Training Team Integration in a Large, Distributed Tactical Team: A Cognitive Approach

Kelly Neville [1], Jennifer Fowlkes [2], Laura Milham [2], Maureen Bergondy [3], Melissa M. Walwanis [3], Tamara Strini [1], Danielle Merket [3]

[1] CHI Systems, Inc., Orlando, Florida
[2] University of Central Florida, Orlando, Florida
[3] Naval Air Systems Command, Naval Air Warfare Center Training Systems Division, Orlando, Florida

ABSTRACT

In this paper, we describe a team cognitive task analysis (CTA) conducted for the purpose of guiding the development of training and training systems for large, distributed tactical teams. This effort is based on the premise that challenges associated with working in a large, distributed tactical team differ from those associated with working in less complex (e.g., smaller or co-located) teams. This difference means that team training paradigms developed in recent years for the latter type of team may not adequately support team integration expertise in the more complex type of team. Thus, our goals include identifying (1) challenges to team coordination in large, distributed tactical teams; (2) knowledge and skills used to achieve coordination in the face of those challenges; and (3) training guidelines and approaches that support the acquisition of team coordination knowledge and skills. To these ends, we performed a training requirements analysis of the naval air wing domain and are performing a CTA to assess the knowledge and skills used by expert versus novice aviators in support of team coordination. The CTA and its implications for training design are the focus of this paper.

ABOUT THE AUTHORS

KELLY NEVILLE has over ten years of experience in human factors and cognitive research. Her primary areas of interest are cognitive task analysis, stressor effects on cognitive performance, cognitive performance limitations, and instructional design. She earned a Ph.D. in Experimental Psychology from Rice University where she studied Applied Cognitive Psychology. Prior to joining CHI Systems, Inc., Dr. Neville worked for the Air Force Research Laboratory.

JENNIFER E. FOWLKES is a Research Psychologist with the Institute for Simulation and Training (IST) at the University of Central Florida. She has over twelve years of experience in the areas of human factors and training which includes team training and performance, training effectiveness evaluations, simulator sickness research, and performance test battery development. Most recently, her research has focused on measuring team performance in distributed training environments. Dr. Fowlkes holds a Ph.D. in Experimental Psychology from the University of Georgia.

LAURA MARTIN MILHAM is a Graduate Research Assistant at the University of Central Florida Team Performance Laboratory, where she has worked for five years. She is currently pursuing her Ph.D. in Applied Experimental and Human Factors Psychology at the University of Central Florida. She has worked on team situation assessment, performance measurement, and computer based training. Her major research interest is cognitive strategies for enhancing training effectiveness.

MAUREEN L. BERGONDY is Head of the Training Technology Development Branch of the Naval Air Systems Command, Naval Air Warfare Center Training Systems Division. She is currently performing research in aviation team training and deployable aviation training system development. Ms. Bergondy conducted her graduate studies in Experimental Psychology at Vanderbilt University.

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INTRODUCTION

In the last decade, the U.S. military and its allies have witnessed many dramatic changes – in world politics, in the nature of the threat environment, and in their role, which is increasingly to serve as peacekeepers and stabilizing forces. Equally significant are recent and ongoing changes in technology – for example, in weaponry, communications systems, and information collection systems. As a consequence of changes such as these, the military has been forced to assess and adapt the way it conducts its operations. One of the ways in which the military is adapting is to use multi-platform, joint, combined force teams and, in general, teams that are more complex.

The complex teams that are becoming increasingly common in modern military operations often consist of a variety of distributed platforms. Because training tends to be focused on the assigned systems and tasks of the individual warfighter, team members may know little about one another's systems, responsibilities, or support requirements. Consequently, they may be ill-prepared to coordinate effectively with teammates, particularly under the time pressure of a tactical mission. It seems clear that training is needed to help personnel acquire the knowledge and skills that support team coordination, especially given the complexity of modern tactical teams. What is less apparent is what skills and types of knowledge are needed by these teams and what training strategies would best support their acquisition.

In this effort, we are using research methods that derive from cognitive psychology to evaluate the team coordination training needs of complex distributed teams. More specifically, we are conducting a cognitive task analysis (CTA) of the naval air wing strike team from the perspective of the team's command-and-control platform, the E-2C Hawkeye. Based on the results of this CTA, we are developing recommendations and experiential techniques for training team coordination. In this paper, we describe the CTA background and methodology, preliminary results, and how these results might be used to guide training that enhances team coordination in large, distributed tactical teams.

CTA Background

To select a CTA approach and framework consistent with our goals, we first performed a high-level domain analysis of the naval air wing (Fowlkes, Milham, & Neville, 2000). This domain analysis laid the groundwork for the CTA in at least three important ways. First, it identified constraints and challenges that make team coordination difficult to achieve in this type of team. Second, it was a source of hypotheses about the knowledge and skills that experts use to achieve team coordination in the face of these constraints and challenges. Third, it identified naval air wing strike mission events that are dependent on team coordination. These events served as the core of the CTA, providing the context for data collection and analysis. Below, we describe the contributions of the domain analysis in more detail.

Large, Distributed Tactical Teams: Challenges

Key to achieving coordination in a large, distributed tactical team is the timely sharing of information. Yet, at the same time, this team must operate under significant communication and information exchange limitations. For example, members of distributed teams are deprived of important nonverbal cues that might indicate a teammate's level of confidence, workload, mood, or the problem on which they are focused. As another example, distributed team members often cannot know whether they have the attention of the person they are addressing – a major problem in a tactical environment in which the demands on attention tend to be high.

Distributed teams often consist of multiple specialized subteams. All too commonly, team training is limited to just the subteams with little opportunity for practice within the context of the larger distributed team – even though real world operations require fluency at both levels. Training within the context of the larger distributed team helps members of subteams develop the knowledge and skills that will allow them to coordinate effectively with members of other subteams. This training can be even more important when subteams are highly interdependent and/or perform unique tasks about which other subteams tend to be ignorant. Furthermore, in a distributed team consisting of subteams, communications among subteams must compete with communications among subteam members. In tactical teams, subteams often have dedicated frequencies that the rest of the team does not typically monitor. This increases the likelihood that communications on one level (e.g., meant for the entire distributed team) will be 'stepped on' by a communication on the other.

Communication in a large, distributed tactical team is further restricted by communication channels that are limited both in number and capacity. Consequences of these limitations include (1) reduced awareness of team members' parallel activities (Milham, 2001); (2) a loss of individualized communications (information tailored to a single individual might distract and confuse teammates); and (3) a loss of flexibility. These, in turn, impair the team's situation awareness and ability to develop and communicate new plans on the fly in response to changes in the task environment (e.g., Bergondy, Fowlkes, Gualtieri, & Salas, 1998).

When a distributed tactical team is also a large team, additional constraints to team coordination must be dealt with. Even if a change in plans is successfully communicated to everyone on the team, execution of unexpected and unrehearsed procedures by a large team is especially challenging and any number of things could go wrong. Further, as the size of the team increases, there are more people to talk to, listen to, keep track of, and support. These requirements both exascerbate communication issues described above and increase workload, making every aspect of mission execution -- including team coordination -- that much more difficult.

Likewise, the fact that a team is working in a tactical environment worsens the difficulties associated with being large and/or distributed. In addition to challenges given above, a tactical team can expect to deal with time pressure and stress, a high information load and workload, ambiguous situations and uncertainty, and a constantly changing situation. Further, the communications of tactical teams are made even more challenging by the need to use code words and follow military communications protocol.

Hypotheses about Team Coordination Expertise in Large, Distributed Tactical Teams

Salthouse (1991) describes expertise as the capability to circumvent the normal limitations of human information processing. Similarly, we propose that expert naval air wing aviators have acquired knowledge and skills that they use to overcome the challenges described above to achieve the team coordination required for successful mission execution. The CTA approach was designed to identify the types of knowledge and skills experts use to support team integration and the ways in which they use them in the context of mission events that require team coordination.

The naval air wing domain analysis performed in an earlier phase of this effort (Fowlkes et al., 2000) suggested that for this type of complex team, the traditional means of teaching conceptual knowledge and skills sequentially is less than ideal. In particular, the tactical environment is constantly changing and demands fast reaction. Thus, a person not only must be able to execute skills proficiently -- he or she also must be able to bring their relevant knowledge to bear to quickly evaluate a situation and select the appropriate skill(s). This suggests that training should target knowledge and the link between knowledge and skill selection in addition to skill execution. Accordingly, an important goal of this CTA is to assess knowledge and how it is used to guide skill selection.

Past studies of how the knowledge and skills of experts and novices differ provided insight into the types of expert-novice differences we expect to find in this effort. More importantly, they suggested types of differences potentially relevant to training team coordination in complex teams. In particular, researchers have found that the *schemata* (i.e., situation-specific knowledge structures) of experts tend to contain (1) more categories of knowledge; (2) more knowledge in support of skill implementation; (3) more knowledge about different situation variations and outcomes; (4) more structured knowledge; and (5) more accurate knowledge about what cues to attend to than novices (e.g., Adelson, 1984; Chase & Simon, 1973; Chi, Feltovich, & Glaser, 1981; Doane, Pellegrino, & Klatsky, 1990; Gitomer, 1988; Lesgold et al., 1988). We hypothesized that these same differences exist between the knowledge structures of expert and novice naval air wing aviators. Findings that support the existence of such differences could contribute to team coordination training by identifying:

- knowledge categories in which novices tend to be deficient;
- knowledge that supports the implementation of various team skills;
- situation variations and outcomes to which trainees should be exposed;
- training techniques that, from initial training on, support the development of expert-like knowledge structures;
- training strategies designed to build and enhance schemata; and
- cues that should be made more obvious to trainees during training exercises.

Below we describe the CTA methodology used to assess these hypotheses, data analyses, preliminary findings, and the implications of this work for training.

METHOD

Participants

Interview data were collected from twelve operationally active E-2C Naval Flight Officers (NFOs) belonging to four different E-2C squadrons, one E-2C NFO in a nonoperational flying assignment, and a retired NFO. E-2C NFOs were chosen as participants because the E-2C is a hub for a majority of the team communications and coordination during any naval air warfare mission. NFOs inform other team elements about the "big picture" and perform battlespace management. Thus, they should be especially aware of team member interdependencies and teamwork issues. Further, the data they provide should be relevant to the team as a whole and rich enough to support the development of meaningful team training recommendations.

Prior to being interviewed, each participant completed a paper-and-pencil survey about his experience and training. Participants had varying levels of experience. For example, as shown in Table 1, their hours in the E-2C ranged from 215 to 2100, the number of operational deployments each reported ranged from 0 to 5, and they represented all NFO designations (designations are associated with level of proficiency).

Procedure

Because the focus of this CTA is on team coordination, data were collected by interviewing naval air wing NFOs about how they and other strike team members work together during teamwork intensive mission events identified during the domain analysis. To establish a context for the interview, each NFO was first shown a videotape of a detailed strike mission brief. Because more events were identified for inclusion in the interview than we had time to cover during the 2-hr interview sessions, two separate semi-structured interview protocols were developed, each containing half of the identified events. Half the participants were interviewed using one protocol and the others were interviewed using the other. The data of one participant were lost as a result of a recording error.

Data Analysis

Data analyses reported in this paper include partial data collected from six NFOs in operational flying assignments. These six were interviewed using the same protocol. Survey data collected from these six NFOs are shown in Table 1.

Table 1. *Training and experience data of the six NFOs whose data are included in the analyses below.*

NFO No.	Rank	Hrs in E-2	Designation	No. of Operational Deployments
1	LTJG	215	RO	0
2	LTJG	600	ACO	0
3	LTJG	450	RO	1 (partial)
4	LT	500	CICO	1
5	LT	1400	ICICO	3
6	LCDR	2100	CICO	5

Note. LTJG – Lieutenant, Junior Grade; LT – Lieutenant; LCDR – Lieutenant Commander; RO – Radar Operator; ACO – Air Control Officer; CICO – Combat Information Center Officer; ICICO – Instructor Combat Information Center Officer.

Interview data were broken down into *knowledge elements* (phrases expressing a single idea or piece of knowledge), and these were organized into tables to aid in their evaluation. The section below describes the techniques used to represent and assess these knowledge elements.

Data Representation

Knowledge elements from the NFO interviews were represented using a schema-based technique. This technique assumes that expertise is associated with the development of schemata (e.g., Lesgold, et al., 1988). Further, it assumes that the knowledge within these structures is organized in a manner consistent with the way in which it is expressed in response to interview prompts, i.e., in categories that map onto the flow of each 'story' told by the SMEs. These categories are referred to as *indices* (e.g., Schank, 1990), *template categories* (Cohen et al., 1998), or, in this case, *schema categories*. These schema categories provide a means of organizing CTA data in a functional way. That is, they capture the way knowledge is used in a naturalistic task setting. The following schema categories seemed to capture the knowledge described in the NFO interviews:

- *Similar Situations* – references to past similar experiences.
- *Situation Variations* – different conditions that might exist within a situation or event.
- *Event-Specific Procedures* – steps or actions taken in response to a specific event.

- *General Procedures* – rules of thumb about how to respond to general types of events.
- *Constraints* – factors that affect what decisions can be made and what procedures can implemented.
- *Team* – knowledge about how teammates should respond to a given event and what they know during that event
- *Consequences* – knowledge about potential outcome associated with a course of action described in response to a given interview event.
- *Explanatory Information* – explanations of how things work, technical capabilities, why things are done the way they are, etc., that extend beyond the scope of the immediate problem, either in terms of depth or breadth.

Tables 4 through 6 summarizes the contents of the schema-based knowledge representations derived from the interview data. Each table represents NFO data for a particular interview prompt (i.e, event). Data are represented as knowledge element frequencies associated with each schema category. The shading of the table columns increases from left to right to represent the increasing experience of the NFOs represented by those columns.

Knowledge and Skill Assessment

Knowledge elements within each schema category were coded using candidate categories of conceptual knowledge that we hypothesize support team coordination. Candidate knowledge categories were identified during a reviw of proposed taxonomies of shared knowledge in tactical teams (e.g., Annett & Cunningham, 2000; Blickensderfer, Cannon-Bowers, Salas & Baker, 2000; Cannon-Bowers, Salas, & Converse, 1993). From these applicable, but general, categories, we derived a more domain-specific and functional set of knowledge catgories based on an analysis of the naval air wing domain by Brobst, Geis, and Brown (1999) and the domain analysis we performed prior to the CTA (Fowlkes et al., 2000). The categories additionally were refined based on initial CTA data analyses in order to improve their representativeness of the CTA data. These categories are listed and summarized in Table 2.

Table 2. *Categories of knowledge hypothesized to support team coordination in large, distributed tactical teams.*

Team Synchronization in Time and Space – Encompasses knowledge about the planned and actual location, movement, and timing of actions by team elements during the course of mission execution.

Team Objectives – Encompasses knowledge about the team's objectives and their implications for allowable risk and rules of engagement. This knowledge is used to guide and constrain team plans, team member behaviors, and decisions.

Mission Environment – Encompasses knowledge about the anticipated and actual task/threat environment; knowledge about enemy capabilities, tactics, and positions.

Team and Teammates' Characteristics – Encompasses knowledge about the team; includes knowledge about teammates' identifying information of (e.g., call signs), assigned roles, tactics and procedures, systems capabilities, knowledge, and support requirements.

Communication Procedures – Encompasses knowledge used to support one of the primary tasks of team coordination, information exchange; includes knowledge about tactical communication codes, syntax, protocols, and mediums.

Own Characteristics – Encompasses knowledge about team member's own tasks, responsibilities, and capabilities.

Knowledge elements within each schema category additionally were coded using categories of team skill that we hypothesize support team coordination. Candidate team skill categories were identified based on a review of the team training literature and our naval air wing domain analysis (Fowlkes et al., 2000). They are being refined over the course of the ongoing data analyses. The identified set of categories, summarized in Table 3, was influenced most heavily by the team dimensional training (TDT) skill dimensions identified by Smith-Jentsch and her colleagues (Smith-Jentsch, Zeisig, Acton, & McPherson, 1998) and by crew resource management (CRM) theory and research (e.g., Prince & Salas, 1993). Further, we suggest that they are, in many ways, consistent with team skills proposed by other researchers (e.g., Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Fleishman & Zaccaro, 1992).

For each event, knowledge elements in each schema category were coded with respect to the team coordination knowledge and skill categories described in Tables 2 and 3. Tables 7 through 9 show the team coordination knowledge and skill categories associated with each schema category for the two NFOS we are considering experts (NFOs 5 and 6). Categories in italics were linked to the interview data of one or both experts and to no data from less experienced NFOs. Categories in normal font were linked with at least one expert and at least one of the less experienced NFOs.

Table 3. *Categories of skills hypothesized to support team coordination in large, distributed tactical teams.*

Mission Analysis & Planning – Skills used to monitor and cross-check teammates and plan execution, assess alternative courses of action (COAs), develop plans, and critique plans.

Information Exchange – Skills used to obtain and provide information needed for coordination (e.g., timing and 'big picture' information); includes skills specialized for an information-rich, communication-limited environment (e.g., filtering and eavesdropping).

Communication – Skills used to convey information effectively; includes talking at appropriate times, conveying information precisely, using voice inflection appropriately, and using communication mediums correctly.

Leadership – Skills used to coordinate and direct teammates.

RESULTS and DISCUSSION

In this section, we describe findings associated with the hypotheses mentioned in the Introduction of this paper and discuss their training implications. These findings are considered preliminary as they are based on data from only 6 of the 14 NFOs we interviewed (see Table 1). Of these 6, 2 are considered experts (NFOs 5 and 6). We anticipate obtaining more robust results in the future, based on the analysis of the data from all NFOs interviewed.

Hypothesis 1. Experts' Schemata Tend To Be More Complete.

To examine this hypothesis, we looked at the number of schema categories used to categorize the knowledge elements of each NFO for each interview prompt (i.e., event). We additionally were interested in qualitative differences in the schema categories of expert versus less experienced NFOs. Such differences may represent types of knowledge and skill that should be targeted by training.

Table 4. *Knowledge element frequency data of six NFOs for an event in which the teammembers responsible for suppressing enemy defenses do not inform the rest of the team of the status of their effort.*

Schema Category	**1**	**2**	**3**	**4**	**5**	**6**
Similar Situations					**1**	**2**
Situation Variations			**3**			
General Procedures				**1**		**1**
Event-Specific Procedures	**1**	**2**	**2**	**1**	**5**	
Constraints				**1**	**1**	**1**
Team					**1**	**3**
Consequences		**1**				
Total Categories Represented	**1**	**2**	**2**	**3**	**4**	**4**

Table 5. *Knowledge element frequency data of six NFOs for an event in which one group of aircrafts falls behind on the mission timeline and therefore is not synchronized with the team.*

Schema Category	**1**	**2**	**3**	**4**	**5**	**6**
Similar Situations		**1**			**1**	**2**
Situation Variations		**1**	**1**	**1**		**2**
General Procedures		**1**			**3**	
Event-Specific Procedures	**1**	**2**	**2**	**2**		**8**
Constraints		**3**	**3**	**2**	**2**	**1**
Team	**1**	**2**			**3**	
Consequences		**2**	**1**			
Total Categories Represented	**2**	**7**	**4**	**3**	**4**	**4**

Inspection of the bottom row of Tables 4 through 6, which shows the total number of schema categories mapped onto the data of each NFO, indicates only a very weak tendency for experts to have more complete schemata. This trend is disrupted by NFO 2, whose data map on to as many or more schema categories as the data of the two experts.

Table 6. *Knowledge element frequency data of six NFOs for communications jamming.*

Schema Category	**1**	**2**	**3**	**4**	**5**	**6**
Similar Situations			**1**	**1**	**2**	**1**
Situation Variations		**9**	**6**		**1**	**2**
General Procedures		**2**		**1**	**1**	**2**
Event-Specific Procedures	**1**	**5**	**5**	**1**	**4**	**4**
Constraints		**4**	**4**		**3**	**3**
Teammate Tasks & Knowledge		**5**	**4**	**1**		**3**
Consequences	**1**	**3**		**2**	**2**	
Explanatory Information		**2**			**5**	**7**
Total Categories Represented	**2**	**7**	**5**	**5**	**7**	**7**

Inspection of Tables 4 through 6 also suggests differences may exist in the knowledge and skills that expert and less experienced NFOs use during the course of responding to an event or situation. For example, the two experts consistently referred to similar situations they had experienced. In contrast, the less experienced NFOs were more likely to describe possible situation variations derived from their knowledge of strike missions in general. Table 6, the only table showing data associated with the schema category ‘Explanatory Information’, additionally suggests that experts may have richer explanatory knowledge than the less experienced NFOs. Thus, for example, they may know more about reasons behind various procedures and capabilities of various systems, both enemy and friendly.

These types of differences demonstrate the potential value of high-fidelity team training exercises, which could help less experienced personnel develop ‘past/similar situation’ knowledge they could draw upon. An accumulation of this type of knowledge may help a person know what to expect and how to respond in future situations because they come to know how a certain type of situation typically unfolds and how it is typically responded to (e.g., Klein, 1993). Similarly, by simply obtaining experience by participating in high-fidelity exercises, personnel may develop a much richer understanding of *why* – for example of why one strategy is better than another, given enemy capabilities.

Table 7. *Categories of knowledge elements used by expert NFOs in their responses to an event in which the teammembers responsible for suppressing enemy defenses do not inform the rest of the team of the status of their effort.*

Schema Category	**Relevant Knowledge Categories**	**Relevant Skill Categories**
Similar Situations	• *Team/Teammate Tendencies* • *Teammate Support Requirements*	
Event-Specific Procedures	• Team/Teammate Tendencies	• Cross-Check & Monitor • *Use Information Sources Correctly* • *Pass Timing Information*
Constraints	• Own Capabilities • *Flow during mission*	
Team	• *Teammate Support Requirements* • *Team/Teammate Capabilities* • *Team/Teammate Procedures*	

Other differences may be more compatible with targeted, or deliberate, practice techniques (e.g., Ericsson & Lehman, 1996) that focus on specific aspects of skill or knowledge. In particular, the data contained in Tables 7 through 9 suggest that expert NFOs utilze knowledge about their capabilities and limitations when describing how they would respond to a situation. This type of knowledge was mentioned more frequently by experts than by the less experienced NFOs. In addition, Tables 7 though 9 show that experts tend to use some skills that less experienced NFOs did not mention. These include ‘Use Correct Communication Medium’, ‘Use Information Sources Correctly’, ‘Pass Timing Information’, and ‘Obtain Information Via Indirect Means’ (e.g., by eavesdropping). These communication and information exchange skills support experts in nondirective and noninvasive means of exchanging information, such as listening and using timeline calls to make a teammate aware of a deviation between their position and the mission plan. Each of these skills represent aspects of NFO task performance that could be targeted with training. Similarly, the knowledge that supports the use of these skills may be targeted for training.

Table 8. *Categories of knowledge elements used by expert NFOs in their responses to an event in which one group of aircraft falls behind on the mission timeline and therefore is not synchronized with the team.*

Schema Category	**Relevant Knowledge Categories**	**Relevant Skill Categories**
Situation Variations	• *Team/Teammate Tendencies*	
General Procedures	• *Communication Mediums* • *Own Capabilities*	
Event-Specific Procedures	• *Team/Teammate Procedures*	• Cross-Check & Monitor • Direct & Coordinate • Assess COAs • *Pass Timing Information*
Constraints	• Own Capabilities • Flow Plan • *Communication Mediums*	
Team	• Team/Teammate Procedures • *Team/Teammates Capabilities*	

Note. COA – Course of action.

Hypothesis 2. Experts’ Knowledge Tends To Be More Functionally-Oriented

Evidence in support of Hypothesis 2 was not revealed by the analyses performed to date. The knowledge of the less experienced NFOs seemed to map onto the same schema categories as the knowledge of the expert NFOs. Further, when the data were assessed qualitatively to determine if novices spoke at a more general level or seemed less oriented toward task execution, no differences appeared. This differs from past studies finding that novices' schemata tend to be organized around superficial dimensions whereas experts' knowledge tends to be organized around domain goals and functions/tasks (e.g., Adelson, 1981; Lynch, Coley, & Medin, 2000). Possibly, this difference reflects the fact that the less experienced NFOs in this study have more experience than a true novice would.

Table 9. *Categories of knowledge elements used by expert NFOs in their responses to a communications jamming event.*

Schema Category	**Relevant Knowledge Categories**	**Relevant Skill Categories**
Situation Variations	• Own Capabilities • Enemy Capabilities • Non-Enemy Threats • *Enemy Order of Battle*	
General Procedures	• Comm Medium	• *Use Correct Medium*
Event-Specific Procedures	• Own Capabilities • *Comm Protocol*	• Use Standard Comm Protocol • Direct & Coordinate • *Use Correct Medium* • *Obtain Information via Indirect Means*
Constraints	• Team/Teammate Capabilities • Own Capabilities • Enemy Order of Battle • *Comm Protocol* • *Commander's Intent*	• Assess COAs
Team	• Team/Teammate Procedures	
Conse-quences	• Enemy Activity • *Team/Teammate Procedures*	
Explana-tory Informa-tion	• Comm Medium • *Team/Teammate Capabilities* • *Team/Teammate Tendencies* • *Enemy Capabilities* • *Comm Protocol* • *Own Capabilities*	

Note. COA – Course of action.

Hypothesis 3. Experts tend to have more knowledge about different situation variations and outcomes

It also was hypothesized that experts would have more knowledge about different situation variations. However, as noted above, the less experienced NFOs (with the exception of the least experienced one) tended to consider different situation variations, as much if not more than the experts, as they reasoned about how they would respond to the interview prompts/events. Further, the less experienced NFOs tended to consider consequences more than experts. This difference can be interpreted as indicating that whereas experts' responses were driven by their past experiences and what worked, the less experienced NFOs, without significant experience to guide them, considered more variables, including potential consequences, as they worked through each event. In other words, their evaluation of an event posed during the interview may have been more involved, an interpretation consistent with other studies of expert-novice differences in which participants somewhere between true experts and novices were included (e.g., Lesgold et al., 1988).

Hypothesis 4. Experts' knowledge tends to be more structured.

This hypothesis was not supported, again possibly because we were not looking at true novices in this research. However, this hypothesis is difficult to evaluate and may be better assessed using data from a larger number of participants. In particular, no group of participants tended to describe knowledge that did not fall within the schema categories defined above or that was not relevant to dealing with the events posed to them. The only evidence that might suggest a difference of this type is the weak tendency for the expert NFOs to describe knowledge that maps onto a greater number of schema categories.

Hypothesis 5. Experts tend to have more accurate knowledge about what cues to attend to

This hypothesis could not be evaluated due to a paucity of cue-related data. This is likely an artifact produced by the interview protocol. Events were described to the interviewees and they were asked to describe what they would do and why, but were not explicitly asked about cues. Thus, a 'lesson learned' from this effort is to review an interviewees' responses with him or her to collect additional details they may not have included initially, such as cue usage, as is recommended by Klein and his colleagues (e.g., Klein, Calderwood, & MacGregor, 1989).

Summary of Findings

This paper demonstrates an approach to using CTA for the purpose of informing team coordination training. Using this approach, we are identifying expert-novice differences in schema categories, conceptual knowledge categories, and knowledge about the team skills used to support team coordination in a large, distributed tactical team. An additional contribution of this effort and the preceding domain analysis (Fowlkes et al., 2000) is the identification of categories of knowledge and team skills that play an important role in team coordination in this type of team (see Tables 2 and 3).

This CTA is revealing categories of knowledge and skills that are linked by their common association with a schema category. However, it does not link them in an explanatory way. To this end, the final step of this CTA may be to ask NFOs why certain skills tend to be used by experts more than by less experienced NFOs (or conversely, why experts have certain types of knowledge). Thus, we may find out that experts pass timing information, for example, about jamming protection, rather than directly inform a teammate that they are behind (i.e., cross check a teammate) because they are aware of reasons why their assessment of the situation might be inaccurate, i.e., they are more aware of their own capabilities.

We anticipate that subsequent analyses of the data of all 14 NFOs interviewed and for all interview events (vs. just the three evaluated in this paper) will reveal additional expert-novice differences and provide a more reliable evaluation of the tentative findings reported herein. The following bullets summarize the expert-novice differences revealed by the analyses performed to date:

- A weak tendency for expert NFOs to have more complete schemata, i.e., to have knowledge associated with more schema categories.
- Expert NFOs' schemata tend to include more knowledge about past similar situations and explanatory information.
- Less experienced NFOs may consider more situation variations and possible consequences in deciding how to respond in a given situation than experts.
- Expert NFOs tend to have more knowledge about their own capabilities.
- Expert NFOs tend to describe using certain communication and information exchange skills that less experienced NFOs do not.
- The structure of expert knowledge representations did not seem to differ from that of less experienced NFOs.

Implications for Team Training

A primary goal of this effort is to produce findings that contribute to team coordination training, particularly for large, distributed tactical teams. For example, our findings are relevant to the identification of team training objectives, training scenario design, and performance measure development for large, distributed tactical teams. We furthermore anticipate that this work will suggest team coordination training strategies and guidelines for complex teams. Although analyses are only partially complete and we expect future analyses to be considerably more revealing (because they will include the data of all study participants and for the full set of interview events), we suggest tentative implications for team training below.

First, the proposed categories of conceptual knowledge and skill that support team coordination shown in Tables 2 and 3 can be used to support many of the aspects of training system design mentioned in the above paragraph. They suggest types of knowledge and skill that should be targeted by scenarios, feedback, performance measures. In addition, the preliminary analyses described above suggest specific knowledge and skill categories in which novices tend to be deficient relative to experts. Thus, team coordination training might be made most efficient if it targeted those deficiencies.

Whereas some of the knowledge categories identified as novice deficiencies might be taught using feedback and verbal instruction, we advocate the use of experiential training techniques. Knowledge about the mission environment (e.g., threats) is arguably best acquired when trying to survive a mission (albeit a simulated mission) and important nuances about working with team members may only be made apparent by actually working with them. Similarly, knowledge the capabilities of one's own platform under various conditions might be best acquired using experiential or immersive training techniques that allow a trainee to discover what he or she can and cannot do or do well and, by extension, tasks for which teammates should instead be responsible. Further, we recommend an event-based approach (e.g., Fowlkes, Dwyer, Oser, & Salas, 1998) to team training in which trainees are given experience performing in situations that require teamwork. Training also should include opportunities to respond to situation variations and challenges using different procedures and strategies/skills.

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REFERENCES

Adelson, B. (1981). Problem solving and the development of abstract categories in programming languages. *Memory and Cognition*, *9*, 422-433.

Adelson, B. (1984). When novices surpass experts: The difficulty of a task may increase with expertise. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*, 483-495.

Anderson, J.R. (1993). *Rules of the mind*. Mahwah, NJ: Erlbaum.

Annett, J. & Cunningham, D. (2000). Analyzing command team skills. In J.M. Schraagen, S.F. Chipman, & V.L. Shalin (Eds.), *Cognitive Task Analysis* (pp. 401-416). Mahwah, NJ: Erlbaum.

Bergondy, M., Fowlkes, J., Gualtieri, J., & Salas, E. (1997). *Team competencies for large tactical teams*. Paper presented at the 1998 Interservice/Industry Training, Simulation, and Education Conference. [CDROM]. Arlington, VA: National Training Systems Association.

Blickensderfer, E., Cannon-Bowers, J.A., Salas, E., & Baker, D.P. (2000). Analyzing knowledge requirements in team tasks. In J.M. Schraagen, S.F. Chipman, & V.L. Shalin (Eds.), *Cognitive Task Analysis* (pp. 431-447). Mahwah, NJ: Erlbaum.

Brobst, W.D., Geis, LA., & Brown, A.C. (1999). *Analysis of NSAWC Aircrew training study: Summary and recommendations (CRM 98-172).* Alexandria, VA: Center for Naval Analysis.

Cannon-Bowers, J.A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N.J. Castellan (Ed.), *Individual and group decision making. Current issues.* Hillsdale, NJ: Erlbaum.

Cannon-Bowers, J.A., Tannenbaum, S.I., Salas, E., & Volpe, E. (1995). Defining competencies and establishing team training requirements. In R. Guzzo & E. Salas (Eds.), *Team effectiveness and decision making in organizations* (pp. 333-380). San Francisco, CA: Jossey-Bass.

Chase, W.G. & Simon, H.A. (1973). Perception in chess. *Cognitive Psychology*, *4*, 55-81.

Chi, M.T.H., Feltovich, P.J., & Glaser, R. (1991). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, *5*, 121-152.

Cohen, M.S., Freeman, J.T., & Thompson, B. (1998). Critical thinking skills in tactical decision making: A model and a training strategy. In J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training* (pp. 155-189). Washington, DC: APA.

Doane, S.M., Pelligrino, J.W., & Klatsky, R.L. (1990). Expertise in a computer operating system: Conceptualization and performance. *Human-Computer Interaction*, *5*, 267-304.

Ericsson , K.A. & Lehman, A.C. (1996). Expert and exceptional performance: Evidence of maximal adaptation to task constraints. *Annual Review of Psychology, 47*, 273-305.

Fleishman, E.A. & Zaccaro, S.J. (1992). Toward a taxonomy of team performance functions. In R.W. Sweezy & E. Salas (Eds.), *Teams: Their training and performance*. Norwood, NJ: Ablex.

Fowlkes, J., Dwyer, D.J, Oser, R.L., & Salas, E. (1998). Event-based approach to training (EBAT). *International Journal of Aviation Psychology, 8*, 209-221.

Fowlkes, J., Milham, L., & Neville, K. (2000). *Carrier air wing domain description in support of the Fleet Integration Training and Evaluation Research (FITER) program* (Task 1 Report N61339-99-C-0080). Orlando, FL: Naval Air Warfare Center Training Systems Division.

Gitomer, D.H. (1988). Individual differences in technical troubleshooting. *Human Performance*, *1*, 111-131.

Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 138-147). Norwood, NJ: Ablex.

Klein, G., A., Calderwood, R., & MacGregor, D. (1989). Critical decision method for eliciting knowledge. *IEEE Transactions on Systems, Man, and Cybernetics, 19*, 462-472.

Lesgold, A., Rubinson, H., Feltovich, P., Glaser, R., Klopfer, D., & Wang, Y. (1988). Expertise in a complex skill: Diagnosing X-ray pictures. In M.T.H. Chi, R. Glaser, & M.J. Farr (Eds.), *The nature of expertise* (pp. 311-342). Hillsdale, NJ: Erlbaum.

Lynch, E.B., Coley, J.D., & Medin, D.L. (2000). Tall is typical: Central tendency, ideal dimensions, and graded category structure among tree experts and novices. *Memory and Cognition*, *28*, 41-50.

Milham, L.M. (2001). *Adaptive use of team skills*. Unpublished manscript. Orlando, FL: University of Central Florida.

Newell, A. (1990). *Unified theories of cognition*. Cambridge, MA: Harvard University Press.

Prince, C. & Salas, E. (1993). Training and research for teamwork in the military aircrew. In E.L. Weiner, B.G. Kanki, & R.L. Heimreich (Eds), *Cockpit resource management* (pp. 337-366). Orlando, FL: Academic Press.

Salthouse, T. A. (1991). Expertise as the circumvention of human information processing limitations. In K. A. Ericsson & J. Smith (Eds.), *Toward a general theory of expertise* (pp. 264-300). Cambridge, England: Cambridge University Press.

Schank, R.C. (1999). *Tell me a story: Narrative and intelligence*. Evanston, IL: Northwestern University.

Smith-Jentsch, K.A., Zeisig, R.L., Acton, B., & McPherson, J.A. (1998). Team dimensional training: A strategy for guided team self correction. In J.A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training* (pp. 271-297). Washington, D.C.: APA.