Information Sharing Patterns in Action Teams: Understanding Cognitive Interactions in Dynamic Environments

Track 10: Other C2 and Cyber Related Research and Analysis

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Abstract

The use of teams to help achieve organizational goals is a ubiquitous phenomenon in today’s workplace. Teams comprise interdependent members who coordinate their work through a process of interactions to share information with each other. These interactions are fundamental to building and updating situation awareness and cognition of the team’s task progress and its dynamic environment. Timely, accurate, properly shared information is critical in order to accomplish team tasks, especially in action teams who perform complex or time sensitive tasks and operate interdependently, such as aircrews, naval ship crews, special operations forces, and coast guard boarding teams.

However, a clear understanding of the interaction processes by which action team members share information remains elusive. Information sharing interactions are the foundation of cognition and contribute to team success or failure, which can be fatal in some situations. Organizations like the military depend upon action teams to accomplish tasks with high reliability. However, incidents like the shoot down of Blackhawks in Iraq (Snook, 2002), the Vincennes shoot down of the Iranian jetliner, or recent naval ship collisions suggest the need to explore the possible ramifications of a relationship between action team information sharing patterns and performance failures. Despite a robust body of research, existing analytical approaches do not fully address the nature of momentary member interactions in the context of team cognition.
“What do I know? Who else needs to know? Have I told them yet?”

Seen on the wall in a military tactical command post

Introduction

The use of teams to help achieve organizational goals is a ubiquitous phenomenon in today’s workplace. Teams comprise interdependent members who coordinate their work through a process of interactions to share information with each other (Salas & Fiore, 2004, p. 4). These interactions are fundamental to building and updating situation awareness and cognition of the team’s task progress and its dynamic environment. Timely, accurate, properly shared information is critical in order to accomplish team tasks, especially in action teams who perform complex or time sensitive tasks and operate interdependently, such as aircrews, naval ship crews, special operations forces, and Coast Guard boarding teams. However, a clear understanding of the interaction processes by which action team members share information remains elusive.

Organizations create teams to accomplish particular tasks or sets of tasks. They designate a collective purpose toward which all team members work. Various definitions of teams exist depending upon the perspectives of different disciplines. Broadly defined, teams are "social work units of two or more people that; 1) have meaningful task interdependencies and dynamic social interaction; 2) share valued goals; 3) exist for a delimited lifespan; 4) have expertise distributed among members; and 5) possess clearly assigned roles and responsibilities” (Salas et al., 2007, p. B78). More specifically, teams of interest in this study are action teams whose members operate in intense task environments (Edmundson, 2003). Action teams “respond to unexpected events in a coordinated way, often requiring a free and open transfer of information to enable real-time, reciprocal coordination of action” (Sundstrom et al., 1990, p. 121). It is incumbent upon each member to rapidly and judiciously determine what information to share, with whom, and to be prepared to act on information received from others.

Action teams are increasingly important, especially in complex operations where failures can be fatal. Many contemporary teams engage in intellectually demanding tasks that exceed the ability of any individual member to access all needed information, time, and cognitive skills (Salas et al., 2004). The need for a range of individual skills, knowledge and abilities in order to perform tasks (Cannon-Bowers & Salas, 1997), makes it common for many action teams to consist of cognitively heterogeneous members (Cooke, Gorman, Myers & Duran, 2013). But, with cognitive heterogeneity and high interdependence come different team member communication styles and information sharing patterns. The differences in how members interact in various dynamic information environments may impact the team’s cognition. Individual and team interaction patterns may vary between stable or routine, versus uncertain, rapidly evolving situations. These observable differences may hold key implications for understanding how teams share information as they conduct their taskwork and teamwork (Glickman, 1987), maintain their cognitive processes, and perform together.
During task work and teamwork (Glickman, 1987), action teams are seen to interact according to both their members’ a priori, organizational roles and also in momentary, ad hoc roles\(^1\) (Cooke et al., 2013). Formal member roles are generally temporally persistent (Borgatti, Everett & Johnson, 2013; Wasserman & Faust, 1990) and are common across team types (e.g. supervisor, subordinate, co-worker). Members also appear to interact through momentary roles, consisting of directing or vectoring information to other team members. In social network terms, the team members create momentary ties or relationships (Wasserman et al., 1990) consisting of as little as one word or a sentence, during which they direct particular information to others.

In action teams whose task and information environment can change in a matter of seconds, information sharing interactions between members are the very foundation of the team’s cognition (Cooke, 2015; Cooke et al., 2013). Research suggests that team cognition affects team task accomplishment and performance (Cooke, Gorman & Rowe, 2009; Wildman, Salas, & Scott, 2014), and researchers have observed “improvements in team performance that are accompanied by improvements in team interactions...” (Cooke et al., 2013, p. 262). What appears to be understudied is how to characterize the information sharing behaviors, operationally define them (Reynolds, 2007) and analyze their patterns to understand how they update a team’s cognition. Social network analysis (Borgatti et al., 2013; Scott, 2013; Wasserman and Faust, 1994) and relational event modeling (Butts, 2008; Pilny, Schecter, Poole, & Contractor, 2016) show promise to help analyze changes in member information sharing patterns as they occur in action teams.

Problem

Information sharing interactions are the foundation of cognition (Cooke et al, 2013) and contribute to team success or failure, which can be fatal in some situations, particularly in action teams. Organizations like the military depend upon action teams to accomplish tasks with high reliability. However, incidents like the shoot down of Blackhawks in Iraq (Snook, 2002), the Vincennes shoot down of the Iranian jetliner, or recent naval ship collisions suggest the need to explore the possible ramifications of a relationship between action team information sharing patterns and performance failures. Despite a robust body of research, existing analytical approaches do not fully address the nature of momentary member interactions in the context of team cognition.

This study will involve observing action teams in situ, as they interact while performing their tasks. Theoretical contributions may include 1) understanding and classifying team member interaction behaviors (Doty & Glick, 1994); 2) generating a typology of the behaviors; 3) generating a model of the process by which members interact; and 4) exploring how interaction patterns vary over time in dynamic information environments, with a view to understand their relationship to team cognition (see Miles & Huberman, 1984). From a practical standpoint, the goal is to contribute a new approach for leaders and trainers to evaluate and reinforce constructive information sharing behaviors. With such a capability, improved analysis tools and methods might eventually support assessments in

\(^1\) Here, the term “role” is used in the context of social network theory, not as in formal role theory.
real time (Schraagen & Post, 2014), during team training or actual operations. With this perspective in mind, the primary research questions ask: What are the patterns in which action teams share information? How do these patterns change over time in dynamic environments?

Conceptual Framework

This research applies a transdisciplinary approach, leveraging relevant work in the domains of team cognition theory, social network theory, decision theory, and interaction analysis. Theory on team cognition provides a foundation on individual team member information sharing interactions occur. Social network theory is approached with a poststructuralist perspective, emphasizing individual agency of team members in addition to the constraining aspects of organizational network structures, and supporting the perspective that “networks represent the dynamic interplay of micro-processes that operate at the level of cognition and interpersonal interaction” (Kilduff & Tsai, 2003, p. 113). It is argued here that task interdependence and member heterogeneity support different representations of reality to mutually co-exist (Kilduff et al., 2003, p. 117) within a team. This research incorporates decision theory by framing team member interactions as occurring in multiple recursive decision cycles, one of which involves the process of deciding to interact to share information with others.

The conceptual model below (figure 1) positions team cognition as a foundation on which recursive multi-level (individual and team) decision cycles occur to share information within the context of a team’s task, and inner and outer environments. The components of the model are explained, followed by a discussion of the decision processes at the individual and team levels.

Figure 1. Ecological model of team cognitive processes
Environmental context

Insofar as action teams are artefacts, they operate in dual contexts; they perform their tasks within an inner environment that comprises endogenous factors, and an outer environment of exogenous factors (Simon, 1996). Both of these environments shape how team members perceive their task situation and progress, and the way in which individual members and the team as a whole cooperate. Taskwork in interdependent, cognitively heterogeneous action teams can be expected to require unique skills, which increases the importance of effective teamwork.

Various endogenous factors influence the nature of team interactions and, therefore, team level cognition (Figure 2). At the individual team member level, key factors include, inter alia, the member’s 1) duty position, 2) proficiency in individual taskwork and teamwork skills, 3) accurate, current transactive memory, and 4) individual mental models of specific schemata, techniques and procedures. At the team level, key factors similarly include the team’s 1) organizational structure, 2) level of training and collective proficiency at taskwork and teamwork, 3) accurate team-level transactive memory system, and 4) accurate, shared team mental models. These factors moderate when, or under which conditions members interact to share information, updating the team’s cognition in support of task accomplishment. While this is not intended to serve as an exhaustive list of potential endogenous factors that could impact individual and team performance, it focuses on salient ones that may pertain in the context of information sharing processes. Each is discussed below.

<table>
<thead>
<tr>
<th>Endogenous Factors</th>
<th>Purpose</th>
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<td>Individual / Team</td>
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<td>• Team Interaction</td>
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Figure 2. Factors influencing information sharing processes
At the individual team member level, key endogenous aspects of one’s assigned duty position in the team include roles and responsibilities, one’s tenure or longevity on the team, unique skillsets and perspectives that bring a degree of cognitive heterogeneity, and the extent to which members are interdependent. A team member’s proficiency at assigned individual taskwork (including skills, knowledge and abilities) and cooperative teamwork (Glickman, 1987) derives in great part from effective individual and collective training. To the extent that training is realistic and challenging, it reinforces information sharing procedures that build and update individual and team level cognition. This includes how to package each message (discussed below). Directly underpinning individual and team task proficiency are the accuracy and currency of each member’s transactive memory (Wegner, 1985) and how well one comprehends and applies mental models of his individual role and responsibilities as well as relevant mental models of his team-level tasks (DeChurch & Mesmer-Magnus, 2010).

At the team level, the endogenous environment includes the team’s organizational structure, its level of collective training and task proficiency, its transactive memory system, and its accurate, shared team-level mental models. The team’s structure, whether hierarchical or flat, guides its members’ conduct of team-level responsibilities, its lifespan and continuity, the heterogeneity of its diverse skillsets, and the degree to which members are interdependent. Team level taskwork and teamwork proficiency (Glickman, 1987) depend largely upon effective collective training, and are, in part, a function of the team’s tenure together. The nature of the team’s tasks and its dynamic information environment will affect the currency of its transactive memory, necessitating continuous updating of who knows what and who knows who knows what in the moment (Wegner, 1985), as its situation evolves. Team mental models (DeChurch et al., 2010) consist of relatively persistent, shared operating techniques and procedures. Principal types of team mental models address the operation of equipment, task types, team procedural models and team interaction models (Cannon-Bowers et al., 1993). Of particular interest among these for this research are team interaction models, which address communication rules such as proper information path routing protocols internally between team members and externally with other teams.

Following Rosen, a team’s outer information environment, or its principal exogenous factors, include 1) information uncertainty, 2) information quantity, 3) the dynamic nature of the information, and 4) tempo and time available (Rosen et al., 2008), each of which can moderate the team’s information sharing interactions, and thereby, its cognition. In action teams, more than other types of teams, these factors become critical considerations. As an action team conducts its tasks, it can expect to have to deal with less than perfect knowledge of its evolving situation, and be constantly in search of additional key decision-making information to reduce uncertainty. Even if a team obtains robust information, it must have the capability to determine whether that information is accurate, current, or perishable at the time of receipt. Perishable information risks degrading a team’s cognition if subsequent events render it outdated, causing the team to reassess its situation. All of these exogenous considerations are subject to time pressures, which may affect team members’ decisions about sharing possibly questionable information.
Deciding to share

The Boyd cycle, commonly known as the OODA loop was chosen as a component of the conceptual model to characterize the individual and group information sharing decision processes. The model leverages a simplified view of the OODA loop as a means to portray the recursive decision processes by which individuals and teams interact to share information. It is also consistent with a fundamental premise that member interactions are the foundation of team cognition (Cooke et al., 2013). Action team members may conduct multiple, simultaneous decision loops in the course of their taskwork and team work – the application of Boyd here is applied with specific respect to member decision steps regarding updating team cognition through information sharing in dynamic information environments.

The OODA loop originated in a series of briefings by Colonel John Boyd, entitled A Discourse on Winning and Losing (Boyd, 1996/2018). It has gained wide acceptance as the equivalent of a decision cycle, albeit often with incomplete understanding (Osinga, 2007). Frequent misperceptions about the nature of the OODA loop include a broad lack of appreciation for the richness of its logic and philosophical foundations, an overriding focus on speed and its applicability at both individual and organizational levels. Detailed discussion of that is beyond the scope of this work. It is important here to acknowledge the usefulness of the loop insofar as it illustrates the operationalization of the steps that constitute information sharing interactions.

While the loop is commonly associated with decision making speed relative to an opponent, its importance here is its focus on team learning and adaptation (Osinga, 2007). The simplified loop as it applies in Figures 1 and 3 reflects a perspective of the decision processes that both individual action team members and the team as a whole undertake to share information. It suggests that members and teams conduct multiple, recursive information sharing cycles or loops specifically with respect to information sharing as they learn and adapt to new situations. Importantly, the loop is not necessarily a rigid cycle. The model reflects that feedback can occur during each step. Feedback facilitates constant adaptation, and the dashed arrows portrayed in the model reflect a team’s “adaptation in a dynamic, non-linear environment” (Osinga, 2007, p. 256).

Recalling that the foundation of team cognition is in the very interactions by team members (Cooke et al., 2013), the model decomposes each interaction, at both individual and team level, into a sequence of steps that reflect how a team member decides whether to share information with others. It is an attempt to describe what is otherwise a “black box,” without applying a psychological perspective; the focus is on what occurs “between the heads” of the members, rather than “in the head” (Cooke et al, 2013). The steps below attempt to operationalize the otherwise unobservable, latent processes by which teams share information.

The four steps in the OODA loop recall the original context of a pilot in a fighter jet, where situations evolve rapidly, on a scale of seconds to minutes. Similarly, an action team member must continuously observe the environment for information with a purpose based
upon his and his team’s task situation. Upon observing an event, the team member orients and determines its relevance and urgency to the team and task. The team member then undertakes to address several message considerations regarding the new information, while deciding whether and how to share the information with others. Depending upon the decision, which may occur on the order of seconds or less, the team member interacts by enacting a momentary role, directing or vectoring the information to others as needed.

Figure 3. Information sharing considerations and momentary roles

Observing is a continuous, deliberate action step in that a team member remains alert for any data or information that might be germane to his or the team’s situation. It represents a constant contact with the dynamic information environment, and correlates to Endsley’s (1988) construct of “Phase I” continuous observations yielding an evolving, ephemeral situation awareness. Situation awareness is the “…perception of the elements in the environment within a volume of time and space” (Endsley, 1988, p. 97). I suggest that the observe step corresponds well to Phase I in Endsley’s situation awareness model.

Following each discreet observation of data or information, a member (or the team) processes it in order to gain situation understanding. Orient is the most important part of the OODA loop, around which the rest of the loop revolves, “developing, maintaining and reshaping one’s orientation” (Osinga, 2007, p. 236). Orientation brings situation understanding, which is the comprehension of one’s environment and its implications for future actions, and corresponds well to Endsley’s (1988) situational awareness model Phases II and III. However, Boyd’s view of orient emphasizes the nature of analysis and synthesis of new information, based upon factors like a team member’s prior experience and cultural traditions to a much greater degree than does Endsley. It is in part for that reason that the OODA loop seems to fit within the conceptual model. Accurate and timely
achievement of situation understanding through orienting is critical in a cognitively heterogeneous, interdependent action team, where each team member must know and apply any of various individual or team level mental models that may pertain to the existing situation.

Orient shapes how one monitors for and observes events in the action team’s inner and outer information environments. It relies on a member possessing a sufficient transactive memory of other team members’ knowledge to be able to decide whether and to whom to pass the data or information. “... it is essential to have a repertoire of orientation patterns and the ability to select the correct one according to the situation at hand…” (Osinga, 2007, p. 236). Boyd emphasized the importance of being able to validate schemata dynamically and to modify existing or devise new ones (Osinga, 2007). Adapting and updating an individual’s or team’s transactive memory and mental models are important aspects of a team’s inner environment, as outlined above. For example, upon orienting on information that is judged to require urgent passage directly to a higher echelon, a team member may decide to adapt an accepted team interaction mental model regarding the standard communication protocols in that instance, instead of directing the information to his immediate supervisor.

It is appropriate at this point to define the relevant information sharing considerations that an action team member must consider (whether done consciously or subconsciously is outside this discussion). It is acknowledged that these considerations are generally latent; they are not observable or measurable in real time. Nonetheless, each member must decide what to do with information once obtained and oriented upon. A comprehensive set of considerations that a team member addresses while deciding to interact is proposed below (figure 4). An overarching consideration that a member makes is whether or not the new information actually needs to be shared with anyone. Various endogenous and exogenous factors and the task situation moderate the decision whether and with whom to share. If in the information there is, for instance, nothing significant or new, then the member may simply opt not to interact to share it. This is a function of correctly orienting and gaining new situation understanding of the task and dynamic information environment.

Should the information be determined appropriate to share, one must consider specifically what to share. If in possession of raw data, should/can it be put in context and shared as information that can be actioned by others? Should the member analyze it and share it as knowledge? In either event, the member must determine how to cull and package the message for effective, efficient sharing. To whom should the message be sent – to one other, or to multiple people? Do the team mental models and team training address designated protocols, pathways or routes along which certain information should be sent, based upon the situation? It might be that procedure calls for a member to share information through a hierarchical structure as opposed to broadcasting it to all others at once. Alternatively, do routing paths depend upon the member’s assessment of the urgency or reliability of the information?

Similarly, a team member must be able to determine where to share; whether the information should be shared outside the team, or only within it. Such a decision depends
upon both correct orientation and mental models that indicate the potential need for the information by other teams. The potential impact of the information, or the consideration of why it should be shared will relate to its relevance. When should it be shared - immediately, or is it routine information that could wait behind other, more pressing interactions? Or if delayed, might it be overcome by subsequent events and then actually confuse the team?

Table of Information Considerations

<table>
<thead>
<tr>
<th>1. What should I transmit?</th>
<th>• What to others need to know?</th>
<th>• Should I send it as raw Data? Or as Information? Or as Knowledge?</th>
<th>• How much do others need to know (thorough vs parsimonious)?</th>
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<tbody>
<tr>
<td>2. Where should I transmit it?</td>
<td>• Who else needs to know?</td>
<td>• Should I pass it internal to the team only? To other higher/peer/lower teams?</td>
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<tr>
<td>3. To/through whom should I transmit it?</td>
<td>• Do I adhere to standing mental model protocols and pass through others?</td>
<td>• Or should I bypass path/routing and send directly to a specific member?</td>
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<tr>
<td>4. Why should I transmit it?</td>
<td>• What is its relevance to a team mate’s or the team’s current task?</td>
<td>• Is it new?</td>
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<td>5. When should I transmit it?</td>
<td>• How urgent is it – is it important to our current task?</td>
<td>• Is it current? Ephemeral?</td>
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</tr>
<tr>
<td>6. How should I transmit it?</td>
<td>• Should I send it verbally? Non-verbally?</td>
<td>• Should I send it via a communication technology (synchronous or asynchronous)?</td>
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<tr>
<td>7. Has it been transmitted yet?</td>
<td>• Have I or someone else already sent this information?</td>
<td>• Has any perceived target recipient acknowledged receiving it yet?</td>
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</tbody>
</table>

Figure 4. Information sharing considerations

The medium, or how the information is shared also matters; a verbal or non-verbal message might be more appropriate than preparing a written note. Should the medium be synchronous or asynchronous, such as ensuring immediate receipt as opposed to entering the information into a log or email format? Finally, a team member must also consider whether the information has already been shared with anyone, and whether it should be resent. Did the intended recipient(s) receive the message? Did anyone acknowledge receipt? Is such acknowledgement required? It is expected that whether formally or informally, all of these considerations are addressed when a team member conducts the decide step in the interaction decision cycle. It is unlikely that these considerations are addressed in any explicit, sequential manner. While the factors might be specified by a team mental model, a team member may consider them tacitly and selectively.

Team cognition as context
Cognition broadly comprises “the many different processes by which creatures understand and make sense of the world.” (Frith, 2008, p. 2033). Team cognition is “essentially the joint activity that teams engage in when they coordinate, communicate, and make decisions” (Cooke et al., 2012, p. 189). It “...emerges from the interplay of the individual cognition of each team member and team process behaviors” (Cooke et al., 2004, p. 4). Team processes are defined as “...the means by which team members’ cognition, motivation, affect, and behavior enable (or inhibit) members to combine their resources to meet task demands” Cooke & Hilton, 2015). This last definition corresponds closely with Bales’ (1950, p. 60) description concerning how members in an interaction system relate to their exogenous environment, discussed below.

Researchers have not yet resolved the theoretical and practical differences between the traditional or “shared” cognition and the interactive team cognition approaches to team cognition (Goodwin et al., 2018). There is still a need for more research as there continue to be calls from the field (Goodwin, 2018; Salas, Cooke, & Rosen, 2008; Wildman et al., 2012; Wildman et al., 2014) for more exploration to reconcile the two constructs. While much research has examined team cognition from the traditional knowledge structure-based or shared cognition construct where cognition is viewed as a product of individual member cognitions, there remains a need for more work on team cognitive interactions (Salas et al., 2007). What has been understudied is conceptualizing the manner in which team members regulate or vector their information sharing during team tasks (Bourbousson & Bourbousson, 2016).

The traditional and predominant view is a knowledge-based construct, shared cognition, which focuses on the static knowledge structures of individual team members. It is based on the aggregation of individual mental models to build team cognition, where team knowledge equates to the sum or overlap of the individual parts. This places the individual team member as the basic unit of analysis (Cooke et al., 2009). Shared cognition comprises stable, emergent team-level knowledge structures that exist within members’ heads and combine to represent the team. This view may be better suited to teams that normally work in stable, routine environments.

Interactive team cognition theory suggests that teams are “cognitive (dynamical) systems” in which cognition is an emergent property arising from the very interactions between team members (Cooke et al., 2013, p. 256), and stands as the main alternative view in current team cognition literature (Salas and Fiore, 2013). Members’ interactions feed a moment-by-moment evolving cognition (Cooke, 2015; Cooke, Gorman, Myers & Duran, 2013). The theory seems most relevant to action teams performing complex tasks in dynamic information environments.

Cooke proposed three fundamental premises that “(1) team cognition is an activity, not a property or a product; (2) team cognition should be measured and studied at the team level; and (3) team cognition is inextricably tied to context” (Cooke et al., 2013, p. 256). These hold that team cognition is a process that constitutes a “dynamic flow of team member interaction” (Cooke et al., 2013, p. 266). Team process behaviors comprise

Accordingly, interactive team cognition is considered an activity more than a part or result of a sequential input-process-output cycle, and it is not “an intervening variable between individual-level (team member) cognitive inputs and team-level performance outputs” (Cooke et al., 2013, p. 256). Team member interactions draw upon each member’s individual cognition in the context of evolving information environments. For example, consider the ever-changing situation faced by a local first responder (action) team at a gang shooting. Their team communications involve a continuous flow of interactions to send or request information to or from each other. Information patterns and flows emerge from team interactions, reflecting the constant updating of the team’s cognition in the context of its task status and dynamic information environment. The team learns and adapts how it observes, orients, and decides through its cognitive interactions.

An essential point is that team cognitive interactions occur between, rather than within the heads of members. Team members themselves do not contain the property of team cognition (Cooke et al., 2013). Their interactions are observable phenomena (Cooke et al., 2013). This suggests the need for an operational definition of individual interactions to observe them empirically. In order to do so, Cooke suggested observing dynamic communication and coordination processes as seen in information flows among teammates. While team cognition itself is unobservable, it is indirectly discernible insofar as interactions manifest themselves as speech acts, written acts, or nonverbal acts (Achille et al., 1995; Emmert, 1989; Searle, 1969) between members.

Operationalizing interactions – a unique network approach

The emergent property of team-level cognition depends upon each member’s ability to contribute individually in formal, a priori, hierarchical roles as well as in momentary, ad hoc information sharing roles at any point during a team task. Cooke contended (2013, p. 267) that:

Individually, they only fill out different a priori roles in a team task (e.g., to fill out a specified division of labor). When they interact, however, team members may be compelled to think in ways not defined in their a priori roles to meet team-level goals. In this way, to meet team-level goals, teams may exhibit cognitive properties that individual team members do not. Again, I hypothesize that this new team cognition property emerges only from team member interaction and is not encoded a priori in team member roles (e.g., team member selection).

How, then, can team interactions be characterized and operationalized in a network context? What are their patterns of directing or vectoring information to each other? How do they vary in dynamic information environments? For example, at any moment during a task, any team member might observe an event or gain a piece of information, orient on it to assess its significance to the team or others, and decide to whom, what, when, how much, and how to communicate it, including whether to verify that the intended
recipient(s) of the information actually receive and assimilate it. He or she must also decide whether to share the information as is or to reframe it and share it in an appropriate way, including how to avoid overwhelming other team members (Cooke et al., 2013). Ultimately, the team member acts, directing the information to others.

In terms of the temporal nature of momentary action team interactions, it is helpful to view them within a larger perspective. Cooke et al. (2013, p. 268) recalled Newell’s (1990) time scales of human action, suggesting that if teams must be able to act in novel situations, they must have the capacity to adapt their interaction patterns. Team interaction patterns unfold over time, and interaction processes must scale with team level goals (Cooke, 2013, p. 268). Newell’s timescales comprise four “bands” (1990, p. 122), spanning from microsecond duration neural interactions to long term societal interactions. They include the:

- Social Band (days to months)
- Rational Band (minutes to hours)
- Cognitive Band (milliseconds to seconds)
- Biological Band (microseconds to milliseconds)

During conduct of a task, a team member communicates with other members in an interaction that may comprise as little as a sentence, a word or a non-verbal gesture. Newell’s timescale band of interest here is the “Cognitive Band” in which deliberate acts occur, up to a matter of seconds in duration. The Cognitive Band may most closely represent that time window in which team members (usually verbally) interact. In his seminal work, Mead (1934) presaged a similar temporal perspective in a model of symbolic vs. non-symbolic interaction among humans. Non-symbolic interaction is exemplified by, for example, instantaneously parrying an expected blow from a boxer (Mead, 1934), whereas a symbolic interaction involves slight deliberation, such as might be seen when a team member responds to a radio call requesting information. This multi-second interaction appears to align with Newell’s cognitive timespan, and is an example of an observable phenomenon whose patterns might be derived over time.

Returning now to Cooke’s third premise that team cognitive interactions are inextricably tied to context, Blumer (1969) earlier explained that in Mead’s symbolic interactionism, humans interpret each other’s gestures through ascertaining the meaning of the other’s actions or remarks. Blumer suggested that 1) “people act according to the meanings that things have for them; that 2) such meanings derive from social interactions; and that 3) “meanings are handled in and modified through, an interpretive process used by the person in dealing with the things that he encounters” (1969, p. 2). Blumer was careful to distinguish that “symbolic interactionism sees meanings as social products” (1969, p. 5) that are formed from the actions of people as they interact. Unpacking Blumer’s points, it is possible to map the importance of an action team’s situational context to its cognitive interactions. Team members interact based on what they observe, how they individually orient, decide, and interact. The team’s evolving cognition is inextricably tied to the information in its dynamic environment.
Observing interactions

Common analytical techniques to understand team member interactions include “pattern” analysis (frequency, sequence, flow), and “content” analysis (utterances, semantic content) (Cooke, et al., 2010; Emmert, 1989; Gorman, et al., 2012; Kaid, 1989; Salas et al., 1995; Wildman et al., 2014). Interaction is a speech act or utterance (also known as an “interact”) or a non-verbal communication between people, which may consist of a sentence, a single word or a simple gesture. Interaction patterns have been studied, inter alia, with respect to the frequency of team members’ speech at very short intervals and for co-occurrence of speech events in time (Cooke et al., 2004, p. 96), yielding various interaction taxonomies. For instance, in a combined frequency and pattern analysis of aircrew communications, Bowers et al. (1998) yielded a set of eight utterances based upon sequence and feedback loops (e.g. uncertainty statements, acknowledgements, action statements).

In Bales’ (1950) landmark study, he analyzed small group patterns and classified 12 categories of interaction (e.g. shows tension, shows tension release, gives opinion, asks for opinion). Focusing on interaction patterns, he posited that, “…individual acts are part of an interactive system” (1950, p. 57) wherein members attempt to solve group problems from the traditional cognitive “What is it?” affective “How does it affect us?” and conative “What shall we do about it?” modes of orientation (Bales, 1950, p. 60; Green & Mayo, 1953). Recalling the model in figure 1, these orientations presage in a basic way three of the decision cycle steps in the OODA loop - observe (what is happening), orient (on an event’s significance or impact to the team), and decide (consider what to do about it).

In an analysis of flight deck communications, aircrew statements were content-coded, yielding 13 speech-type categories, such as commands, agreement and embarrassment (Foushee & Manos, 1981). Similarly, Hutchins et al. (2007) process-coded multiple maritime interdiction and air warfare experiment scenarios, generating 19 content categories (e.g. team knowledge development, solution alternatives, critical thinking). Team interaction content has also been studied using techniques such as latent semantic analysis “to determine similarity among utterances” (Cooke et al., 2004, p. 96; Wildman et al., 2014). More broadly, Fiore et al., noted (Salas & Fiore, 2004) that team cognition manifests itself through “the seamless execution of coordinated behaviors” (p. 236). They explored how team member skills, the roles that team members perform, and their communication strategies result in coordinated action (p. 237). Rogers and Farace (1975) proposed an analytical procedure based upon a transactional and process oriented approach.

However, few studies have undertaken to analyze cognitive team interactions from a network oriented approach to the directing or vectoring of information. Nor have many done so in a field environment that presents few or no artificial factors to affect observations, compared to laboratory studies. Cooke (2015, p. 418) called for additional unobtrusive measures of team interaction, including analytical capabilities to capture
interaction dynamics. To address research questions by observing interaction processes unobtrusively in situ as they unfold in real time could contribute to greater understanding (Bakeman & Gottman, 1997), avoiding several threats to internal validity. Researchers have long agreed that human communication is patterned and that interaction patterns are observable; this has been studied robustly since the 1950’s. The challenge is to apply an inquiry approach that can yield sufficiently useful characteristics and patterns with which to evaluate action team interactions (Fisher et al., 1979, p. 3). In addition, few have applied a network theory approach (see Barth, 2015; Bourbousson, 2015) that might facilitate the validation of a new typology.

Network perspective

As just noted, amid a robust body of research into teams in the context of network theory, an approach that has received sparse consideration is that of viewing cognitive team interactions from a network perspective. As a subset of network theory, social network theory addresses the social measures of people’s interactions, and stands to offer insights into team interactions. Social network theory has helped to explain social interactions in diverse contexts, has been called for as a method with which to find innovative measures of team cognition constructs, and has already been applied to team situational awareness and team mental model research (Wildman et al., 2014).

In basic terms, a network is a “set of relationships, a set of objects or nodes, and a mapping or description of the relations between them” (Kadushin, 2012, p. 14). There are various definitions of networks from different perspectives. One useful definition for observing interactions describes communication networks as patterns of contact based upon the flow of messages among interconnected communicators (Hare, 1994; Monge & Contractor, 2003; Rogers, 1986). For the purposes of this study, team members equate to network nodes, and their individual communication interactions are the ties or relationships.
(Borgatti et al., 2013) between them. In the context of communication networks, team members demonstrate observable patterns of ties as they share information.

Several network theory concepts support an examination of interactions among action teams. Of particular interest in this research are emergence, ties or relationships, and network roles. In broad terms, emergence occurs when an entity manifests properties that its parts do not possess; it arises from the interaction of the parts. Just as Cooke (Cooke et al., 2013; Cooke, 2015) suggests that team cognition is said to emerge from the interactions of team members, a pattern of sharing information manifests as an emergent communication network that can be observed through team member interactions. Emergence is a bottom-up phenomenon (Kozlowski & Klein, 2000), that “is emergent when it originates in the cognition, affect, behaviors, or other characteristics of individuals, and is amplified by their interactions, and manifests as a higher level, collective phenomenon” (Kozlowski et al., 2000, p. 35; Katz & Kahn, 1966). Emergence of a tie or a relationship in the context of action team interaction refers to the creation of a “...communication structure that connects different people and groups in the organization irrespective of their formal positions or roles.” (Monge et al., 2003, p. 19).

Emergence is shaped by patterns of momentary, ad hoc interactions as members choose to communicate (Bordetsky & Dolk, 2013) within or outside their team. The patterns of these interactions transcend formal boundaries and work-flows (Kozlowski & Klein, 2000). Emergence arises in these interaction patterns, which in turn result from dynamic role exchanges (Katz et al., 1966). And, since the emergent phenomenon of team cognition “is based upon patterns of interaction, even small changes in individual behavior or dyadic interaction can yield big changes in the nature of emergence” (Kozlowski & Klein, 2000, p. 33). In effect, it brings into question whether and how team members exhibit various interaction patterns during team task accomplishment.

Network roles

It is here suggested that network ties or relationships can be characterized in two general temporal categories. Borgatti et al. (2013, p. 4) characterized relatively persistent “relational states,” under which they described several subcategories, including “relational events”. I contend that these actually may comprise two parallel relational categories, which differ temporally. A “relational state” describes a persistent relationship between nodes (which may or not be permanent), such as a “relational role” (Borgatti, 2013), (e.g. a team leader of; a friend of; a student of). Longer in duration, relational states differ from “relational events,” which are relatively ephemeral phenomena, and consist of brief, ties between nodes (e.g. giving a speech; coordinating while performing a team task; sharing information or knowledge) (Borgatti et al., 2013). Here I depart from Borgatti, and suggest the need to explore and potentially characterize team member interactions from the perspective of an information directing or vectoring function. There currently is no definition for such a phenomenon. If a “relational event” is a momentary tie or relationship between nodes, then one might ask how to characterize the nature of the correspondingly brief, microsocial action that team members perform (e.g. broadcasting or redirecting a specific message between nodes).
Table 1. Typology of Social Network Relations (*adapted from Borgatti et al., 2013)

<table>
<thead>
<tr>
<th>Temporal Context</th>
<th>Persistent</th>
<th>Momentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenomenon</td>
<td>Relational “State”</td>
<td>Relational “Event”</td>
</tr>
<tr>
<td>Role</td>
<td>Relational “Role”</td>
<td>undefined</td>
</tr>
<tr>
<td>Modes</td>
<td>Liaison; Isolate; Gatekeeper; Star</td>
<td>undefined</td>
</tr>
</tbody>
</table>

Network states and roles

Extensive prior work describes various persistent relational roles that network nodes occupy. These include inter alia, hubs, stars, gatekeepers, isolates, liaisons, bridges, boundary spanners (Barabási, 2002; Brass, 2003; Jackson, 2011; Monge & Contractor, 2003; Tushman, 1981). However, these roles describe nodes with respect to their position in a network over a given duration equate in a temporal sense to Newell’s social band of actions. Social network theory literature does not currently characterize the phenomenon of the momentary information sharing interactions by team members (nodes) as they communicate with others. This study acknowledges time as a key factor, and suggests that theory should track “recursive relationships among variables of interest over time,” ranging from “split-second coordination of action to long term development patterns” (Arrow, et al., 2000).

Figure 6. Typical social network measures (Brass, 1995a)
Relational event roles are characterized in terms of the directing or vectoring of a message that consists of an utterance or speech act between two or more team members. They may contain just a word, a phrase, a sentence or a non-verbal message. In a temporal context, they generally last only for a matter of seconds to perhaps minutes, principally in Newell’s “cognitive” band (Newell, 1990), and as simple statements, are basic components of communication between team members. These interactions may be in the form of statements, imperatives, questions, agreement, disagreement, etc., but characterizing them in this manner is different from the scope of this research. Rather, the aspect of interest is the nature of the tie that the sender generates when interacting with the target recipient(s). Any time that a member communicates with one or more others, it involves a relational event and a unique relational event role enactment.

Conclusion

Contemporary action teams are employed in increasingly complex tasks in dynamic information environments. Timely, accurate, properly shared task information can be a critical factor in team performance. Situations can spiral out of control rapidly, and, as numerous military and civilian examples illustrate, task failure can result in fatalities. It is important to understand action teams and the nature of the momentary information sharing roles that team members appear to enact. While we know much about teams in general and action teams in particular, we need to learn more about their information sharing patterns and flows.

In this concept paper, I have generated a conceptual model that places individual and team cognitive interactions into the larger context of an information sharing environment. The model uses team cognition not as an experimental objective, rather as an underlay, on which to examine the decision processes that action team members appear to undertake, including various information sharing considerations and possible network-type information sharing roles. It positions further research into how team members direct or vector information. Follow-on work includes sequential exploratory mixed method research to study the patterns and flows of team information sharing interactions. Appropriate research venues will be selected where military action teams can be observed unobtrusively, in situ, performing tasks across a spectrum of dynamic information environments.

Desired theoretical contributions include understanding and classifying team member interaction behavior patterns in the context of dynamic information environments (Doty & Glick, 1994), generating a typology of the behaviors, modeling the decision processes, and exploring how interaction patterns vary over time in those dynamic environments. Implications for practice are that leaders and trainers might gain a tool with which to evaluate interaction patterns in order to improve individual and team cognitive processes and performance.
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