DO YOU SEE WHAT I SEE? INSTRUCTIONAL STRATEGIES FOR TACTICAL DECISION MAKING TEAMS

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ABSTRACT

Military tasks often require the coordinated effort of a team of operators for successful execution. In tactical decision making situations, team members must gather, integrate and communicate crucial information in support of decisions where an incorrect response can have catastrophic consequences. Therefore, a viable goal of training for tactical decision making teams must be to improve the quality of teamwork and team coordination. It has been argued recently that the nature of teamwork and coordination behavior can be understood in terms of mental model theory. The notion of "mental models" has been invoked as an explanatory mechanism by those studying skilled performance and system control for a number of years. With respect to training, several researchers have suggested that the goal of instruction should be to foster accurate mental representations of the task. It is contended in this paper that the mental model construct may be particularly useful in developing team training strategies and understanding the nature of teamwork. Specifically, the ability of teams to coordinate activity and adapt to task demands in absence of overt communication opportunities may be hypothesized to be a result of shared mental models of the task and team among members. A rationale for adopting the shared mental model hypothesis is presented, along with the implications of such a position for training design.

INTRODUCTION

Critical performance in many complex systems depends on the coordinated activity of a team of individuals. Military teams, in particular, must operate in situations where ineffective performance can have disastrous consequences. Despite a considerable amount of research into the area of team performance and team training, however, relatively little is known about how to train teams or to manage team performance effectively. This is particularly true in the area of team decision making where teams must gather, process and integrate information in support of a decision. Recently, several authors have suggested that team performance can be understood in terms of shared mental models of the task and team among team members [5, 17, 18]. The purpose of this paper is to show how the mental model construct has the potential to advance understanding of the nature of teamwork and development of team training interventions. To accomplish this goal, the areas of mental model research and team performance research will be introduced and reviewed briefly. Following this, the notion of shared mental models will be discussed, including a description of its utility in explaining teamwork behavior and its implications for team tactical training system design.

MENTAL MODELS

The notion of "mental models" has been invoked as an explanatory mechanism for a number of years by those studying skilled performance and system control [26, 12, 22]. According to Rouse and Morris [22], a mental model can be defined as a "mechanism whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" (*p. 360*). *In* the area of cognitive psychology, researchers have suggested that mental models are important to the understanding of how humans interact and cope with the world [22]. For example, Williams, Hollan & Stevens [29] maintain that mental models allow people to predict and explain system behavior, and help them to understand the relationship between system components and events. Wickens [28] contends further that mental models provide a source of people's expectations. In an even more general view, Johnson-Laird [13] suggests that people "understand the world by constructing working models of it in their mind" (p. 10). Mental models enable people to draw inferences and make predictions, to understand phenomena, to decide what actions to take, to control system execution, and to experience events vicariously [13].

Rouse and Morris [22] concluded that a number of common themes can be drawn among theories that describe the purpose of mental models; namely that mental models serve to help people describe, explain and predict system behavior. It must also be noted that most theorists conceptualize mental models as more than simple mental images. Instead, mental

models are manipulable, enabling people to predict system states via mental manipulation of model parameters (see Johnson-Laird, [22] for a detailed description of mental model functioning). Klein [15] has suggested, for example, that expert decision makers engage in a mental simulation that allows them to predict the ramifications of a potential decision prior to taking action.

Overall, the mental model construct has been popular as a means to explain people's understanding of complex systems. The mental model construct has also been useful as a basis upon which to derive hypotheses regarding training strategies for complex systems. A number of studies have been conducted to date; these will be summarized briefly in the following section.

Mental Models and Training

With respect to training, a number of theorists have hypothesized that training that fosters development of accurate mental models of a system will improve performance. According to Rouse and Morris [22], for example, one of the purposes of instruction is to develop mental models necessary to execute the task. Research results regarding mental models and training can be summarized as follows:

- teaching only general principles of system design and function [2, 19]is insufficient; instead, trainees seem to require some form of guidance or cueing in how to apply system knowledge in accomplishing a task [14, 22].
- the manner in which people cognitively structure information about a task has an impact on the way new information is assimilated and learned [7, 28]; new information interacts with existing mental models of the system.
  the impact of pre-existing models of the task can also have a negative impact on training [22]; they can impede learning and may be difficult to eliminate [6].
- the manner in which information is presented has an impact on the formation of initial mental models; that is, people can be led to acquire a particular organization of the material [23, 24, 8].
- allowing people to simply interact with a device or system will often lead to impoverished or incorrect mental models [1, 9].

The implication of findings regarding mental models for training tactical teams will be delineated following a brief review of research into teamwork and team training.

TEAMWORK AND TEAM TRAINING

Despite a considerable amount of research over the past 50 yeasrs, relatively little is known about the nature of teamwork or how best to train teams to perform effectively [3, 4, 11]. In particular, past research has done little to identify specific teamwork skills or investigate how teams acquire, maintain or lose critical teamwork skills. Recently, however, a series of studies conducted with military command and control teams and aircrews has made significant progress in understanding team performance [10, 25]. To summarize the overall findings of this work, the following conclusions can be drawn:

- Behaviors that are related specifically to team functioning (i.e., independent of the particular task at hand) are important to task outcomes [21, 25]
- Effective teamwork behavior appears to be fairly consistent across tasks [21]
- Team process variables (e.g., communication, coordination, compensatory behavior) influence team effectiveness [25]

In terms of specific teamwork behaviors, McIntyre et al. [18] recently reviewed studies of team performance and concluded that teamwork appears to be comprised of a complex of behaviors including: closed-loop communication, compensatory behavior, mutual performance monitoring, giving/receiving feedback, adaptability and coordination. Further, McIntyre et al. suggested that in effective teams, members seem to be able to predict the behavior and needs of other members.

TEAM PERFORMANCE AND MENTAL MODELS

Research cited above provides support for the contention that teamwork behaviors can be isolated from other task-related behaviors. In terms of training requirements and strategies, further research is needed to translate identified teamwork behavioral dimensions into requisite knowledge, skills and abilities (KSAs). For several classes of teamwork behavior such as communication, giving and receiving feedback and mutual performance monitoring, KSA development seems to be fairly straightforward. It is in the area of defining and training skills associated with coordination of action and adaptability that little is known because these skills appear to involve the ability of team members to predict the needs of the task and anticipate the actions of other team members in order to adjust their behavior accordingly.

For example, a study reported by Kleinman and Serfaty [17] investigated the ability of distributed decision-making teams to adapt their behavior to increased workload demands. A significant finding of this work indicated that as workload increased, the team adjusted its strategy so as to affect a trade-off between acceptable performance and sustained workload. Kleinman and Serfaty described two mechanisms by which intra-team coordination changed as workload increased. First, as workload increased to moderate levels, the demand on explicit coordination channels (i.e., where team members coordinate openly via more interactions and sharing of

resources) also increased. However, high workload produced changes in coordination strategies such that constant performance was maintained with a marked reduction in communication. Kleinman and Serfaty [17] interpreted this phenomenon as an "implicit coordination" strategy, where decision makers exercised mutual mental models to anticipate each other's resource needs and actions.

Several other researchers have also suggested that shared mental models may be the basis for effective team functioning. Based on a number of investigations of team behavior in military teams, for example, McIntyre et al. [18] suggested that effective team coordination may be the result of shared mental models of the task. These authors maintained further that effective teams may share mental models of the team as well as of the task. Such a notion may be useful in explaining, for example, the ability of teams to compensate for weaker team members or to distribute responsibility effectively across members.

In other work, Orasanu [20] recently studied the performance of commercial cockpit crews in a simulated emergency scenario. She found that effective aircrews built shared models of the situation that enabled them to manage the emergency. In addition, Whol, Entin, Kleinman & Pattipati, [27] hypothesized that in command and control decision making, a team must have a mutual model of the co-functioning of team members. Finally, in a more extreme position, Klein and Thordsen [16] have introduced the construct of "team mind." These researchers suggest that teams can be conceptualized as a unified information processing unit, analogous in some ways to the individual mind.

In summary, it is clear that the notion of shared mental models has been invoked to help explain complex team behavior, particularly the unique ability of teams to maintain performance in absence of overt communication. In the following sections, the shared mental model hypothesis will be expanded and a discussion of the implications of adopting such an approach for training design will be presented.

Utility of The Mental Model Construct in Teams

The ability of teams to coordinate their actions and adapt to external demands may be best understood in terms of expectations. When a novel situation arises, teams that cannot formulate strategies overtly must anticipate the actions of teammates and demands of the task in order to respond appropriately. The role of mental models in explaining team behavior, then, stems from their ability to allow team members to generate predictions about task and team demands. In fact, the complexity of many team tasks suggests that behavior may be best explained in terms of multiple mental models.

An example may help to illustrate this contention. One of the tasks facing a team of operators in a Navy combat information center (CIC) is to defend the ship against hostile aircraft. Briefly, this task is accomplished by a team who must operate sensor consoles to detect aircraft, integrate and exchange pertinent situation assessment information regarding the aircraft's intent, transmit information to key decision makers, and take action based on the aircraft's believed intent. Typically, such tasks occur under several adverse situational conditions such as high workload, severe time pressure and threat; all conditions that mitigate against explicit coordination strategies.

To be effective in such a situation, a team member must understand the system at several levels. First, he must understand the dynamics and control of the equipment with which he is interacting to extract information. Second, he must understand the task and how to accomplish it (i.e., the significance of information, what information is needed, how information must be combined, and so forth). Third, he must understand his role in the task, that is, what his particular contribution is to the task, how he must interact with other team members, who requires particular classes of information, and so forth. Related to this, he must also know when to monitor his teammates' behavior, when to step in and help a fellow member who is overloaded, and when to change his behavior in response to the needs of the team. Situations of this complexity seem to require, therefore, multiple mental representations of the task: one that describes the equipment, one that describes the task and one that describes the team and his place in it.

Taking this notion one step further, it seems reasonable to hypothesize that the complexity and stability of such models is not equivalent. Specifically, the "equipment" model is likely to be consistent across particular instances of performance; the operator always interacts with the equipment in a similar manner. The "task" model is likely to be more dynamic and complex since a host of situational parameters will vary across task instances and dictate different accomplishment strategies. Still more dynamic is the "team" model which depends not only on the situation, but also on the particular team members involved. In fact, the notion of team adaptability is most clearly understood at this level. Effective teams adjust their strategy to a situation by adopting roles that are most critical to particular task demands and that allow information exchange to be accomplished most efficiently. Implicit coordination (i.e., without communication) can also be explained as a function of mental models of the team, since these allow team members to predict the behavior of teammates and anticipate information requirements in absence of overt strategy formation.

A reasonable hypothesis that stems from the notion of team mental models is that the extent of overlap or commonality among team member mental models will have an impact on team effectiveness. Teams who share common mental models of the task and team are more likely to have accurate expectations regarding the needs of the team, allowing them to adjust their behavior effectively.

Implications of the Team Mental Model Construct

The notion of a shared or team mental model and how it relates to team effectiveness has several implications for the understanding of team performance and training. As an explanatory mechanism, the team mental model construct is useful in understanding how teams are able to coordinate behavior and select task strategies in absence of explicit coordination activities. Under conditions of high workload, time pressure and other kinds of stress, such implicit coordination appears to be crucial [17].

With respect to training, the shared mental model idea suggests that training strategies designed to foster development of shared mental models has the potential to improve team performance. Research cited earlier regarding the success of efforts to train mental models for system operation offers preliminary evidence that such training may be possible. For example, research suggesting that particular knowledge structures (i.e, mental models) can be trained provides support for the notion that common expectations for the task and team can be developed through training.

From what has been presented to this point, it may be hypothesized that specific training strategies which may be useful in training shared mental models include:

1) Positional clarification--interventions designed to provide information regarding the structure of the team and task, the interrelationships among team member positions, and the roles and responsibilities of each team member could be hypothesized to improve team performance by enhancing common task and team expectations. Such training, which represents requisite team and task knowledge, could be presented via lecture, computer assisted instruction, or via written material. Such training would represent initial preparatory training, but would probably not be sufficient to develop shared mental models. Another potential training technique that may be useful for this purpose is role playing, which also has the benefit of making the trainees more active participants in the training.

2) Guided practice and feedback--Results cited above showing that unguided practice can lead to inaccurate mental models suggests that teams should practice tasks under the guidance of instructors. Feedback and debrief mechanisms must be designed to result in accurate, common expectations for the task and team. In addition, feedback regarding specific behaviors that must be changed should be more effective in establishing accurate expectations than general, less specified feedback. Simulation facilities would be a most appropriate means to provide such practice opportunities. Recent evidence with aircrews suggests that low-fidelity simulation may also be viable (Stout et al., 1990).

3) Cross training--A potentially useful strategy to train common mental models may be to cross train team members on tasks that are related to their own task. Such training would be beneficial to the extent that it helps team members to learn what their teammates will need (in terms of resources, information, assistance) given various task demands.

4) Instructor training--Much of the success of team tactical training depends on the quality of instructors. With respect to shared mental models, instructors must be trained to recognize effective teamwork behaviors and other evidence that team members share common mental models as a basis to deliver feedback.

5) Team leader training--Training team leaders to foster development of shared mental models also has potential value. It can be hypothesized that team leaders who are trained to articulate their own view of the task and team, who encourage discussion and strategy formation among team members, and who make clear their expectations of team member behavior should be successful in helping their teams to develop shared mental models.

SUMMARY

It has been argued in this paper that the notion of shared mental models in teams may have value as a means to understand effective team performance and as a basis to develop team training strategies. Particularly with respect to adaptability and coordination, the mental model construct helps to explain how teams are able to perform effectively in absence of overt or explicit avenues of strategy formation. However, several areas of research are necessary if the shared mental model hypothesis is to be useful. First, methods to measure team mental models must be developed. Second, a means to diagnose and compare mental models across team members must be devised so that their relationship to effectiveness can be determined. Finally, training strategies that will have an impact on shared model development (such as those listed above) must be established. Based on evidence regarding mental models in system control and the nature of team performance, such investigation may provide crucial data regarding how to train teams to perform optimally.

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