Paper Presented at the Human Factors and Ergonomics Society 47th Annual Meeting
September 30th – October 4th, 2002, Baltimore, MD.

USING GOAL DIRECTED TASK ANALYSIS WITH ARMY BRIGADE OFFICER TEAMS

Cheryl A. Bolstad
Jennifer M. Riley
Debra G. Jones
Mica R. Endsley
SA Technologies, Inc.
Marietta, GA

A greater understanding of team cognitive processes can be facilitated by identifying the individual goals of the team members and their situation awareness (SA) requirements. In some environments, such as military operations, the shear complexity, size, and composition of the team make this research quite challenging. Using a form of cognitive task analysis, we have developed an approach to address some of these team issues. In this paper we discuss the use of goal directed cognitive task analysis (GDTA) to obtain an accurate depiction of the SA requirements and key goals for several brigade officers. We further discuss how this information is being used to address team issues such as designing systems for enhancing team performance and decision making with Army brigade officers.

INTRODUCTION

In many complex systems, tasks often need to be accomplished through the joint effort of several individuals. When a number of individuals work together or are involved in a combined endeavor to meet a common goal, they are referred to as a team. Examples of teams of individuals working together to perform everyday tasks include fire fighters, aircraft cockpit crews, and air traffic controllers. In each of these cases, the critical role of effective collaboration (i.e., teamwork) in accomplishing these tasks is unquestionable. Successful performance depends upon the coordinated efforts of these individuals (Cannon-Bowers, Salas and Converse, 1993).

Team performance is a growing research field. At present, however, little is known about the nature and performance of teams in real-world settings (Salas, Prince, Baker and Shrestha, 1995). Even less is known about ways to improve team performance. Researchers have begun to recognize that work systems are often based on teams of people, and in recent years efforts have been made to evaluate team behavior, improve team performance, assess effects of team structure and roles, investigate designs for collaborative problem solving and find better ways of training team activities (e.g. Caldwell, and Everhart, 1998; Cannon-Bowers et al., 1993). Recently, a special issue of Ergonomics (vol. 43, no 8, 2000) was dedicated to research and literature discussing team factors and functional issues that must be considered to ensure the design of successful industrial and military systems. Efforts directed at such research have demonstrated some interesting findings, however, we have only begun to explore the area of team performance.

Some keys to understanding team performance include a greater awareness of the cognitive processes of teams, the individual goals of the team members, and the overarching goal of the team. While this may seem straightforward, in some environments the shear complexity, size, and composition of the team make this research quite challenging. One such environment is that in military operations. The U.S. Army is composed of multiple teams that function with multiple echelons and levels of responsibility. Teams of Army decision makers must coordinate and communicate within their immediate groups (e.g., a brigade tactical operating center (TOC)), as well as with individuals or teams across echelons that may be above (e.g. at division level), below (e.g. at battalion level), or lateral to them (e.g. other brigades). This introduces a great deal of complexity, specifically when attempting to design systems for enhancing team performance and decision making. For example, the design of visual displays and other interface tools that allow team members to have access to all of their information requirements, which involves information sharing within and across teams, is a very pressing need for these TOCs. This access is essential if they are to effectively participate in making decisions with and on behalf of the team. To begin to address such issues, research must begin with the identification and illumination of what the individuals in the team need to do (i.e., what the individual tasks are), how they must interact with one another to meet the common goals, and what information is needed to

perform these tasks. Historically, forms of task analysis have been used for this purpose.

This paper will discuss the use of a form of cognitive task analysis, the goal directed cognitive task analysis (GDTA). While GDTA has been used extensively for analyzing SA requirements of individuals (Endsley, 1993, Endsley and Rodgers, 1995), in this paper we extend its use for supporting team research by illuminating the shared information requirements of teams of various types. These information requirements have often been referred to as shared SA or collaborative SA and are critical for the design of systems to support important team processes and interactions. The GDTA was selected because, unlike traditional cognitive tasks analysis, a GDTA is 1) not pinned to a fixed timeline, a feature that is not compatible with the work flow in many dynamic systems, 2) independent of the technology being used to perform a task (i.e., it is not tied to how tasks are done with a given system, but to what information is really needed), and 3) not just focused on what data people need, but on how the data need to be combined and integrated to support decision making and goal attainment (Strater, Endsley, Pleban & Mathews, 2001).

GOAL DIRECTED COGNITIVE TASK ANALYSIS FOR THE ARMY

The GDTA methodology was also chosen because it focuses on obtaining an accurate depiction of the SA requirements and key goals for each individual. For example, in the context of the Army, a GDTA for Brigade Intelligence Officer (S2), would include data on basic goals and subgoals of the S2 (e.g., determine gaps in the intelligence data), the major decisions that are relevant to these goals (e.g., what areas are not being assessed?), and the information requirements required for each decision (e.g. projected information needs).

SA requirements are established in terms of the basic data that are needed (e.g., location and capabilities of reconnaissance teams; Level 1 SA), required integration of the data for comprehension of system and environmental states in light of the goals (e.g., accuracy of enemy location; Level 2 SA), and projection of future trends and events (e.g. projected areas of enemy movement; Level 3 SA) that allow the officer to address each decision associated with goals (e.g., what is the best location to place additional and future reconnaissance teams) (Strater, Endsley, Pleban & Mathews, 2001).

In completing a GDTA, a researcher obtains all of the information requirements for each team member, and thus for the entire team. Therefore, the researcher has essentially gathered all of the information needs required to meet Team SA. Team SA is defined as "the degree to which every team member possesses the SA required for his/her job" (Endsley, 1995, p. 31). Team SA is a key component of successful task performance. Only if *each* member has the SA they need for successful performance can the team successfully meet its goals. A weak link in the chain can undermine the entire team.

Additionally, the GDTA allows for comparisons between the SA requirements of the various positions in order to identify overlapping goals and information requirements — their shared SA requirements (see Figure 1). In smoothly functioning teams, each team member shares a common understanding of what is happening on those SA requirements that he/she has in common with one or more other teammates. This is known as shared SA - "the degree to which team members possess the same SA on shared SA requirements" (Endsley and Jones, 1997, p. 54). For example, the S2 and the S3 both need information on enemy locations and areas of cover/concealment. They may both be aware of these data elements, though they do not make use of the information in the same way. Conversely, if one has knowledge of certain information, but does not share it, or if they each have a different understanding of the same information, shared SA will be low.

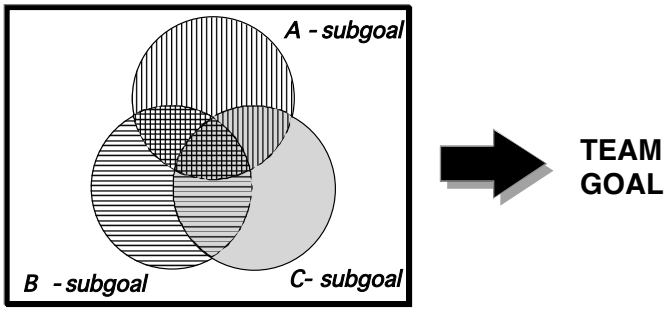

Figure 1. Commonalities among team member goals lead to shared SA requirements (from Endsley and Jones, 1997).

Complete knowledge of the other person's SA requirements is not necessary. A team member does not need to know everything other team members know. Actually, sharing every detail of each person's job with each team member would likely create a great deal of noise for people to sort through to get needed information. Only those portions of the overall information requirements that need to be shared between team members should be passed on, and need to be illuminated in order to develop systems that support collaborative SA in team operations.

METHOD

An Army brigade is composed of many different officers. We performed an initial analysis of several key brigade positions: Intelligence Officer (S2), Operations and Training Officer (S3), Logistics Officer (S4) and Brigade Engineer. The GDTAs were conducted through one-on-one interviews with brigade officers who either currently held each position or had performed the job in the recent past. The interviews were held at the U.S. Army Command and General Staff College at Ft. Leavenworth, Kansas and the U.S. Army War College in Carlisle, PA. A minimum of three officers were interviewed for each position.

After several interviews, draft goal hierarchies complete with SA requirements were constructed. These goal hierarchies were then further refined and brigade officers were asked to evaluate and make corrections or additions as needed. Subsequently, the goal hierarchies were analyzed to identify shared information requirements.

Information Requirements

The analysis of the individual SA requirements revealed many similarities across positions. For example, all positions require knowledge of terrain information (see Table 1 for terrain SA requirements). However, the detail to which they need the information and the way in which they use the information varies among positions. As can be expected, the Engineer requires the greatest terrain detail. This position entails moving and creating obstacles for the brigade and terrain plays an important role in this job. The majority of SA requirements differences appear in how the officers comprehend and make projections (Level 2 and Level 3 SA) with the same information (Level 1 data). For example, the S2 and S3 officers are primarily concerned with how the terrain affects friendly as well as enemy troop movements, assets and capabilities. The S4 and Engineer are more concerned with how terrain affects vehicle movement and the placement of objects such as obstacles and assets. By understanding not only what data each officer needs, but also how that information will be used by each officer, displays can be generated that provide only the level of detail needed for a particular position without presenting unnecessary information.

Shared SA Items

The GDTAs were also used to evaluate overlapping information requirements. Overlaps in the goals of each team member exist in that they all share a common goal. These goal overlaps lead to the ability to identify overlapping SA requirements (Endsley, 1995, Endsley & Jones, 1997). Table 2 shows some of the shared information requirements for the S2 (Intelligence) and S4 (Logistics) officers. The analysis of shared SA items indicates that the S2 and S4 officers do not share many specific details. Instead, they share general information regarding troops, infrastructures and courses of action. While they each have many different uses for this information, they have a number of different future projections (Level 3 SA) that are also in common. Interestingly, these types of projections are rarely conveyed in display design, but instead must be communicated verbally by the team members for successful coordination in most systems. Unfortunately teams are often poor at sharing Level 1 and 2 SA requirements, communicating low level data (Level 1 SA), with the (often false) expectation that it will be interpreted the same way by other team members (Endsley and Robertson, 2000).

IMPLICATIONS AND APPLICATIONS

At this time the GDTAs have proven to be very valuable for understanding the SA requirements of Army brigade officers and the information that needs to be shared between them. The information requirements generated by the GDTA are technology and process independent and thus are not tied to current Army methods of operation. For this reason, they have not only provided very useful information, but are also being considered for use in a variety of current Army applications and may be applicable to future Army operations where technology use may be significantly more sophisticated (e.g., the Objective Force or Future Combat System). The shared requirements can also be used to develop methods to increase shared SA between these brigade officers, which will be increasingly important as future operations are likely to be more distributed. One way to provide high levels of shared SA in these teams is to use the identification of overlapping SA needs to create shared displays or a common relevant operating picture (CROP). This method has proven effective in other team tasks (Bolstad & Endsley, 2000). The analyses also indicate that a single display will not meet the needs of all the brigade officers and therefore such displays need to be tailored to each officer, yet provide a window into the relevant SA of other officers in the team.

SA LEVEL	S2 (INTELLIGENCE)	S3 (OPERATIONS)	S4 (LOGISTICS)	ENGINEER

1	• Areas of cover/concealment
	• Enemy boundaries
	• Engagement areas
	• Location of restrictive terrain
	• Map of the area
	• Restrictive Points
	• Significant terrain characteristics
	• Type
	• Conditions
	• City Plan
	• Map of area
	• Subsurface
	• Features
	  • Vegetation
	  • Hydrology
	  • Location
	  • Swamps
	  • Lakes
	  • Wet Lands
	  • Rivers
	  • Bank Slopes
	  • Water tables
	• Obstacles
		• Areas of cover/concealment
		• Key terrain
		• Type
		• Conditions
		• City Plan
		• Map of area
		• Subsurface
		• Features
		  • Vegetation
		  • Hydrology
		  • Location
		  • Swamps
		  • Lakes
		  • Wet Lands
		  • Rivers
		  • Bank Slopes
		  • Water tables
		  • Obstacles
			• Areas of cover/ concealment
			• Potential choke points due to terrain
			• Type
			• Conditions
			• City Plan
			• Map of area
			• Subsurface
			• Features
			  • Vegetation
			  • Hydrology
			  • Location
			  • Swamps
			  • Lakes
			  • Wet Lands
			  • Rivers
			  • Bank Slopes
			  • Stream beds/drainage
			  • Water tables
			• Obstacles
			• Contour/elevation
			• Firmness of ground
			• Grade
				• Type
				• Conditions
				• City Plan
				• Map of area
				• Subsurface
				• Features
				  • Vegetation
				  • Hydrology
				  • Location
				  • Swamps
				  • Lakes
				  • Wet Lands
				  • Rivers
				  • Locations
				  • Conditions
				  • Bank
				  ▪ Slopes
				  ▪ Condition
				  • Water tables
				• Obstacles
				  • Type
				  • Location
				  • Quantity
				  • Rocks
				  • Houses
				  • Terrain
				  • Roads
				  • Vehicles
				  • Villages
				  • Buildings
				  • Trees
				  • People
				  • Mines
				  • Location enemy
				  • Location friendly

2	• Enemy limitations/ advantages due to terrain • Friendly limitations/ advantages due to terrain • Effect of terrain on enemy and friendly assets • Effect of terrain on anticipated troop movement time • Effect of terrain on system detection capability	• Accessibility of routes • Effect of terrain on movement times/time to position troops • Effect of terrain on rate of enemy closure • Effect of terrain on visual capabilities • Effect of terrain on communication capabilities • Effect of terrain on route difficulty	• Suitability of land for unit • Effect of terrain on ability to access location with each vehicle type • Effect of terrain on type of vehicles to be supported	• Potential approaches and exiting areas • Potential staging areas • Potential terrain suppression areas • Traffic ability • Visibility of the locations • Critical obstacle information • Past enemy usage of obstacles • Effect of terrain on location of enemy counter attacks
3	• Predicted effects of terrain on enemy COAs • Projected effects of terrain on friendly COAs • Projected terrain • Projected effect of terrain on troop movements	• Predicted effects of terrain on enemy COAs	• Projected effect of terrain on usage rates per item per unit • Projected effect of terrain on security of resources	• Estimated obstacle effectiveness • Predicted most secure location for assets, soldiers, vehicles • Predicted most survivable routes

Table 1: Terrain SA Requirements

SHARED SA REQUIREMENTS
Level 1
Enemy • Number • Type • Proximity

Friendly Units
• Current mission status
  • Equipment
  • Experience level
  • Size
  • Type
  • Status
• Power
• Weaknesses

Infrastructures • Roads • Types • Condition
Level 2 (none)
Level 3
Course of Action • Predicted enemy COAs • Projected friendly COAs
Enemy • Projected enemy actions • Projected enemy location • Projected enemy number • Projected enemy type
Mission • Projected mission tasks

Table 2: Shared SA Requirements for S2 and S4

While there are many benefits to performing GDTA for multiple echelons, it presents a number of challenges as well. The shear size and intricacies of the Army team is incredible. Not only are there almost 20 officers commanding a brigade, but also 4-5 battalions to each brigade and numerous platoons and companies per battalion. It does not end there, each brigade belongs to a Corp and each Corp belongs to a Division. Thus, the size of the teams in the Army is large which makes the use of methodologies for understanding team interactions and information needs so important.

ACKNOWLEDGEMENTS

This work was supported through Army Research Laboratory's Advanced Decision Architectures Collaborative Technology Alliance (Contract # DAAD19-01-2-0009). We would like to thank Colonel Larry Shattuck, Major James Merlo, and Dr. Anna Waggener for their invaluable support of this effort.

REFERENCES

Bolstad, C. A., & Endsley, M. R. (2000). The effect of task load and shared displays on team situation awareness. In Proceedings of the 14th Triennial Congress of the International Ergonomics Association and the 44th Annual Meeting of the Human Factors and Ergonomics Society (pp. 189-192). Santa Monica, CA: HFES.

Caldwell, B. S. and Everhart, N. C. (1998). Information flow and development of coordination in distributed supervisory control teams. International Journal of Human-Computer Interaction, 10(1), 51-70.

Cannon-Bowers, J. A., Salas, E., and Converse, S. (1993). Shared mental models in experts team decision making. In N. J. Castellan, Jr. (Ed.), Current Issues in Individual and Group Decision Making, (pp. 221-246). Hillsdale, NJ: Erlbaum.

Endsley, M. R. (1993). A survey of situation awareness requirements in air-to-air combat fighters. International Journal of Aviation Psychology, *3*(2), 157-168.

Endsley, M. R. (1995). Towards a theory of situation awareness in dynamic systems. Human Factors, (37(1), 32-64.

Endsley, M. R., and Jones, W. M. (1997). Situation awareness, information dominance, and information warfare (AL/CF-TR-1997-0156). Wright-Patterson AFB, OH: United States Air Force Armstrong Laboratory.

Endsley, M. R., & Robertson, M. M. (2000). Situation awareness in aircraft maintenance teams. International Journal of Industrial Ergonomics, *26*, 301-325.

Endsley, M. R., & Rodgers, M. D. (1994). Situation awareness information requirements for en route air traffic control, Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, (pp. 71-75). Human Factors and Ergonomics Society: Santa Monica, CA.

Salas, E., Prince, C., Baker, D. P., and Shrestha, L. (1995). Situation awareness in team performance: Implications for measurement and training. Human Factors, 371(1), 123-136.

Strater, L. D., Endsley, M. R., Pleban, R. J., & Matthews, M. D. (2001). Measures of platoon leader situation awareness in virtual decision making exercises (Research Report 1770). Alexandria, VA: Army Research Institute.