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Information behavior in dynamic group work contexts: interwoven situational awareness, dense social networks and contested collaboration in command and control

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Abstract

In many dynamic work situations, no single individual can acquire the varied and often rapidly expanding information needed for success. Individuals must work together to collect, analyze, synthesize and disseminate information throughout the work process. Perhaps one of the most dynamic work contexts is command and control in the military at the battalion level which directs 300 to 1000 soldiers on the battlefield. This paper reports on a study that explores human information behavior in command and control (C2). Data was gathered from simulated battle exercises, interviews with experienced C2 personnel and documentation on C2. During data analysis, three important themes that highlight the why, what, how and consequences of information behavior in C2 emerged. The first is the concept of interwoven situational awareness consisting of individual, intragroup and intergroup shared understanding of the situation. Interwoven situational awareness appears to facilitate response to dynamic, constraint-bound situations. The second theme describes the need for dense social networks or frequent communication between participants about the work context and situation, the work process and domain-specific information. The third theme is called 'contested collaboration', a phenomenon where team members maintain an outward stance of cooperation but work to further their own interests, at times sabotaging the collaborative effort. These results provide insights to the complex nature of human information behavior in dynamic and complex work contexts and lead to recommendations for training and further research.

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1. Introduction

In many dynamic work situations, people must seek, collect, integrate, analyze and disseminate information from multiple domains and resources under multiple stringent constraints. Perhaps one of the most dynamic work contexts is command and control (C2) at the battalion level in the military. A battalion typically consists of 300 to 1000 soldiers; C2 for the battalion is performed by a team consisting of small groups of experts from a variety of domains. The team must dynamically seek information from multiple sources and explore and integrate the information and their specialized knowledge to create and execute plans. Their plans and subsequent actions should accomplish the intent of the battle mission, be achievable within the constraints of the situation and be synchronized with other organizational units, including joint and coalition forces, who are typically geographically distributed and new collaborators. Furthermore, while supervising and performing tasks before and during the battle, they must continually evaluate their units' performance and the situation to determine what additional specialized information and activities are required. These activities must be achieved on demand under increasingly strict time deadlines imposed by the battle tempo and continually for periods lasting days to months to years.

Increasingly, as the diversity and complexity of the battlefield and complexity of information pertaining to the battlefield increases, no single individual can acquire and process the diverse and often rapidly expanding information needed to create and execute battle plans effectively. Individuals must work together to seek, synthesize and disseminate information throughout the C2 process. They must seek, synthesize and disseminate several types of information, including information about the current battle situation (e.g. troop strength and location); information about the C2 process (e.g. who needs what information when); and specialized domain or technical information related to C2 (e.g. weapon system capabilities). This diversity of types of information implies that experts in a variety of areas must collaborate during the C2 process to effectively create and execute battle plans. These experts may come from different disciplines (or specialties), different branches of the military and even different countries.

It is essential to understand the characteristics of human information behavior in this context. This understanding is necessary to provide insights with respect to best practices, training, organizational structures and information systems that better support human information behavior in the context of command and control. Furthermore, understanding this context may provide general insights applicable in other dynamic work contexts, such as power plant operations, emergency response teams and design teams, that also require experts from several domains to seek, synthesize and disseminate rapidly-changing information under multiple stringent constraints.

This paper reports on a qualitative study that explores information behavior in C2 at the army battalion level. In the study we observed simulated battlefield training exercises, interviewed experienced military personnel and analyzed written documentation on current C2 practices. These data were analyzed using a semantic concept analysis technique. From this analysis, three primary themes, or characteristics, emerged with respect to human information

behavior. The first focuses on interwoven situational awareness — a new concept that suggests teams benefit when members develop interwoven patterns of situational awareness, consisting of individual, intragroup and intergroup shared understandings of the situation. The second theme is the importance of social networks. Dense social networks, operationalized as frequent bi-directional information flow among team members, appear to contribute to team performance as perceived by team members. The third finding concerns a phenomenon called "contested collaboration" (Sonnenwald, 1995). When contested collaboration occurs team members challenge the contributions of others. They may also maintain an outward stance of cooperation but work to further their own interests, at times sabotaging the collaborative effort. When this occurs, it hinders the achievement of the superordinate team goal. These themes help explain the why, what and how of information behavior in the dynamic group work context of command and control. These results have implications for current and future practice and future research.

2. Related research

Research in human information behavior has primarily focused on the individual in general and in relationship to tasks, computer-based information systems, or social situations. For example, Kuhlthau (1993) proposed a model of the individual information search process. In her model, the information search process is divided into seven stages: task initiation, topic selection, prefocus exploration, focus formulation, information collection, search closure and starting writing. Kuhlthau identified feelings, thoughts, actions, strategies and moods for each stage. She also proposed the 'uncertainty principle' in information behavior, i.e. "uncertainty due to a lack of understanding, a gap in meaning, a limited construct initiates the process of information seeking". (Kuhlthau, 1993, p. xxiii) The principle further asserts that uncertainty is a cognitive state which causes anxiety and stress and that can be expected in the early stages of the information search process. Thus, Kuhlthau's information search process model and uncertainty principle highlight the importance of viewing human information behavior as a process and understanding that cognitive and affective components influence human information behavior.

Also focusing on the individual, Wilson (1997) proposes an interdisciplinary, general model of human information behavior. In particular, Wilson draws on research in health information, advertising, economics, communication and organizational behavior. His model includes the following elements: character or context, of an information need; activating mechanism, including stress/coping theory, that links needs and action; intervening variables (or barriers to seeking information), including psychological, demographic, role-related or interpersonal, environmental and source characteristics; activating mechanism (or the decision to engage in information seeking behavior), including risk/reward theory and social learning theory. He proposes that these elements combine in a linear sequence to yield information seeking behavior, including passive attention, passive search, active search and ongoing search behavior. From his work, we see the importance of drawing on research outside our field; it suggests the importance of exploring information behavior in C2 where the context, activating

mechanisms and intervening variables may be different from the academic, library and corporate environments typically studied in our field.

Byström (1997) replicates previous findings on the relationship between tasks and information seeking. Her study confirms that task complexity influences information behavior. In particular, as task complexity increases, individuals tend to consult more information sources, prefer to consult persons rather than other documentary sources and prefer easily-obtainable internal information resources.

Belkin, Ingwersen and others focus on human information behavior in relationship to computer-based information retrieval (IR) systems. Belkin (1993) proposes a set of information seeking strategies that incorporate the goal of the interaction (learn/select), method of interaction (scan/search), mode of retrieval (recognize/specify) and type of resource (information/meta-information). He further suggests that users should share control and responsibilities with systems and that during the IR process, users interact with texts (including humans who provide information). Ingwersen (1996) also focuses on information retrieval aspects of human information behavior. Stressing the cognitive perspective, Ingwersen proposes a polyrepresentation approach. That is, the individual user's cognitive space, including work task or interest, current cognitive state, problem or goal, uncertainty, information need and information behavior and the social or organizational environment, including domains, strategies or goals and tasks and preferences, should be represented in IR systems. These approaches highlight the importance of cognitive and situational components in human information behavior.

Other research has highlighted the impact social networks have on information behavior. For example, Chatman (1992, 1996); Taylor (1991) and others point out that social networks play an important role in providing information as well as hindering information seeking behavior.

Thus, research in human information behavior suggests the importance of investigating human information behavior as a process, taking into account cognitive, affective, social and contextual factors and drawing on research from multiple disciplines to increase our understanding.

However, research has not focused on information behavior in group, or collaborative, work situations[2]. Similarly, research on groups has not focused on information behavior. For example, a taxonomy of team performance, or behavior, functions was proposed by McGlynn, Sutton, Sprague, Demski and Pierce (1997). Their taxonomy is based on a survey of performance and team literature in social psychology, including the conceptual and empirical research by Fleischman and Zaccarro (1992). The taxonomy reflects a focus on cognitive behavior and includes the following functions: information exchange, resource matching, coordination, error checking and motivational functions. Clearly, information exchange is only one component of information behavior and research (e.g. Allen, 1977; Kraut & Streeter, 1995; Solomon, 1997; Sonnenwald & Lievrouw, 1997) indicates the importance between information

[2] One exception is Sonnenwald (1995, 1997) who investigated communication and human information behavior in design. Sonnenwald proposed a taxonomy of communication roles that support information dissemination and sharing in design situations.

behavior and team performance. Thus, studying information behavior in dynamic work contexts such as C2 is of critical importance.

3. Research methodology

In this study three research methods were used: document analysis, observation and interviews. This approach allowed us to analyze formal and informal and current and retrospective data. This variety of data is highly appropriate and often required to gain an understanding of the complexity and texture of information-intensive and dynamic organizations and situations. It permits data triangulation, i.e. the opportunity to understand human information behavior using multiple types of data and data from multiple sources.

3.1. Document analysis

US Army documents selected for analysis focused on current practice, including general doctrine that describes the overall battlefield organization and command processes (US Army Field Artillery School, 1992; Battle Command Battle Laboratory, 1994; US Army Command and General Staff College, 1995; Headquarters Department of the Army, 1984; 1986; US Army Training and Doctrine Command, 1994). It also included documentation on C2 tasks (Harrison, 1995; Jarrett, 1995; McIlroy, 1995). These documents provided a formal perspective of C2 on today's battlefield. As illustrated in previous research in human information behavior, knowledge about the organization, goals and tasks is required to develop a deep understanding of information behavior in context.

3.2. Observation

To augment our understanding of practice as stated in formal documentation, a simulated battlefield training exercise was observed. The battlefield training exercise took place at the US Army Field Artillery School Battle Simulation Center at Fort Sill, OK. Janus, a two-sided, interactive, stochastic simulation program used to stimulate battlefield forces and to stimulate information exchange and decision making within and among units, was used to drive the training exercise. The observed exercise was performed at the end of an Officer Advanced Course. The students were field artillery captains who had been together in the training course for six months at the time of the exercise. They had participated in multiple field training exercises and three other Janus simulation exercises; several had also participated in other simulations. When asked, they replied they felt comfortable participating in simulations and had confidence in their ability to do so effectively. Furthermore, course instructors reported this group had demonstrated a high level of performance on previous tasks and exercises.

During the exercise, a researcher (Sonnenwald) observed the air assault Tactical Operations Center C2 team during their preparation for the battle, participation in the battle and instructor-led discussion session after the conclusion of the exercise. The peripheral membership role (Adler & Adler, 1987) was chosen when observing to minimize the potential

of the study to influence the participants' behavior. Interactions among team members and interactions between team members and others were observed.

In the ethnographic tradition (cf. Lofland & Lofland, 1994), note taking was used extensively to record data. Exhaustive notes were made while observing events during the exercise. Later, away from the setting, these field notes were augmented with: sketches of areas where the exercise took place; additional details about events and interactions, using the field notes as prompts; and summaries of overall impressions about events which occurred during the simulation.

The observational data were not from an actual battlefield situation per se because it was impractical to observe an actual battlefield situation. However, the high degree of cognitive and emotional involvement of participants in simulations and the similarity of their behavior, to behavior in actual situations, has been observed in other studies (e.g. Raser, 1969).

3.3. Interviews

We also employed semi-structured and critical incident interview techniques to gather additional data on C2 experiences. These methods have been shown to yield accurate accounts of people's previous experiences (Flanagan, 1954). Seven interviews with experienced military personnel were conducted. Each interview participant had between 8 and 23 years of military experience with 116 combined years of experience. They had served in Desert Storm, Vietnam, Germany, Saudi Arabia, Korea and the US. At the battalion level they had performed the duties of Commander, S3 Operations Officer, Assistant Operations Officer, S2 Intelligence Officer, Fire Support Officer (FSO), Signal Officer, S1 Personnel Officer and S4 Logistics Officer[3]. In addition to these positions at the battalion level, they had also served as Brigade FSOs, instructors at Army schools and colleges, General Staff and NATO Army Group Level Officers and Operations Research and Systems Analysts. Their experience came from Maneuver, Field Artillery and Signal Corps branches as well as the Army National Guard.

During the interview non-directive and open-ended questions, or probes, were used to initiate face-to-face discussions with interview participants. These questions were used loosely to allow each respondent to shape the content of their answers. The first set of questions focused on participant's military experience. The second set of questions focused on participant's experience in C2 organizations. Each participant was shown a sample organizational chart of a battalion level TOC and asked to compare the chart with their experiences in TOCs. The third set of questions focused on critical incidents. The critical incident technique was used to collect additional self-report data about the participants' most memorable positive and negative experiences in (battalion level) C2. This technique is especially useful for getting respondents to talk about conflicts and failures, which are often considered to be 'private' in organizational cultures and not to be discussed with outsiders. Critical

[3] The names of these positions include both an alphanumeric designation (e.g. S3, S2, S1 and S4) and a short text description, e.g. Logistics Officer. The alphanumeric designations do not indicate the grade of the position, e.g. the S4 Logistics Officer is not a Specialist Grade 4; rather 'S4' indicates that the position is a staff position (S) dealing with logistics (historically given the number 4). Each alphanumeric designation and their associated text description are used interchangeably throughout this text.

incident interviews allow participants to recall and describe events and conflicts in a fairly reliable way.

Each interview ranged from 1 to 2 h in length; the average length was 1.5 h. A combination of note taking and audio-recording was used during the interviews. Audio-recordings were transcribed.

3.4. Data analysis

These data were analyzed to discover characteristics of human information behavior and its role in C2. The data was analyzed through a series of steps using open and axial coding (Berg, 1989). During open coding all data were read thoroughly and carefully and basic practices and concepts were identified. For example, basic practices and concepts that emerged from the data included organizational structure, job tasks and responsibilities, communication patterns, information exchange and challenges in collaboration. These concepts then served as categories or coding frames and were used in the following stage of axial coding. During axial coding the data were reread and organized according to the categories. The results were summarized in topic memos (Lofland & Lofland, 1994) that included descriptions and evidence of categories discovered in the analysis.

This approach permits data triangulation and appears to reflect the multi-perspective nature and 'art' of dynamic group work better than any single-method approach. By looking at C2 from multiple vantage points as provided by documents, observation and interviews with a variety of participants, we may be more likely to discover a general descriptive model applicable across a range of dynamic work contexts and situations.

3.5. Study limitations

This study does not cover all variations of C2 practice, or dynamic group work in general. To some degree, the US Army culture encourages individuals to be creative problem solvers, using their own initiative to solve difficult problems. We attempted to overcome this limitation by investigating multiple C2 situations; however, further research covering a broader range of C2 situations and participants may provide additional insights. An additional limitation concerns the type of data collected and analyzed. In the study, we use qualitative research methods. This approach provides rich descriptions of the C2 process and limited statistical data. For example, a complementary or alternative approach would be to collect and analyze all communication among participants in a C2 exercise to provide a quantitative description of information behavior in dynamic group work contexts.

4. Command and control practice today

C2 at the battalion level is performed by a team consisting of groups of experts and staff from a variety of domains including leadership and management, military science, logistics, enemy intelligence, field artillery (fire support) and telecommunications. These experts contribute to the C2 process in several ways. They explore and integrate their specialized

knowledge to create plans that will accomplish the intent of the battle mission and are achievable within the constraints of the situation. For example, their mission may be to take "Objective Eagle" and they must determine how best to achieve this goal with available resources in synchrony with other battlefield assets. They also prepare for the battle, supervising personnel and performing tasks to support the battle plan and mission. In addition, they apply their expert knowledge to supervise and perform tasks during the battle and continually evaluate their units' performance and the situation to determine what additional specialized information and tasks are required. Throughout these activities they communicate and share information, ideally, developing a shared understanding of the mission and battle and working in a coordinated fashion to achieve the mission. As one participant explained:

> They're information-handlers. They're managing a knowledge base and that knowledge base allows them to develop an understanding of their situation and to assess within that understanding whether or not there's a problem. The second thing that they have to manage is decision making... The third... is actual implementation.

4.1. Organizational structure and responsibilities

Personnel typically involved in C2 at the battalion level are illustrated in Fig. 1. Usually personnel are divided into three major geographically-distributed groups: the command group, the administrative logistics operations center (ALOC) and the tactical operations center (TOC) (Headquarters Department of the Army, 1984, 1986). The command group, specifically, the Commander, assigns and gives the battlefield mission to the TOC. The commander shares the mission and intent of the higher echelon (the Brigade), evaluates and selects courses of actions,

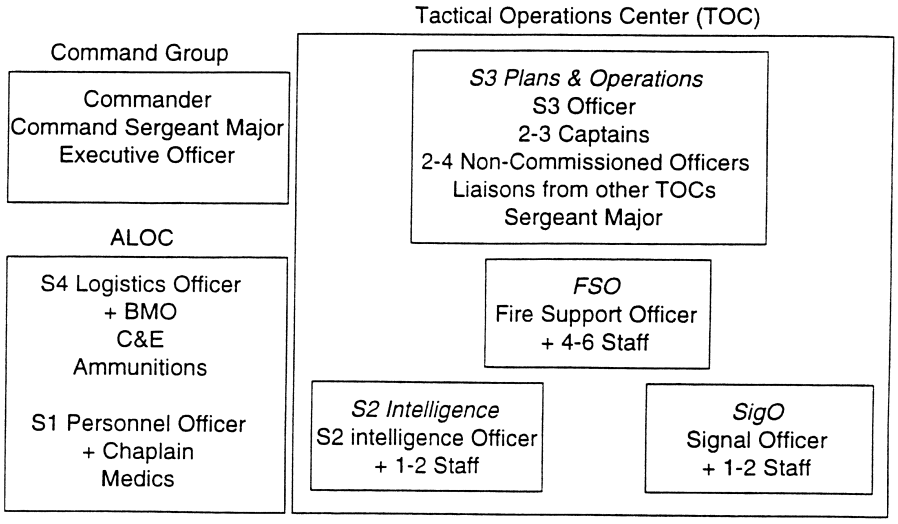

Fig. 1. Typical organizational structure in C2 at the battalion level.

identifies critical information needs[4] and provides leadership as needed throughout the C2 process. The ALOC collaborates with the S3 and Commander in planning and preparing for the battle to ensure that the companies will have the supplies, personnel and personnel services when and where they are needed. Our focus in this study is the TOC.

The tactical operations center (TOC) typically consists of four groups, including the S3 Plans and Operations, S2 Intelligence, Fire Support Officer (FSO) and Signal Officer (SigO) group. The S3 Plans and Operations group typically consists of 6–9 people from various organizational levels: a major (the S3), 2 or 3 captains, a Sergeant Major and 2–4 non-commissioned officers. The S3 is usually responsible for planning, including creating a series of alternative plans and analyzing these alternatives with guidance from the Commander and in collaboration with the S4, S1, S2, FSE and SigO. The results of the planning and analysis are presented to the commander who will ask clarifying questions, possibly suggest refinements to the plan and select a plan. The S3 may also be responsible for supervising battle preparation and execution. As such, the S3 is responsible for creating situational awareness of the battlefield among the battalion staff and the companies that report to the battalion. He also needs to maintain an awareness of the logistics situation and how it may impact the battle and, perhaps, the civilians in the area. In addition, the S3 might also be considering future events. As one interview participant explained:

> The S3 should be working to be trying to deduce missions so he can keep the commander informed of what is happening, of what he expects might happen with respect to missions stated or unstated.

In addition, several other officers may be part of the S3 group. These include biological and chemical (NBC) officers and liaisons from other TOCs. The NBC officer is commonly referred to as the 'bugs and gas' person and is responsible for advising the S3 and Commander on NBC threats. The liaisons represent their TOC and help coordinate collaborative efforts among the two TOCs. For example, battalions sometimes pass through each other's area; these passages must be well coordinated to avoid fratricide. As interview participants noted, it may be very important that a battalion understand the intent and mission of units on their flanks.

> Each guy is sending a member of his staff over to keep you posted on what's going on with respect to operations that may or may not have an effect on what you're doing. We do a lot with respect to these liaisons.

Other officers in the TOC include the S2 Intelligence Officer, Fire Support Officer (FSO)[5] and SigO. These officers are usually captains or senior sergeants and assisted by 1 to 6 staff members. The S2 group is responsible for gathering and interpreting intelligence information on the enemy, including enemy equipment, enemy movement, estimates of enemy strength and

[4] These are often formalized as the commander's critical information requirements (CCIR) which may include priority intelligence requirements (PIR), friendly forces information requirements (FFIR) and essential elements of friendly information (EEFI) (Battle Command Battle Laboratory, 1994).

[5] In some battalions, the FSO will not be attached to the TOC but will be with its Field Artillery organization.

locations, possible enemy targets and the enemy's potential course of action. The S2 also provides information on the weather and terrain.

> The S2 contributes in many ways. He is providing information on the enemy's order of battle and whatever we can learn about who our opponent is on the opposite side. How is he equipped? What is his doctrine? How can we expect him to behave in combat? [We use this information to devise] means by which to counter expected or anticipated activity and [to devise] ways of depriving the opposing force [battle] capabilities.

The FSO plans fire missions and provides (or calls for) fire support during the battle. For example, the FSO must integrate information about firing capabilities, ammunition status, enemy targets, the friendly situation, troop movement and geographic areas in creating and executing plans for fire. The FSO and SigO may report organizationally to other units. The SigO provides telecommunications support for the battalion. The SigO and their group may go into the battle area in advance to set up telecommunications networks, as well as work to maintain those networks and keep them secure during the battle. One participant proposed:

> You could, perhaps, look at the quality of the Signal Officer as a predictor of how effective C2 will be in that unit because most of the problems that we have are not difficult problems if you can communicate the vital information.

On occasion, other groups may be assigned to the TOC as needed. For example, an engineering or air defense artillery unit may be assigned to help the battalion traverse obstacles, such as rivers, in the terrain or provide air artillery support, respectively.

As indicated by this description of the organizational structure and responsibilities, the C2 process is complex and requires interaction among diverse individuals and groups. An analysis of C2 tasks documented in Harrison (1995), Jarrett (1995) and McIlroy (1995) shows that the majority of tasks (14/24 or 58%) require everyone's participation. An additional six tasks require participation by everyone except one person. Thus 20 out of 24 (or 83%) of the tasks require participation by everyone or everyone except one person. Thus human information behavior is critical in C2. This is corroborated by interview participants who reported:

> I don't believe that [battlefield plans] are necessarily an S3 product. It's the product of a team working together and I think that's going to include somebody from the ALOC, FSO, the S2 and the S3.

> Everyone plays a role — feeding or drawing information from the process.

5. Information behavior as determinants of success

In our analysis of human information behavior in C2, three themes or characteristics of information behavior emerged as determinants of success. The three themes are: interwoven

situational awareness, dense social networks and 'contested' collaboration. They help explain the why, what and how of information behavior in the dynamic group work context of command and control.

5.1. Interwoven situational awareness

Because C2 tasks are collaborative in nature, an interwoven situational awareness appears to facilitate task completion. The concept of situational awareness originated to describe jet pilots' need to have a continual awareness of current events and future anticipated events during their flight. It is defined as (Vidulich, Dominquez, Vogel & McMillan, 1994, p. 11):

> Continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture in directing further perception and anticipating future events.

Similarly, C2 team members need to collect, synthesize and disseminate information to create an understanding of the current battlefield situation and to anticipate future battlefield events. Because the amount of information for an entire battle situation is diverse and can be overwhelming, we propose that an interwoven situational awareness that includes individual, intragroup and intergroup situational awareness is an important aspect of information behavior in the dynamic, group work context of C2 (see Fig. 2).

Each individual in C2, ideally, has specialized domain knowledge and expertise. For example, an FSO is interested in information about firing capabilities, ammunition status, enemy targets, the friendly situation, troop movement and geographic areas when creating and executing plans for fire. In comparison, a SigO is interested in telecommunication transmission rates, antennae positions and directions and switch connections. Thus, individual team members strive to develop a specialized and unique individual situational awareness that is a

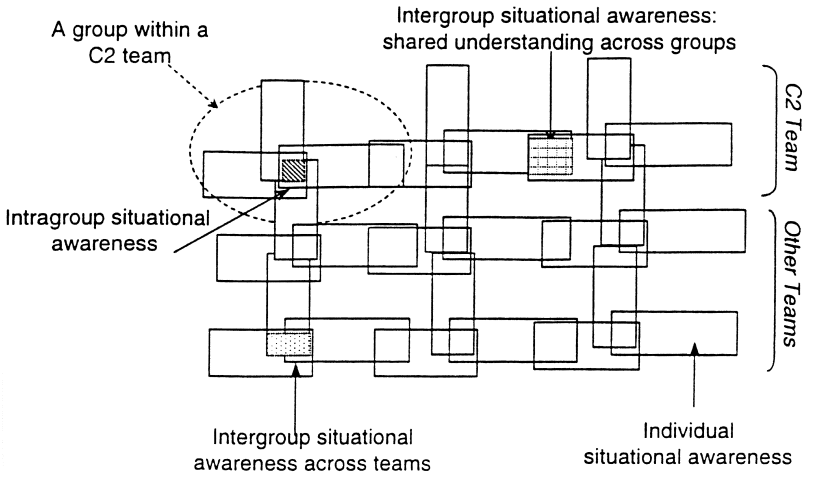

Fig. 2. Interwoven situational awareness.

synthesis of their domain knowledge and knowledge about the current situation to facilitate completion of their domain-related tasks.

In addition to developing an individual situational awareness, individuals may need to develop and maintain an intragroup situational awareness, i.e. a shared situational awareness among group members. The intragroup situational awareness makes it possible for group members to proactively provide information needed by other group members, analyze and synthesize information collaboratively and orchestrate or synchronize actions within their group. For example, the radio operator in the S2 group needs to understand the type of information other S2 group members need to know to be able to effectively filter the deluge of information coming across multiple telecommunications networks for the group.

Similarly, group members often must have a shared working understanding of the situation with other members of the C2 team and with other participants, e.g. participants in nearby C2 teams. We refer to this as intergroup situational awareness. As an interview participant explained:

> I think it's critical that these people – the S3, FSO, S1, S4, SigO — all see a common picture of the battlefield...that they understand the temporal and spatial relationships about the objects on the battlefield and they understand how to enhance their effectiveness whether through positioning, through timing, through risk taking, through massing — a whole bunch of things like that. And I think the common understanding of the relative combat power of forces is pretty darn important when you get down to this level.

Similarly the C2 team and officers on the battlefield must share an awareness of the battle situation. During the observed battle training exercise, officers 'on the battlefield' dispatched troops without informing their commanding C2 team. As a result, the S3 did not order artillery support (as had been planned) and causalities were incurred.

No one individual can develop and maintain a situational awareness that covers all domains, groups and teams due to the complexity of the work situation. Thus, an interwoven pattern of individual, intragroup and intergroup situational awareness appears necessary (see Fig. 2). In such a pattern, there are shared working understandings of the situation among individuals, groups and teams.

5.2. Dense social networks

To create and maintain an interwoven situational awareness, information flow among C2 team members (and others) is critical. An important question is what information needs to be communicated and what social network structure best facilitates information flow?

Three categories of information appear to be important in C2. These are: information about the dynamic work goal and situation, the work process and specialized domain knowledge. *Information about the dynamic work goal and situation* includes the 'environmental information' mentioned in the definition of situational awareness. This typically is information about the mission, enemy, terrain/weather, troops and time available (METT-T) (US Army Command and General Staff College, 1995). It may also include knowledge about obstacles, cover and concealment, observations, key terrain and avenues of approaches as well as information about

logistics and the political environment. This diverse information must be explored and integrated to create and execute a comprehensive battle plan. The information may not necessarily be complete or 100% accurate, however C2 team members must use whatever information is available. They must evaluate its validity using error checking and feedback techniques and continue performing their tasks in the face of this uncertainty.

Information about the work process includes: information about work practices, e.g. tasks, formal task procedures (how tasks can be done) and informal task procedures (how tasks are really done in particular situations); changes in the situation that require you to shift your focus of attention and change tasks; information other C2 team members need or can provide; effective communication methods; and information about leadership, support and encouragement. This type of information includes a variety of explicit and tacit knowledge pertaining to the C2 process and appears to be important. As one interview participant explained:

> The most important thing that allows you to command... is the ability to express clearly, to communicate clearly, your intent and what your expected outcomes are and allowing your people to produce that outcome... providing enough latitude or flexibility in their execution so they have a reasonable chance to succeed.

Information from specialized domains, or functional areas, also appears to be required to perform C2. For example, information about battle tactics, decision analysis algorithms or methods, biological chemicals, enemy profiles/characteristics, telecommunications networks, civilian government, etc. may be utilized, or applied, in any given particular battle context to the processes of creating and evaluating activities on the battlefield (US Army Command and General Staff College, 1995). The amount of detailed information in each domain and the number of domains will undoubtedly increase as the diversity and complexity of the battlefield increases to include a wider variety of peacekeeping situations.

Team members need some information from all three categories to be effective. Everyone needs information about the battlefield, the C2 process and specialized domain knowledge. However, today the team is primarily organized and trained along functional lines in accordance with domain specialties. A challenge is to share appropriate information effectively across these boundaries.

An effective information flow strategy for C2 appears to be an n-way communication network and information flow among groups emerges (see Fig. 3). That is, each group interacts with all others. This often creates a synergistic and effective exchange and integration of information. Study participants described instances when this occurred:

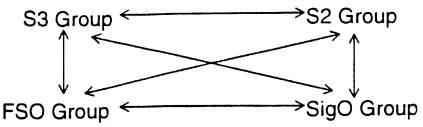

Fig. 3. N-way information flow among C2 groups.

> We all worked together. We were the best team. Everyone cooperated and understood their jobs. The S3 was open-minded and willing to accept advice and information from outside his shop. The S2 was respected and the S4 and S1 were strong people. Everybody realized there were limits we were working under and that we could also achieve the mission within these limits if we could modify the plans.

> Well, [we had] a good flow of information.... Good information in a timely manner... It got to you [in a way that] it was effective. It was real clear. You had time to process it out to your guys and your guys had time to ask questions. They understood it.

Furthermore, the dense social network needs to include connections to other organizations. As mentioned previously, information needs to be shared with nearby units, higher organizational groups, technical specialists, etc. This appears to require the ability to bridge, or span, differences in language, organizational priorities and work practices. As a signal officer explained:

> I translated information between the S3 and Signal Corps [a separate organizational unit.] They speak different languages. I also knew what information not to pass. I didn't send everything. Signal Corps didn't need to know what the S3 was planning (sometimes it's nice, but it's not necessary).

Maintaining the dense social network is difficult when supporting continuous operations over several days or weeks. As one study participant explained, "The enemy doesn't stop for chow at 5.00 p.m.". Because task performance degrades without sufficient sleep, C2 team members need to work in shifts to enable everyone to sleep on a daily basis. Shift turnovers are difficult in information-intensive and dynamic work settings such as C2. The team, which has been working intensely together over the past 12 h, has had the opportunity to develop an interwoven situational awareness and understanding of the work and information flow. Personnel coming on board usually have not had this opportunity; they do not share a common situational awareness of the battle or understanding of the work situation because they have not had the opportunity to develop it together as a team.

To manage these difficulties, a variety of turnover practices have emerged. As reported by study participants, the most effective practice is one we named the 'interspersed' strategy[6]. In this strategy, shift times are different for each group. For example, the S3 group might shift at 1500 h, the S2 at 1800 h, the FSO at 2400 h, etc. The reported advantages to this approach included: no marked decrease in quality of work; soldiers in the field were less likely to notice personnel changes because interpersonal communication did not change all at once; and there was never a sudden lack of, or no, communication or information flow. The problems reported with this approach were logistical and cultural in nature. Getting people fed and awake at the right times is difficult, although not impossible, to work through. It may also be difficult to get

[6] Other strategies described include a 'change by organizational level' strategy where every team member at a certain level would leave/begin at the same time and an 'overlapping' strategy where team members spent 2 h of their 14-h shifts working side-by-side to update the oncoming shift.

people to accept this strategy. In many organizations, people work hard to be on the first team because it is considered a reward for good work. This is altered under the interspersed strategy and organizations are challenged to find other reward mechanisms.

In summary, dense social networks appear to facilitate establishment of an interwoven situational awareness. This is accomplished through the communication of multiple types of information and maintaining a continuous flow of information among team members.

5.3. Contested collaboration

Interview and observation data suggest that creating and maintaining effective human information behavior may be difficult to achieve. As participants explained:

> Sometimes, the S3 devises a grandiose plan autonomously and then expects people to accomplish it. He doesn't realize that he doesn't have the necessary resources to achieve the plan... the S2 is left out because he was a lower officer. The S1 and S4 are left out because he expects them to execute whatever plan he develops. Sometimes resources just aren't there however.

> We argue constantly over definition of terms. What does 'destroy' mean? To artillery, it may mean 30% causalities; to someone else, it means everything dead. What does 'suppress' mean? What do you mean 'interdict'? We are constantly worried about how I define 'how do I achieve the commander's intent?' When the commander tells me what his intent is and my perception of what his intent is may be different from the guy sitting right next to me. I mean, our minds work like that. I can hear something that you don't hear.

These data support the concept of "contested collaboration" (Sonnenwald, 1995). This concept suggest that team members' unique past experiences, specialized work language and terminology, differences in perceptions of quality and success, different organizational priorities and technical constraints may cause team members to challenge, or contest, one another's contributions. This may seriously degrade team performance. In one C2 situation, a participant recalled:

> We had no unity of effort. There were cross-purposes and misdirection, no coordination and it was a nightmare. It was crazy. It was insane.

> Success is when you can fight the alligators at the other end of the pool and not worry about C2.... Can't think of a single instance.

In these situations team members may appear to maintain an outward stance of cooperation but strive to advance their own particular interests or information claims. For example, in the observed battlefield simulation exercise, a group did not correct their early erroneous report of a nearby enemy sighting. When discussing this amongst themselves, they rationalized that correcting their report would reduce their priority for receiving fire support. They did not appear to have an interwoven situational awareness or understanding that their priority status for fire support would negatively impact others who urgently needed fire support. Contested

collaboration may not only lead to an unnecessary waste of staff resources but lives may also be threatened as a result.

6. Discussion

This study highlights the phenomenon of interwoven situational awareness, which we define as interwoven patterns of individual, intragroup and intergroup situational awareness. The types of information needed to develop and maintain interwoven situational awareness includes information about the dynamic work situation, the work process and specialized domain knowledge. A dense social network with n-way communication of this information among team members and links to outside groups appears to support the development and maintenance of an interwoven situational awareness. Another important issue with respect to human information behavior in complex group work contexts is the necessity of information exchange during continuous and sustained operations. The 'interspersed' approach to shift change-overs appears to be the most effective strategy. Contested collaboration appears to occur because team members have different specialized language and terminology, different organizational and individual goals and priorities, differences in perceptions of quality and success and different past experiences and work practices. These differences increase a member's value to the team effort while at the same time, making it more difficult to collaborate. In the worst case scenario, team members maintain an outward stance of cooperation but strive to advance their own interests and knowledge claims.

We propose that this understanding these characteristics of human information behavior in the C2 context can help inform current and future practice. For example, current C2 training primarily consists of domain-related training. Separate classes are held for signal officers, fire support officers, etc. Even when students participated in C2 simulation exercises in these classes, the students assume all roles, even though outside their area of expertise. It is primarily only in large-scale field simulations where individuals with different domain specialties have the opportunity to work with each other. This study suggests that additional training that addresses and provides opportunities for intergroup collaboration has merit.

Emerging military doctrine (EER Systems, 1996a, 1996b, 1996c, 1996d) proposes that at every point in time there should be three C2 teams in action — one creating its plan, one adjusting its plan and one implementing its plan. Each activity would, ideally, take 4 h and a single team would sequentially create a plan, adjust its plan and execute its plan. This future scenario will place new information behavior requirements on team members. We propose that the complexity of establishing interwoven situational awareness will increase because a shared understanding among C2 teams that are simultaneously creating, preparing and executing battle plans will be required. In many complex, dynamic work situations, plans change as they are implemented in response to unanticipated events or in response to new information. This flexibility in plan implementation can lead to success. However, it implies separate, geographically distributed teams will need to continually maintain a shared understanding of the battlefield across distances. Furthermore, the interspersed shift turnover strategy that helps maintain an interwoven situational awareness will not be possible in this scenario. This is a complex problem and further research is needed to identify what information is required and

how that information can be best communicated to create and maintain an interwoven situational awareness among C2 teams to support the proposed changes.

Furthermore, emerging military doctrine posits that information systems will play an increasingly vital role in C2; all team members will need to interact with computer-based communications and information systems to complete their tasks. Thus, the critical nature of these systems and the human–computer and human–human computer interfaces will increase. That is, when two or more team members collaborate, they may need to consult, or interact, with one or more information systems during their collaboration. For example, an S2 may wish to analyze an enemy's most likely course of action with the S3 and use an electronic map to help illustrate his analysis. Both the S2 and S3 may wish to temporarily highlight and move symbols on the map during the discussion. From this and similar examples, the question, how can systems be designed to support human–human–computer interaction, emerges.

To further support information behavior and the role information systems may assume, the SigO job could be expanded to include skills and knowledge in technical and social aspects of information systems, including human–computer interaction. With such knowledge, the SigO could customize human–computer interfaces and applications for team members, as well as troubleshoot problems they may encounter. The skills required in this position are similar to those skills provided in many graduate Information Science programs at universities today that give students a broad background in technical and social aspects of information and communication systems.

These results may also be applicable to other dynamic work contexts. For example, international emergency response teams may face challenges similar to those in C2. Challenges include: geographically distributed teams consisting of groups of experts who must collaborate; dynamic situations with rapidly changing information; and stringent constraints concerning available resources to solve problems. Furthermore, teams in some corporate work situations may face similar challenges. For example, challenges design and development teams may face include: a need for shorter design and development cycles to bring products to market more quickly in response to world-wide competition; global collaborations that include international and multi-disciplinary expertise to create new, innovative products; and a reduced work force who must deliver new products and services in a rapidly changing technical and political world. Design team members must seek, synthesize and disseminate information about the design context, information about the design process and technical information from a variety of disciplines. such as software engineering, hardware engineering, telecommunications, marketing and human factors. Furthermore, the phenomenon of contested collaboration has been observed in design situations (Sonnenwald, 1995). The similarities between the types of challenges faced and types of information required imply that the results of this study may be generalizable to other dynamic work contexts. Further research is necessary to validate this hypothesis.

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