UNDERSTANDING SOLDIER TASKS FOR EFFECTIVE SIMULATION

Teena M. Garrison
Mark D. Thomas
Daniel W. Carruth
Center for Advanced Vehicular Systems
Mississippi State University
Mississippi State, MS

ABSTRACT

Military personnel involved in convoy operations are often required to complete multiple tasks within tightly constrained timeframes, based on limited or time-sensitive information. Current simulations are often lacking in fidelity with regard to team interaction and automated agent behavior; particularly problematic areas include responses to obstacles, threats, and other changes in conditions. More flexible simulations are needed to support decision making and train military personnel to adapt to the dynamic environments in which convoys regularly operate. A hierarchical task analysis approach is currently being used to identify and describe the many tasks required for effective convoy operations. The task decomposition resulting from the task analysis provides greater opportunity for determining decision points and potential errors. The results of the task analysis will provide guidance for the development of more targeted simulations for training and model evaluation from the driver's perspective.

INTRODUCTION

Maintaining a fast, consistent pace in active operations improves the likelihood of a successful campaign. A key issue for military campaigns is getting equipment to remote or difficult-to-access areas safely and effectively. First, there are the general logistical concerns of transporting large pieces of equipment, technologically sensitive materials, etc., which demand specific procedures protecting the materials being transported from damage and loss while minimizing transportation costs (e.g., time, fuel, man-hours); these are challenges faced both by the military and by civilian logistics firms every day. Additionally, military operations frequently face challenges in security, a lack of transportation infrastructure, and the sheer magnitude of the transportation tasks that must be managed (e.g., maintaining communication among a convoy of specialized vehicles through a potentially hostile environment).

Due to the many challenges faced during transportation convoy operations, the U.S. Army is interested in improving current simulation and modeling methods to better prepare soldiers. However, before one can effectively simulate convoy operations, one must first understand the myriad of factors that may impact soldier performance during the actual task. One method for gaining the requisite understanding is the use of a task analysis approach.

Task Analysis Method

In complex tasks such as convoy operations, there are many opportunities for errors to occur. Errors may occur due to limited protocol flexibility, limited information availability, or perceptual overload. Due to the complexity of the task environment, each error may impact task performance in several different and sometimes subtle ways, making tractability difficult. Generally, a task analysis (TA) is a method used to examine the interactions between mental processes and behavioral responses (e.g., human-machine interaction, training effectiveness, etc.) that lead to effective complex task performance (1, 2, 3), so that the sources of likely errors can be addressed in task redesigning and training.

Stated another way, a TA attempts to identify the underlying knowledge and skill structures that result in domain-specific expertise for a specified task or set of closely related tasks (4). TA involves cognitive and/or human performance researchers working closely with subject-matter experts to determine what aspects of a complex task are most important to effective performance. Thus, the domain-specific information provided by experienced practitioners can be combined with known cognitive and human performance limitations from the scientific community. The effective application of human performance information to understanding a specific domain can then result in more effective simulations, models, and training protocols.

A hierarchical task analysis (HTA; 1) follows a seven-step process, beginning with determining the purpose of the analysis up through the development of hypotheses for validating the analysis. The HTA process considers multiple viewpoints and discussions with stakeholders early in the analysis. Tasks are then decomposed to a specified level, referred to as the 'stop rule'. An example stop rule would be to stop the decomposition when the potential cost or impact of an error in a task at the current level is considered acceptable. As is true for most TA methods, the HTA process is designed to be iterative, so that revisions and refinements can be integrated and validated with stakeholders as the analysis progresses.

Team-based Task Analysis

During convoy operations, many soldiers have to interact and communicate effectively as a team. Team interaction adds an additional dimension to an already complex task domain. Each team member must be able to communicate the appropriate information to other team members at an appropriate time, so that the team's situation awareness reflects an effective aggregation of each individual team member's situation awareness. Fortunately, similar knowledge elicitation methods underlie both TA and several analyses of team cognition (5, 6).

A commonly accepted definition of a *team* is a group of individuals with interdependent and specialized roles working toward a common goal. A well-designed TA of a team-based task must then consider not only the individual roles of each team member but also the interactions between team members. Effective simulation of team-based tasks is similarly complicated, because each 'individual' (real or simulated) may respond to a given circumstance in a number of ways, each of which may elicit a different reaction from other team members. With regard to simulation methods, understanding team behavior and communication is integral to developing effective artificial agent interactions, both with other agents and with the simulation participants.

CONVOY OPERATIONS TA PROCESS

As previously mentioned, an HTA approach was used to structure the initial analysis, with the most basic concepts and roles (e.g., navigating, maintaining security) considered first, at the level of a single vehicle. Each basic concept was then decomposed into smaller elements. Currently, the result is a semantic map representation, rather than a step-by-step description of the convoy operations tasks considered. A more detailed description will be included in future work, once the general knowledge structure has been validated.

It is necessary to note that the task decomposition described in the following section is somewhat arbitrary, because many 'tasks' completed by soldiers during convoy operations (as in other dynamic, complex domains) are interrelated and difficult to separate meaningfully from their context. Also, it is likely that many of the activities of soldiers during convoy operations involve adaptive behavior, further complicating an accurate mapping of the requisite expertise and knowledge relationships. Thus, fully describing soldier behavior requires a strong understanding of convoy expertise, training, and protocol. Despite the limitations inherent in the arbitrary nature, the task decomposition is still required in order to provide a framework for more detailed and targeted discussions with subject-matter experts. The analysis that results from the described process is not intended to be complete, and the resulting framework is expected to undergo significant revision and refinement.

It is also necessary to recall that the purpose of the HTA in this instance is to support more effective simulations, rather than training or evaluation directly. Therefore, the analysis may take a slightly different direction than that commonly used in expertise and work analysis research, wherein TA has its roots. As an example, a common stop rule recommends ending the decomposition when the cost of an error in a component task is deemed acceptable with regard to higher task performance (1). In contrast, the stop rule used for the current project states that decomposition of a task ends when the individual task components could be defined as functions in a simulation program. Therefore, the focus here is more on being able to replicate the markers of performance of individual team members, rather than reflect the details of their performance per se.

PRELIMINARY RESULTS

Preliminary results are presented anticipating a continued analysis designed to support more effective simulation and model development. Information for this analysis was pulled from two general sources: reviewing available training documentation and interviewing individuals experienced in convoy operations. It is common practice to include interviews with subject-matter experts during a TA (4). Two subject-matter experts (a former Army National Guardsman and a former Marine Reservist) volunteered to answer questions about their experiences during convoy operations. Both subject-matter experts had served recent tours of duty in Iraq, Pakistan, and/or Afghanistan.

The subject-matter experts described seven general roles for soldiers in a single vehicle, i.e., a convoy unit: driver, gunner, assistant gunner, vehicle commander, convoy commander, dismount, and dismount commander. In most cases, a single role is maintained throughout a convoy's duration, although there may be exceptions. For instance, the assistant gunner may also serve as support for dismount surveillance and security. The seven roles are generally distributed across five soldiers, with additional tasks delegated across vehicles by the convoy commander.

The task decomposition has four major divisions: driving, security, communications, and support. The following sections describe each division in turn. Of highest importance for current purposes are the driving and security aspects, these being more clearly defined at the individual level and thus more easily represented in a simulation environment.

Driving

The first division of the convoy operations TA is driving performance. The complex task of driving includes monitoring the environment and maintaining awareness of the vehicle's position, both in the convoy and in the driving environment. Several senses, in particular vision, are involved, and fine motor control is necessary to maintain vehicle direction and speed. The skills necessary for vehicle control are generally considered to be over-learned in experienced drivers.

However, there are additional demands on a driver in a convoy due to the necessary interactions between vehicles. Drivers need to maintain their situation awareness to navigate in potentially unfamiliar and hostile areas, and drivers need to be comfortable enough with the vehicles they are controlling to manage (relatively) high speeds and tactical maneuvers in case hostile forces are encountered.

First, there are additional knowledge requirements for convoy drivers. Knowledge about the general capabilities of the driver and the vehicle are important, as is the current status of each. Road terrain may vary more greatly in military operations than in most civilian driving situations, and this impacts vehicle dynamic performance in a number of ways. As a general example, a large transport vehicle will not have the necessary dynamics to respond quickly to a sudden hazard whereas a smaller vehicle might. In contrast, a larger vehicle is likely to support heavier armament and armor. With regard to human performance, a fatigued soldier will likely react more slowly and less precisely than will an alert soldier, potentially increasing the likelihood of committing a tactical error. Knowledge of the dynamics of one's own vehicle and team as well as the capabilities of vehicles nearby is central to being able to respond effectively to a change in conditions.

There are also additional skill requirements and demands; drivers are expected not only to maintain a set headway between themselves and a leading vehicle (i.e., 'standard' driving tasks) but also to be prepared to provide and respond to signals from other vehicles regarding hazards that are not directly driving-relevant (e.g., hostile forces). Thus, the demands on visual attention are greater than in everyday driving situations. Information available in the environment may also impact detection and expectations for the drive, e.g., drivers may adapt their scanning patterns to address lower visibility in dark or constrained locales. Finally, the physical demands of convoy driving are likely to be greater due to stress, fatigue, and exposure to rough terrain and stiff vehicle response. These aspects similarly impact other members of a team in their activities, but are particularly pertinent to the driver who is placed in a long-term multitasking situation.

Security

The importance of scanning the environment has already been mentioned with regard to driving, but it is equally important to maintaining the security of the convoy and its members. The security of a convoy also requires that the members understand the capabilities, limitations, and protocol for use of the various weapons available to them, as well as protocol for dealing with different types of threats. The effective detection of and response to hostile forces and other potential hazards (e.g., improvised explosive devices) is necessary for the convoy to continue movement through unfamiliar or unfriendly areas. The subject-matter experts described the role of gunner as one of the most important tasks to convoy operations, with the lead vehicle gunner's role specifically mentioned as one of the most difficult tasks.

Convoy operations protocol emphasizes driving through potentially hazardous zones over engagement, in the interest of both time and prevention of casualties. Thus, security personnel (e.g., gunners) must be prepared to maintain situation awareness and provide suppressive fire while the vehicle is in motion. There is no specific doctrine guiding firing from a moving vehicle, although there are recommendations based on past experience. Gunners and vehicle commanders may take differing approaches to security tasks, complicating both team performance and training practices. There may also be instances where continued movement through an area is not possible, whether due to obstacles, damage to equipment, or other reasons. Therefore, in addition to when the convoy is in motion, establishing and maintaining security during dismount and in the establishment of rally points for consolidation and reorganization purposes is also necessary.

Although all drivers and vehicle commanders are expected to scan their respective areas of responsibility for hazards and respond to threats, it is probable that the lead gun truck is relied upon by subsequent convoy vehicles to alter their scans for possible threats. For example, the lead vehicle and first few convoy vehicle drivers may consider a concrete block beside the road as more of a potential threat than the last few vehicles in a convoy simply because the block has been looked at and dismissed as a threat by several other soldiers. Similarly, if a threat is positively identified, personnel in subsequent vehicles may limit their search area to the specific location the threat was allegedly reported to be (e.g., behind the burned-out vehicle).

Communications

Maintaining communications among the various vehicles, and their requisite roles in the convoy, is clearly important to the security and safety of the operation. Communications are managed by the vehicle commanders, the second position described as 'most important' by our subject-matter experts. The use of radio, pyrotechnics, and even vehicle turn signals is constrained by Army protocol and standards. It is necessary that each team member understand the meaning of the various signals that may be used throughout the operation and that each soldier effectively monitors both the radio and the environment for potential directions to action. There are several difficulties in modeling communications between soldiers, as radio communications may be quite varied in their structure and information content. Additionally, a soldier's response to a visual or radio signal may be determined based on a combination of environment and vehicle factors, some of which may not be immediately apparent.

The integration of and reaction to communicated information is of primary interest. It is assumed that direct information about threats is more relevant to an immediate circumstance than indirect or second-hand information, which indicates immediate threat knowledge is more pertinent to situation awareness. For example, at the time one is under fire knowing that another vehicle is under fire a few miles up the road is not very important unless one has a reason to suspect a full-on set flanked assault. However, as one leaves the first area of engagement and approaches the new threat area, the information that was unimportant becomes relevant and the information about the new threat area must be recalled and evaluated in the context of the current situation. Alternatively, if one has no immediate threat, the reaction to communicated knowledge about a threat a few miles up the road may differ and the integration of the information may also differ. The vehicle commander who is under fire will probably not have an opportunity to look at the potential threat's location on a map, but the vehicle commander who is not under fire might be able to determine and mark the location. Thus, the same communicated information is integrated differently and may allow one vehicle commander to have more knowledge about the potential threat than another. An in-depth analysis of interactions and communications are postponed until more information is available with regard to protocol and common practice.

Support

The fourth division of the TA as an overview of convoy operations is the positioning, responsibilities, and status of support teams such as maintenance and medical personnel. Team members throughout the convoy need to know where the team is located and how quickly the team can react when needed, so that the security of the convoy can best be maintained if and when delaying circumstances arise. Because of the interactive nature of support teams, both within a team and with other members of the convoy, a detailed description of this aspect is beyond the current scope.

Summary

Previous research in other complex domains has found support for expertise effects in managing large amounts of dynamic information (e.g., aircraft piloting, 7). It is important to note that the previous description reflects convoy operation tasks in the most general terms. Different roles within the operation will require a different combination of the tasks; specific roles of individuals are not clearly defined in this preliminary analysis. Nevertheless, all team members, within the constraints of a single vehicle and among the potentially many vehicles in a convoy, must maintain some level of situation awareness and remain in communication with each other to ensure the security of the convoy. For the initial stages, factors that impact driver and gunner performance are of primary interest. Driving performance is already somewhat supported by previous modeling efforts, whereas a gunner's actions are constrained by protocol (i.e., standard operating procedures and rules of engagement).

FUTURE WORK AND REFINEMENT

The primary goal of the work just described was to provide an initial framework for the researchers to understand the complexity of the many tasks involved in convoy operations. Soldiers face numerous challenges during the course of their work, and it would be extremely difficult to grasp the inherent complexity of the job without some foundational knowledge of the field. Thus, it is not intended to be a finalized version at any level, but rather to provide a guide for more detailed conversations with soldiers and related subject-matter experts. In order to evaluate and refine the preliminary HTA, the researcher will interact with experienced soldiers in structured meetings within the laboratory to develop a comprehensive concept mapping of their knowledge (1, 2). The knowledge elicitation process will also include requesting detailed descriptions of routine and non-routine tasks (e.g., Critical Decision Method; 8), highlighting where difficulties most often arise. Finally, empirical studies may be designed to provide insight into tasks that have particular relevance not only to military interests and applications but also to scientific theory regarding human performance in order to address the final step of the HTA process.

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