapon, booby-trap exfil route.	ID Tags removed from dead sentry indicate potential infiltration of a facility
Personality Database	2	0900	Social network analysis should indicate target individuals in each area	
3: Fenwick Staff Car <u>Ambush</u>	2	0905	Cross-referencing personality database indicates that the target was being treated by a nurse - Elford.	
4: Convoy Attack	2	0955		
05: <u>Attack</u> on Radar Site	2	1010	Captured items indicate the following: Uniform and rubber boots - confirms formal organization; rubber boots only issued to elite units. Paybook - Minary's address can be found in database - team should search his house.	
6: Staff car <u>Ambush</u> Follow- up	2	1055	Team will see firing points and target on captured map. Close examination of map will reveal pin-hole of cache site.	
7: <u>Shooting</u> at VCP	2	1230	Team could infer next target as a VIP aircraft from message in tennis ball. Team should infer that tennis ball is a dead drop.	
8: LTC Friedelman brief	2	1400		
9: Kyloe hide materials	3	0900	Team should infer the following from the materials: Paper w/ partial locations - locations of cache sites and relationship to activity should give operating radii Training Documents - indicate British army training Food & bomb material - cache to support insurgents and preparation for a short period	Team should infer the following from the materials: ID material was from kidnapped German soldier Staff car pennants (from Report 3) - indicates disguised infiltration
10: Search of Minary's House	3	1055	Followup from serial 5. Team should find support for organized military resistance hypothesis. Dr. Clark Adam letter - suggests AU training program, treatment of several AU members, existence of multiple cells, and training facility at Coleshill in Hampshire (should be disseminated) Team should ID the members & search houses, revealing more names and events (Report 20)	
11: <u>Fire</u> at Government Offices	3	1320		

Table 4 – Normative Interpretations for both analytical problems - according to scenario designers, participants have the information required to make the following inferences. All attacks are underlined to indicate that they contribute to pattern analysis relevant to these inferences.

Report	Day	Time	Normative Interpretation - Garden Path (Commandos)	Normative Interpretation - Emerging Path (Attack on Alnwick)
12: <u>Attack</u> on Train - Newlands Burn	3	1335	Existence of a Sionside Cell, with leader G. Bell, carrying out attack	Team may consider intent (along with later Felton railbridge attack) is to isolate Alnwick from rail & road (ambush threat) Team may consider intent is to force VIP travel by air (Condor) only Team may consider intent is to disrupt military resupply/export
13: Abandoned Car Search	3	1430	Cross-reference Dr. Holliman with database and search his house	
14: <u>Attack</u> on S Boat - Seahouses	3	1450	Related to Report 4 - Truck Theft Existence of Swinhoe cell	Team may consider how torpedo could be used and/or moved.
15: Staff Car <u>Ambush</u> - Hebron	3	1540	Existence of Hebron cell Primary target as the A1 main supply route	
16: Burned Out Trucks Found	4	0840	Related to Report 4 and 14 Note use of stolen trucks for transportation and fuel	Proximity to alnwick
17: <u>Sniping</u> at Vehicle Check Point	4	0940		
18: Search of Baird's House	4	1030	cancelled rail tickets have names to be cross-refenced with database Addresses associated with these names should be searched Destination of rail tickets may be determined to be location of training school	
19: Search of Elford House	5	0830- 1005	ID Mary Elford as nurse and special duty operator Team should use instructions on how to decode. Reveal locations and frequencies of radio sites that can be found on the map gazeteer.	Nurse Elford has access to Alnwick, has purchased tickets for upcoming party and has given them to Home Guard.
20: Railway Bridge <u>Attack</u>	5	0900		Attack on bridge isolates Alnwick, can't resupply troops or travel VIP's
21: <u>Attack</u> on Blackbrook Airfield	5	0910	Identify Felton cell.	Team notes that cells may revisit past targets, so they could target Alnwick again.
22: Results of Jackson's Garage	5	1100	Infer logistics role Note that individuals all live in west adjacent to rails or rivers- primary means of moving supplies Infer that rails move supplies within area and rivers move supplies from outside of the area	Use of PIAT anti-tank weapon is more conducive to urban ambushes
23: Results of Alnwick Searches	5	1150	List of suspect homes, ID no males are home, ID Baird as cell leader and Kinch as cell member/ naval engineer Diary, hide sites and map - indicate training, command structure and resources Infer method for attack on boat (Report 14)	Search J Mack's house, find torpedo body and empty fertilizer bags in workshop Could infer that fertilizer, not warhead, used in Govt office attack
24: Sabotage <u>Attack</u> on Scremeston Foundry	5	1235	Targeting critical production capabilities	
25: <u>Attack</u> on FG Station	5	1340	ID Sionside cell with leader Gareth Bell	

Table 5 – Normative interpretations (continued)

Data Collection

In order to observe this exercise, a team of six observers was assembled to conduct the data collection. This team consisted of cognitive systems engineers, political scientists, and psychologists with no formal training in intelligence analysis. As shown in Figure 3, the observation team took part in a two-day accelerated version of the same exercise in order to gain familiarity with the scenario and the operational language of the domain. By performing the work in a similar context as their participants, the researchers could anticipate vulnerabilities and appreciate the

challenges of such concurrent team tasks as personality network analysis and activity pattern analysis. For the study, one observer was assigned to each of the four squads while two observers established a command post in an adjacent room from which to monitor and facilitate communication between observers. The primary investigator (PI) retained the ability to move between squads and the command post.



Figure 3 – Research Team Conducting Scenario - The research team conducts a compressed version of the scenario they will observe.

An ad-hoc wireless network was deployed enabling communication between observers, the PI and the command post. Each observer used a laptop (Windows and Macintosh platforms) to communicate with the command post over a wireless 802.11x connection. Observers took notes by having 'conversations' with the central command post using asynchronous instant messaging software utilizing the ZeroConfig protocol. Each of the chat programs allowed observers to transfer files as well as initiate one-way and two-way audio and video connections with the command post, allowing more robust data collection and providing the command post with an on-call direct remote presence. Digital photos were taken of artifacts as they were created and used by the squads. Video and/or audio recordings were made of daily briefings. Figure 4 depicts the architecture used for observations in this study.

With four observers, it was important to establish and maintain common granularity in reports. Observers were primed with a "scenario map" which was created by the PI and the instructors who had designed the exercise. This scenario map consisted of short titles for scenario reports along with possible interpretations or action to be taken by the team. Observers were instructed to create a script of all activity. They were asked to pay particular attention to how squads reacted to each report and to capture discussions and briefings, to include instructor interventions. While they were free to make inferences about their observations, these had to be indicated as such in the chat logs.



Figure 4 – Distributed observation over an ad-hoc wireless network. In this instance, the situated observer in Room Three is transmitting audio, video, and text from a commander briefing back to the observation command center. Inside the command center, observers focus on the briefing while the other three teams continue in local observation

Inside the command center two to three members of the observation team monitored the streams of incoming observer data. Their purpose was to provide a global frame of reference for the scenario to the situated observers, technology support, and to facilitate cross-cueing of observers at rich probe points. The command post also served as a real time quality control for the chat logs. By reading the scripts as they were being made, they could ask for clarification when the text messages were ambiguous to the non-situated observer. Furthermore, they could request to video chat during interesting segments in order to serve as a distant situated observer. Throughout the study, observers could query the PI through the command center. This allowed the PI to discuss confusing matters with the instructors and clarify issues with the observers with minimal disturbance of the participant teams.

At the end of each day, full transcripts of each observer's chat logs were combined together with any supplementary multimedia. The observation team met for a "hot wash" in which lessons learned were shared and revisions to the recording protocol were made. General trends in the observations noted by the command center or PI were shared as well. Afterward each observer was responsible for summarizing their transcripts in accordance with the structure of the scenario map for that day. Preceding the next day's observations, trends and lessons were reviewed again.

CHAPTER 4

ANALYSIS

Analysis of this field study will be broken down into four parts. We will begin our analysis with a brief summary of the performance and outcomes for the four teams. This will be followed by noting data related to three areas in which patterns arose – Workspace configuration and utilization, Cognitive work balance, and Analytical strategies.

As mentioned earlier, each team was provided with the same materials for their workspace. While they were reminded by the instructors to consider how they configured their workspace, it was up to them to determine how to arrange and use their workspace. Consequently, no two teams arranged their workspace the same. Additionally, all teams were reminded about the types of analysis that they would have to perform (i.e. terrain, geospatial, temporal, modus operandi, and social network), but it was up to them to determine task organization. In general, teams divided into subgroups of two and task organized as follows:

> Team leader and Assistant team leader – designated the production schedule, read all incoming reports and held discussions about global team hypotheses.

- Social network analysis group focused on database exploitation; these individuals never rotated out of this function
- Terrain team (this team was only needed for the first day, after which the terrain analysis products did not change; consequently, these individuals changed to plotting incoming reports)
- Enemy situation two or three responsible for geospatial and temporal analysis
- Briefing production two individuals dedicated to making briefing slides or other artifacts for the end of the day briefing

The first significant distinction that was observed between the performance of the four teams was their inferences relative to the garden and emerging path problems. In general, all teams arrived at the correct hypotheses for both problems before the end of the exercise. All teams noted evidence of an attack on Alnwick (their regimental headquarters) by Day 2 or 3, but most reserved definitive declarations of this target until the Commander's brief at the end of Day 4 or later (Team One favored this hypothesis almost as soon as it was proposed.). While Team Four accepted that the Home Guard was in charge of the insurgency, they never dismissed the involvement of commandos. More interestingly, they had correctly assessed Alnwick as the target on Day 4. At that point, their assessments for both the garden and emerging path problems were on par with Team 3, which passed. However, after a change in leadership the following day, they reverted back to an earlier, incorrect assessment. Table 6 summarizes the selection of the teams' final favored hypotheses relative to these problems.

In the end, the instructors judged that two teams passed and two teams failed. In the final briefing, passing teams had correct hypotheses about both analytical problems and articulated how their assumptions were supported by facts within the scenario. Failing teams were incorrect or unable to communicate sufficiently rigorous analysis. Teams One and Three correctly assessed that multiple elements of the Home

Guard were conducting an insurgency in their area of operations and were planning to attack the Regimental Headquarters in the near future. In their final briefings, they adequately communicated the facts and assumptions that led them to their assessment. Team Two had the correct assessment, but their final briefing did not convey sufficient analytical rigor (i.e. they did not articulate how their assumptions were supported by facts). As mentioned above, Team Four failed due to reverting to earlier incorrect assessments.

	Reframing from Garden Path	Deducing Emerging Path
	(Commandos are not involved)	(Primary target is Alnwick)
Team 1		Introduced – Day 2 – 0830
	Day 5 – 1157	Selected – Day 2 – 0905
Team 2		Introduced – Day 3 – 0900
	Day 5 – 1345*	Selected – Day 5 – 1500
	(Never dismissed commando involvement)	
Team 3		Introduced – Day 3 – 1450
	Day 4 – 1035	Selected – Day 4 – 1500
Team 4		Introduced – Day 3 – 1427
	Day 4 – 1030*	Selected – Day 4 – 1500
	(Never dismissed commando involvement)	Dismissed – Day 5 - 1400

 Table 6 - Hypothesis selection for Garden and Emerging Path problems.

Process trace

While it is always important to plan for analysis prior to collection, it is often difficult to establish an analytical framework in advance for field studies. For this reason, the observers were asked to script all observable activity and then summarize that data into a coherent reflection of what happened. This first pass on the data was done in order to temporally align the observations with the sequence of reports. During and immediately following the exercise, the command center and PI noted the following classifications for the observations:

- Team interpretation of report
- Team hypotheses for scenario
- Behavior related to instructor interventions
- Other team activity

We initially believed that Requests for Information would be a relevant category, but these were not consistently observable for all teams.

Using these categories, the PI and two other researchers then created a process trace (c.f. Woods, 1993) for each of the four teams by summarizing the first passes from the observers. Subsequently, the PI created his own process trace for all four squads and discrepancies were discussed and reconciled. These spreadsheets were then printed on wall sized panels and used in order to identify trends within and between squads. When data from the first pass appeared incomplete or subjective without sufficient explanation, the raw transcripts were used for further detail and clarification. In order to minimize subjective interpretations of the data, two other researchers reviewed the data for alternative interpretations. Using this analytical process, we deduced interesting patterns in workspace utilization, cognitive work balance, and team analytical strategy.

Workspace

Despite having the same assigned tasks and building blocks for their workspace, there was significant variability in how the teams setup and used their workspaces. As Figure 5 indicates, Teams One and Three tended to use a centrally located artifact, their table mounted situation map, as an orienting and collaborating tool. Evidence of the extent of collaboration around the central situation map can be seen in Figure 6. These

photos depict seven and six chairs, respectively, oriented around the map. Additionally, Team Three has ten beverage cups and a bag of sunflower seeds on the map board.

While, some individuals on these teams worked predominantly by themselves (e.g. the social network analysis team), the team shared information relevant to their analysis at multiple daily coordination meetings. As seen in Figure 6, both used wall-sized calendars in order to post reporting information and conduct temporal pattern analysis.



Figure 5 – Comparison of Room Layout and Activity - Teams 1 and 3 used centrally located shared artifacts (i.e. maps, diagrams) to orient and collaborate. Teams 2 and 4 set up private workspaces and individuals performed uncoordinated sub-tasks on multiple computers. As indicated by the footpath in Team 4, the leader served as a coordinating agent for sub-groups.

On the other hand, Teams Two and Four established private workspaces and individuals performed uncoordinated sub-tasks. While Team Two's workspace was similar in physical arrangement to Team One, the manner in which they used it differed dramatically. Neither team relied on a centrally located situation map for discussions (see Figure 6). In fact, Team Four did not hold its first team meeting until Day 5 of the exercise, when they met for an hour.



Figure 6 – Workspace comparison –This comparison shows rooms that initially look similar, but were used differently. All photos were taken during mid-day breaks in activity.

While physical arrangement and type of tools used influences the openness of workspaces, multiple examples of privately used workspaces were observed. Figure 7 shows two from Team Two. The first is the computer database for personalities that was used by all teams for social network analysis. The social network analysis subgroup for Team Two created a rudimentary link analysis product on the computer. On Day 2, they printed the product, but they posted it in the corner of the room away from the team work areas. Many in the team never looked at it until the end of the exercise. Team Two also used the dry erase board to externalize the reports from their predecessors. However, as Figure 7 depicts, the reports were written in such small print, that they were unusable to anyone standing further than arms distance from them. They were also not formatted in such a way as to support trend analysis from a long shot view.



Social network analysis team searching personality database

Use of Dry Erase Board for calendar of past events

Private Workspaces (Team 2)

Figure 7 – Private Workspace Examples



Figure 8 – Open Tools/ Workspace Examples

In contrast, were the uses of the same tools by Team Three. In addition to their wall-sized calendar that facilitated long-shot trend analysis, and their centrally located situation map, they also externalized other aspects of their team cognition. They posted the results of their social network analysis (Item A in Figure 8), a working list of their requests for information that indicated answers to fulfilled requests (Item B), and a detailed diagram of their assessment of the insurgent's modus operandi (Item C).

Cognitive work balance

Time constrained intelligence analysis can be seen as a cognitive workflow. While the process is certainly iterative, their overall success depends on balancing the requisite functions within the allotted time. A model of how intelligence teams might balance their cognitive work is illustrated in Figure 9. In this model, the team receives the initial analytical task, or completes a briefing to the commander (CDR), and plans their analytical work for the upcoming cycle. Once division of labor, initial guidance and a production schedule are issued, the team begins to process available information. Intermittent episodes of coordination complement sensemaking in established working groups.

Experienced military intelligence teams use backward planning in order to ensure that they have adequate time to select a course of action (COA) and prepare the commander's brief. Additionally, a system of indications and warnings facilitates ongoing problem detection. For larger organizations, this function may be specifically assigned to a sub-group. When an anomaly has been detected, experienced teams begin to adapt and the resulting replanning causes further time compression as the sensemaking and coordination must begin anew.



Figure 9 – Model of macrocognitive work in time constrained analysis – prolonged period of sensemaking coincides with intermittent periods of coordination. At some point, team must decide on favored hypothesis and prepare briefing for commander to communicate their analysis. Mechanism for anomaly detection is present throughout, which can cause a further time constrained process.

This study elicited multiple instances of inexpert teams falling behind in their cognitive work. These instances can be generally characterized as one of two types of cognitive work misbalance. The first type (Type I), as depicted in Figure 10, includes instances where sensemaking tasks (i.e. working in sub-groups, individual analytical tools, reading reports, hypothesis exploration) get in the way of coordination efforts. This usually results in teams being unable to share their assessments with a decision maker or being rushed to prepare briefings. This was the most common misbalance observed in this study and was seen on five occasions.

Team One experienced this misbalance on two occasions. On Day 3, they decided that many of the team members were unfamiliar with the many reports that they had received, so they decided to review all of them in a team meeting. This two and a half hour meeting lasted until the instructor entered for the end of the day brief, leaving them with no time to prepare. On this same day, the social network analysis

sub-group worked independently the entire time. They dedicated no time to preparing a product based on their analysis, so they had no way to share their analysis and struggled to articulate it themselves. On Day 4, the instructor prompted them to depict their hypotheses for testing and briefing. Instead of doing this, they spent the day discussing and elaborating on their favored hypothesis.

Team Two experienced this misbalance on Day 1. They spent all day making analytical tools (e.g. terrain analysis product and calendar of past events), but did not complete geospatial pattern analysis and had not formed a coherent assessment by the end of the day. As the time for their briefing arrived, the instructor stated that he would be 25 minutes late for the briefing. Interestingly, despite noticing the shortcoming in synthesis and preparation for coordination, they did no further work during this extra time.





Team Four experienced this misbalance on both Days 1 and 2. On Day 1, two individuals rapidly developed a temporal analysis of past events, but the team produced no geospatial analysis. They spent two days working in insular sub-groups on individual

intelligence products and held no team meetings. There were several hours in the first day in which no words were spoken. This was made worse because they had no one assigned to read incoming reports until the end of Day 2.

This team also demonstrated a second type (Type II) of work misbalance that may have been over-compensation from their shortcomings in Days 1 and 2. As Figure 11 illustrates, Team 4 spent most of its resources preparing briefing slides during Day 3. This misbalance can result in inadequate resources being dedicated to sensemaking (i.e. hypothesis exploration) at the team level. Consequently, it also leaves teams vulnerable to undetected anomalies.

Type II Misbalance				
Macrocognitive functions				
Sensemaking		1		
Coordination	Brief Prep	Brief Prep		
Decision making		Select COA	CDR Brief	
Planning				
Problem Detection				
Adaptation/ Replanning				



Team Four actually exhibited their most balanced cognitive work during Day 4. Due to the coordination and team-level sensemaking efforts of the leader, they were prepared with an accurate assessment for their daily briefing. In Day 5 of the exercise, a new team leader for Team Four held the longest (1 hour) sustained team meeting to discuss their assessment.

Table 7 summarizes the instances of cognitive work misbalances that were observed in this study. Team Three was the only team that exhibited no discernible evidence of falling behind and they passed in the end. Team Four exhibited the most instances of misbalance and they ultimately failed.

	Balanced	Type I Misbalance	Type II Misbalance
Team 1 (Pass)	Days 1, 2 & 5	Day 3, 4	
Team 2 (Fail)	Days 2,3,4,5	Day 1	
Team 3 (Pass)	Days 1,2,3,4,5		
Team 4 (Fail)	Days 4 & 5	Days 1 & 2	Day 3

 Table 7 - Summary of Cognitive Work Balance – numbers indicate the days in which cognitive work was balanced or classifiable as Type I or Type II Misbalance

Analytical Strategy

Each of the four teams exhibited different styles of team cognition. Team One could be characterized as making a weak commitment to their favored hypothesis and holding multiple, extended team meetings. Team Two picked a favored story, elaborated on it, and defended it throughout the exercise. Team Three made persistent attempts to explore hypotheses about individual reports as well as the general scenario. And Team Four worked in insular sub-groups throughout the exercise.

We noted that all teams moved through various states in their analysis. As the scenario unfolded some moved more rapidly towards the nominal solutions to both the Garden Path and Emerging Path scenarios, and others experienced more difficulties. As suggested earlier, this scenario had multiple opportunities for reframing. These included reports (R1-R25), commander briefings (B1-B5) and leader changes (LX1 & 2). Tables 8

through 10 depict the hypothesis development for Teams 1 through 4 respectively.

Figures 12 through 15 graphically depict this same development.

Probes	Garden Path (Commando involvement)	Emerging Path (Attack on HQ)
R1		Lunar attack cycle
B1	Commandos	
R2	Debate # of insurgent	
	cells	
R3		Attack HQ again
R5		
R6	2-3 groups of trained	
	insurgents	
R7		
R8		
LX1		
R10		
R11		
R12		
R13		
R14	"This is probably the	
D15	commandos"	
B3	9 cells of Home Guard	
R16		
R17		
R18		
B4		Attack HQ
LX2		
D20		
R21		
R22		
R23	"Not commandos after	
D24	all"	
R24		
B5		Attack HQ

Table 8 – Hypothesis Development for Team 1 – R= Report; B = Briefing; LX = LeaderChange

Probes	Garden Path (Commando involvement)	Emerging Path (Attack on HQ)
R1 B1	Commandos Other insurgents with commandos	
R2 R3 R4 R5 R6 R7 R8 LX1 B2	Commandos with support from locals	
R9 R10 R11 R12 R13 R14 R15 B3		Threat to HQ
R16 R17 R18 B4	Commandos training Home Guard	
LX2 R19 R20 R21 R22 R23 R24 R25 B5	Home Guard with commando support	HQ

Table 9 – Hypothesis development for Team 2 – R= Report; B = Briefing; LX = Leader Change

Probes	<i>Garden Path (Commando involvement)</i>	<i>Emerging Path (Attack on HQ)</i>
R1		Lunar attack cycle; target roads and impending Airfield attack (only team to notice this)
B1	Commandos	
R2 R3 R4 R5 R6 R7 R8 LX1 B2	Commandos	Attack Airfield
R9 R10 R11	Commandos train	Attack HQ
R12 R13	Home Guard is behind attacks	
R14 R15 B3		HQ, Airfields, Radar and communication assets
LX2 R16	Home Guard is trained paramilitary	
R17 R18 B4	No Commandos	HQ
R19 R20 R21 R22 R23 R24 R25 B5	10-12 cells of Home Guard; no commandos	HQ; Fuel depot; Port facility

Table 10 – Hypothesis Development for Team 3 – R= Report; B = Briefing; LX = Leader Change

Probes	Garden Path (Commando involvement)	Emerging Path (Attack on HQ)
R1	Commandos	Lunar attack cycle; no geospatial pattern deductions
B1	Commandos	
R2	_	
R3		
R4	-	
R5 D4		
D7		
R8	-	
LX1	-	
B2	Commandos	Attack Airfields and Supply routes
R9		
R10		
R11	Commandos recruiting	
D12	locals	Disrupt logistics
R12		Disiupt logistics
R14	-	
R15		
B3	Commandos recruit	Attacks on Supply routes,
	locals	Airfields and potentially HQ
R16		
R17		
R18	Home Guard is in	
DA	Charge	Attack on HO in payt 24
D4	commando support	hours
R19		
R20		
LX2		
R21		
R22		
R23		
R24		
R20	Home Guard with	Attack on Fuel Donot: Attack
	commando support	on HO in 48 hours (third
		priority for security)

Table 11 – Hypothesis Development for Team 4 – R= Report; B = Briefing; LX = Leader Change



Figure 12 – Hypothesis states for Team 1



Figure 13 – Hypothesis states for Team 2


Figure 14 – Hypothesis states for Team 3



Figure 15 – Hypothesis states for Team 4

Two analytical strategies were observed in this study – Story construction and "conventional intuitive analysis" (cf Heuer, 1999). Conventional intuitive analysis may use a process similar to ACH, but does not consider a full set of alternative explanations, judge the relative likelihood of competing hypotheses, or seek disconfirming evidence. Despite one of the goals of this training exercise being to teach ACH, the preponderance of analysis resembled story construction. Only two instances which approximated ACH were observed during the 5 day exercise, both were in Team Three on Days 4 and 5.

While all teams exhibited a tendency to construct stories in order to explain the available data, Team Two was an extreme example of this strategy. After reviewing the

background material which indicated two possible courses of action (i.e. disgruntled locals or clandestine commando operations), they debated the face validity of both options. They noted that previous insurgent attacks had used Anti-tank weapons and this was interpreted as an indication of regular army activity. They also agreed that the second course of action (i.e. commando operations) was more likely to be used in the simulation. Based on these arguments, they selected their favored story (commando involvement). From this point forward, they used existing and incoming data to elaborate on their favored story. The following is a summary of how they fit 13 of 25 reports into their story. It also indicates the extent to which they resisted the suggestions of their instructors. That is to say, that the team responded negatively to 4 out of 5 instructor interventions.

I1 – "They didn't want us to get so close so quick"

R2 - Silenced attack used as evidence for commando involvement

12 – Instructors are withholding data

R3 - Viewed as an important attack. L-shaped ambush seen as evidence of highly trained force.

R4- Training manuals are seen as evidence of commando cell - ties this to current methods of US SF.

R9 - Contamination of fuel and attacks on radar site are seen as evidence of frogman infiltration in August and air insertion in July - supports favored hypothesis of commandos coordinating with insurgents. Member finds pattern of railway strikes followed by attacks on rail assets. Used as "clear connection" between commandos and insurgents.

R10 - Team convinced that there are 2 commando units based on pattern of eliminating ISR assets. Member notes the need to "fit" the crane and truck into their theory.

I3 – Complain about unanswered Requests for Information (RFIs). "There's no point in trying so hard if [the instructors] won't give us good replies on our RFIs."

R11 – Fire in government building indicates support for commando activity.

R12 - Seen as support of theory of connection between railway strikes and commando attacks on trains. View attack as means of weakening coastal area for impending attack or to tie forces down instead of being sent to Eastern Front. Abwehr report that they cannot invade until 1943 is discounted because "they have been known to be wrong before - i.e. Normandy" (note this has not even happened yet in this scenario).

R13 - Commandos/ Insurgents lack organic medical assets, so they kidnap or coerce local doctors to treat their wounded.

R14 - Attack seen as confirmation of commando sea invasion hypothesis.

I4 – Resist team member suggestion to review facts (i.e. pattern and social network analysis) relative to their hypothesis. Team agrees they should be on the same page. "We have the story figured out, we just need to find the actors." The instructors are just trying to throw us off.

R18 - initially uncertain about the impact on their commando hypo; but come to explain that the commandos are training the old guard

I5 – "We must be the only team that actually figured something out" (e.g. decoded a message in a report). They try to list hypotheses, but have difficulty generating alternatives.

R20 - Supports their hypothesis of weakening German strategic movement in prep for invasion.

R21 - Seen as another attack on strategic ISR asset. Fits with their invasion story.

R24 - Concludes this is tied to the invasion. (two actually shout "invasion" in unison) Insurgents would not attack such a long range strategic target. They are unwilling to discuss other hypotheses. *"We just need to pick one and defend it."*

While no perfect example of Analysis by Competing Hypotheses was observed,

teams demonstrated various aspects of the process at some point in the five day exercise (see Table 12). All teams produced lists of hypotheses and identified evidence to support their favored hypothesis. No teams explicitly listed evidence as contradictory to any hypothesis. However, Teams One, Three and Four listed competing supporting evidence for contradictory hypotheses, so this was considered as successful application of this step. Team Two never classified information as supporting any alternative hypotheses as they deemed all diagnostic reports as supportive of their initial favored story.

Only Team Three actually constructed a comparison matrix, and they did so for both the Garden Path and Emerging Path problems. However, not even Team Three refined the matrix as the process indicates. All four teams drew conclusions based on their data, but none of them demonstrated any attempts to disprove their favored hypothesis, or perform any sensitivity analysis on their assessments. All teams presented their conclusions in the command briefings, but none articulated alternative hypotheses or relative likelihoods. Finally, all teams except for Team Two made some

references to future collection to clarify gaps in their analysis or indications for

reframing.

The following sequence of activities was observed for Team Three and illustrates

the closest approximation to ACH:

Day 1: Reviewed available material, listed three possible hypotheses for insurgents - Untrained civilians, trained Home Guard, Commandos.

Days 2 and 3: Constructed a matrix of evidence for three hypotheses. Because they had no evidence to support untrained civilians, it was eliminated.

Day 4: Reviewed information that they felt supported two remaining hypotheses. They felt that sophisticated attacks on specific targets were indications of commandos. However, since the Home Guard would be provided some training to perform similar operations, it could be either. Because ports that could support a larger invasion would be unavailable for a year and the attacks were happening in the vicinity of population centers, they settle on the Home Guard hypothesis.

Day 5: Used a similar process in order to identify the likely target for a stolen warhead – their headquarters. They reported the results of their analysis in the command briefing, but did not discuss the relative likelihood for their alternative hypotheses (i.e. Commandos and targets other than the headquarters).

In every command briefing, Team Three articulated suspected individuals, possible

insurgent targets, and targets for friendly searches. While their analysis was sufficiently

rigorous, it did not replicate the prescribed process, and, in fact more closely resembled

"conventional intuitive analysis" as described by Heuer (1999).

ACH Steps	Team 1	Team 2	Team 3	Team 4
1 - List Hypotheses	YES	YES	YES	YES
2 - List Supporting Evidence	YES	YES	YES	YES
List Contrary Evidence		NO		
3 - Construct Comparison Matrix	NO	NO	YES	NO
Analyze "diagnosticity" of evidence			NO	
4 - Refine Matrix	NO	NO	NO	NO
5 - Draw Conclusions	YES	YES	YES	YES
Attempt to disprove	NO	NO	NO	NO
6 - Sensitivity analysis	NO	NO	NO	NO
7 - Report Conclusions	YES	YES	YES	YES
Include relative likelihoods	NO	NO	NO	NO
8 - Plan Future Observations/	YES	NO	YES	YES
List Indicators for Reframing				

Table 12 – Team Usages of Analysis by Competing Hypotheses (ACH)

Instructor Interventions

Instructor interventions were timed to follow situations in which the teams would likely fail or perform poorly. As such they were good indicators of areas that the instructors viewed as difficult and served as a source of data for our research team. As opportunities to help the students change their analytical strategy or workspace use, they met with limited success. On Day 1, Team Four made no changes to its insular work groups based on the recommendation to improve coordination. Team Two resisted the instructor's suggestion to consider alternative hypotheses, stating "[The instructors] just did not want us to get so close, so quick". However, Team One did make a concerted effort to externalize their assessment, and Team Three significantly reorganized their workspace in order to align it with the flow of information through their team.

On Day 2, no teams altered their strategies based on the suggestions of the instructors to list indicators. On Day 3, Team One attempted to use ACH by listing some

hypotheses and indicators on the dry erase board. However, they never associated the two lists and erased their work the following day. As suggested before, Team Three was the team that performed analysis that most closely approximated ACH. This followed instructor interventions on Day 3 and 4. On Day 4, there were no changes to analytical strategy following further guidance by the instructors; however, Team Three continued to try ACH based on encouragement of the instructors. Finally, on Day 5, Team Four held its first team meeting following the suggestion by the instructor and the replacement of the team leader. Throughout the five day exercise, only six of the nineteen observed interventions produced positive changes in team cognition. Table 13 summarizes these outcomes.

Interventions	Team 1	Team 2	Team 3	Team 4
	Weak commitment/	Pick story,	Persistent	Insular
	Team Meetings	elaborate and	hypothesis	sub-groups
		defend	exploration	
1 – workflow,	YES – make	NO – "They just	YES – team	NO
products	concerted effort to	did not want us to	rearranges	
	externalize their	get so close, so	workspace	
	assessment	quick″		
2 – Modus	NO, but scrutinize	NO – complain	NO	NO
Operandi (MO)	reports much more	that instructors		
		are withholding		
		information		
3 – MO and ACH	ALMOST – list some	NO – complain	YES – team tries	NO
	hypotheses and	about	ACH twice in	
	indicators, but don't	unanswered RFIs	following days	
	associate the two			
	lists			
4 – MO and ACH	NO, but revise their	NO – very	(YES) team	NO
	hypothesis after	defensive and	already trying	
	lengthy discussion of	angry when	ACH; leads to	
	past reports and MO	directed to	refinement of	
		overlooked data	hypothesis	
5 – ACH and	N/A	NO- Try, but find	(YES) team	YES –
insurgent use of		it difficult to	already trying	leam
resources		generate	ACH; causes	holds first
		alternative	refinement of	team
		hypotheses	hypothesis	meeting

Table 13 – Instructor Interventions which produced changes in analytical strategy or workspace – interventions are listed with their predominant themes; teams are listed with their predominant team cognition styles

A separate researcher rated the receptivity of the teams toward their instructor

interventions (See Table 14, adapted from Grossman, 2007). Based on the responses of

the teams to the instructor interventions, he rated their receptivity as High, Mixed or

Low. These assessments of receptivity show a high level of congruence with this

researcher's judgments. Of the nineteen interventions that were independently rated,

only two (Team 2, Intervention 3 & Team Four, Intervention 3) were discrepant. This

indicates a strong interrater reliability index (17/19 or kappa = 0.89).

Interventions	Team 1	Team 2	Team 3	Team 4
1	High	Mixed	High	Low
2	Low	Mixed	Mixed	Mixed/Low
3	Low/mixed	High	High	High
4	Mixed	Low	High	Low
5	N/A	Low	High	High

 Table 14 – Receptivity of teams to instructor interventions (adapted from Grossman 2007)

Leader Changes

Twice during the exercise, instructors changed the team leaders. The purpose was to provide leadership opportunities for more students, but it also provided opportunities for the teams to alter their cognition. Specifically, we reviewed our observations for changes in strategy or style, workspace arrangement or use, and favored hypotheses. Of the eight leadership changes between the four teams, only two produced observable changes in any of these areas, both were in Team Four (See Table 15).

Team Four's first leader divided the team into sub-groups and assigned tasks. For the next day and a half (the entirety of his time in charge), the team worked in insular sub-groups with no team interaction over one minute in duration. There was one period of an hour and a half in which no words were spoken in the team. After the team leader changed, the new leader retained the insular sub-groups, but began performing the functions of coordination and sensemaking at the team level. On Day 5, the third leader, despite being the quietest in the team on earlier days, held the first entire team meeting to discuss hypotheses. This meeting lasted for an hour and when it was complete, the team had changed its favored hypotheses from a correct one (i.e. Home Guard will attack the Headquarters in 24 hours) to an earlier one that was incorrect (i.e. Home Guard is supported by Commandos and will attack a fuel depot and possibly the Headquarters in 48 hours).

Leader Changes Followed by Changes in Team Cognition			
	Strategy/ Style	e Workspace	Hypotheses
Team 1			
LX 1	NO	NO	NO
LX 2	NO	NO	NO
Team 2			
LX 1	NO	NO	NO
LX 2	NO	NO	NO
Team 3			
LX 1	NO	NO	NO
LX 2	NO	NO	NO
Team 4			
LX 1	YES	NO	NO
LX 2	YES	NO	YES

Table 15 – Leader changes which were followed by changes in team cognition.Instructor directed changes in leadership were followed by observable changes in Strategy/Styleand favored Hypotheses in only one of 4 teams.

CHAPTER 5

FINDINGS

The data from this study suggest three general findings for team cognition in intelligence analysis training. The first is that teams using open workspaces are likely to exhibit more rigorous analysis than teams using private workspaces. The second is that teams face a work balance dilemma with regard to the functions of macrocognition, and the third is that story construction is a persistent analytical strategy for intelligence analysts. We will discuss each in turn and then discuss lessons learned from our methodology.

Open workspaces aid team cognition

While all teams in this study had the same physical building blocks, it was up to the teams to create their workspace as well as their process. We observed notable differences in physical arrangement, but more important were differences in how the spaces were used. On first inspection, open and private workspaces can look quite similar. In fact, private ones may even look preferable due to a more orderly appearance. While Teams Two and Four appeared to be cleaner or neater workspaces, both teams exhibited poor intra-team coordination and ultimately failed. The two teams that passed (i.e. One and Three) used open workspaces. While open tools contribute to effective teamwork, our data indicate that the manner of use matters as much as physical arrangement. Table 16 summarizes some key differences between open and private workspaces.

Characteristics of Open Workspaces	Characteristics of Private Workspaces
Shareable artifacts	Hidden or individual artifacts
Observable cognitive work (aided by open tools)	Artifacts that are only
	understood by the creator
Facilitates and includes team coordination (i.e. opportunities	Reliance on individual
for sharing guidance, knowledge and perspectives)	computers
Externalizes working produces; avoids "keyhole" effect	Sub-groups without interaction

Table 16 – Open vs. Private Workspaces

We also noted that one team (Team Four) was able to compensate for private workspaces when their leader was serving in the role of coordinator for the team. The risk for this approach is that the team has a single point of failure for their shared mental model. This vulnerability was realized by Team Four when their leader was replaced and the team reverted to an incorrect hypothesis.

Cognitive work balance dilemma

"Where did the time go?"
 "It's 1030 already?"
"We just have to get something down, it will have to suffice"
 "We're just going to make some [stuff] up."
"At least we have a really nice [terrain analysis product]"

Given the nature of intelligence analysis, we expected to see evidence of time constraints influencing work. Work bottlenecks often occur in time pressured situations

and lead to four coping strategies: resource recruitment, shedding, delaying, or performing tasks poorly (Huey and Wickens, 1993; Woods and Hollnagel, 2006). In this study, we observed two types of falling behind that suggest a tradeoff relationship between the macrocognitive functions – sensemaking overcoming coordination (Type I misbalance); and coordination overcoming sensemaking (Type II misbalance). The Type I misbalance was the most predominant, being observed 5 times, while the Type II was only observed once. The one instance of Type II misbalance occurred after two consecutive days of Type I misbalances for Team Four. So, it is possible that the Type II misbalance that Team Four experienced was a form of overcompensation from earlier Type I misbalances. Our data indicates that managing the cognitive workload in intelligence analysis is difficult and results in a work balance dilemma.

Story construction is persistent

"We have the story, we just have to find a way to fit the crane into it." "We know the story, we just have to find the actors."

We noted that analysis within all teams resembled story construction as described by Pennington & Hastie (1993). Teams persisted in story construction as an analytical strategy despite instructor interventions and leadership changes. The team that was most persistent with this strategy also exhibited a strong early commitment to their favored hypothesis and significant attitude polarization in the face of instructor interventions that suggested reframing or altering their analytical strategy.

Each team received 3 interventions on 3 separate days and only one team shifted to a close approximation of ACH. Two other teams tried to use the method, but

gave up after experiencing difficulty in generating alternative hypotheses. It would appear that putting the process into effect is not intuitive to inexpert analysts. Furthermore, the process may create more work for analysts because they often rely on narratives to brief their analysis to decision makers.

From our observations, we noted that both ACH and story construction could be good or sufficient analytical behavior. Despite the goal of the training exercise being to apply ACH, our data did not show a relationship between its application and successful analysis. More indicative of good vs. bad analysis were teams' efforts to consider multiple explanations, and their ability to support their explanations with associated facts. In its traditional sense, ACH would not benefit the latter, as it suggests that analysts focus on developing conflicting data for available hypotheses. Given severely time constrained analysis, this creates added work for the analyst who is only required to articulate supporting facts to the decision maker.

Our data indicates that data availability does not equate to accurate mental models or effective sensemaking. A comparison of the evolution of hypothesis states across all teams (Figure 16) indicates that teams provided the same data, guidance and similar situations do not find it equally easy to make sense of their environment.



Figure 16 – Comparison of hypothesis states for all teams

Our data show that leader changes were generally ineffective in changing strategy, workspace use and hypothesis exploration. Only 25% of leader changes were followed by observable changes in analytical strategy or style, and only 12.5% were followed by reframing. This indicates that internal reassignment or re-tasking of personnel may not be very effective in broadening or avoiding fixation.

Finally, instructor interventions met with low success relative to their purposes. Only 6 of 19 (31.5%) interventions were followed by changes in team cognition. Four of eleven interventions (36.4%) that were intended to encourage ACH were successful. On the other hand the two of the four interventions that were intended to shape workspace use were effective (50%). This may suggest that teams have less investment in their workspace design and use than they do in their methods of analysis.

It is possible that other conditions that were created by the course at large influenced the effectiveness of the instruction. Prior to this exercise, the students had been given predominantly slideshow based lessons. This absorption model of learning is insufficient preparation for in-depth adult learning, as it does not afford self-direction or leverage the experiences of the learners (Knowles, et al., 2005). During the exercise, the instructor interventions were typically pedagogical in nature (i.e. expert imparting knowledge), and did not attempt to leverage relevant expertise of the students. Although this exercise was an excellent example of problem-based, collaborative group learning, it was not modeled as a cognitive apprenticeship. An unsolicited complaint made to the research team by a student was that they (the students) would like to see more examples of "what right looks like". These conditions and our data indicate the predominance of pedagogical education strategies may have contributed to a low readiness to learn cognitively challenging applications such as ACH.

Methodology Lessons Learned

Researchers may find it difficult to understand the nuances of work in complicated domains: domain-specific doctrinal language and peculiar procedures often demands that researchers intervene with the practitioners in order to comprehend interactions, thought processes, or mindsets. For this study, the pre-collection orientation exercise was important for familiarizing observers with the scenario, domain operational language, and cognitive work that would be observed. In order to inculcate lessons from this exercise, time between the orientation exercise and the actual study would have been beneficial for re-planning collection activities. Ultimately, interventions with the squads were very rare and could be reserved for the end of the day. While not instrumental for quality observations, the diverse interdisciplinary team enabled the leveraging of multiple perspectives throughout data collection and initial analysis.

The command and control center allowed for the conduct of this federated observational study. While instrumental for situational awareness for the observers and providing tech support, it allowed for coordinated observations of concurrent activity in geographically separated locations. The command center allowed for cross-cueing of observers during collection and provided a means for clarifying confusing occurrences throughout the exercise. The command observers performed cross-checks across the situated observers to detect emerging trends and directed attention toward anticipated events.

The asynchronous communication tools provided status-at-a-glance cues that helped to dynamically calibrate focus and assisted the observation team in coordinating the real-time distributed protocol analysis. Asynchronous chat also allowed for video integration of the command center team as additional observers for periods where knowledge or process were crystallized and externalized (i.e. briefings).

The command center experienced a trade-off between the functions of coordination and analysis of reported observations, however. During periods where the command center was reviewing records or directly assisting one particular observer, there would be a lag in response time to address other issues in the team. Ironically, this is a limitation that real analytical teams experience in that they find themselves only

able to receive information or analyze it. For research purposes, this impact can be minimized with a structured schedule of operations.

Finally, the end-of-day hot washes provided the ability to calibrate within the team, broaden perspectives of the observers and direct attention for the next day. These daily reviews greatly aided in the shaping and re-planning of observational strategies. To increase the productivity of these hot washes the Command Center can select items of interest and note general trends for discussion.

This innovative method provided several advantages in the study of distributed complex group work (summarized in Table 17). Ultimately, we created our own open workspace and used asynchronous command center interaction and periodic face-toface meetings in order to achieve balanced cognitive work within our own research team.

Setup and Methods	Advantages
Diverse interdisciplinary team	Multiple perspectives
Found scaled world study	Robust representative training scenario
Researchers perform representative work	Enhanced appreciation for domain specific work and domain familiarization
Federated observation	
Multiple observers	Ability to observe distributed work
Command center	Ability to cross-cue observers
End-of-day calibration meetings	Observers as analysts
Wireless collaborative observation	Co-located observation teams

Table 17 - Advantages for this study's unique methods – From Trent et al., (2007)

CHAPTER 6

DISCUSSION

This study has generated findings relative to macrocognitive teamwork and intelligence analysis training. Given time-constrained problems, inexpert teams experience a cognitive work balance dilemma that can result in poor analysis. In this tradeoff, they may devote too many resources to sensemaking at the expense of coordination, or vice versa. This can result in an inability to share their analysis (as seen in Type I misbalances) or shallow analysis (under Type II misbalances). This dilemma is further challenged by the nature of intelligence analysis. Determining sufficient granularity in analytical process is a function of skill, the problem set and time. So recognizing when to stop is challenging for inexpert teams or teams working on novel problems (Zelik, Patterson & Woods, 2007a). Although our data only indicated two types of misbalance, it is likely that other misbalances occur as the demands of one or more macrocognitive functions strip resources from other functions. Furthermore, because the macrocognitive functions are generic and occur in most natural settings, it is likely that misbalances affect other domains as well.

We observed ineffective sensemaking and degraded common ground. Similar to Weick's (1993) findings, sensemaking broke down due to poor communication (as in Team Four) and persistent incorrect hypotheses (as in Team Two). Team Four was interesting because it had arrived at the correct solution, but reframed after a leader change. This loss of common ground was likely brought about by four conditions: the team's inexperience in working together on such a problem, their insular workgroups creating conditions where teammates had access to different data, and poorly communicated logic from the leader who was serving as the team sensemaker. These conditions have all been noted elsewhere as barriers to effective coordination (Klein, et al., 2005).

The persistence of story construction over ACH indicates that story construction is a default strategy for novices and those under time-pressure. We saw evidence of teams trying ACH, but going back to story construction when they were time stressed and had difficulty generating multiple hypotheses. This is consistent with the findings of Lehner and colleagues (1997), with respect to "unnatural decision making processes". We noted multiple similarities between intelligence analysis and jury decision making (a domain in which story construction predominates). In both domains, the data is presented or collected over multiple days, causal relations between data are important, and available information comes from multiple sources of unknown and variable reliability. Analysts are further challenged because they must decide for themselves what the alternative stories are. Table 18 summarizes factors that likely contribute to the persistence of story construction.

Characteristics of Intelligence analysis	Barriers to Adopting ACH
Data presented over multiple days	Process is not intuitive to inexpert analysts
Causal relationships between data are	Generating multiple, distinguishable hypotheses
important	
Information from multiple sources of	Does not aid in briefing complex data to decision
unknown and variable reliability	maker, which relies on narratives
Analysts must generate, test and select	
from alternative explanations	

Table 18 – Aspects of intelligence analysis that contribute to persistence of story construction

As suggested earlier, both strategies can be sufficient or inappropriate under certain circumstances. It is important for practitioners and designers to understand the limitations of both and how they can be improved. Story construction, for instance, might be improved by encouraging the development of distinct alternative explanations. Creating and leveraging diversity within the teams creates multiple perspectives, which likely aid in the creation of these alternatives. Additionally, experts in this study demanded explication of facts and assumptions. Doing so highlights for the analyst and decision maker the evidence versus the inferences and thus aids in testing and understanding the strength of the explanation.

This study also has demonstrated important findings for those who educate or lead teams of analysts. Similar to findings in naval navigation (Hutchins, 1995), airport operations (Suchman, 1996), and software development (Teasley, Covi, Krishnan, & Olson, 2000), we have observed that workspace design and use influence team performance in analytical tasks. We found little evidence of internal team changes resulting in better hypothesis exploration, hypothesis testing or workspace use.

Additionally, we found that pedagogical instruction may not be effective for teaching challenging analytical strategies. Several factors may have contributed to a poor readiness to learn problem-solving skills such as ACH. Prior instruction was predominantly slideshow based and poorly leveraged relevant experiences in the students. Although the exercise was a good example of guided problem-based team learning, Gagne and colleagues (2005) suggest that a cognitive apprenticeship model would work better. Cognitive Systems researchers have suggested that workgroups should have a system that allows an expert to parse out representative components of more complicated work in order to mentor and supervise novices on the job (Hoffman, Lintern & Eitelman, 2004).

Contributions and Limitations of this study

This study demonstrates an ambitious innovative attempt to capture complex distributed work. The robust observation methods afforded concurrent repeated measures for comparative analysis. Established teams with professional working relationships at stake created realistic team dynamics. The absence of intelligence support tools that are common in many real workplaces reduced the influence of these technologies on cognitive work. The multi-day exercise contained distractions and competing demands on team members that interrupted the flow of analysis. For example, participants left the exercise to plan transportation appointments, promotion ceremonies, and take off for the weekend. This balance of conflicting goals is typical of real work in this and other domains, and can be lost in smaller scale exercises. The extended exercise also provided an event horizon that has been reported to affect sustained attention in real world settings (Trent, Patterson, Woods, 2007). This may explain the lack of revision and hypothesis exploration during the last day of the

exercise. Because their mission was culminating, they may have had difficulty sustaining attention or believed that they had all of the relevant information.

This field study, like most, has a small sample size (N=4). We made no effort to attain a random or representative sample of intelligence analysts. Our participants were a convenience sample given that they were already participating in a mandatory exercise in the course of their regular training. This potentially limits the extent to which we can generalize our findings. Additionally, there are three aspects which potentially confound our analysis – situated observers, post hoc categorizations of observational data and instructor interventions. We maintain that these had nominal impacts on our findings, however. Participants conducted their work and non-work related socialization as if the observers were not present. Post hoc trend analysis is common practice for field research, and the instructor interventions and subsequent reactions were important sources for data.

This study focused on two classes of analytical problems that are common in intelligence analysis – Garden Path problems and Emerging Path Problems (or deductive reasoning). Our participants also struggled with a third class of problem – the Puzzle Problem. Puzzle Problems present all relevant data all at once and the analysts have to determine relationships between the data. The social network analysis conducted on the personality database was a puzzle problem, but our collection protocol did not support findings relative to this problem. A fourth type of problem that can exist in adversarial interactions is deception detection. In this case, an adversary presents stimuli indicative of a false explanation of his or her capabilities, limitations, goals or intent. Analysts in multiple domains often deal with more than one or all of these

classes of problems concurrently. Further studies of analytical performance and the interactions of these problems are warranted.

However, this study included some tradeoffs in realism that may limit generalization of the findings. Because it took place in a school environment, team members were assigned to positions of leadership and teams were generally homogenous in experience and expertise. Real teams of analysts have more established hierarchies and more variety in experience and expertise. This simulation had a low rate of reporting (i.e. 2-4 one-page reports per day) and was not concerned with creating data overload conditions. Real teams often have more variety in data sources and much higher volume of information. All collaborations were collocated, while real teams often require geographically separated and asynchronous collaborations. Finally, given the tactical nature of this scenario, it is worth noting the similarities and differences between two approaches or perspectives for intelligence analysis – strategic and tactical.

Tactical vs. Strategic Intelligence Analysis

Military doctrine describes three levels of warfare and analysis - strategic, operational and tactical (JP 2-0, 2000; JP 3-0, 2001). At the strategic level, planners, analysts and decision makers are concerned with developing national strategy and policy, determine weapon system and force structure requirements. Operational level practitioners focus on accomplishing strategic objectives within a theater of war by planning and conducting campaigns and major operations. This particular level of warfare is under-studied due to the ad hoc and temporary nature of the organizations established for this role. Tactical units are responsible for planning and conducting

battles and engagements. The tactical analyst provides their commander with information on imminent threats.

Within to the intelligence community system, this spectrum of responsibility is analogous to the Sharp-end/Blunt-end continuum of a joint cognitive system (Woods, Johannesen, Cook, & Sarter, 1994). At the sharp end of practice, agents work more directly with the hazards and system components. They must pursue multiple goals while acting according to local constraints and are also more sensitive to changes in their environment and system. At the blunt end, practitioners have a more global perspective, control resources (in this case, processing capacity and collection assets). Either side is capable of mismanaging their responsibilities and creating disturbances throughout the system. For example, unmet reporting deadlines or inaccurate reporting at the sharp end of analysis can lead to poor assumptions by those at the blunt end. On the other hand, insufficient detail in global updates from the blunt end of analysis can erode trust at the sharp end. The analogy breaks down, however, when we consider the similarities of the cognitive tasks at either end of the analytic spectrum.

According to Joint doctrine on intelligence operations (JP 2-0, 2000), all levels of analysis perform similar tasks. Analysts must:

- □ Plan and direct intelligence operations
- □ Collect information
- □ Process and exploit information
- □ Analyze and produce intelligence
- □ Disseminate and integrate
- □ Evaluate intelligence operations

Cognitive engineers have refined these tasks based on research in the domain. They

have arrived at support functions of analysis that include Down collect, Hypothesis

exploration, Conflict and Corroboration and Produce/disseminate (adapted from Elm et

al., 2005 and Trent, Patterson, Woods, 2007). Military doctrine suggests that only the down collect and production tasks differ in qualitative ways.

These differences result from differences in focus, resources, and the tightness of the feedback loop. Tactical intelligence has more proximal consequences: "Tactical intelligence tasks are distinguished from those at other levels by their perishability and ability to immediately influence the outcome of the tactical commander's mission" (JP 2-0, 2000, p. 111-7). Additionally, tactical intelligence analysts typically have much more well-defined geographic or organizational areas of responsibility. This can result in tactical analysts relying more on local collaborations than strategic analysts. Strategic analysis, however, has a much looser feedback loop and focuses on the interactions of tactical activity. These differences (summarized in Table 19) and similarities can contribute to weaknesses in real analysis, which is federated over multiple echelons.

Tactical Analysis	Strategic Analysis
"Sharp-end"	"Blunt-end"
Focus on imminent threats; execution	Focus on policy, resource requirements, strategic planning
Sensitive to environment and system changes	Global perspective
Rapid feedback	Slow or no feedback
Well-defined areas of responsibility	General areas of responsibility; concerned with interactions of tactical activity
Greater control over fewer resources	Typically has access to far more resources
More local collaborations	May collaborate more with distant analysts

Table 19 - Differences in Tactical and Strategic analysis

Vulnerabilities for analysis

"Why do they keep telling us what we just told them!?" – Battalion commander expressing frustration about intelligence summaries from higher echelons.

An infantry battalion in the Balkans is assigned the mission of providing safety and security to the local population while interdicting insurgents moving across the border to conduct operations in a neighboring region. This unit reports observed military activity as well as disturbances in the civilian population on a continual basis. Additionally, they submit daily reports that summarize their assessment of the local situation. Higher echelons receive reports from multiple units such as these and have the responsibility of assessing global implications for local events. They are concerned with cross-boundary or cross-scale interactions and long term trajectories of stakeholders, and they disseminate these assessments back down to lower echelons.

As tensions increase in the region, events that occur in the infantry battalion's sector become more salient (i.e. frequency and magnitude increase). A threat to coalition forces is made to a local patrol which then reports this instance in accordance with operating procedures. The battalion staff notices that intelligence assessments from higher are becoming increasingly similar to the ones that they are sending up. One officer in the battalion notes that the report reads "more like the news" than useful guidance for further operations. It appears as if less and less attention is being paid to more global issues. One morning, the battalion commander is handed a report that the Commander of U.S Forces in Europe has ordered an increase in force protection measures (i.e. increase in body armor, weapon systems and personnel on patrols) based on information that suggests a threat to U.S. forces in the region. The source of the information was missing from the order, but the text of the message is exactly that of the report the battalion had submitted two weeks prior.

This story, taken from personal experience of the author, describes the interplay between strategic and tactical analysis. In doing so it illustrates two vulnerabilities for intelligence analysis. The first is the pull of a cognitive vacuum, or an information gap that arises in systems with insufficient feedback (Woods, 2002). The second vulnerability is creeping validity can result from analysis that is not sufficiently rigorous.

Evidence of the cognitive vacuum has been noted in the congressional review of intelligence operations in the wake of the September 11, 2001 terrorist attacks. The *9/11 Commission* noted that strategic analysts are often duplicating work and are unaware of other agencies' perspectives and information (9/11 Commission Report, 2004). Woods (2002) asserts that people act in a way such that they fill gaps in

knowledge with their own interpretations. These interpretations can be faulty when people lack relevant information or the appropriate perspective to formulate hypotheses. In this story, due to the difficulty of communicating context with data and the mechanics of reporting through multiple echelons, a gap in knowledge about the local situation developed at strategic echelons. Consequently, a lot of attentional and processing resources were devoted to filling this gap.

Unfortunately, in filling this gap, the analyst lacks or loses his/her global perspective. "Supervisors who attempt to function as local actors will quickly lose sight of high-level organizational goals. They cannot continuously monitor all processes, filter the information, and determine the appropriate course of action for each local actor. They must remain detached from the details of the local actors' environments so they can evaluate the system's progress relative to the high-level goals" (Shattuck, Woods, 2000, pp 283). Similarly, the local agent who attempts to interpret global events lacks the broader understanding of cross-boundary interactions. Simply transitioning between strategic and tactical approaches may be cognitively difficult. Novices in health care have demonstrated difficulty transitioning between strategic and tactical problem solving (McHugh, Crandall, & Miller, 2006).

The second vulnerability that is illustrated in this story is creeping validity which can result from so-called circular reporting. Circular reporting occurs when one report confirms another and both were based on the same primary source or when one was based on the other. The result is that the analyst gets a false sense of validity when the reports are actually unconfirmed. In this case, the battalion commander was able to cope with the lack of critical source reporting by recalling the text of his earlier report. No one else in this system was able to make this correction, with the result being

unnecessary constraints being placed on local actors. This vulnerability is greater when analysts are processing assessments that have insufficient audit trails (e.g. it is unclear what data or process was used to arrive at the conclusions) and data with no context. Given these vulnerabilities, it is likely that analytic approach has an effect on analytic rigor and utility.

Analytical Rigor and Utility

Rigor has been said to be a "scrupulous adherence to established standards for the conduct of work" (Final Report of the Return to Flight Task Group, 2005, p. 188). As such, rigor can be seen as a metric or criterion for evaluating analysis. Unfortunately, analytical rigor is not well-defined, and can be quite subjective. In fact, research has indicated supervisors have difficulty in assessing rigor when simply reviewing analytical products (Zelik, Patterson, Woods, 2007a). However, when information about the process is provided, most supervisors revised their assessment of the rigor involved in the analysis. Zelik, Patterson and Woods (2007b) have proposed an eight dimension model of analytical rigor. This model includes Hypothesis exploration, Information search, Information validation, Stance analysis, Sensitivity analysis, Specialist collaboration, Information synthesis, and Explanation critiquing as critical to the assessment of analytical rigor. They emphasize that these dimensions are not quantifiable, and sufficiency in rigor is context sensitive.

In this study, instructors (i.e. experts in the domain) based pass/fail based on their judgments of utility and analytical rigor. Utility of the assessments was partially dependent on accuracy, but also on whether the team informed the commander of facts that he could influence. Rigor was assessed in the end of day briefings according to

whether the teams were sufficiently articulating their facts and assumptions behind their assessments. While these are indicators of process, it is interesting to note that the instructors did not demand to see explicit discussions about the teams' process. So while they were intending to teach ACH, they placed no expectations on the teams for demonstrating its use in briefings to commanders. Quite the contrary, meeting their requirements for sufficient rigor were just as easily served by telling a story based on the data, rather than depicting a matrix of confirming or conflicting evidence.

Future research

In order to build on these findings, we suggest similar studies with teams of analysts in other information analysis domains. We have already initiated a Cognitive Task Analysis (CTA) in another high-risk domain – urban firefighting - that involves information analysis and command and control. The goal of this research will be to study distributed synchronous and asynchronous collaborations in a multi-echelon time constrained environment. It will address many of the shortcomings of the current study by establishing a robust team of researchers with commitments to multiple studies designed in collaboration with domain experts. We will study established teams with official hierarchies working under elevated stress from data overload, fatigue, and variable time pressures. (Table 20 summarizes the important contributions of this line of research.) This research project will be include two vectors – domain orientation, and staged world studies.

> Urban Firefighting Research Planned staged world studies at multiple echelons Observe established teams with official hierarchies

Data overload and variable time pressures Distributed, asynchronous collaborations Established team of researchers

Table 20 – Important contributions for research with metropolitan fire department

The first vector, domain orientation, will serve the purpose of building a knowledgeable research team with a solid relationship with authorities in the domain. While summarizing relevant research findings, the research team will share these findings with the firefighting organization in a series of papers. This will sustain a dialogue with domain experts and decision makers about challenges particular to their work. Concurrently, we will review doctrinal publications such as training and operations manuals. After action reviews of past large scale incidents will also provide accounts of breakdowns, vulnerabilities and successful adaptations in the domain.

Hutchins (1995) has noted that written procedures are not used by practitioners as structuring resources and they are not reflective of tasks that are performed. While doctrine, written operating procedures, and historical accounts are not truly indicative of the real work performed, they are a valuable starting point for further discovery. While not a complete specification of action, they serve as a basis for orienting and educating new practitioners in the domain. These documents can also reflect what is viewed as best practice, and provide an invaluable introduction to organizational constraints, domain language and expectations for the researcher.

Domain orientation will continue with knowledge elicitation and naturalistic observations. Interviews with experts and trainees will be augmented by observations of actual incidents and training exercises. Data collection for these various opportunities will be structured to collect information supportive of a functional goal decomposition (cf Elm, Potter, Gualtieri, Roth & Easter, 2003). This will provide an analysis of the system based on tasks or functions that need to be completed and the information and coordination requirements necessary to support these functions in the real world. It is independent of the way they do things, as this is often be shaped by other factors (i.e. tradition, politics, personality, etc.). This product will serve as the basis for scenario design to support further data collection and eventual prototyping.

The second vector of this research will be the conduct of planned staged world studies using methods similar to the current study. Rather than rely on existing exercises to shape data collection, our research team will design and execute training exercises in conjunction with domain experts. These face valid scenarios will be of variable fidelity and focus on critical functions that are identified in the first vector. As indicated above, established teams with official hierarchies will serve as participants in these studies, which will facilitate the completion of our CTA. In the end, our CTA will identify critical functional properties of the system, decision sequences for typical situations, and acceptable mental strategies for practitioners of various skill levels (cf Rasmussen, 1986).

Conclusion

This study has illustrated the complexities and necessity of research in training and team cognition in realistic settings. Our data indicates further support for earlier calls for open tools and workspaces to support collaboration (i.e. Hutchins, 1995; Suchman, 1996; Teasley, et al., 2000). Furthermore, we have observed that it is not merely the material or tool that is important, but rather it is also how the workspace is used that creates open or private work. Our data suggests that inexpert teams find it difficult to manage macrocognitive workloads, and often find themselves falling behind as a result. Designers and educators for analytical communities should account for and support analysts with this work balance dilemma. We also found further support for earlier observations that data availability is a poor indicator of situation awareness (Endsley, 1995) and sensemaking (Woods & Hollnagel, 2006, and Klein, et al., 2006a). Our four teams of participants had access to the same data under similar conditions and exhibited variable performance.

Finally, this study suggests the persistence of story construction as an analytical strategy. A challenge for decision making under explanation based reasoning is that people can tend to elaborately weave all available data into their favored or first story. Inexpert analysts find it difficult to adopt new strategies and it is likely that time constrained or fatigued teams will revert to these strategies. Furthermore, it is not entirely clear that one strategy is better than the other. Further research is warranted in determining when particular analytical strategies are weak or sufficient. Because the persistence of story construction and the strength of decisions which are based on narrative transport, we should investigate ways to support what can be a weak process.

While experts are more likely to perform more rigorous analysis, resilient organizations should anticipate that their expertise will not always be valid in the face of fundamental surprise. Currently, the demand for skilled intelligence analysis is increasing in all related fields (i.e. military, law enforcement, and business). This suggests that intelligence organizations should place an emphasis on helping novices achieve expertise in order to support long-term organizational proficiency.

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