10

An Investigation of Technology-Mediated *Ad Hoc* Team Operations

Consideration of Components of Team Situation Awareness

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Technological advances have yielded significant changes in the way people work. Decision makers dealing with complex, ill-structured problems, dynamic environments with significant time stress, shifting or competing goals, and significant consequences for failure are particular targets for technological support. In fact, these same characteristics are key task indicators in naturalistic decision-making (NDM) contexts (Zsambok, 1997). In many environments, the employment of technology has led to teams in which members are more mobile, more versatile, and more distributed in time, space, and purpose. Often these teams are *ad hoc*—they are brought together for a limited time span to address a specific problem and often have diverse backgrounds and technical expertise that form the basis for their selection onto the team. This expertise provides a second key distinguishing characteristic of NDM research; that is, it does not address naïve participants, but rather experienced decision makers.

In this chapter, we present research aimed at investigating factors that influence *ad hoc* team operations and decision processes in technologically sophisticated operational environments, thus providing a third distinguishing characteristic of NDM research—that it addresses complex problem spaces. Finally, due to the complexity of the environment, our research focuses on the situation awareness (SA) of the decision maker, which highlights a fourth and final significant characteristic of NDM research: a concern with situation assessment. We begin with a brief overview of the challenges faced by *ad hoc* teams, then introduce a theoretical framework of team SA, and describe a preliminary study that evaluated elements that may affect factors of this framework.

Ad Hoc Teams in Complex Operational Environments

Organizations, including businesses and military forces, increasingly rely on *ad hoc* teams. These teams are intentionally composed of individuals with diverse skills, backgrounds, and experiences to bring their multiple perspectives and competencies to bear on a problem. *Ad hoc* teams have several defining characteristics, including the following: limited time span, assembled to address a specific problem, limited common training, diverse backgrounds, distributed in space, formed or disbanded asynchronously, and team duties that supplement rather than replace regular duties. Each *ad hoc* team may possess all or a subset of these characteristics.

While these characteristics provide advantages to the team, they can also complicate team operations. Specifically, *ad hoc* team members may be less homogeneous; thus, they may not share common operational vocabularies or fully understand the expertise and capabilities of fellow team members. This may result in poor team communication and collaboration. Furthermore, traditional teams benefit from common training and background, as this allows the development of relationships built on mutual trust and understanding and promotes the ability to accurately assess the input of individual team members. Lacking this background, *ad hoc* team members must rely on one another for critical information in order to quickly develop an understanding of the situation. This understanding, or situation awareness (SA), is formally defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1995b, p. 36), and forms the foundation for decision making and action.

Ad hoc teams are further challenged by the temporal timelines within which they operate. Team members may cycle in and out of the group, which can result in the loss of specific aspects of team SA resident in the departing team member. They may also multitask between duties on other teams. *Ad hoc* teams members may also be physically distributed, and so the means and timing of communication may impact operations. Distributed teams (*ad hoc* or permanent) must rely heavily on technology mediated communications (e.g., voice or text chat, email), and members with different backgrounds may prefer different information exchange strategies. Geographic distribution can create challenges for the team leader in monitoring team status (e.g., which teams are operational, what specific tasks are being done) and team membership (e.g., who is currently on the team and what are their task assignments). While many of these challenges exist to some degree in other types of teams, *ad hoc* teams face a greater number of these issues, and often lack the common background to ameliorate the difficulties.

Investigating Technology Mediated *Ad Hoc* Team Operations: A Case Study

A better understanding of *ad hoc* team operations in complex environments requires evaluating how the implementation of automation and collaboration technology may influence critical team collaborative processes. In this case study, we examined a short-term *ad hoc* team that was formed for the purpose of a military exercise. We used a framework for team SA to direct our investigation of *ad hoc* team operations. Extending the definition of SA presented earlier, team SA is the degree to which all team members have the SA necessary to perform their roles on the team, and ultimately to contribute to achieving the team's goals (Endsley, 1995b). Endsley and Jones (2001) defined a framework for team SA that describes four interacting factors: team SA requirements, team SA mechanisms, team SA processes, and team SA devices (see Figure 10.1).

Team SA requirements are those pieces of critical information needed by each individual team member to perform his or her specific assigned tasks. Team SA requirements are influenced by the mechanisms, processes, and devices utilized by the team. *Team SA mechanisms* refer to internal cognitive structures that drive the process of sharing information, such as mental models and knowledge derived from common training. *Team SA processes* refer to external processes and include standard operating procedures, information sharing strategies, and communication protocols. For both team SA mechanisms and processes, limitations in common training and background are likely to produce a greater degree of variability among *ad hoc* team members than among members of traditional teams. *Team SA devices* describe the physical means by which information is exchanged and include displays, communication devices, and other equipment used for information exchange. Our framework illustrates that an investigation of *ad hoc* team operations relies not only on the information needs of the team (which by themselves are critical to building team SA), but

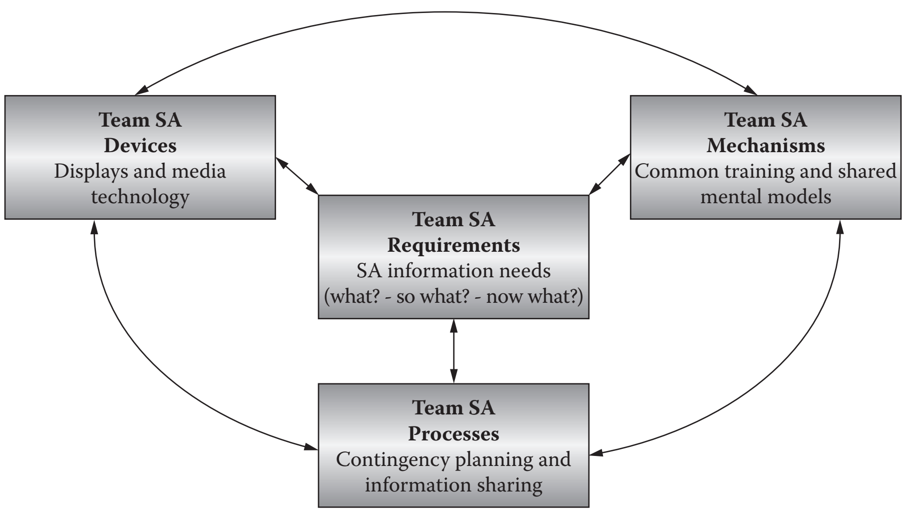

FIGURE 10.1 Framework of team SA. (Adapted from Endsley, M. R., and Jones, W. M., in M. McNeese, E. Salas, and M. Endsley (Eds.), *New Trends In Cooperative Activities: Understanding System Dynamics in Complex Environments*, Human Factors and Ergonomics Society, Santa Monica, CA, 2001, pp. 46–67.)

also consideration of the mechanisms, processes, and devices that enable information transfer.

To investigate forces that may influence these transfer factors, we collaborated in a large-scale three-part experiment, within a military command and control (C2) setting that employed a variety of collaboration technologies. The specific team SA devices (collaboration technologies) were varied between sessions, enabling us to focus on measuring team SA requirements (objective SA of team members) as well as constructs related to team SA mechanisms (team mindfulness) and team SA processes (social network analysis) as a function of technology type. The research goal was to determine whether higher levels of technology facilitated SA in *ad hoc* teams.

Team SA Requirements

SA requirements are those critical information requirements needed to meet both individual and team goals, and are assessed using objective measures of SA. Developing and maintaining SA involves being aware of what is happening around you to understand how information, events, and your own actions will impact your goals in the present and near future.

Team SA Mechanisms

SA mechanisms are the cognitive structures (e.g., mental models) through which data are filtered to produce the individual's SA. Generally, traditional teams develop similar mental models through common training and shared experiences, which are limited for *ad hoc* teams.

Team Mindfulness

At the individual level, mindfulness refers to the ability to be sensitive to information in context. It results from a propensity to draw novel distinctions, notice new information, consider alternative perspectives, and adapt to new situations (Langer & Moldoveanu, 1989). At the group level, collective mindfulness has been studied with respect to the success of high-reliability organizations (e.g., Weick & Sutcliffe, 2001) and is defined as the organization's ability to respond effectively to novel situations. Five components of collective mindfulness include (1) preoccupation with examining and learning from failure; (2) concern with achieving a reasoned, analytical solution; (3) attention to operations; (4) commitment to success; and (5) dynamic decision-making structures and deference to expertise. These factors are related to team SA mechanisms as they define how the team members interact with one another and what the team values. We hypothesized that team mindfulness would be positively correlated with SA scores, as team mindfulness scores reflect the individual's assessment of team attitudes, priorities, and values.

Team SA Processes

Team SA processes are those team-related behaviors that team members employ to enable team operations, such as communication and collaboration, self-checking and confirming, prioritizing and questioning. Developing efficient processes can be a challenge for *ad hoc* teams.

Social Network Analysis

To investigate team communication, we employed methods and measures from social network analysis (SNA) (Borgatti, 1994; Scott, 1992) to assess team communication and information flow among *ad hoc* team members. In any team, individuals influence not only each other, but also the ideas being exchanged and how those ideas are transferred. Thus, a social network represents not only the organization of team members, but also how they interact with one another. SNA methodology maps entities as nodes in a network, and uses links between nodes to represent relationships or information flow between entities. Many SNA measures are relevant for military *ad hoc* teams (Graham, Gonzalez, & Schneider, 2007), but we calculated the two most common: (1) social network distance, the shortest social path separating two people within a network (Borgatti, 1994), and (2) network density, the number of links observed among the members of an organization divided by the number of possible links (Freeman, 1979). As improved collaboration technologies are introduced, we hypothesized a decrease in social network distance and an increase in network density as indications of increased cohesion, closer communications, and tighter relationships.

Method

Participants

The Urban Resolve experiment involved 86 military personnel (mean age = 49 years; range = 22 to 67 years) brought together from multiple specialties, duty stations, and service branches (Army, Air Force, and Marines) to fill between 52 and 59 roles. Personnel included two retired generals, 70 active duty and retired officers (ranks ranging from captain to colonel), nine warrant officers, and five enlisted soldiers. When possible, personnel were placed in roles related to their past rank and experience, yet this was not strictly controlled due to changes in personnel availability over the course of the experiment. Because only a subset of participants was involved in the entire study, it is the complete data from only those 60 participants that are reported here. Although their data are not reported here due to limited participation, coalition forces (British personnel) were also participants during the second experimental session.

This analysis investigates the study participants as a single team, though they were actually organized into teams of teams. This organization, however, was far more complex than it seems, as many personnel had multiple team membership. As an example, the surgeon had membership both in the headquarters staff team and on the medical support team. Most positions had at least dual team membership, and some had membership on multiple teams. For simplicity, the current analysis considers all participants as members of a single team.

Urban Resolve Simulation

The Urban Resolve experiment employed a distributed military C2 simulation. The operational setting was a joint force (multiple service branches) conducting stability operations (e.g., detect and respond to improvised explosive devices, negotiate with local officials, restore local services, and deliver humanitarian aid) while opposed by an adaptive enemy. The headquarters elements, consisting of the Joint Force Land Component Command (JFLCC) along with four other joint force military organizations, were geographically distributed across the United States. The JFLCC headquarters executed C2 over six maneuver brigades, four support brigades, and eight theater units, ranging in size from the battalion to the command level. The data presented in this study were collected only from the JFLCC and subordinate brigade, theater, and support staff, located at Ft. Leavenworth ($N = 60$). Study participants were distributed across three separate rooms in the Battle Lab at Ft. Leavenworth. Approximately two-thirds of the participants were located in a single room, the JFLCC headquarters. Although a seating chart was developed prior to the commencement of the experiment, personnel were relocated during and between experimental sessions to facilitate collaboration and communication. JFLCC personnel included all major staff functions, such as the commander, intelligence, operations, planning, logistics, knowledge management, and critical liaison personnel, such as those providing support for aviation, medical needs, and space-based assets.

Prior to the beginning of actual data collection, participants completed a one-week training session, which included briefings on the purpose of the experiment, collection of demographic data, familiarization with the simulation, and training on the collaboration technologies to be used. Urban Resolve was then executed over three separate two-week (Monday through Friday) human-in-the-loop (HITL) sessions, one per month for three consecutive months. For nine days of each HITL, participants took part in an eight-hour battlefield simulation exercise followed by an after action review, with the final day of each session abbreviated to four hours. See Table 10.1 for an overview of the experimental design and schedule.

TABLE 10.1 Overview of Experimental Design and Schedule

	2 Times/ Day	Weekly (Thursday p.m.)	2 Times/ Day	Weekly (Thursday p.m.)	2 Times/ Day	Weekly (Thursday p.m.)
	HITL 1 2 weeks		HITL 2 2 weeks		HITL 3 2 weeks	
IVs	2005 Technology (C2PC)		2015 Technology (CPOF + space assets and predictive tools)		2015+ Technology (CPOF + additional space assets and predictive tools)	
DVs						
Team attitudes scale		✓		✓		✓
SA audit	✓		✓		✓	
SNA survey	✓		✓		✓	

Collaboration Technology

The primary manipulation across HITLs in the experiment was to modify the technology provided to participants. HITL 1 simulated current technology and employed the Command and Control Personal Computer (C2PC; http://www.ms.northropgrumman.com/). C2PC uses one screen, though another screen is available for additional collaborative displays, such as chats and email. With C2PC, users can view and edit a shared display of the Common Operating Picture (COP), apply overlays, display imagery, and send and receive tactical messages. HITL 2 and 3 were meant to simulate future battlefield capabilities, and employed technologies anticipated to be in use in 2015 (HITL 2) and 2015+ (HITL 3). These technologies included the use of space-based assets, such as real-time satellite imagery and decision support tools with predictive capabilities. The difference between HITL 2 and 3 was in the extent of assets provided, with HITL 3 personnel having access to more assets than HITL 2 personnel.

In addition, in HITL 2 and 3, 31 key personnel (just over half of the participants) received information via the Command Post of the Future (CPOF; http://www.gdc4s.com). The other participants had access to C2PC only. The CPOF employs three screens and provides a shared environment for distributing, manipulating, and displaying information to support the planning of operations. Features included a shared display, Voice over Internet Protocol (VoIP), a graphical user interface (GUI), mapping tools, and enhanced briefing capabilities.

Measures

Objective individual situation awareness was measured using an SA audit questionnaire, administered twice each day. At a predetermined time, participants' display screens were blanked and the questionnaire was presented on participants' monitors. After two minutes, the simulation resumed and any unanswered queries were scored as incorrect. Based on the SAGAT methodology (see Endsley, 1995a), each individual SA audit included 10 items from a total pool of 21 queries about relevant aspects of the situation at that point in time. Unlike traditional SAGAT queries, the SA audit queries were broadly applicable, not tailored to each role. The questions were developed from SA requirements analyses conducted for various Army C2 staff positions using the goal-directed task analysis methodology (see Bolstad & Endsley, 2003; Bolstad, Riley, Jones, & Endsley, 2002; Strater, Endsley, Pleban, & Matthews, 2001). Personnel responsible for designing and running the simulation scenarios selected the queries from a candidate list based upon their broad relevance and applicability across all staffed roles.

In order to obtain a sufficiently large query pool for administration over the six weeks of the experiment, two types of queries were developed: single-response and multiple-response queries. Single-response queries allowed only one response and were scored as either correct or incorrect. Multiple-response queries were multiple-choice queries for which several response options could be correct. Scoring for these queries required assessing whether each response option should have been selected or not selected, and combining scores for each response option into a single score for the query; thus, each query could be fully correct, fully incorrect, or partially correct. The SA audit queries were classified by SA level: Level 1 (perception; 4 queries); Level 2 (comprehension; 11 queries); and Level 3 (projection; 6 queries). Scores were computed for each participant for each administration for overall SA audit, along with Level 1, 2, and 3 SA audit scores. Both Level 1 and Level 3 queries were evenly distributed across single and multiple-response types; Level 2 queries were predominantly multiple response (9 of 11).

Team mindfulness was measured using the team attitudes scale, developed by our research team from the constructs of collective mindfulness. This instrument consisted of 50 statements (both positive and negative) that asked participants to rate their degree of agreement with each statement on a 7-point scale. Questions were targeted for a military C2 environment from each of the five key components of collective mindfulness. Sample positive and negative statements from each component are listed in Table 10.2. Ten statements were created for each component. The scale was administered once per week, on Thursday afternoon. Data from HITL 1 were not included in the analysis, as errors in the survey mechanism resulted in the collection of incomplete data from this HITL.

Social network analysis was assessed using the SNA communication frequency scale, administered twice each day, once in the morning and once in the afternoon. To identify information flow patterns during the simulation, participants identified the person with whom they communicated most frequently, then second, third, fourth, and fifth most frequently. These data were recorded and translated into XML files for use in the ORA social network analysis tool, with each role represented by a node in the network, and the reports of communication frequency represented by lines between the nodes. The data in ORA were then employed to construct social

TABLE 10.2 Sample Team Attitude Items From Each Collective Mindfulness Component (CMC)

Sample Team Attitude Statements	CMC
• Team/staff members feel comfortable reporting mistakes to other team members. • Team/staff members should fix any problems they find without talking about them; there is no need to discuss mistakes.	Concern with learning from failure
• Team/staff members focus on finding out what they don't know. • Team/staff members listen more to people with similar backgrounds and experience.	Concern with analysis
• Team/staff members listen carefully to each other when talking about military operations. • Team/staff members are concerned with their own tasks, not with operations as a whole.	Attention to operations
• Team/staff members frequently help one other with tasks. • Team/staff members rarely talk about what insurgent groups will do next.	Commitment to success
• When personnel are unable to solve a problem, they seek help from team/staff members with more experience. • Team/staff members sometimes feel uncomfortable expressing their opinions and ideas, especially to those of higher rank.	Dynamic decision making and deference to expertise

Note: The second statement listed for each CMC is reverse scored.

network graphs, as well as to calculate social network distance and network density in the networks. Values were then averaged across HITLs.

Results and Discussion

The analysis and interpretation of the results for each of the measures are presented below.

SA Audit

Analyses of the SA audit questionnaire revealed that overall SA declined across HITLs: $F(655, 6) = 4.28$, $p < .01$ (see Figure 10.2). Both Level 1 and Level 3 SA remained consistent across HITLs, and the statistically significant decrease in overall SA was due to the decrease in Level 2 SA (comprehension). As noted earlier, compared to the Level 1 or 3 queries, Level 2 queries were primarily multiple response. Arguably, multiple-response option queries are more difficult than single-response queries, as the participant must evaluate whether each response option is true or false rather than identifying the option that is *most* correct. The decline in Level 2 SA across HITLs may reflect decreasing motivation to answer these more difficult queries. As mentioned earlier, the study occurred over three separate two-week sessions, and researchers noted an apparent decline in motivation for some aspects of the study, including the SA audit questionnaire. The combination of more challenging queries and decreased motivation may account for the decline in Level 2 SA across HITLs.

The objective data contrast with subjective assessments by expert observers at the experiment who believed that SA improved over the HITLs. The decline in SA audit scores may reflect the fact that the queries did not exclusively consist of items of immediate relevance to the participant. The general questions asked in this SA audit

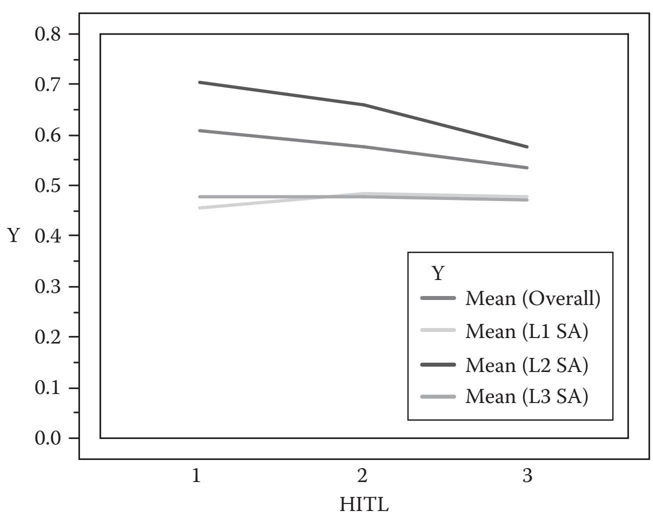

FIGURE 10.2 SA audit scores across HITLs, showing level 1 (perception), level 2 (comprehension), level 3 (projection), and overall SA.

may not accurately reflect overall SA in this particular large and diverse *ad hoc* team exercise, as the globally relevant items may not have been of interest to participants in all roles and echelons represented.

Team Mindfulness

As the team attitudes scale was a new measure developed for this experiment, the first step was to evaluate the psychometric properties for the overall scale and for the subaggregate component area scores at each point in time. While the overall score for internal consistency revealed high consistency across administration times, in part due to the large number of overall items, the internal consistency scores for the subaggregates were lower than desired. Several items that were negatively correlated with the subaggregates were dropped due to the possibility that the item phrasing may have been confusing. Once all negatively correlated items were dropped, resulting in a 37-item scale, all internal consistency scores for the overall scale and subaggregates improved, indicating that the scale was consistently found reliable over time (see Table 10.3). Only the subaggregate "concern with failure" at Times 1, 2, and 3, and the subaggregate "attention to operations" at Times 2 and 6 yielded insufficient reliability, although the reliability is certainly acceptable for exploratory analyses. Thus, all further data analysis reported here is based on this reduced scale.

Social Network Analysis: Network Distance and Network Density

Both social network distance and network density represent the cohesion, communication, and tightness of relationships among members of an organization. As improved collaboration technologies were introduced across HITLs, we expected that social network distance would decrease and network density increase. Statistical analyses are not appropriate on SNA data, but as expected, the network density, that is, the number of links observed among team members divided by the number of possible links, increased over the three HITLs, indicating a possible effect of the collaboration technologies introduced. Specifically, density increased from 0.03 in HITL 1, to 0.04 in HITL 2, and to 0.05 in HITL 3. In general, this team's network density is

TABLE 10.3 Revised Internal Consistency Scores With Sample Size for the Team Attitudes Scale at All Six Administration Times

Time	HITL	Overall Scale α (N)	Concern With Failure α (N)	Concern With Analysis α (N)	Commitment to Success α (N)	Attention to Operations α (N)	Fluidity in DM α (N)
1	1	**.94 (37)**	.63 (8)	**.84 (8)**	**.88 (5)**	**.76 (8)**	**.81 (8)**
2	1	**.92 (37)**	.63 (8)	**.82 (8)**	**.83 (5)**	.67 (8)	**.81 (8)**
3	2	**.95 (37)**	.67 (8)	**.83 (8)**	**.87 (5)**	**.82 (8)**	**.81 (8)**
4	2	**.95 (37)**	**.76 (8)**	**.83 (8)**	**.87 (5)**	**.77 (8)**	**.83 (8)**
5	3	**.95 (37)**	**.78 (8)**	**.85 (8)**	**.84 (5)**	**.73 (8)**	**.85 (8)**
6	3	**.94 (37)**	**.72 (8)**	**.76 (8)**	**.85 (5)**	.69 (8)	**.86 (8)**

Note: α in bold are acceptable scores for internal consistency, as measured by Cronbach's alpha.

low when compared to the network density reported in other studies involving military organizations (e.g., 0.10 in Graham et al., 2007). However, the C2 organization investigated in the present study is *ad hoc*, and is also larger and more diverse than previous organizations studied. It is reasonable to posit that the challenges to communications in an *ad hoc* team would be even greater in a large, diverse, and distributed *ad hoc* team. So, although modest, the increase in density suggests an improved understanding and use of communication technologies across the HITLs.

Also as predicted, the social network distance of this organization decreased across HITLs, indicating that, on average, the shortest path length separating two people within the network decreased over time, and that any one individual needed to go through fewer nodes to communicate with others in the network. Social network distance decreased from 3.4 in HITL 1, to 3.3 in HITL 2, and to 3.1 in HITL 3. Again, in general, these values are low when compared to the social network distance values of previous studies (e.g., 5 in Graham et al., 2007). This decrease, nonetheless, suggests a better use and understanding of the technology across HITLs.

In addition to the quantitative findings presented here, qualitative analysis, reported in depth elsewhere (Cuevas, Caldwell, Strater, Gonzalez, & Ungvarsky, in preparation), revealed that the structure of the network changed over time. With the introduction of the improved collaboration technology, the personnel responsible for updating display information emerged as key nodes in the social network. Because the updating process could be accomplished without the direct team member-to-team member communications captured in the SNA questionnaire, this change indicates the importance of the information updating function and the relevance team members placed on accurate and timely updating. In addition, the network became less fragmented across HITLs, with more alternate routes for information flow. This is important, as busy personnel in key positions can hinder efficient information flow in a fragmented network. It is impossible to attribute this change to the collaboration technologies, as personnel also became more familiar with each other over time and may have developed information exchange strategies to ensure efficient information flow through the team.

Team Mindfulness and Situation Awareness

AU: Please introduce TAS.

A correlational analysis was conducted to provide evidence for a relationship between the subjective TAS and the objective SA audit measure. Because of changes in items for both the SA audit and the TAS from HITL 1 to HITL 2, these correlations were performed only for the data collected during HITL 2 (Times 3 and 4) and HITL 3 (Times 5 and 6). Due to the expected positive relationship between team attitudes and SA, all correlations are one-tailed. Overall, some support was found for a relationship between the TAS and SA audit data. Specifically, when correlating the scale subaggregates to overall SA performance, and performance at each SA level (i.e., Level 1, perception; Level 2, comprehension; and Level 3, projection), significant relationships were found across time.

Team Attitudes and SA at HITL 2 (Times 3 and 4)

The subaggregate "concern with failure" at Time 3 significantly correlated with overall SA ($r = .33$, $p = .01$), Level 2 SA ($r = .32$, $p = .01$), and Level 3 SA ($r = .27$, $p = .03$).

At Time 4, "concern with failure" was found to significantly correlate with Level 2 SA ($r = .283$, $p = .04$).

Team Attitudes and SA at HITL 3 (Times 5 and 6)

The subaggregate "concern with analysis" at Time 6 significantly correlated with overall SA ($r = .43$, $p < .01$), Level 1 SA ($r = .36$, $p < .01$), Level 2 SA ($r = .36$, $p < .01$), and Level 3 SA ($r = .32$, $p < .01$).

Team Attitudes Baseline as a Predictor of Future SA Performance

A further analysis was performed to look into the relationship between the first team attitudes scores and the final SA audit scores. This was an exploratory analysis to verify whether or not team attitudes expressed at the beginning of HITL 2, which can be regarded as a baseline assessment, can predict future performance on SA, as measured in Time 6 (HITL 3). The goal was to further establish the diagnosticity of team attitudes for predicting SA performance. Linear regression was performed using each baseline subaggregate (Time 3, HITL 2) as an independent variable, and each level of SA as well as overall SA as the dependent variables. Table 10.4 summarizes the findings, which indicate that all but one baseline subaggregate (commit to success) did predict overall SA at Time 6.

In sum, the TAS was demonstrated both to be reliable across time and to be valid to the extent that it shows a relationship with actual SA. However, because not all subaggregates consistently correlated with SA, work remains to be done to revise items to further increase the validity and reliability of the scale. Nevertheless, these results highlight the potential diagnostic utility of the team attitudes scale for predicting SA performance.

Implications for Expert Team Performance

As society's problems increase in complexity, *ad hoc* teams will emerge as a valuable organizational unit to engage for finding solutions. Gathering specialized domain expertise when needed most, these rapidly forming teams offer organizations an effective means of dealing with unanticipated and urgent problems (Engwall & Svensson, 2004). Such teams can support organizational productivity across a variety of domains, including military (e.g., military transition teams), healthcare (e.g., coordination of patient services among healthcare providers from varying disciplines), manufacturing (e.g., engineering design teams), and disaster response (e.g., multinational teams responding to disaster relief efforts), among others. Lessons learned from the investigation of *ad hoc* teams can provide insights into how traditional teams respond to emerging unforeseen events.

Researching *ad hoc* team processes in order to better support these teams through automation design and collaboration technology is a vital objective. While a number of collaborative tools exist (Bolstad & Endsley, 2005), few, if any, are focused around the unique needs of *ad hoc* teams, such as dealing with dynamic temporal timelines and changing membership. Lessons learned from our research on the challenges faced by *ad hoc* teams suggest several key design goals to keep in focus: (1) Provide *team SA devices* that facilitate the timely and effective exchange

TABLE 10.4 Linear Regressions Between Team Attitude Subaggregates as Predictors of Overall SA and Level of SA

	Overall SA				Level 1 SA				Level 2 SA				Level 3 SA			
Predictor	R^2	*SEB*	*F*	*p*	R^2	*SEB*	*F*	*p*	R^2	*SEB*	*F*	*p*	R^2	*SEB*	*F*	*p*
Concern with failure	**.17**	**.09**	**6.9**	**.01**	**.20**	**.17**	**8.8**	**.01**	**.11**	**.08**	**4.1**	**.05**	.28	.16	2.8	.10
Concern with analysis	**.11**	**.09**	**4.4**	**.04**	.10	.18	3.6	.07	.02	.09	0.6	.44	.07	.16	2.6	.12
Commit to success	.28	.09	2.8	.10	.01	.19	0.3	.58	.03	.09	1.1	.30	.02	.17	0.6	.43
Attention to operations	**.19**	**.56**	**7.8**	**.01**	**.22**	**.17**	**9.5**	**.01**	.03	.09	0.9	.35	.07	.16	2.5	.12
Fluidity in DM	**.15**	**.09**	**6.1**	**.02**	**.04**	.19	1.5	.22	.06	.09	2.3	.14	.04	.16	1.4	.25

Note: p-Values in bold are significant linear regressions (two-tail).

of critical task-relevant information among team members, and thus encourage improved *team SA processes*; (2) support *team SA mechanisms* by enabling members to develop a shared understanding of the task environment as well as each other's competencies; and (3) support the team leader's *SA requirements* by improving the ability to monitor and manage the activities of a diverse group of experts across time and space.

Achieving these design goals requires designing automation and collaboration technology that facilitates awareness of shared workspaces (Gutwin & Greenberg, 2004; Vick & McNamara, 2005), which in turn leads to improved team SA and shared SA. In addition, such technologies should support knowledge management and information flow to ensure that members have timely and ready access to the distributed expertise of their a*d hoc* team members (Caldwell, Palmer, & Cuevas, 2008).

Conclusions

This chapter presents preliminary work aimed at investigating the team processes within an *ad hoc* military C2 team with increasing levels of technology. Improvements in team SA processes with higher levels of technology were suggested by decreases in social network distance and increases in density across HITLs. While SA audit scores did not show improvement across HITLs, this may reflect a lack of motivation to accurately respond to the more challenging level 2 SA queries. In addition, because of the nature of the experimental conditions, some of these queries may have been insufficiently relevant to study participants. Thus, the decline in SA audit scores may reflect an actual decline in SA, or it may reflect that participants were more adept in later HITLs at focusing only on the information relevant to their goals, objectives, and task demands. Additional analysis will investigate the data within varying team structures.

Finally, results from the new team attitudes scale indicate that the scale is consistently measuring a cognitive construct over time, while the correlation demonstrated between the scale and objective SA audit scores indicates that the cognitive construct measured is, indeed, related to situation awareness. These results also indicate that the team attitudes scale provides some diagnostic capability to predict objective SA. Although further research is needed to refine and validate this scale, these results provide promising support for the team attitude scale's potential benefit for investigations of team performance.

Overall, results from this study support the relationship between team SA mechanisms, team SA devices, team SA processes, and team SA requirements as presented in Endsley and Jones's (2001) framework of team SA. This framework may provide utility for guiding future NDM research in team operations.

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