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A Measurement Approach for Analysis of Team Communications

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ABSTRACT

While team exchanges have been studied extensively for years, there has been no consensus on a measurement approach that provides insight into whether technology supports a command team’s communications and decision making. One approach to understanding effectiveness of war fighter team communications has been to look at how information flows to and from decision makers. Other approaches have used knowledge elicitation techniques with transcription and coding to understand how submarine control room displays aid the command team in building the picture and building the plan. In the current work, the authors of this paper applied research on information push (sharing) and pull (requesting) to the team tasks of building the picture and building the plan. to develop a

straightforward approach that helps analysts understand submarine command team sensemaking. In a large-scale simulation event testing new submarine technologies, the authors found patterns in the communication events that could be used to understand how command teams’ information sharing changed across segments of the scenario. This theory-based measurement approach combines qualitative and quantitative approaches for analyzing communication events of high functioning teams.

INTRODUCTION

Submarine command teams work continuously to determine their position relative to nearby contacts, under rapidly changing conditions and frequently with incomplete information. Understanding whether or not a submarine

command team's decisions are supported by control room technology has been a primary interest of Navy sponsors of this work. In this paper, the authors describe the process by which we developed a theory-based measurement approach useful for the evaluation of a submarine command team's decision-making, and we outline the process itself. We propose that this approach is generalizable across domains for the evaluation of other operational teams.

MEASURING AND ANALYZING TEAM COMMUNICATIONS

In general, there are aspects of team decision-making that are relatively easy to observe, as there are specific protocols in place for communications, such as the call-out of tripwires and other public announcements that allow researchers to track the flow of information throughout a control room (Klein, 1998). For example, how a submarine command team executes its plan can be tracked through the loudly-spoken orders an officer of the deck gives to change direction, depth, or speed. However, there are other aspects of team cognition that are not observable and are, therefore, more difficult to capture, categorize and analyze. For example, it is typically impossible to observe a team member's thoughts or decisions unless they are verbalized. Researchers must instead analyze team communication as team members contribute to the team's understanding or question both the operational picture and the plan for navigating that picture. Team communication analysis can present a framework for understanding whether a command team's decisions are supported by the system. This framework structures analysis into four categories into which each communication event can be grouped. The distribution of these categories can be further analyzed by individual officers and the researcher can compare the distribution of these four categories by individual officers to their defined role in the command team.

DEVELOPMENT AND APPLICATION OF APPROACH

The overall two-day simulation event involved two five-officer command teams. The event was

called Gaps & Seams; its goal was to identify gaps and seams in the current operating system which should be addressed in future technology innovation proposals. Over the two days, the watch teams completed four watch periods, including two watch turnovers. Our analysis was limited to the audio transcription of a one-and-a-half hour period which contained critical events. Command team members each wore their own synchronized and calibrated microphone. Each officer's utterances were transcribed within a spreadsheet and organized by discrete communication events which included: start time, stop time, speaker and content.

Prior to the event, our team of analysts had developed a multi-level coding structure with which to analyze transcripts. After transcription, with data in hand, we tried out this coding approach (see Table 1).

One of our initial code sets was based on Entin and Serfaty's (1999; Serfaty, Entin, & Deckert, 1994) work regarding team communication analysis. In their work, Entin and Serfaty hypothesized that "highly effective teams adapt to stressful situations by using effective coordination strategies" (1999), including the unsolicited sharing of critical information with the team's decision maker(s). Entin and Entin (2001) outlined an approach for the capture, coding and analysis of communication events linked to the pushing (sharing) of information and pulling (requesting) of information. The analysis described by Entin and Entin looked specifically at the ratios of pushes to pulls, making note of when those ratios rose above one, signifying that team members were asking for more information than they were volunteering. Of significance is the hypothesis that *high-performing teams respond to stressful situations by providing more unasked-for information to the decision maker*. This team behavior allows the decision maker to focus on integrating and deciding, rather than spending valuable time and energy seeking information from various team members. We coded for requests and transfers to determine whether teams in our event responded to stress in this way.

Others' research examining communications in a Norwegian ULA-class submarine team applied a similar methodology for understanding how information flow changed when team members were known to each other (Espevik, Johnson, Eid, & Thayer, 2006). When this method was used in our analysis of the submarine command team, we were able to identify periods of time when specific officers were requesting more information than they were receiving, but those periods did not coincide with critical events in the scenario such as important command team decisions, periods of high taskload or confusion in the control room. We decided to modify this approach to yield a stronger link to the simulated stressors.

The coding approach shown in Table 1 proved difficult to analyze, as the content and technology codes were often ambiguous and overlapping. One communication event might be viewed from multiple perspectives and, therefore, be subject to multiple codes. As a consequence, this approach had poor inter-rater reliability ratings associated with it ($i = 0.15 - 0.35$). In addition, the quantitative depictions of coded data that this coding structure yielded did not provide meaningful insights about team performance, nor did it highlight gaps and seams of the technologies tested.

Although the original set of codes was problematic as described, it did suggest an interesting pattern in the data. Analysis of these codes suggested that nearly every utterance in the transcripts could be categorized as a Transfer or Request of Information. In addition, most

utterances could also be categorized according to either 'What was going on with ownship (Plan)?' or 'What was going on with everyone else (Picture)?' These codes reflect a model of team process that is well-accepted in the operational community (depicted in Figure 1). Regarding other parts of the cycle, Execute the Plan reflected decision making, rather than team sensemaking, and Assess the Plan communications overlap with Build the Picture

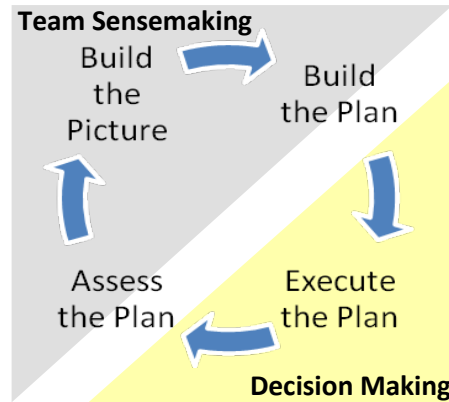


Figure 1. Submarine operational community planning-action cycle. Execute the plan reflects decision making, whereas the other three elements reflect team sensemaking and situation awareness.

and Build the Plan to an extent that they cannot be isolated. The insight that most communications could be organized into a 2x2 matrix of sharing and requesting information crossed with picture- and plan-building provided us with a clean, simple, and operationally relevant coding structure with which to examine team sensemaking.

Requests vs Transfers	Content Type	Technology Code From Mathieu, Goodwin, Heffner, Salas, and Cannon-Bowers, (2000)	Sonar, FC, Command	Other notes
R: Requests, questions T: Transfer, sharing of information	I: Information T: Action and Task R: Resource utilization C: Coordination E: Exclamation	TF: Technology Functioning – current status of technology, SA of system OP: Operating Procedures: steps to carry out a function using the technology TL: Technology Limitations LF: Likely Failures technology OI: Operator Issues – operator limitations in technology use	Code indicated in which of these three areas the technology referred to was located	Indicating announcements, confusion, surprise, etc.

Table 1. Original theory-based coding scheme

Examining picture- and plan-building in submarine research builds on work done by Fallon and Dominguez (2009). This research described analysis of a large-scale interview-based study of submarine command teams. The study indicated that building the picture and anticipating the future state of the world, command teams can provide a safety net for possible missteps in decision making.

In this paper we expanded on the work of Fallon and Dominguez (2009) regarding how technology supports the command team in picture- and plan-building cognitive activity. Through transcribing and coding communications, we tracked information communicated to members of the command team, assuming that they would make appropriate decisions if equipped with the right information.

The resulting two-by-two matrix of codes had transfer and request codes on the X-axis and picture and plan codes on the Y-axis. Each communication event was coded as either a transfer of information or a request for information. Often, requests had a question mark within the communication event, but not always. For example, the communication event of “Get a

Communication Events	Transfers	Requests
Building the Picture	Sharing Information about the Picture	Requesting Information about the Picture
Building the Plan	Sharing Information about the Plan	Requesting Information about the Plan

Figure 2 Four Categories for Communication Events

laser on him.” was coded as a request for information. Each communication event was also assigned an additional code as either referring to building the picture (“What is going on with other contacts?”) or building the plan

(“What is going on with ownship?”). In the instances where a communication event qualified as referring to both what is going on with someone else and ownship (e.g., a closest point of approach (CPA) with another contact) we decided that the statement would be coded as referring to building the plan as nearly all CPAs resulted in an own ship maneuver. With this simple coding scheme, we began to see our inter-rater reliability values climb ($i \geq 0.9$).

The result was that approximately 98% of the communication events could be coded into one of four categories: Sharing Information about the Picture, Sharing Information about the Plan, Requesting Information about the Picture and Requesting Information about the Plan. Our transcripts also provided a record of which officer expressed a given communication event and when the event was expressed. This record allowed the four categories in the matrix to be traceable by officer and time, and we were able to track the command team’s decision-making across the various stressors that occurred throughout the simulation.

At this point in the analysis, our research showed the proportion of what each individual officer said regarding sharing the picture or the plan and requesting information about the picture or the plan. What we did not have is a way to evaluate whether those proportions were normal, expected command team interactions for the situation underway.

Each member of a submarine command team has a specific role to play. Those roles may vary according to specific commander preferences. Effective performance underlying these roles supports the boat navigation in even the most challenging of circumstances. The next step our research team took was to present our 2 x 2 matrix to former submarine command team members for feedback. Once they understood our approach, they provided guidance as to what the normal proportion of the four categories should be for each individual officer role. We sought guidance on these normal proportions of communications from three different former submariners.

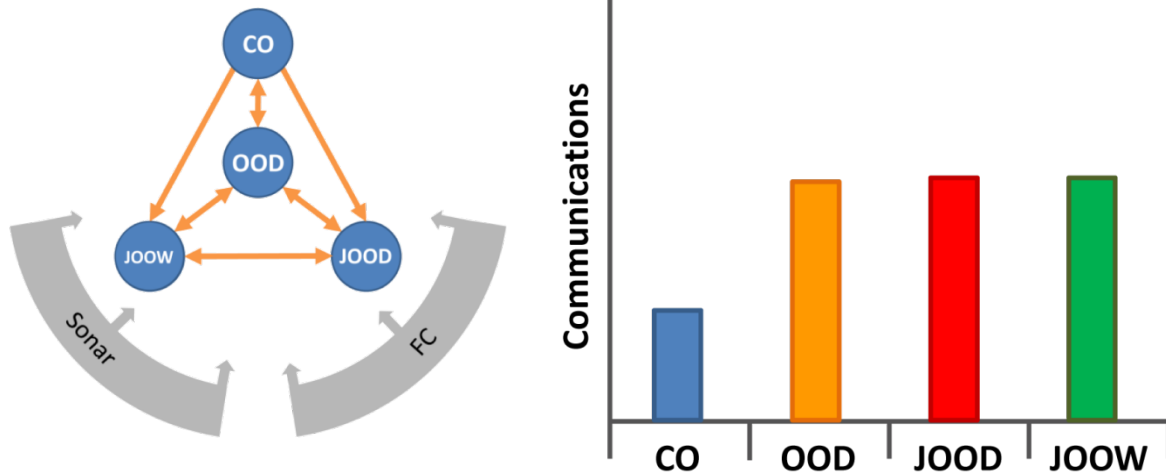


Figure 3. Representative Proportion of Communications Falling into the Sharing Information about the Picture Category

Each of the four categories was then tallied for the entire command team as well as by individual officers. These tallies were then divided into 15-minute periods and displayed on the scenario timeline alongside an image of what the normal proportions of the communication category should look like. We added an overlay of high-risk events (close contacts) to the timeline. As a final analysis step, we examined the transcript content around the high-risk events to understand the team’s current understanding and reaction to these events. This qualitative analysis enabled understanding of what the team’s situation awareness was during those mission segments.

RESULTS

As predicted, when the command team found itself in high-risk situations, the patterns in team communications deviated, in terms of proportion and frequency from ‘normal’ communication levels. Although we are unable to share specific data in this paper, we did observe trends that are of value.

First, in the time segments directly after a close contact, there was a drop in communications of all types across the command team. This may reflect a “stunned regrouping” effect, a reaction involving more introspection than speaking aloud.

In addition, the category with the largest share of communications was Sharing information about

the Picture, followed by Sharing information about the Plan. The category with fewest communications was Requesting information about the Plan. Because team members were more likely to assert than to question, the time periods where there were more requests are candidates for qualitative analysis to understand what was going on.

Finally, due to time constraints we were forced to limit the scope of the transcription, coding, and analysis to a shorter period of time than the entire 2-day event. We targeted a 1.5 hour period in which there were three higher-risk situations and did an in-depth analysis on that period of time. Resources that would be required to transcribe, code, and analyze long periods of communications are not available in most research efforts of this type. Therefore, focusing on a short, critical time period in a scenario is a recommended alternative.

DISCUSSION

Combining quantitative analysis of this coding approach and qualitative examination of communications revealed important insights into team coordination and decision making. In this paper we have explained how this communication analysis approach can be used to better understand command team performance during high risk events. The results from this analysis approach may also be used as an indicator of the quality of technology support in

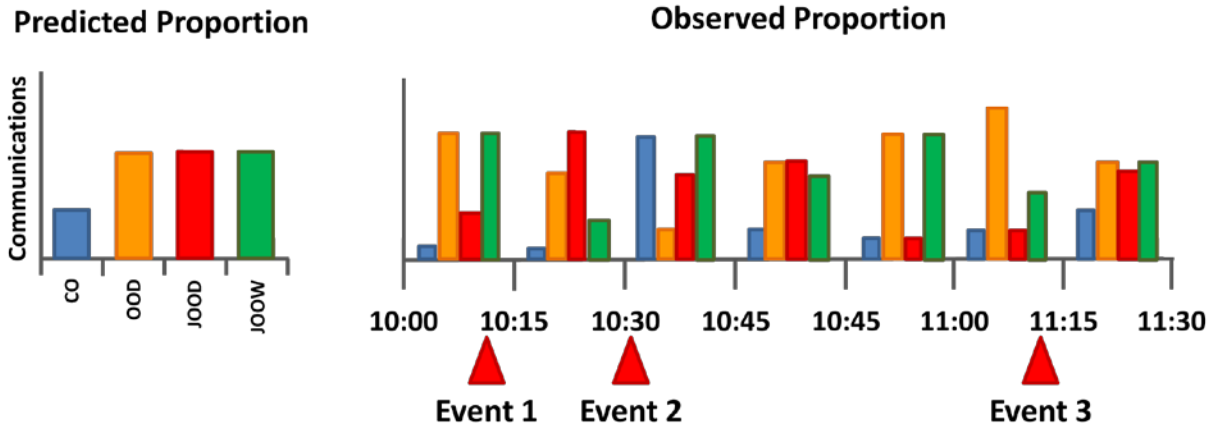


Figure 4. A hypothetical representation of observed communication events within the Sharing Information about the Picture Category as they relate to time and critical events.

the control room. In the submarine control room team members are typically able to maintain accurate awareness of the tactical picture and future state of the world if they are well supported by their technology. Awareness allows team members to anticipate the decision makers' needs and provide information before it is requested. Conversely, breakdowns in awareness might be attributed to lack of technology support; this lack of awareness may lead to a higher proportion of requests for information. Because technology plays such an integral role in the control room, analysis of communication related to the transfer of information about the picture and plan provides an indirect assessment of the technology's ability to support its team. This event did not include a baseline vs new technology experimental design. Analyzing and comparing the quantity and quality of communications via this approach is expected to be of high value in assessing technology support in future events which include such a comparison.

CONCLUSION

Although we are unable to share any data from our theory-based measurement approach, our goal in this paper is to present the methodology we employed to assess team communications. At its core is a combination of evaluating sharing and requesting information across a team with a model of thinking and acting which has authenticity in a domain, such as the one shown in Figure 1. This approach could be applied to investigate team communications in a broad

range of domains, and could be especially useful in comparing results from different technology configurations. The ultimate result of this process is a generalizable approach for analyzing team communications. The simplicity of the approach seems to lend itself to high inter-rater reliability values, adding validation to the approach.

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BIOGRAPHIES

Robert Strouse, M.F.A., is a Designer and a Scientist in the Cognitive Solutions Division of Applied Research Associates. He is currently involved in projects to better understand the decision making processes in command and control environments, including the Naval Expeditionary Combat Command and Submarine Warfare. In addition, he works with other members of ARA to develop prototypes and visualizations that capture and convey the insights gained through cognitive research.

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Corey Fallon, M.A., is a Human Factors Psychologist in the Cognitive Solutions Division of Applied Research Associates. He conducts applied research for both government and private industry. He is currently involved in supporting the submarine near term technology evaluation process for Advanced Processor Build and in the testing and evaluation of trust between humans and various technologies. He has worked as a Cognitive Systems Engineer for the U.S. Navy supporting submarine technology development and implementation since 2007.

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