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Analysis of Team Communications in þÿ H u m a n - i n - t h e - L o o p E x p e r i m e Joint Command and Control

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Analysis of Team Communications in "Human-in-the-Loop" Experiments in Joint Command and Control[1]

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Abstract

Successful mission accomplishment depends on more than individual skills and knowledge. Communication is essential to team performance in complex tasks. Interaction processes that occur via team communications are critical for appropriate use of individual resources, especially when situations call for sharing resources and coordinated responses. This paper reports on results of an analysis of team communications to document the extent to which specific communication behaviors can be identified as indicative of high performance in teams who participated in Experiment Four under the Adaptive Architectures for Command and Control (A2C2) research program. Recently emerging findings on teamwork skills that characterize high performing teams were used as an organizing framework to examine team communications. Team communications can represent several important aspects of team performance such as shared situation awareness and coordination. High- and low-performing teams were identified using composite performance scores. Transcripts of videotaped scenario play were coded by two independent raters. Our goal was to examine the degree to which A2C2 participant teams exhibit cognitive behaviors reported to characterize highly successful teams and examine the relationship of these behaviors to mission performance.

1. Introduction

Future military operations will increasingly involve Joint and Coalition operations—which are among the most complex and demanding of all military activities. These demands are coupled with the U.S. military's goals of reducing personnel and creating flatter organizations designed to minimize hierarchy [Strategic Studies Group, 1998]. Hence, developing an effective command and control (C2) architecture is one of the most important steps a commander can take to ensure successful completion of the mission [Cruz, 1996]. Adaptive Architectures for Command and Control (A2C2) is a multidisciplinary, multiyear research effort designed to advance our understanding of the characteristics of effective organizations in the context of Joint and Coalition mission environments.

The process of organizing for Joint and Coalition operations must be driven by the disparate missions and the requisite tasks involved. The diversity of future anticipated operations—from

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"traditional" military combat to "peace-keeping" to humanitarian assistance—requires a wide variety of Service capabilities under a Joint Force Coalition. These new missions add complexity to command and control due to such factors as: (*i*) multiple layers of threat, (*ii*) potentially competing sets of engagement rules, (*iii*) an extremely high level of uncertainty about the intentions of contacts, and (*iv*) the public's expectation that peacetime operations should be executed without loss of personnel.

All of these factors combine to produce situations of complexity and uncertainty that can add to the already high levels of work demand and stress. When decisions have to be made within extremely short time windows, with varying degrees of degraded and/or ambiguous information, and with rules of engagement that do not provide clear guidance, the process of decisionmaking can break down. Thus, one issue of interest for this research is how to capture the *process* that is used during decisionmaking to understand why and how decisions are made, based on analysis of team communications.

Findings from a variety of researchers point to the value of improving team coordination and communication processes as a vehicle to improving mission performance. For example, Serfaty and colleagues [Entin, et al., 1993; Serfaty, et al., 1994; Serfaty, et al., 1998] conducted a series of experiments to understand the way teams adapt their decision-making and coordination strategies to a changing tactical environment in order to lower their communication/coordination overhead, thus improving performance. These early studies investigated team training interventions. These researchers found that teams who were highly successful in the adaptation process use coordination strategies based on the development of a shared situational mental model of the task, and a mutual mental model of interacting team members' functions and abilities. These findings provided the theoretical underpinnings and the basis for modelers to develop C2 organizational architectures that are designed to accomplish these same goals stated above. Current empirical studies conducted under the A2C2 program focus on *structural* adaptation of the organization to reduce communication and coordination overhead, in addition to addressing the distribution of task responsibility.

Several additional studies of decision making in teams support the critical role of communication in decision making. Teams use communications to develop shared problem models for nonroutine situations [Orasanu, 1990]. Cockpit resource management training programs, implemented by several commercial airline companies, train crews to develop critical team skills for successful flight. These team skills include the ability to: manage information, resources, and workload, coordinate activities, and communicate more effectively.

Finally, communication behavior is an observable aspect of coordination. And coordination capability is argued to be an important mechanism for organizational adaptation in the face of uncertain, complex interdependent task environments [Galbraith, 1977]. Thus, by examining communication behaviors that predict high performance, we may gain insights into processes that enhance organizational adaptability.

2. Characteristics of Good Team Performance

In the past few years several researchers have identified team level behaviors that influence how well the team is able to accomplish its mission. For example, Serfaty and colleagues [Entin, et al., 1993; Serfaty, et al., 1993b] have reported several team coordination and communication strategies — such as making and interpreting periodic situation updates concerning the current tactical priorities and problems — used by highly effective teams in Naval combat information centers. A very brief review of some of these recent findings from the team performance research literature will be presented in this section.

Orasanu [1990], studying airline cockpit crews, delineated the factors that influence the effectiveness of team decision making. She reported that good crews are much more (1) explicit in defining the problem and articulating plans and strategies for coping with it; (2) observant of relevant information; (3) likely to explain the rationale for a decision; and (4) able to allocate and coordinate responses among the crew. Based on a flight simulation study, Orasanu reported a positive relationship between decision strategies and overall task performance. More effective crews exhibited greater situation awareness, obtained decision relevant information in time to use it, adapted a resource-conserving strategy while they acquired needed information, and factored in more constraints on their decisions. Captains of high-performing crews (defined by procedural and control errors) explicitly stated more plans, strategies, and intentions, considered more options, provided more explanations, and sounded more warnings or predictions.

Teaching information management skills to teams has been shown to improve performance, make teams better able to adapt to changes in workload, and enable teams to perform better under high workload (Serfaty, et al., 1993a). These information management skills include the ability to: (1) preplan; (2) capitalize on idle periods; (3) adapt ratio of informative to administrative communications; (4) push information to teammates; (5) balance workload among team members; and (6) recognize the symptoms of information overload. Other researchers report that behaviors such as providing backup to overworked team members, using proper phraseology when communicating, and making sure that all of the teammates know the mission priorities have been demonstrated to facilitate effective performance [Smith-Jentsch, et al.,1998].

Regarding speech patterns, a study of fatigue effects on crew coordination and performance of airline cockpit crews found that high performing crews' conversations were characterized by great homogeneity. The use of a standardized pattern of speech facilitated coordination by enabling crews to interact in a predicable manner [Kanki, et al., 1989].

From the literature described above, it is evident that there is important agreement about some of the communication behaviors that have been associated with effective team performance. Table 1 summarizes the key characteristics that are emerging from research. This table acknowledged that, in some cases, different researchers use different terminology for behaviors that conceptually overlap. It represents an integrated conceptual framework that can be used to guide the assessment of team communications and their relationship to team performance.

Table 1

Cognitive Behaviors Characteristic of High Performing Teams

1.	Develop shared understanding of problem, goals, information cues and strategies
2.	Anticipate other's resource needs and actions
3.	Require little negotiation of what to do and when to do it
4.	Volunteer information when needed
5.	Provide backup to overworked team members
6.	Ensure all members know mission priorities
7.	Make and interpret periodic situation updates
8.	Provide rationale for decisions
9.	Balance workload among team members
10.	Use homogeneous, conventional speech patterns

3. Method

Complex research problems involving human interaction require several approaches for a full understanding of the issues being investigated. This is especially the case in large research programs that use a combination of modeling, simulation, field-based research, and analysis of real-world events. Questions of interest to the A2C2 research team include: (a) how to select the best architecture for an organization, (b) defining characteristics of adaptability within a given organizational structure, (c) identifying diagnostic variables that indicate when the adaptability of a given organizational structure is inadequate and a new structure is required, (d) what factors enable, mediate, or affect adaptability without an unacceptable degradation in performance.

3.1 Joint Operational Mission and Source of Data

The source of data used in this study is a simulation of a Joint operational mission involving Naval and Marine forces (see [Benson, et al., 1998] for more information on the simulation and [Entin, 1999] for details on the experimental design). The Joint Task Force mission was to conduct an amphibious operation to seize, occupy and defend a port and an international airfield in a fictitious country for the use of entry for follow on forces. Experiment Three in the A2C2 research program focused specifically on evaluating both the performance of comparative organizational structures and the willingness of research participants (military officers rank 03-05) to change organizational structure in the face of a "trigger" event (e.g., the loss of one-third of their assets). Experiment Four incorporated some refinements in design and participant training to clarify and extend the results of the previous study.

3.2 Performance Results

In two companion papers in this Proceedings, Entin [1999] and Hocevar, et al., [1999] report on performance results of several objective and subjective measures used to assess team performance

in Experiment Four. Two main sources of performance effectiveness data used in these analyses are: (1) the Distributed Dynamic Decision-making (DDD) software used to run the simulation and (2) expert ratings by military officers of both performance and teamwork. In the Entin paper the focus is on improved process and performance in optimized architectures. In Hocevar, et al., the focus is on the comparative performance of three architectures using accuracy measures for planned mission tasks (e.g., taking the airport) as well as less certain, more adaptive tasks such as response to missile threats.

3.3 "Human-in-the-loop" Simulation

One of the important features of the A2C2 research strategy is the aspect of "human-in-the-loop." This refers to the component of the research where predictions generated by pre-experimental models are tested in the laboratory simulation with human subjects. This compo-nent is critical to establishing both the reliability and validity of models, particularly given the complexity of human behavior. Other benefits of the human-in-the-loop process are the insights that participant/experts contribute to the interpretation of model assumptions (e.g., Hutchins, et al., [1998] had participant/experts rate the architectures on several critical principles of war to determine the degree to which the architectures supported these principles), extrapolating the organization designs and laboratory simulation to a "real" war-fighting environment, and offer-ing constructive feedback to improve future simulation experiments. By way of example, Hocevar [1998] used the simulation participants' qualitative rationales for choosing a particular organizational architecture to elaborate strategies of decision choice and the role of resistance to change. These insights were useful in interpreting the performance outcomes of Experiment Three in which the organizational structure predicted to perform optimally, did not.

The focus of this paper is to utilize the human-in-the-loop perspective to further develop our knowledge base from Experiment Four of the A2C2 research program. Our goal is to refine our understanding of the team processes used that may influence effectiveness. These processes include the quality of coordination as evidenced by communication behaviors such as developing team situational awareness and the use of information management skills. To explore the relationship between communication process and performance effectiveness, team communi-cations were analyzed and compared for high- and low-performing teams.

Our focus for this analysis was on team coordination. We examined task-related communications to better understand how well team members accomplished mission tasks that required a coordinated effort between members in two or more nodes of the organization. Three mission subtasks were selected for detailed analysis and coding: "taking" the hill, North Beach, and the seaport. These subtasks were selected because their successful completion required a combination of resources owned by at least two decisionmakers be used in a synchronized, i.e., time-dependent manner.

The objective was to characterize qualitatively the features of "poor" and "effective" communi-cations that occurred during the accomplishment of the mission. A composite performance score was used to identify highest- and lowest-scoring teams for the subtasks of interest. This composite performance score was comprised of a combination of the DDD simulator score on the

team's overall mission accuracy, observer ratings of how well the team accomplished each mission subtask, and simulator scores on how well the mission subtasks (taking the hill, the north beach, and the seaport) were accomplished. Verbatim transcripts were made of the teams' communications (from videotapes of teams engaging in the scenarios) and the portions associated with the identified subtask performance were examined to look for evidence of the behaviors that characterize effective team performance. The goal was to determine if high performing teams also evidenced behaviors reported in the research literature as indicative of high performing teams. Detailed analysis and coding of team communications for the highest- and lowest-scoring teams were conducted to document evidence of behaviors reported in the research literature on effective team performance.

3.4 Data Coding

A selected set of the findings reported in the literature on team communication and performance was used to examine team communications. This set of behaviors characterizing high-performing teams derived from the literature is summarized in Table 1. These behaviors were selected based on three criteria: 1) grounding in the literature; 2) relevance to the types of tasks included in the A2C2 scenario (i.e., behaviors likely to be observable based on the mission requirements); and 3) communication behaviors that were clearly differentiable. For example, tempo was not manipulated, thus we did not include behaviors associated with adapting to changes in tempo in the coding process. Table 2 represents the coding scheme derived from the literature. It presents the conceptual characteristics from Table 1 that met the criteria described above. Each conceptual characteristic is elaborated with specific behavioral indicators and illustrative examples.

All communications sequences that took place for the selected subtasks were reviewed and coded to indicate the presence of the characteristics listed in Table 2. Each utterance was reviewed for positive or negative (i.e., the opposite of the behaviors listed) occurrences. Two raters independently coded each transcript. For each behavior that corresponded to one of the items listed in Table 2, the number for that characteristic, with a "+" to indicate a positive occurrence or a "–" to indicate a negative occurrence, was written in the transcript. This means that a team identified as either a high-performing or low-performing team could evidence both positive and negative team characteristics in any given subtask sequence. The number of positive and negative team characteristics was tallied for each subtask sequence for the high- and low-performing teams. Understanding the scenario requirements was necessary, in some cases, to interpret the quality of the team communications. For example, to know when resources were being launched proactively, that is, implicit coordination was occurring, the rater needed to be aware of events occurring in the scenario and the information or assets that would be useful at that point in time in the scenario.

Table 2

Samples of Coded Videotape Behavior Measurement and Examples*

Conceptual Characteristic	Behavioral Indicator	Example
Develop shared understanding of problem, goals, cues, strategies	Describe the situation as they see it Inform others of intentions Explicit in defining problem, articulating plans and strategies Share situation assessment with team members Ensure members know mission priorities Periodic situation updates	Getting ready to move the infantry down the road. Once he gets that mine cleared I can bring that infantry down and use CAS** to get it. (Which is the west road of the North Beach?) (How do we know whether that attack went or not?)
Anticipate other's needs	Volunteer resource or information without being asked	Sending Medevac down to South Beach.
Require little negotiation	Responds immediately to request for action, resource; no discussion needed	Roger, we've got to confirm it's an enemy first.
Volunteer information	Clarify situation/ remind teammate of critical information	I don't think the SAT*** should move that far away from the roads until we get the lead vehicle.
Provide backup	Help with teammate's job when he/ she is overloaded	You have an unidentified truck coming down the N bridge Rd
Homogeneous, conventional speech	Identify speaker and receiver of message Use proper phraseology and wording No excess verbiage Acknowledge received message	(Outstanding, thank you.) (Thanks a lot; appreciate it.)

* Examples in parentheses indicate negative examples. **CAS is close air support (fighter aircraft).
***SAT is satellite.

4. Anticipated Impact

The primary benefit of the proposed analyses is to enhance our understanding of the more quantitative performance results generated by DDD and observers' ratings by examining the communication processes of teams as they conducted the joint mission scenario. By mapping

communication characteristics of highly effective teams with teams identified as high-performing in A2C2, we can examine the role of communications in effective teams. We seek to understand the factors that contribute to effective outcomes and identify variables to be refined or included in future models.

5. Results

Data analysis is ongoing and will reported at the Command and Control Research and Technology Symposium in June.

6. Discussion

This paper was motivated by the goal of examining the characteristics of teams that influence effectiveness. A full discussion of the results will be presented at the CCRT Symposium in June. Some preliminary results confirm existing theory. For example, the low performing teams in A2C2 Experiment Four scored extremely low on the use of a homogeneous and conventional speech pattern. This lack of homogeneous, conventional communications was evidenced by the team members' failure to: (1) use standard operating procedures to communicate, such as the failure to use "call signs," (i.e., identify self when speaking and identify the person you are addressing), (2) use proper phraseology, e.g., use of a standard way of reporting and receiving information, (i.e., "Roger" to acknowledge receipt of a communication versus "Outstanding, thank you very much!"), and (3) keep excess verbiage to a minimum. Military communications during an operational mission should be based on this homogeneous, conventional speech pattern so there is no question regarding who is giving and receiving the information, what the message is, and no excess talk to clutter the communications environment. Statements should reflect a coherent thought expressed in the standard style with no irrelevant information. The failures to use homogeneous, conventional speech are interpreted to contribute to poor performance by increasing the cognitive workload on team members (by increasing the effort required to decipher the message, etc.) and thereby reducing their mission performance.

7. Conclusions

The majority of critical military tasks are performed by teams at various levels within an organization. Understanding the implications of team structure, and the associated decision making strategies and communication patterns are important to describe the relationship between organizational structure and the team's functioning. This understanding can provide feedback to the model developers for further refinement of future proposed organizations and as input to commands responsible for training units for Joint and Coalition operations.

Since, by definition, team decision making entails more than one information source and includes task perspectives that must be combined to reach a decision (Orasanu, 1993), an analysis of communications for teams operating in a simulated Joint environment can provide valuable insight into what constitutes effective performance. We have examined task-related communications to understand the relationship between team behavior and performance.

8. Future Work

This has been an exploratory effort to develop an understanding of the patterns and types of communication that are indicative of successful team performance and how they are linked with criteria-determined high-performing and low-performing teams. We have developed a prototype that can be applied to tier-2 and tier-3 studies with higher fidelity tasks where the processes will more than likely involve more complex tasks and communications.

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