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EMPIRICAL ASSESSMENT OF A MODEL OF TEAM COLLABORATION

Track 4: Cognitive and Social Issues
Track 1: C2 Concepts, Theory, and Policy
Track 3: Modeling and Simulation

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In line with the theme of this year's symposium, Adapting C2 to the 21st Century, this paper describes research on team decision-making in complex, data-rich situations to better understand the cognitive processes employed when teams collaborate to solve problems. A model of team collaboration was developed that emphasizes cognitive aspects of the collaboration process and includes the major processes that underlie this type of communication: (1) individual knowledge building, (2) developing knowledge inter-operability, (3) team shared understanding, and (4) developing team consensus. This paper describes research conducted to validate this model and determine how these processes contribute to team performance. Team communications that transpired during three complex problem solving situations were analyzed and coded: Maritime Interdiction Operations (MIO), air-warfare decisionmaking scenarios, and communications that transpired between firefighters during a large scale emergency. The MIO scenario involves a boarding team that boards a suspect ship to search for contraband cargo (e.g. explosives, machinery) and possible terrorist suspects. The air-warfare scenario involves identifying air contacts in the combat information center of an Aegis ship.

Introduction

The majority of military and business tasks today are performed by teams who collaborate to share information and task perspectives in order to reach a decision. Military forces are beginning to operate as a networked force, which allows them to plan, decide, and act collaboratively and concurrently to accomplish many tasks simultaneously. Rapid access to current, accurate, and relevant information, and the ability to engage in real-time collaboration with other decisionmakers who are geographically distributed, have become indispensable elements of the command and control planning and decision-making process.

In line with the theme of this year's symposium, Adapting C2 to the 21st Century, this paper describes research on team decision-making in complex, data-rich situations to better understand the cognitive processes employed when teams collaborate to solve problems. A model of team collaboration was developed that emphasizes cognitive aspects of the collaboration process and includes the major processes that underlie collaborative team problem solving: (1) individual knowledge building, (2) developing knowledge inter-operability, (3) team shared understanding, and (4) developing team consensus. In this paper we describe research conducted to validate the model and determine how these processes contribute to team performance by analyzing three complex decisionmaking tasks.

Model of Team Collaboration

A cognitive model of team collaboration emphasizing the human decisionmaking processes used during team collaboration was developed by Warner, Letsky, & Cohen (2004). This model includes domain characteristics, collaboration stages, meta- and macro-cognitive processes, and the mechanisms for achieving the stages and cognitive processes. Four unique but interdependent stages of team collaboration are included in the model. These stages are knowledge construction, collaborative team problem solving, team consensus and outcome, and evaluation and revision. The cognitive processes within each stage are represented at two levels: meta-cognitive, which guides the overall problem-solving process, and macro-cognitive, which supports team members' activities within the respective collaboration stage.

The cognitive mechanisms in this model that are described at a macro level include knowledge building, knowledge interoperability, team shared understanding, and team negotiation to reach team consensus. The model's macro-level definition of the cognitive processes permits empirical assessment of these cognitive processes with currently available measurement techniques (e.g., verbal protocol analysis, communication analysis). Analysis of data captured from teams performing their tasks in a collaborative environment can provide valuable insight into what constitutes effective collaboration performance.

The types of problem-solving situations this model describes are ill-structured decision-making tasks, characterized by time pressure, dynamic information, with high information uncertainty, high cognitive workload (i.e., a large amount of knowledge is brought to bear), and human-system interface complexity. The model focuses on three tasks; (1) team data processing, (2) developing a shared understanding among team members, and (3) team decisionmaking and course of action selection. The objective is to better understand the cognitive processes employed when teams collaborate to solve problems.

Definitions of the cognitive processes included in the model were applied to three different decision-making domains. All three problem situations involve team collaboration to solve complex problems. Four unique but interdependent stages of team collaboration are included in the model. As depicted in Figure 1, the stages include knowledge construction, collaborative team problem solving, team consensus, and outcome and evaluation and revision. Cognitive processes within each stage are represented at two levels: meta-cognitive processes, which guide the overall problem-solving process, and macro-cognitive processes, which support team members' activities within the respective collaboration stage. The model's macro-level definition of the cognitive processes permits empirical assessment of these cognitive processes with currently available measurement techniques (e.g., verbal protocol analysis, communication analysis).

Team types described by the model include teams who operate asynchronously, whose members are distributed, and culturally diverse, where members possess heterogeneous knowledge, due to the unique roles played by each team member, and operate in a hierarchical organizational command structure, and in some situations involve rotating team members (Warner, et al., 2004).

The model focuses on three tasks: (1) team data processing, (2) developing a shared understanding among all team members, and (3) team decisionmaking and course of action selection. The model consists of general inputs (e.g., task description), collaborative stages that the team goes through during the problem solving task, the cognitive processes used by the team and final team outputs, such as the selected course of action.

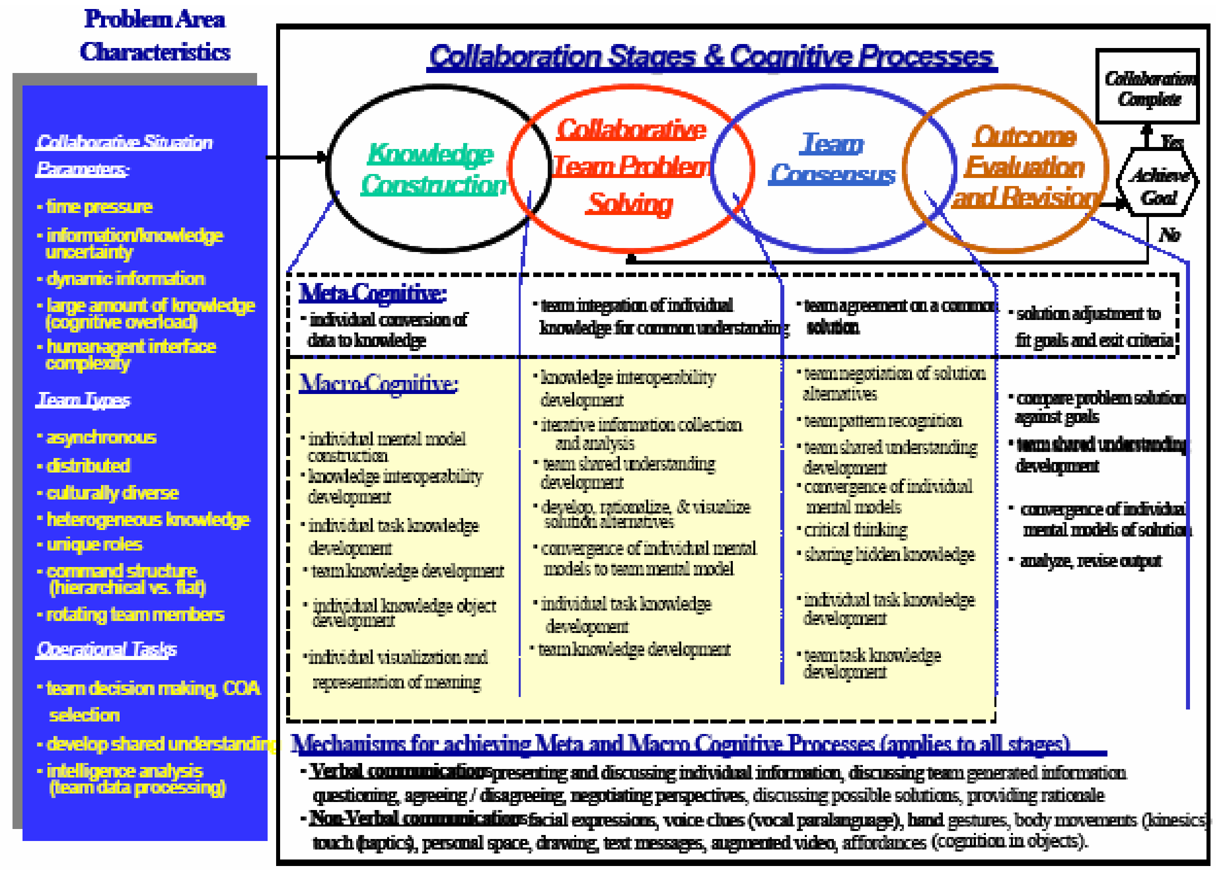

Figure 1. Model of Team Collaboration. (From Warner, Letsky, & Cowan, 2004).

Knowledge construction begins with team members building individual task knowledge and the construction of team knowledge. Knowledge represents a pattern that connects and generally provides a high level of predictability regarding what is described or what will happen next. The focus of all the macro-level cognitive processes in the knowledge construction stage is to support individual and team knowledge development. This knowledge will be used during collaborative team problem solving sessions to develop solution alternatives to the problem.

During collaborative team problem solving sessions, team members communicate data, information and knowledge to develop solution options to the problem (Bellinger, Castro, & Mills, 2004). The majority of collaboration occurs during this stage. The focus of the macro-cognitive processes during this stage is to support development of solution options for the collaborative problem.

During team consensus the team negotiates solution options and reaches final agreement by all team members on a specific option. The macro-cognitive processes support the team in reaching total agreement on the final solution to the problem. During the outcome, evaluation and revision stage the team evaluates the selected solution option against the problem-solving goal and revises the solution option if that option does not meet the goal.

Domain Characteristics. Situation parameters that influence team collaborative performance include time pressure, information/ knowledge uncertainty, dynamic information, and a large amount of knowledge that must be brought to bear to resolve the problem.

Team Types. Team types described by the model include asynchronous, distributed, culturally diverse, heterogeneous knowledge, unique roles, command structure, and rotating team members. Members of both the boarding party and air warfare teams each have distinct roles and bring their respective expertise (e.g., radiological detection) to bear, and combine their heterogeneous knowledge. Team members for both the MIO and air-warfare scenarios were not culturally diverse and did not have rotating team members.

Method

Verbatim transcripts were produced of communications that occurred between all team members as well as with decisionmakers at the distributed sites. Our approach was to analyze and code team communications data using the cognitive process definitions developed by Warner, Letsky, and Cowen (2004). The focus of the collaboration model was on knowledge building among the team members (TMs) and developing team consensus for selection of a course of action. This research builds on previous work to validate this model (Warner, et al, 2004). The current effort uses a similar methodology, applied to two different, higher fidelity decisionmaking scenarios.

Maritime Interdiction Operations Scenario. Based on intelligence, the US Coast Guard has ordered one of its cutters to stop, board, and search a commercial vessel of foreign origin suspected of transporting uranium enriching equipment. The boarding party brings radiation detection and biometric gear, drawings of dangerous equipment and people, and video recording capability. Data is collected on suspicious material, equipment, and people and sent to specific experts at distributed reach back centers. A network extension capability was utilized from the cutter to the boarding team; the network was able to reach back to Lawrence Livermore National Laboratory (LLN) and Defense Threat Reduction Agency (DTRA) to assist in identification of suspect cargo. Support from the National Biometric Fusion Center was used to quickly and accurately discriminate between actual vessel crewmembers and non-crew suspect persons.

The Groove collaborative workspace brought expert services into the boarding party team's tool set and facilitated voice and text communications between all members of the virtual boarding party and physical boarding party. For example, expert services provided at LLNL quickly determined the need for additional data capture of longer length and different angles of approach. Requests were transmitted by text message and taken for action, and radiation source spectrum captures were made of suspect containers that were detected to have a radiation signature presence. Analysis of this data led the boarding officer to recommend that the vessel be quarantined for further inspection. The biometric team took digital prints of the crew to be compared to known criminal prints and latent prints from terrorist and crime scenes.

Air Warfare Decisionmaking. Critical air contacts had to be identified based on ambiguous information under time pressure to determine if the track posed a threat to the ship. Operational tasks for all three scenarios include team decision making, course of action (COA) selection, developing shared understanding, and team data processing.

Results

Differences between the two scenarios in terms of how the team's behavior maps to the model of team collaboration will be discussed in the paper. One difference was that course of action selection tends to be done less collaboratively in a Navy combat information center. Decisions tend to be made unilaterally by the tactical action officer or the commanding officer, (sometimes these two collaborate) but do not typically involve discussion with the rest of the team. This phase of the problem solving process did not entail collaboration.

Table 1 presents an excerpt of the communications coding where the team is developing solution alternatives by using data to justify a solution (1), individual TMs are clarifying data (2) and exchanging knowledge among each other (3), based on information provided by one of the remote centers. An individual exchanges knowledge with other TMs (4) to develop knowledge interoperability (5). Finally, TMs combine individual pieces of knowledge to achieve a common understanding (6).

Table 1. Excerpt from MIO Scenario Communications Coding: Developing Solution Alternatives

	MIO Team Communications		Cognitive Process Coding	
	Speaker		Code	
1	**DTRA**	**Cesium 137 can be used to make an RDD. If there are no explosives, then it is not configured as a weapon yet. Recommend material be confiscated.**	**MCsa**	**Develop, rationalize and visualize *solution alternatives*; using data to justify a solution**
2	**BO**	**Roger will confiscate.**	**MCitk**	***Individual task knowledge* development; individual TM clarifying data.**
3	**BO**	**Make sure you handle carefully. Cs-137 is an external gamma hazard.**	**MCkio**	***Knowledge interoperability*: TMs exchanging *knowledge* among each other.**
4	**BO**	**Roger. Will take precautions.**	**MCkio**	***Knowledge interoperability*: TMs exchanging *knowledge* among each other.**
5	**SOCOM**	**Does CG ship have proper storage area for material confiscated?**	**MCitk**	***Individual task knowledge* development: individual TM clarifying data, asking for clarification.**
6	**SOCOM**	**Search team will report size of material and its current containment condition; then make recommendations.**	**MetCcu**	**Team integration of individual TM knowledge for *common understanding*; one or more TMs combine individual pieces of knowledge to achieve common understanding.**

References

Bellinger, G., Castro, D., Mills, A. (2004). Data, information, knowledge and wisdom. Retrieved August 31, 2004, from http://www.systems-thinking.org/dikw/dikw.htm

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