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Communication Processes and Patterns in High-Performing Networked Teams – A Qualitative Analysis

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Abstract

The performance of networked teams depends both on the quality of the information infrastructure and team processes such as information sharing, sense-making, and collective decision-making. Communication represents a core factor enabling information exchange, development of shared mental models, discussion of options, and joint decision-making. Moreover, communication serves socio-emotional purposes such as trust building and the development of cohesion.

This study explores the behavioral and leadership patterns emerging in the communication processes of teams playing a networked simulation game in which players had to identify targets randomly distributed over a virtual area. As sensors differed in coverage and precision, the team members needed to communicate and cooperate to develop shared awareness and arrive at the best possible decision. The recorded chat message data were content-analyzed and used for validation of existing team decision-making models. The results show that effective teams could be differentiated from less effective teams in terms of task-knowledge coordination, communication patterns, and emergent role structures. The results also suggest that certain communication behaviors influence team performance to a different degree depending on the phase of the decision process.

The results of this study contribute to current knowledge on relationships between communication processes and performance outcomes, and have practical implications for network-enabled collaboration training.

Keywords: Network-enabled collaboration, task-knowledge coordination, communication patterns, emergent leadership

Introduction

Complex endeavors in the 21st century increasingly build on network-enabled collaboration structures, with the quality of the information infrastructure substantially influencing the effectiveness of networked teams. In addition, the skills with which electronic communication means are utilized appear crucial for overcoming the challenges of spatial, temporal, and configurational dispersion. Also, networked collaboration has to cope with the lack of nonverbal cues which essentially enrich and facilitate communication, in particular as it comes to complex decision-making tasks that require information sharing, collective sense-making, developing shared situational awareness, and jointly making a decision that is well-informed by the information gathered and preceding joint evaluation of options. Thus, in networked collaboration it becomes particularly important that verbal communication is as effective as possible.

This paper presents a study exploring the behavioral and leadership patterns emerging in the communication processes of small teams that had to solve a tactical allocation problem in a networked simulation game. In the first section the theoretical foundations of the study are pre-

sented. Relevant aspects of network-enabled collaboration, process models of team decision-making, current knowledge of relationships between communication patterns and effectiveness of team decisions, and emergent role structures within teams are discussed. However, current knowledge is almost exclusively based on studies of face-to-face teams in contexts other than command and control (C2), while little research has so far been conducted with respect to the specificities of the network-enabled C2 context. To begin addressing this research gap four research questions are derived, based on state-of-the-art knowledge in the domains introduced above, and describe the research setting and sample involved in the empirical analysis underlying this research. Then, the data and methods are described that were used for the qualitative and quantitative content analyses of the communication data recorded while the teams played the networked simulation game, and the results corresponding to the previously posed research questions are presented. Finally, theoretical and practical implications of these findings are discussed.

Theoretical foundations and research questions

In this section, the current literature relevant for the purpose of the paper is reviewed. Challenges for networked collaboration are summarized and discussed, process models of team decision-making are described, existing findings on the effectiveness of communication patterns in team decision-making are outlined, the role of emergent group structures is highlighted, and finally these aspects are linked with the concept of shared situational awareness.

The networking challenge

Collaboration in networked teams is becoming more frequent in complex endeavors of the 21st century. It involves dispersion of team members which may be spatial, temporal, and configurational (O'Leary & Cummings, 2007). Challenges for collaboration in dispersed teams are compensation for the lack of face-to-face interaction, building effective relationships, and accessing and employing team members' unique knowledge so that the team goal can be achieved (Roebuck, et al., 2004). Furthermore, collaboration of networked teams is regularly supported by communication technologies which have been shown to support information exchange, but also challenge important cognitive and social processes in teams. Geographical distribution and the use of communication media replaces a data-rich by a more data-lean environment focusing on cognitive cues so that team members' awareness of each other's actions decreases. Additionally, task interdependence inherently bears the risk of, or lead to, process loss (Fiore, et al., 2003).

A number of studies comparing the effectiveness of decision-making processes in computer-supported and directly interacting teams suggest that virtual teamwork faces serious challenges (Hedlund, et al., 1998). Furthermore, use of electronic communication media has been shown to require more cognitive effort from team members than face-to-face interaction does (Kock & DeLuca, 2007). A recent meta-analysis (Baltes, et al., 2002) comparing computer-supported and face-to-face decision making has shown somewhat mixed results. Decision effectiveness appears to be poorer in computer-supported teams when team members are not anonymous, and when teams have only limited discussion time. However, independently of the task type computer-supported teams appear to generally perform more poorly than teams interacting face-to-face. Most studies suggest that computer-supported teams take significantly longer to make a decision which is particularly apparent in groups of at least four individuals. Furthermore, anonymity in computer-supported teams significantly decreases member satisfaction as compared to face-to-face teams. Finally, the difference in satisfaction between computer-supported and face-to-face

teams, in favor of the latter, was larger in teams of at least four individuals. Task type plays an important role in computer-mediated collaboration: Whereas information conveyance seems to be done equally well by face-to-face and computer-mediated teams, face-to-face teams outperformed computer-mediated teams when a decision had to be reached on the basis of convergence of the team members' opinions (Murthy & Kerr, 2003). Similarly, Dennis (1996) found that computer-supported teams did not necessarily make the better decisions although information exchange was more complete in the computer-support conditions. Apparently, networked collaboration may on the one hand support information exchange, but on the other hand cannot guarantee high decision quality. Another comparison of computer-supported and directly interacting teams found that computer-support significantly altered communication patterns and improved the quality of decision-making in both disjunctive and conjunctive tasks (Lam, 1997). In particular, computer-supported teams as compared to directly interacting groups dedicated more discussion to procedural issues, engaged more in open discussion, were more critical and experienced more task-related conflict but less threat, which eventually lead to higher decision quality.

Fiore et al. (2003) describe information flow (synchronous, asynchronous) and information format (text, audio, video), information management (pre-, in-, and post-process), team members' attitudes (trust, cohesion, collective efficacy, collective orientation), behaviors (cooperation, coordination, adaptability), and cognition (working memory, memory activation, and long-term memory) as factors that may be influenced by dispersion of team members and that may in turn affect the effectiveness of decision-making in dispersed teams. In this study, the focus is on cognitive aspects of decision-making processes. Team cognition involves working memory, memory activation, and long-term memory. Effective task performance requires activation of the *working memory* that maintains and integrates differing mental representations which in turn allow for effective processing of incoming information. The proper functioning of the working memory during teamwork requires team members sharing mental models and employing transactive memory systems (TMS) which are associated with three dimensions (Kanawattanachai & Yoo, 2007; Lewis, 2003): Expertise location (awareness of knowledge specialization among team members), cognition-based trust among team members (beliefs about each other's ability and reliability to effectively perform the task), and task-knowledge coordination which requires that the team develops representations of how the tasks can be divided, how the resulting subtasks are related, and how these may be assigned to individual team members (Cannon-Bowers & Salas, 2001). Since interaction in distributed teams is limited to verbal communication, explicit communication and common ground which are enabled by effective TMS is particularly important for team effectiveness. Consistent with this, the quality of a team's TMS significantly influences team performance (Austin, 2003; Liang, et al., 1995). In particular, the impact that two dimensions, expertise location and cognition-based trust, have on team performance seems to be mediated by the third dimension, task-knowledge coordination (Kanawattanachai & Yoo, 2007).

This paper focuses on cognitive aspects of decision-making processes in networked teams, exploring communication patterns that support task-knowledge coordination, as a direct antecedent of a team's performance. In particular, answers to the following question are sought:

> *Research Question 1: What are the key factors in terms of task-knowledge coordination that distinguish effective from ineffective networked decision-making teams?*

Team decision-making processes

Research has been striving to describe processes of collective cognition, i.e., how information is acquired, stored, transmitted, manipulated, and used collectively (Gibson, 2001). Collective cognition is core to decision-making and problem-solving in teams as prerequisites of effective collective action. Valuable contributions have been provided from domains such as social sciences (e.g., Hirokawa & Johnston, 1989), information sciences (e.g., Stahl, 2006), and C2 research (e.g., Richards, 2003).

Team decision-making process models building on the rational perspective are generally composed of several well-definable stages (e.g., Finnegan & O'Mahony, 1996; Harrison, 1999). Once the emergence of a problem has been realized, the planning stage implies the setup of a framework and specific conditions under which the problem is to be solved. Planning refers to aspects such as identification of available resources and the time frame, and the establishment of coordination and collaboration patterns. Then, information is collected to gain a more accurate understanding of the problem. Depending on the amount of information that needs to be scanned and processed team members usually need to agree on some kind of distribution of the workload in this stage which implies that not all team members will have access to the same information. To reach the best possible solution, however, information uniquely held by individual team members, has to be shared (Dennis, 1996). Information exchange may be affected by several variables such as the relevance attributed to a specific piece of information by the individual owning it, or the social motivation to avoid negative evaluation of contributed information. Furthermore, appropriate exchange of information doesn't necessarily imply proper information use. Preferences regarding a possible decision are often shaped by information that has been common from the beginning rather than by previously unique information contributed by individual team members. These initial preferences lead to selective information exchange and processing, and it influences the focus of the team's discussion (ibid.; Gigone & Hastie, 1996; Kelly & Karau, 1999; Stasser & Titus, 1985). Based on the information accumulated, a number of alternatives are created to solve the problem. The proposed alternatives are evaluated in the next stage. Whereas some are excluded early, others are repeatedly discussed and compared in more detail. The evaluation stage smoothly transits into the stage where one alternative is chosen finally. Frequently, substantial negotiation takes place before the alternative is chosen – sometimes, but not always, by consensus. If the team cannot act fully autonomously, the alternative has to be justified in a following report to other teams or decision-makers; otherwise, the alternative can directly be implemented by the team members themselves.

This widely accepted rational decision-making model is clearly applicable to individual decision-making as well and thus contains no group-level specificity. Other models of problem-solving processes have been focusing more strongly on the collective aspects of problem-solving processes (e.g., Gibson, 2001) and issues occurring in the phases and connecting the phases. The described stages are also reflected in models describing team members' cognitions during the process, highlighting the significance of macro-cognitive aspects such as construction of individual and team mental models, development of shared understanding, sharing of hidden knowledge (Stasser & Stewart, 1992), mental model convergence, or output analysis (Letsky, et al., 2007). These aspects of the team decision-making process clearly contribute to the development of shared awareness, and ultimately to decision effectiveness. An integration of the models presented above (Finnegan & O'Mahony, 1996; Gibson, 2001; Letsky, et al., 2007) revealed the integrative process model of collective cognition and problem-solving illustrated in Figure 1.

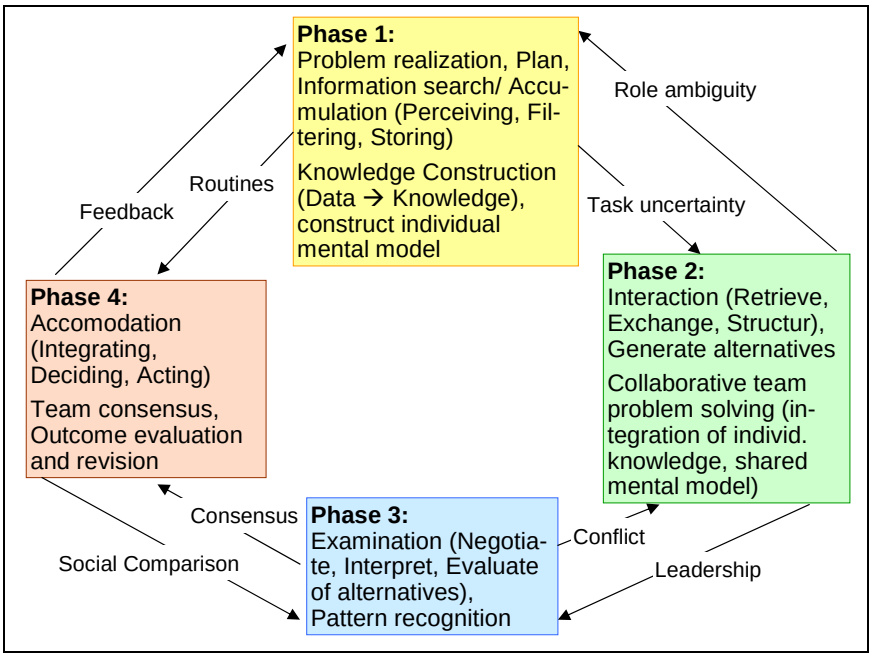

Figure 1. Integrative process model of collective cognition and problem-solving

Clearly, these models describe the processes of collective decision-making in a simplified manner, with the distinct phases evolving sequentially. However, rather than being strictly sequential, phases overlap and occur iteratively, and a team may go through phases more than once as several alternatives are discussed. Furthermore, decision-making processes need not always be as explicitly observable as the model might indicate. Interaction-based analyses imply, for instance, that decisions may as well be embedded in the team's complex work practices (Alby & Zucchermaglio, 2006) so that the actual 'event' of decision-making is all but easy to identify.

Effective team decision-making usually promotes the emergence of shared situational awareness. Situation awareness (SA) by itself may be defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988, p. 97). In more recent conceptualizations, it has been suggested that situational awareness is multifaceted in that it comprises contextual, task- and process-related, and socio-emotional information (Sonnenwald, et al., 2004). Situational awareness at the collective level is referred to as shared SA, group SA, or team SA and may be defined as "two or more agents' active construction of a situation model which is partly shared and partly distributed and from which they can anticipate important future states in the near future" (Artman, 2000, p. 1113). This definition emphasizes the process aspect of team SA, and its interpretative and distributed nature, bearing in mind that team SA is more than just the sum of individual SA. Rather, it has been accomplished by active communication and coordination among team members. A concept closely related to shared awareness is that of shared mental models (Cannon-Bowers, et al., 1993) that refers to team members' models of issues within the team, e.g., coordinating routines (Artman, 2000). Shared mental models enable the team members to have the same ideas as to what the task exactly is about and the roles each one plays (Mathieu, et al., 2000) and to anticipate each other's (informational) needs and adapt their behaviors to the demands of the situation and the task (Cannon-Bowers et al., 1993; Urban, et al., 1996). They constitute the basis for developing shared SA (Endsley & Jones, 1997) and team

effectiveness (Waller, et al., 2004). Thus, developing shared mental models and shared SA is crucial for effective team decision-making.

Based on the assumption that the group decision-making processes analyzed in this paper consist of distinguishable phases, the following research question is posed:

> *Research Question 2: In what terms do phases and processes within the phases differ between effective and ineffective networked teams engaged in decision-making?*

Interaction patterns and decision-making effectiveness

This paper focuses on the analysis of the chat messages exchanged by highly effective and ineffective teams during the decision-making process. The research presented here is informed by the functional perspective (see Wittenbaum, et al., 2004) which is a normative approach describing and predicting team performance as a function of inputs and processes. Based on the functional perspective, researchers explain how communication impacts on group decision-making effectiveness. Effectiveness in group decision-making is considered to depend on group interactions enabling fulfillment of essential task requirements. In line with the functional perspective, a meta-analysis showed that decision effectiveness depends on an accurate understanding: (a) of the problem (problem analysis); and (b) of the requirements for an acceptable choice (establishment of evaluation criteria); (c) on the generation of realistic alternatives; and on the appropriate assessment of (d) positive and (e) negative consequences of alternatives (Orlitzky & Hirokawa, 2001). These aspects are reflected in the above presented process models of team decision-making and problem-solving. Three of the five functions, problem analysis, establishment of criteria and assessment of negative consequences, repeatedly appeared as the most relevant ones. Surprisingly, other functions such as establishment of task procedures and socio-emotional talk, have revealed no significantly positive, or in some studies even negative, effects of team performance which has been explained in such a way that teams being under time pressure but dedicating too much time to these functions may be distracted from pursuing their actual goals (Hirokawa & Salazar, 1999; Li, 2007; Orlitzky & Hirokawa, 2001).

Based on the conceptualizations of the functional perspective, the idea that the type of communication among team members and its appropriateness in a given situation influences the quality of a team's decision or effectiveness is not new (e.g., Gouran & Hirokawa, 2003). However, available results from corresponding research are somewhat mixed. Hirokawa has long been conducting research in communication in decision-making teams that interact face-to-face. In an early study, he did not find any differences in the type of verbal communication between effective and less effective teams, except that effective teams spent more time interacting and produced a slightly larger number of statements that served to achieve agreements upon procedural matters (Hirokawa, 1980). Furthermore, they differed significantly in their overall interaction patterns, which implies that the effectiveness of decision-making depends on the communication sequencing over time rather than on the types of communication behaviors shown during the process. Another study (Hirokawa & Pace, 1983) revealed no particular sequence of interaction phases leading to successful problem-solving. However, successful teams appeared to first analyze the problem before starting to search for potential solutions whereas unsuccessful teams started to search for solutions immediately.

In regard to the type of verbal behavior, Innami (1994) found that reasoning orientation among team members, i.e., the extent to which team members exchanged facts, gave reasons supporting

a particular judgment, and clarified conditions and assumptions of judgments, increased the quality of the group decision whereas a high positional orientation in the team's verbal behavior, i.e. the extent to which team members insisted on their own positions and expressed defensive arguments, decreased decision quality.

Whereas there is ample research concerning the effectiveness of decision-making teams that interact face-to-face, there are hardly any studies on communication in computer-supported decision-making teams (Baltes, et al., 2002). A comparative study found that face-to-face teams quantitatively and qualitatively performed better than computer-mediated teams in problem analysis and establishment of solution criteria (Li 2007). In some of the few so far available studies, task-oriented communication and other interactive patterns such as the frequencies of elaborations and no-responses and of positive emotional expression were found to have a significant effect on team performance (Fischer, et al., 2007; Kanawattanachai & Yoo, 2007).

In this paper, communication patterns that distinguish effective from ineffective decision-making teams in networked C2 environments are of particular interest. Thus, the following research question is posed:

> *Research Question 3: In what terms do observed communication patterns differ in highly effective vs. ineffective networked teams engaged in decision-making?*

Emergent structures

In the course of action, team members dynamically change and adapt their behaviors and ways to contribute to the team goal, giving rise to the emergence of role structures.

A role can be defined as a cluster of goal-directed behaviors that are characteristic of an individual in a certain situation (Stewart, et al., 2005), and comprises a set of behaviors that fellow team members expect from them. Roles help to define group structure (Ronson & Peterson, 2005) and provide a sense of orientation. Research suggests that a balanced mix of team roles that are supplementing each other's functions, is positively linked to team performance (Leung, et al., 2003; Senior, 1997). Team role research is ample and has a long tradition (e.g., Bales, 1950; Belbin, et al., 1976; McCann & Margerison, 1995). Yet, many of the offered role typologies share a common pattern. For instance, the team roles described in Belbin's (1993) model, one of the best known concepts, are similar to those found by Zigurs and Kozar (1994) based on a literature review: Proceduralist, record-keeper, devil's advocate, explainer, opinion-seeker, opinion-giver, idea generator, listener, motivator, gatekeeper, conflict handler, tension-releaser. The first seven roles were labeled task related, the latter five socio-emotional. This fits the role typology based on a recent comprehensive literature review on team roles, comprised of task roles, social roles, and boundary spanning roles as the three super-ordinate categories (Mumford, et al., 2006).

In addition to the classical concept of team roles, the notion of emergent leadership has received broad attention (De Souza & Klein, 1995; Eby, et al., 2003; Limon & France, 2005; Taggar, et al., 1999; Yoo & Alavi, 2004). It may be particularly relevant in networked collaboration which implies that formal vertical leadership may not be as effective in these settings as in teams that interact directly. Emergent leadership can be defined as influencing other team members significantly although that person does not possess formal authority (Schneier & Goktepe, 1983). Research suggests that task ability and commitment to the group goal are significantly positively related to leadership emergence, and that emergent leaders are more likely to direct the activities

of the other group members (De Souza & Klein, 1995). Furthermore, groups with emergent leaders have been found to outperform groups without leaders (ibid.; Kim, 2006).

In ad hoc and temporary virtual teams, emergent leaders can be distinguished from other team members in that they (a) generally engage more strongly in sending messages to other team members, which is in line with a previous meta-analytical finding (Mullen, et al., 1989); (b) send more task-oriented messages than others (Hawkins, 1995); in particular procedure-oriented (Ketrow, 1991, 1999) or coordination-related messages; and (c) appear to enact three roles: initiator (e.g., sending the first task-structuring messages), scheduler (e.g., taking initiative of setting up a temporal rhythm), and integrator (e.g., integrating other team members' work into a final product). No differences were found between emergent leaders and other team members in regard to the number of expertise- or relationship-oriented messages, or messages referring to technology management (Yoo & Alavi, 2004). However, Kim (2006) found differential effects of emergent leader communication: Whereas in earlier stages of the process emergent leaders are more effective when they send comments on clear group objectives and interaction structure, in later stages it appears to be more important that the leader encourages interaction and strives to maintain group cohesion.

Increasing complexity and ambiguity in contemporary and future endeavors make it unlikely that a single team member can perform all required leadership functions. Also, decentralization as a key element of network-enabled C2 stress the necessity of leadership emerging from within a team (see Carson, et al., 2007, for an application to the business context). Research indicates that team members' roles can dynamically change throughout a decision-making process. Specifically, leadership functions may be shared among team members throughout the process, or a specific member fulfills the leader's role at a given time. This implies that emergent leadership is not always tied to a specific person, but may also shift from one team member to another during the decision-making process (Alby & Zucchermaglio, 2006; Carson, et al., 2007). Specifically, already Bales (1953) had found emergent leadership to be often distributed among a task-focused and a relationship-oriented leader. The "emergent team property that results from the distribution of leadership influence across multiple team members" (Carson, et al., 2007, p. 1218) may be termed *shared leadership*. Pearce and Manz (2005, p. 134) suggest that shared leadership is dependent on all team members being engaged in the leadership of the team and "entails a simultaneous, ongoing, mutual influence process within a team". Hoegl and Muethel (2007) suggest that shared leadership can be conceptualized in terms of two elements that are both necessary for its effectiveness in terms of coordination, information exchange, and cohesion: mutual influence and proactive followership. Mutual influence implies that environmental changes and interdependencies between tasks are continuously monitored and reflected, information needs are anticipated, followed by initiation and facilitation of information exchange and decision-making processes, and initiation of social influence on fellow team members' behaviors. Proactive followership implies active feedback seeking and subsequent adaptation to environmental circumstances, if necessary. Shared leadership has been suggested to depend on cognition-based trust (Bligh, et al., 2006) and the team environment as composed of shared purpose, social support, and voice (Carson, et al., 2007). In turn, shared leadership has been found to predict team performance (ibid.; Pearce & Sims 2002). Similarly, in teams performing under extreme uncertainty and being engaged in urgent, unpredictable and interdependent tasks that bear high risks in case of failure, 'dynamic delegation' was found to enable high effectiveness (Klein, et al., 2006). An example of shared leadership, this phenomenon implies that more experienced team members

dynamically delegate specified leadership positions to, and withdraw them from, selected (less experienced) team members, contingent on situational requirements.

Provided that emergent team roles, in particular emergent leadership, may be identified in the analyzed group interactions, the following research question is posed:

> *Research Question 4: In what terms do emergent team roles and emergent (shared) leadership differ in effective vs. ineffective networked decision-making teams?*

Method

Sample and Setting

Study participants were at large students of the German Air Force officer school. The sample consisted of 86.4 percent males, and the participants' average age was 20.8 years (standard deviation (s.d.) = 2.1 years). One hundred and thirty teams, each consisting of four students, played the multi-player computer game *Collaborative Game For First Experiences In A Networked Environment (CAFFEINE)* by Schäfer (2005). The basic idea of the game is similar to the concepts of StrikeCOM (Twitchell, et al., 2005) or ScudHunt (Stahl & Loughran, 2002). In each team the members are spatially separated, but connected via a computer network offering different means of communication such as voice, text chat, or whiteboard. In this study, only text chat was used as communication means. The teams' objective was to search for a specified number of adversaries ('targets') that are randomly distributed over a rectangular area. This area, usually a grid square, is divided into cells each of which is clearly defined through coordinates (see Figure 1).

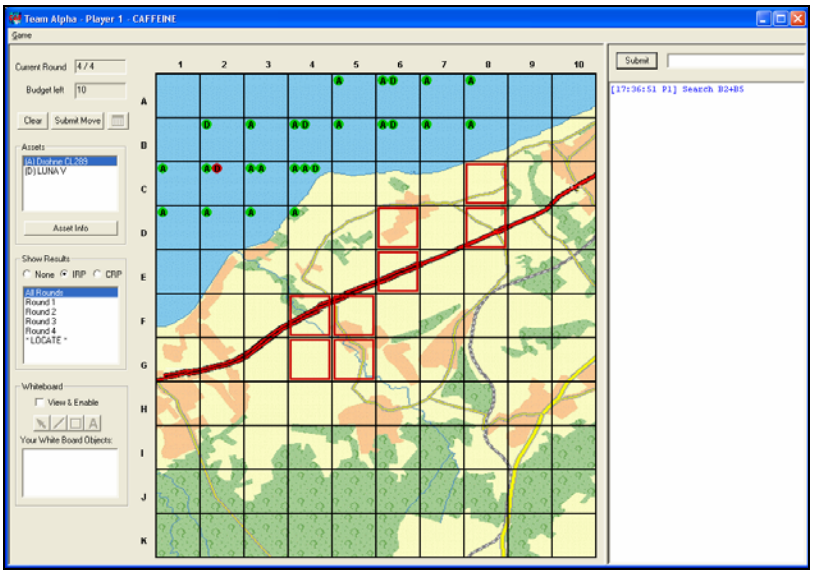

Figure 1. CAFFEINE Screenshot

Each player owns a specific portfolio of sensors that they may use throughout usually four reconnaissance rounds in order to detect the hidden targets. Each player is limited to a fixed budget that may, but need not, be entirely spent on sensor deployment. The sensors differ in coverage, i.e., the number and arrangement of cells they can cover (e.g., squares of 2*2 cells, or of 5*5 cells), precision, i.e., the probability of target detection, false alarm, and beta errors (provided as % data), and cost per deployment (provided in terms of monetary units). In the utilized standard

setup of *CAFFEINE*, players 1 and 2 were provided sensors with somewhat smaller coverage and higher precision while players 3 and 4 owned sensors with large coverage and low precision. The limited sensor coverage and the uncertainty of the reconnaissance results raise the need for team members to communicate and cooperate within their teams to obtain the best possible reconnaissance picture and shared situational awareness of potential targets' locations.

After an introductory briefing explaining the basic idea of the game and its features, teams of four individuals could perform an exercise run in order to get acquainted to the procedure. After that, teams played the game in different (random) compositions in regard to membership. Another challenge the teams faced now was that each member had only their own reconnaissance results available. Thus, the *Individual Result Picture* (IRP) provided to each player which simulated individual situational awareness required the team members to collaboratively share their individual results in order to develop shared situational awareness. The four reconnaissance rounds were followed by a 'strike' round which required all team members to select up to nine cells where they suspected one of the seven targets to be hidden, based on the available information and the preceding team decision process. The team members could, but were not required to, strike identical targets.

Measures

Team activities, i.e., chat messages and actions (reconnaissance and strike moves), and their outcomes were recorded in log files. The outcome measure, team effectiveness, was assessed on the basis of the number of a team's hits and fails. Because team efficiency was calculated as another outcome measure, the teams were told that the time required to complete the task was relevant as well.

To obtain results referring to the research questions introduced above, qualitative analyses of the team decision-making processes were conducted. To analyze the communication patterns within the teams the Interaction Process Analysis (IPA) scale developed by Bales (1950) was used. Although the IPA was originally developed for and has since then been extensively used to analyze face-to-face communication (e.g., Gorse & Emmitt, 2007; Hutson-Comeaux & Kelly, 1996; Kanawattanachai & Yoo, 2007; Keyton, 2003) it was utilized in recent computer-mediated communication studies as well (Maloney-Krichmar & Preece, 2005; Peña & Hancock, 2006). The IPA scale (see Annex Table A1) consists of twelve communication categories grouped into four areas: (1) Socio-emotional area positive; (2) Task area (problem-solving attempts); (3) Task area (questions); and (4) Socio-emotional area negative. To explore whether team effectiveness was affected by the interaction patterns regarding to the task-related or socio-emotional categories of the IPA, a qualitative analysis with the 12 most effective and the 12 least effective teams of the sample was conducted. These two groups could be clearly distinguished from each other in regard to the above presented measure of team effectiveness.

Results

Task-knowledge coordination

Research question 1 referred to key factors in terms of task-knowledge coordination that would distinguish highly effective from ineffective networked teams. The qualitative analyses of the team processes revealed differences between effective and ineffective teams in regard to four as-

pects: expertise location, task division, integration of subtasks, and coordination of team members' actions following the decision.

In the experimental setting, expertise location was realized as the team members' awareness of who in the team possessed what sensors to identify potential targets in the area displayed on the screen. The sensors differed in terms of their probability to release a false alarm (alpha error) and to miss a hidden target (beta error), in terms of the area they cover and the cost associated with each deployment. Reasonable coordination of the individual players' sensors may be expected to enhance team effectiveness, but requires that all team members know how the sensors are distributed among them. Analyses revealed that of the eleven analyzed effective teams, eight teams exchanged information on who had what sensors available, mostly at the very beginning of the game, whereas this information was not shared in three of these teams. In the twelve analyzed ineffective teams, sensor information was not exchanged by eight teams, while of the four teams that shared this information one team did not actually use it for the reconnaissance task.

In regard to task division, two distinguishable reconnaissance strategies emerged. The first strategy was to divide the area shown on the screen into four approximately equally large regions and to assign each region exclusively to one of the team members. This strategy that may be considered as *de-conflicting* was labeled the 'quadrant strategy', or *Strategy Q*. In the teams employing the second strategy, which required that the individual team members first exchanged information on their sensors (expertise location), the (two) members owning the sensors with large coverage but high alpha and beta error probability scanned the area first and reported those coordinates where their sensors had obviously detected potential targets. After that, the (two) team members owning sensors with low coverage but high precision focused on these coordinates, trying to validate the results of the low-precision sensors. This strategy was labeled the 'filter strategy', or *Strategy F*. The analyses showed that most teams employed exclusively one of the two strategies from the very beginning of the game. In particular, of the twelve ineffective teams five teams employed Strategy Q, only one team employed Strategy F, and two teams changed from Strategy Q to Strategy F in the course of the decision-making process. Two of the ineffective teams, however, did not discuss, not to mention agree on, any recce strategy at all. Also, some of the teams that had agreed on Strategy Q nevertheless faced problems with clear assignment of areas to team members. Misunderstandings, and thus potential unintended overlapping of two team members' reconnaissance areas, occurred several times and could only be dissolved with substantial communication efforts and time investment. Finally, in some of the ineffective teams individual team members simply stated their own intentions but didn't suggest that the team make a joint decision concerning procedures. Of the eleven analyzed effective teams, three teams used Strategy Q, and eight teams used Strategy F. Examples of the strategies employed by the teams are presented in the Annex (Table A2).

Integration of subtasks turned out as another factor distinguishing effective from ineffective teams. Whereas all of the analyzed effective teams appeared to do a very good job in integrating the results collected by the individual team members, only five of the twelve ineffective teams showed at least attempts to integrate their results whereas seven teams did not integrate results at all. In particular, in most effective teams all team members participated in jointly evaluating the reconnaissance results and developing a final list of targets they wanted to attack whereas in most ineffective teams the individual members presented assumed targets based on an individual pre-evaluation of their results and appeared unable to develop a final list of targets out of these suggestions. Table A3 in the Annex shows examples of both cases.

Strike coordination was also identified as an aspect of task-knowledge coordination distinguishing effective from ineffective teams. Whereas most effective teams either jointly developed a list of targets to be attacked or complied with the target list developed by one or two players, only two of the ineffective teams reached an agreement on the targets whereas in six teams all players acted completely autonomously and in four teams one or two players stroke as the group discussion on potential targets was still going on. Table A4 (see Annex) presents examples of effective and ineffective strike coordination.

Team interaction phases and processes

Research question 2 referred to how the interactions of effective and ineffective teams may be described and distinguished in terms of phases and processes within the phases. Qualitative analyses of the team decision-making processes revealed the phases presented in Table 1. These phases may be described more generally and thus be transferred to other, but similar, C2 contexts as also shown in Table 1.

Phase (general)	**Phase (study)**	**Communication**	**Actions**
Team Forming	Team forming	Greet other players, small talk	
Problem analysis	Problem analysis		
Resource orientation	Resource orientation	What sensors do we have? What qualities do the sensors have? I have sensor XY. Sensor has these and those qualities.	
Plan information gathering	Plan recce strategy	How shall we proceed? Who goes where? Who goes first? Procedural suggestion, assignment; Declaration of ‘self-assignments’; Feedback: agreement, refusal;	
Information collection	Recce rounds	Scan request (general, directed to specified team member/s); Request others’ process status; Request recce results; Report (un)weighted recce results; Reaction to others’ recce requests;	Scan according to or dissenting from tactic; Reaction to others’ recce request;
Information integration, list alternatives	Result integration	Evaluate (weighted) recce results; List target alternatives mentioned by at least two players;	
Option assessment, decision	Evaluation, target selection	Declaration of target alternatives; Refuse others’ target suggestions;	
Action	Strike		Strike (agreed) targets

Table 1. Emergent phases in the team decision-making process

Differences between effective and ineffective teams could be found in regard to several but not all of the phases described above. No differences were identified for the first and second phase, i.e., for team forming and problem analysis, both of which were very short in the analyzed team interactions, with a fast transition to the actual task process. However, the resource orientation phase presents striking differences: Most of the players in ineffective teams did not give much attention to what sensors their fellow team members possessed although they had been received information on the distinct qualities of the sensors in the introductory game briefing. In most effective teams, however, resource orientation was treated as an important phase and as a true starting point of the actual decision-making process. This finding fits well with the above presented finding that effective groups tended to place more attention on expertise location than the ineffective groups.

The phase of reconnaissance procedure planning was usually comprehensive in effective teams whereas members of ineffective teams gave rather short notice of either what they were going to do themselves or what they suggested the whole team to do to collect the required information. In some of the ineffective teams, information collection planning was completely missing, as the sample protocol in Table A5 (see Annex) shows.

Actual information gathering was clearly separated and following the information collection planning phase in effective teams. Ineffective teams, however, often showed substantial overlapping between these two phases, with information collection starting even before an agreement about the information collection strategy had been reached. Table A6 (see Annex) presents sample protocols of this critical phase.

The phase of result integration often appeared to be missing in ineffective teams. Instead, reconnaissance results were merely interspersed by the individual team members without any of them responding to results reported by others. In effective teams result integration represented a core phase in the decision-making process as Table A7 (see Annex) shows.

All sensors have specified probabilities to correctly detect targets or incur alpha or beta errors. Thus, the results obtained by the individual team members also require critical evaluation in terms of the probability that potential targets represent actual targets. The evaluation and target selection phase is thus another critical phase in the team decision-making process. The qualitative analyses revealed that effective teams did a good job in evaluating reported results and, finally, in the joint selection of the targets the team wanted to go for. Ineffective teams tended to neglect the evaluation phase and often did not succeed in jointly reaching a final decision, as Table A8 (see Annex) illustrates.

As is also presented in Table A8, the final phase, i.e. the strike phase, appeared to frequently overlap with information gathering or result discussion attempts in the ineffective teams whereas effective teams tended to first complete their evaluation and joint target selection phase before any of the team members set strikes.

To summarize the results of the analysis of team decision-making phases, effective teams tended to go through all identified phases in a diligent way whereas in ineffective teams the phases of resource orientation, information collection planning, result integration as well as result evaluation and joint target selection were frequently missing or only very short and executed superficially. Additionally, in ineffective teams, substantial overlaps of the phases were observed to a degree that seems to have impeded effective coordination of the individual team members' efforts.

Communication patterns

Research question 3 referred to whether team effectiveness is affected by the patterns of communication among team members. These patterns were analyzed in terms of task-related or socio-emotional categories as described in the IPA scale (Bales, 1950). Table 2 shows the percentages of chat messages in the four IPA areas. Analyses of the percentages of the IPA areas of the total number of messages showed significant differences for two areas. Whereas in ineffective teams half of the messages were devoted to answering questions by fellow team members and more than 20 percent of the messages were negative reactions to suggestions of others, effective teams devoted more than two thirds of the messages to give answers, and only 6.6 percent of the messages were negative reactions. To more precisely assess these differences, T-tests were conducted for the four IPA areas. Results showed that there were no significant differences between effective and ineffective teams in regard to the percentage of positive reactions (T = - .13, not significant [n.s.]) and questions (T = - .35, n. s.), but in regard to the percentage of attempted answers (T = 3.72, p < .01) and negative reactions (T = - 2.24, p < .05).

	Positive reactions	**Attempted answers**	**Questions**	**Negative Reactions**
Effective teams	11.03	69.76	12.56	6.65
Ineffective teams	11.87	52.34	14.49	21.30
T, p, significance	- .13, .90., n.s.	3.72, .00, sign.	- .35, .74, n.s.	-2.24, .04, sign.

n.s. = not significant; sign. = significant

Table 2. IPA results for effective and ineffective teams

For a more detailed explanation of effective teams' success and ineffective teams' failures and to identify the key factors at play, a second analysis was conducted, re-categorizing the chat messages in a more unprejudiced inductive manner. The categories were developed to particularly focus on the analysis of the task-oriented messages. Table 3 presents the category system that emerged from this effort and descriptions of the categories, along with sample messages.

Category	**Description**	**Examples**
Strategy	Player suggests a procedure referring to a longer sequence of the game.	Division into 4 squares. Top left, right, bottom left, right. Recce tools with large coverage go first and report. I try to confirm afterwards.
Guidance	Player wants another player to act in a specific way.	Echo 1 and 2, wait for the report of Echo 3 + 4! Please announce the nearly 100% targets!!!
Request guidance	Player asks for assignments or direction.	I can still scan. Any suggestions? Where should I scan? Loupe?
Coordination	Communication acts trying to figure out the situation in the field or in the team to coordinate the next moves.	Please indicate again which areas you can scan. Luna 1x2 at i10. I have Tornado. I check for targets at c5, d1, d4.
Quality assessment/ Validation	Additional information referring to the evaluation of a potential target.	I confirm i1, j10 two hits. H3 no, h4 one hit. … and three hits at j10.
Information	Task-related information, e.g., target coordinates.	d8 e3 g4. d2, d1 for sure.

Table 3: Category system of inductive qualitative content analysis

After assigning the contents of the messages into the emerged categories, the number of communication units assigned to each category was determined. Table 4 shows the results of the inductive qualitative content analysis. Figures represent the absolute numbers of the communication units assigned to the categories. As can be seen, effective teams exchanged a slightly larger number of task-related communication units (60.6 as compared to 50.8) than the ineffective teams did.

	Categories						
Teams	Strategy	Guidance	Request guidance	Coordi-nation	Quality assess-ment/ Validation	Information	Total
Effective	4.14	11.71	1.00	12.86	12.86	18.00	60.57
Ineffective	1.50	9.00	2.83	7.00	9.00	21.50	50.83
T	-2.30	- 2.10	1.62	-2.44	-1.53	.87	- .94
Significance	.04, sign.	.05, sign.	.13, n.s.	.02, sign.	.14, n.s.	.40, n.s.	.36, n.s.

n.s. = not significant; sign. = significant

Table 4: Task-related communication of effective and ineffective teams

In regard to the question in what terms, i.e., in which categories, effective and ineffective teams differ significantly, T-tests were calculated. The results show that effective teams engaged significantly more in discussions of the reconnaissance strategy to be employed, guidance given among team members, and coordination effort. Communication referring to confirmation of suggested target coordinates were also found to emerge slightly more frequently in effective teams although the difference was not significant. Finally, ineffective teams appeared to place more guidance requests than was the case in effective teams.

Emergent role structures

Finally, the team decision-making processes were analyzed in terms of different roles that may emerge in the teams. Again, effective and ineffective teams were compared.

Our first focus was on the question whether effective and ineffective teams could be distinguished in terms of leadership. The term *leadership* referred to either leadership by one team member or shared leadership here. Qualitative analyses of leadership processes revealed that both in effective and ineffective teams only a small subsample of the teams did not show any leadership attempts. However, team members trying to take on leadership roles in effective teams were clearly more successful whereas leadership attempts in ineffective teams were frequently refused or simply neglected. Table A9 (see Annex) illustrates the example of an ineffective team where player 1 tries to take on leadership which is however completely neglected by player 4 who refuses to report any results as requested by player 1. Also, player 2 does not comply with the request by player 1 to wait for the results of players 3 and 4 in that he scans three times after only two hits have been reported in total. In the effective team, however, player 1 takes on leadership immediately and asks fellow team members to follow his coordination suggestions. He also gives a reason for his suggestion which facilitates acceptance of his suggestions by the team.

Another interesting finding was that emergent leaders in ineffective teams often influenced, or attempted to influence, their teammates' behaviors only at the beginning in that they suggested

an information collection strategy, or toward the end in that they integrated recce results of their teammates whereas for the rest of the team process no leadership was observable. In effective teams, however, emergent leaders either were in charge throughout the entire process, or leadership shifted to another team member. This also means that only effective teams were capable of sequentially sharing leadership functions among at least two team members. The illustration in Table A 10 (see Annex) gives an example for successful shifting leadership among three players. At the beginning, players 1 and 2 lead together, suggesting a reconnaissance strategy and coordinating the reconnaissance process, while toward the end player 4 takes over the leadership function, in particular as it comes to the integration of reconnaissance results.

The next issue explored was the communication behaviors of the identified emergent leaders. In particular, the following questions were to be answered: (a) do emergent leaders communicate more than other team members; (b) do emergent leaders send more procedure-oriented or coordination-related messages than their fellow team members; (c) what roles do emergent leaders appear to enact in networked C2 teams; (d) what kind of proactive followership do team member enact; and (e) what roles can be observed in general? All of these questions were particularly explored with respect to potential differences between effective and ineffective teams.

There was in fact a tendency for emergent leaders in both effective and ineffective teams to send a larger number of messages. However, results were not entirely clear since players not in charge also tended to send a large number of messages, in particular in order to report their reconnaissance results or to ask for validation of these results. In some of the ineffective teams, a larger proportion of the messages sent by team members communicating nearly as much as the emergent leaders came from socializing or responding to critique by other players.

Furthermore, it turned out that emergent leaders tended to send more procedure-oriented messages than their fellow team members did. These findings seem to apply to effective as well as to ineffective teams.

Emergent leaders enacted different roles. The most important function they seemed to perform was making suggestions or assignments referring to the reconnaissance procedure (see Annex, Table A11). Second, emergent leaders contributed essentially more than other team members to integrate the individual participants' reconnaissance results and promoted the joint result evaluation process in order to eventually arrive at a jointly made decision (see Annex, Table A12). Interestingly, this function was performed clearly more frequently and in particular more forcefully by emergent leaders in effective teams as compared to their counterparts in ineffective teams. Finally, most emergent leaders also engaged in making sure that all team members sufficiently contributed their reconnaissance results and generally participated in the group process in that they addressed individual team members personally. This behaviour also apparently served to maintain group cohesion (see Annex, Table A13). Again, this function was observed more frequently and more clearly in effective teams as compared to ineffective teams. To summarize the results in regard to roles of emergent leaders, three outstanding functions were identified: Proceduralist, content integrator, and socio-emotional integrator.

The most important role proactive followers seemed to play was to appropriately respond to procedural assignments given by the emergent leader, i.e. to scan assigned areas in a coordinated manner as outlined by the leader, to diligently report their individual reconnaissance results in a way that allowed for joint evaluation, i.e., to report results that they had not pre-evaluated themselves, and to actively participate in the process of integration of the team members' results (see

Annex, Table A14). Again, differences between effective and ineffective teams were observable in that members of ineffective teams often tended to neglect procedural suggestions and thus leadership attempts in general, to pre-evaluate their results so that the team had no chance to compare target probabilities, and in some cases even failed to report their reconnaissance results at all (see Annex, Table A15).

The team roles evolving from the process comprised the functions of the emergent leaders and proactive followers. In addition, in some cases imposing time pressure on individual or all fellow team members appeared as another role, the time-observer, that could neither be reasonably categorized as explicit leadership nor labelled as proactive followership.

Discussion

The qualitative analyses revealed a number of findings in regard to the proposed research questions related to task-knowledge coordination, process phases, communication patterns, and emergent role structures in effective and less effective decision-making networked teams.

Research question 1 referred to possible key factors in task-knowledge coordination that may distinguish effective from ineffective teams. As described in the theory section, together with expertise location, i.e. the awareness of knowledge specialization among team members, and cognition-based trust, task-knowledge coordination is a component of a team's transactive memory system (TMS) and refers to team members' representations of how a task can be divided, how subtasks may be assigned to the team members, and how these subtasks are related (Kanawattanachai & Yoo, 2007). The qualitative analyses of the team processes revealed differences between effective and ineffective teams in regard to four aspects: expertise location, task division, integration of subtasks, and coordination of team members' actions following the decision. The results thus confirm that core dimensions of a team's transactive memory system are of equal importance in both networked C2 teams and teams where members interact face-to-face and/or in other contexts. First, whereas most effective teams tended to extensively exchange information on available reconnaissance tools at the beginning of the game, most ineffective teams did not share this information and thus seemed to fail to develop expertise location. However, if team members did not exactly know what and how others may contribute to the decision-making process, coordination remained difficult, thus impeding effective team functioning. Hence, expertise location appears to be one of the key factors of team effectiveness. It was also found that ineffective teams tended to engage in a division of the task driven by a de-conflicting strategy in that the area to be explored was divided into separate quadrants for each of which one specified team member was responsible .However, effective teams, building on their expertise location knowledge previously developed by sharing sensor information, showed a more sophisticated reconnaissance strategy in that they employed a filter strategy. This mode of interaction is more mature than de-conflicting and may be labeled collaborative in terms of the NNEC maturity model (Moffat & Alberts, 2006). Furthermore, all sensors available in the game had specified probabilities of correctly detecting targets or incurring alpha or beta errors, i.e. the results reported by the sensors were more or less imprecise. Thus, the results obtained by the individual team members not only needed to be collected but also required critical evaluation in terms of the probability that potential targets reported by the sensors actually represent targets. The phase of evaluation and target selection is thus another highly critical phase in the team decision-making process. Effective teams succeeded in integrating the subtasks of their individual mem-

bers in that individual reconnaissance results were reported rather than potential target coordinates based on pre-evaluations by the individuals (a tactic primarily employed by ineffective teams). This enabled effective teams to jointly evaluate and compare the results reported by the individual members. Based on the joint evaluation, effective teams developed a list of those targets that they planned to strike. Compiling the strike plan was again done jointly, or one or two team members volunteered to do so and were supported by their fellow team members. Ineffective teams, however, often enough failed to integrate reconnaissance results and/or to develop a list of presumed targets Their members executed the strikes at presumed targets rather autonomously while this was done in form of a concerted action by effective teams

In regard to research question 2 referring to identifiable phases within the team decision-making process, the qualitative analyses revealed nine distinct phases: team forming, problem analysis, resource orientation, (strategic) reconnaissance planning, information gathering, integration of reconnaissance results, assessment of action options, decision, and action. From a process perspective, effectiveness appeared to substantially depend on how much attention, if any at all, was given to resource orientation (a finding in line with the identified importance of expertise location), strategic planning (a finding that supports results of previous research involving face-to-face teams (e.g., Hirokawa, 1980), result integration, and assessment of apparent options. Effective teams appeared to diligently go through all of these phases and reach decisions required before further steps (dependent on these decisions) were taken. In ineffective teams, these core phases were often non-existent or were given very little attention, and appeared to overlap to a degree that essentially inhibited effective execution of further steps as the decisions on which they depended had not been made or were just under way. Corresponding to this finding, appropriate communication sequencing has previously been shown to be relevant for team effectiveness in face-to-face teams (Hirokawa, 1980).

Research question 3 referred to whether team effectiveness is affected by the patterns of communication among team members. Analyses using Bales' (1950) IPA revealed that effective teams devoted significantly more effort to conveying information and answering questions (task-related communication), but at the same time showed significantly fewer negative reactions (socio-emotional communication) than ineffective teams. In particular, the higher percentage in (negative) socio-emotional communication in ineffective teams indicates that they had less time available for task-related communication which eventually impacted their effectiveness adversely. These findings are well in line with previous suggestions that team effectiveness seems to depend on the proportion of communication devoted to the task rather than to socio-emotional issues (e.g., Fischer et al., 2007; Kanawattanachai & Yoo, 2007), in particular when teams are under time pressure (e.g., Hirokawa & Salazar, 1999; Li, 2007; Orlitzky & Hirokawa, 2001). An additional more inductive qualitative interaction analysis showed that team effectiveness seemed to essentially depend on the attention given to communication on the reconnaissance strategy the team wanted to use, messages intended to provide guidance to others, and coordination efforts. Also, communication to validate or confirm targets suggested by others appeared to positively influence team effectiveness although this result did not show statistical significance, which may be largely attributable to the relatively small sample size involved in the statistical analyses.

Research question 4 concerned role structures emerging in effective and ineffective teams. It was found that although leadership attempts were equally made in both groups, the respective individuals were more successful in the effective teams. In ineffective teams attempts to take the

leadership role were often dismissed by some or all of the other team members. This finding clearly indicates that successful leadership depends just as much on acceptance by followers as on the quality of the leader candidates' behaviors. It was also found that leaders in effective teams frequently gave the reasons for their suggestions and decisions. This is in line with Innami's (1994) finding that reasoning orientation among team members, i.e., the extent to which team members exchanged facts, gave reasons supporting a particular judgment, and clarified conditions and assumptions of judgments, increased team decision quality. Temporary leadership occurred both in effective and ineffective teams. But whereas leaders in ineffective teams simply appeared to lose or quit their leadership role later in the process, emergent leadership in effective teams tended to harmoniously shift from one member to another which supports previous findings from effective face-to-face teams (e.g., Alby & Zucchermaglio, 2006). Both in effective and ineffective teams, emergent leaders tended to send a larger number of messages in general and of task-related, especially procedure- and coordination-oriented, messages in particular. Again, this findings are in line with previous findings from face-to-face teams (e.g., Hawkins, 1995; Ketrow, 1999; Mullen, et al., 1989; Yoo & Alavi, 2004). Emergent leaders tended to assume various roles: The proceduralist was primarily concerned with making procedure-oriented or coordination-related suggestions and assignments, the content integrator engaged in integrating the results gathered by the individual team members and promoting the evolution of a joint decision, and the socio-emotional integrator cared for team cohesion and participation of all members throughout the process. The second of these roles corresponds to the integrator role identified by Yoo & Alavi (2004), the first role appears to resemble these authors' initiator role. The scheduler role identified by these authors could not be found in this study, but based on the findings the role of the socio-emotional integrator could be added. Proactive followership, primarily found in effective teams, was characterized by appropriately responding to the emergent leader's suggestions, assignments and requests, providing sufficient information in time, and participating actively in the integration process. Thus, team roles performed particularly in effective teams were those of the identified emergent leader and proactive follower roles, complemented by a role that may be termed as time-observer.

Practical implications

The findings discussed above have a number of practical implications. First, it turned out to be essential that a team pays sufficient attention to the exchange of information on available resources right at the very start of an endeavor. These resources may include information or specific expertise that at least one team member owns (expertise location), available methods and tools and their performance characteristics, or even contacts to others who are not members of the team but may contribute to completing the team task.

Another essential implication is the capability of networked teams to make full use of the potential inherent in the network configuration. This refers especially to training of networked teams to improve the 'maturity' of their collaborative capability so that true resource sharing and sophisticated coordination becomes a matter of routine, replacing mere de-conflicting that appears to be frequently employed in contemporary endeavors. These considerations pertain to several aspects such as information gathering, timely information exchange, joint evaluation of options, decision-making that should be truly collective, and sufficiently concerted execution of agreed decisions. High-level collaboration satisfying these requirements will then facilitate the emergence of true synergy of collective efforts. However, it appears that realization of these aspects

requires that team members have had the chance to develop shared mental models which in turn enable shared situational awareness to emerge. Network-enabled collaboration training will have to take this into account.

The finding that collaboration under time pressure seems to be more effective when teams are focused on task-related rather than on socio-emotional communication underscores the importance of task-oriented training. However, especially in highly challenging and complex endeavors this may be effective only if teams have had enough time and chance to evolve through the classical team process phases of forming, storming, and norming (see Tuckman, 1965). In particular the storming phase involves conflict and thus often substantial negative socio-emotional communication which was found to impede effective team functioning. In regard to task-related communication, a particular focus should be placed on sufficient discussion of procedural and coordination matters.

Finally, with regard to emergent role structures, training should give attention to the development of leadership qualities, in particular with respect to the performance of essential emergent leadership functions such as proceduralist, content integration, and maintenance of cohesion. In addition, both effective proactive followership and possibly required shifts of leadership functions, or enactment of shared leadership, require that the team has had a chance to develop an appropriate level of at least cognition-based trust which is a dimension of the transactive memory system of a team (see Kanawattanachai & Yoo, 2007).

Limitations and future research

There are limitations to this study that have to be taken into account also with regard to implications for future research. First, the sample size was relatively small in that only eleven effective and twelve ineffective teams were analyzed. Future studies should try to include larger samples to increase the explanatory power of the findings. Second, the task the teams had to complete in this study was well-structured which may not be the normal case in complex endeavors of the future. Studies involving more complex problems may be required. Furthermore, the study used small and thus easily manageable teams of four individuals whereas future endeavors may more often than not include substantially larger teams. Finally, the teams in this study were quite homogenous which may again not be the standard case in complex endeavors that require collaborative employment of all mechanisms of national and international security policy: Diplomatic, information, military, and economic (DIME). Thus, in addition to more complex team tasks involving effects in additional functional arenas, future studies thus should attempt to employ teams composed of members that are heterogeneous in terms of type and level of training, service branch, rank, organizational affiliation (e.g., military and non-military such as various kinds of international governmental and non-governmental organizations), and culture.

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Annex

Area		Description of behaviors	Problem of …
Socio-emotional area: Positive reactions	1	shows solidarity, raises other's status, gives help, reward	Reintegration
	2	shows tension release, jokes, laughs, shows satisfaction	Tension reduction
	3	agrees, shows passive acceptance, understands, concurs, complies	Decision
Task area: Problem-solving attempts	4	gives suggestion, direction, implying autonomy for other	Control
	5	gives opinion, evaluation, analysis, expresses feeling, wish	Evaluation
	6	gives orientation, information, repeats, clarifies, confirms	Communication
Task area: Questions	7	asks for orientation, information, repetition, confirmation	Communication
	8	asks for opinion, evaluation, analysis, expression of feeling	Evaluation
	9	asks for suggestion, direction, possible ways of action	Control
Socio-emotional area: Negative reactions	10	disagrees, shows passive rejection, formality, withholds help	Decision
	11	shows tension, asks for help, withdraws out of field	Tension reduction
	12	shows antagonism, deflates other's status, defends/asserts self	Reintegration

Table A1. IPA scale by Bales (1950)

Strategy Q	Strategy F
Player 3: I take on top left. Player 4: Me top left. Player 2: Me south. Player 3: Okay, me top right. Player 4: Bottom left. Player 2: Coverage H-K. Player 1: Partition into four quadrants: top left, right, bottom left, right. Me bottom right. Player 2: Top right. Player 3: No! Player 2: What is still vacant? Player 3: Bottom right. Player 1: That's what I have! Player 3: Top left then. Player 2: Top left. Coverage A-D. Player 1: Definitely a target at G10. Player 3: Strike: a10, c8. Player 4: Here are my strikes: J2, I4, H1. Player 2: Strike c4, d5.	Player 3: Satellite [low-precision] recce, please report assumed targets and make assignments for precision recce. After that, comparison of results and confirmation for strike. Player 4: Ok. Player 3: Alpha 1 and Alpha 2, please confirm! Player 2: Yes. Player 1: Yes. Player 3 scans. Player 3: ok, assumed targets: C5/ D1/ D4/ D8/ E3/ G4/ H3/ H4// I1/ J10. Player 2: I have Tornado [high-precision sensor], will check targets c5, d1, d4. Player 1: I have Drohne and Luna [high-precision sensors]. [Will check] d8, e3, g4. Player 2: [I can] confirm c5, d1, additional target e3. Player 2: h5 not confirmed, i6, c5, d1, e3, j10 confirmed. Player 3: Who else can confirm i1! I have 5/6. Player 1: i1 two hits out of two with 5%.

Table A2. Chat protocol samples illustrating different reconnaissance strategies

Individual evaluation, no integration	Joint evaluation and subtask integration
Player 2: Report assured targets. Player 2: B1. Player 2: Who else has targets? Player 2: B1. Player 3: I have finished. Player 2: Which targets? Player 4: A7, C10, perhaps K6. Player 2: The others. Player 2: B 10 assured. Player 2: Hey guys. Player 2: What's up. Player 4: Only targets, not what is assured! Player 2: Whatever you think where targets are. Player 4: Avoid unnecessary messages! Targets so far: A7, B1, C10, perhaps K6. Go ahead! Player 1: A7, perhaps C8. Player 2: Bravo 1, [what about] your targets. Player 4: Four targets are still missing. Player 1: Still targets? Player 2: B1. Player 4: What about Bravo 3? Don't you have any targets??	Player 4: Somebody with Tornado [high-precision sensor], please summarize and report all data. Player 2: e6 three red, h2 two red, h4 two red, b10 one red but with Tornado, a3 one red non-assured. Player 1: b10 e5 e6 f3 h2 h4 Player 3: I have three red at a3. Player 4: Yes, a3 is good, I have two red ones, no green there. Player 1: What about j9. Player 3: 4 green. Player 1: Ok. Player 2: Ok, then a3, too; I have one red at j9. Player 4: j9 green red non-assured. Player 2: Ok, then targets from Echo1 and a3?! Player 4: b10 e5,6, f3, h2,4 strike?? Player 4: yes, and a3. Player 1: Ok, here are the targets: a3, b10, e5, e6, f3, h2, h4. Player 1: ssssstrike.

Table A3. Chat protocol samples of result evaluation and subtask integration

Ineffective strike coordination	Effective strike coordination
Player 4: And in which rounds are you guys? Which targets should we all attack? Player 2 strikes. Player 1: I am in round 3, have confirmed targets e7 h6. Player 4: I take h6 and e7 and e8 for strike. Player 4: Took f4. Player 3: E8+F4 are no targets. Player 4: Whole C-series. Player 1: a3 confirmed. Player 3 strikes. Player 1 scans in recce round 4. Player 4 strikes. Player 1: Do you still have targets? Player 1: I have only three, which ones did you strike? Players 2, 3, 4: n? Player 1 strikes.	Player 3: Confirmed are: 7b, 10e, 1i, 7i, 9j. Player 3: Check 10b and 10j! Player 1: All north data from Charlie 4 negative, what shall I do? Player 2: 10b is a target, probably 10j isn't. Player 3: ok, than we have 6 already. Player 1: Shall I check anything else? Player 3: Try 7j. Player 3: and 9f. Player 1: Ok, will do. Player 1 scans. Player 1: 7j assured, 9f not. Player 2: 7j could be a target. Player 3: Ok, than we have all! Player 2: One of you, please list all. Player 3: 7b, 10e, 1i, 7i, 9i, 7j, 10b. All players strike.

Table A4. Chat protocol samples illustrating effective and ineffective strike coordination

Ineffective teams	**Effective teams**
Player 4 scans. Player 4: first round completed? Player 3: not yet. Player 3 scans. Player 2 scans. Player 4: scanned top lines with 5*5 Player 1 scans. Player 2 scans. Player 3: scanned everything from F2-K9 with 3*3 Player 2: I did the quarter bottom right Player 1: scanned f/g 1-9, one adversary g2 Player 4 scans.	Player 1: Fox2 leads, ok? I have Drohne sensors 3*2 10%failure, 1*2 5%failure. Player 4: Ok. Player 2: Ok. Player 3: I have rough sensors 5*5, 3*3. Player 2: Fox 4 starts with large-coverage recce. Player 4: I have 5*5 and 3*3. Player 3: Me too. Player 2: 5*5 Player 4: Ok. Player 3: Shall we divide the task? Player 2: Fox 3, too. Player 4: I start top left. Player 2: Large-coverage recce. Player 3: Fox 4 does top half completely to line e, I do from there to bottom. Player 4 scans. Player 2: Then only Fox 4 reports results first. Player 4 scans. Player 3 scans.

Table A5. Information collection planning in effective and ineffective teams

Ineffective teams	**Effective teams**
Player 2 scans. Player 1: I go top left. Player 4 scans. Player 4: Me bottom left. [All players scan; no more communication about task division for information gathering]	Player 3: I have 5*5. Player 4: Me too. Player 2: Ok, the large-coverage sensors scan with 5*5 and report coordinates of interest. Player 1: I do high-precision recce North. Player 4: I do West. Player 2: Me South, but we first wait for coords. Player 3 and 4 start scanning.

Table A6. Information collection in effective and ineffective teams

Ineffective teams	**Effective teams**
Player 3: G5 and H5 two hits each. Player 1: Echo 4, your results????? Player 3: J6 two hits. Player 4 strikes. Player 4: Echo 1 I don't understand??? Player 2: c4,a1,b9,d3 Player 1: Where are your hits? Player 4: One of us has not finished yet. Player 3: A1 A2 A8 three hits. Player 3: No, I am ready for strike. Player 4: Echo 1, are you ready? Player 2 strikes. Player 4: Faster!!! Player 1 scans twice, strikes. Player 3 strikes.	Player 2: c3 is one. Player 3: e2 too. Player 3: i8 too. Player 4: c3 looks gut, 3 hits at 3 scans. Player 3: please check h3. Player 1: c3, d2, e3, i8 red for sure. Player 3: I have 4 green, 2 red at d2. Player 2: h3 is one. Player 3: What about b1. Player 4: H3: 2 hits 1 fail (2:1). Player 4: b1: 2:0 Player 3: b1 two red. Player 1: b1, h3 100% red. Player 3: c8 2red, 1green. Player 1: I repeat: at d2 e2 i8 b1 h3 red, at c8 I have 2 green. Player 2: Do we have all? d2, e2, i8, c3, h3, e3, b1.

Table A7. Result integration in effective and ineffective teams

Ineffective teams	**Effective teams**
Player 4: Assured: d1, f3; rather likely (50%) f5. Player 3: I have hits at a2,a6,c1,d1,e5. Player 3: In the North. Player 4: I have 2 green ones and no red at c1. Player 4: Bravo 1 and 2? Player 4: strikes? Player 4: We still need 1or 2 coords. Player 2: All clear in my area. Player 1: I have already finished. Player 3 strikes. Player 4: No targets???? I can still offer f5 as very uncertain, and k4. Player 3: Too late, stroke already.	Player 2: I can confirm b10 c8 f2 i8 k3. Player 4: I have f2,b10,c8,d10,i7,i8 for sure. Player 4: Then the targets are f2,b10,c8,d10,i7,i8,k3. Player 1: Targets with 95% probability at B10;C10;D10;C8;F2;I8;K3. Player 4: Now the question is c10 or i7? Player 3: No: B10, C8, D10, F2, I7, I8, K3. C10 has 6 green ones. Player 1: 6 assured targets: C8; B10; D10; F2; K3; I8; no target for sure: C10. Player 4: Ok, then strike.

Table A8. Evaluation and target selection in effective and ineffective teams

Ineffective teams	**Effective teams**
Player 3: I do G H I. *Player 1: Large-coverage sensors, report as soon as you have results, then I try to confirm.* Player 2: I have Tornado and Breguet. *Player 1: G H I, that's nonsense.* Players 4 and 3 scan. *Player 1: I do a b c.* Player 4 scans twice. *Player 1: Echo 1 + 2, wait for reports of Echo 3 + 4.* Player 3: G5 and H5 two hits each. Players 4, 2 and 3 scan. Player 2 scans twice. *Player 1: Echo 4, your results?????* Player 3: J6 two hits. Player 4 strikes.	*Player 1: Tactic: 5*5 sensors scan all 4 rounds and then please report hot cords! (50% hits).* Player 3: Let's directly report likely targets! Player 3: We don't have a common result picture. *Player 1: That's why 5*5 sensors should assign possibly targets to high-precision sensors. So, 5*5 sensors, scan through.* Player 3: Ok. Players 3 and 4 scan.

Table A9. Leadership attempts in effective and ineffective teams

Player 2: All large-coverage sensors go first, the high-precision sensors check afterwards.
Player 3 scans.
Player 4: 4: 5*5 15%,3*3 10%.
Players 4 and 3 scan.
Player 1: Please report interesting coords for high-precision recce after large-coverage scans.
Players 3 and 4 scan twice each.
Player 2: E2*2 10% 5% 3*2 15% 10%
Player 4 scans.
Player 3: Interesting coordinates: B10, C8, D10!, E4, F2, H9, I7, I8!, K3!
Player 2: I check: B10 C8 E4 F2 H9I7.
Player 2 scans twice.
Player 4: Can someone check g2.
Player 1: I check D10, I8, K3, G2.
Players 1 and 2 scan.
Player 1: Target at K3, I8, D10 with 95% probability; nothing at G2.
Player 2: I can confirm b10 c8 f2 i8 k3.
Player 4: I have f2,b10,c8,d10,i7,i8 for sure.
Players 1 and 2 scan.
Player 4: Then the targets are f2,b10,c8,d10,i7,i8,k3.
Player 1: Targets with 95% probability at B10;C10;D10;C8;F2;I8;K3.
Player 4: Now the question is: c10 or i7.
Player 3: No: B10, C8, D10, F2, I7, I8, K3. C10 has 6 green ones.
Player 1: Six assured targets: C8;B10;D10;F2;K3;I8; no target for sure: C10.
Player 4: Ok, then strike.

Table A10. Shifting leadership in an effective team

Player 3: Reconnaissance with Satellite sensor – report assumed targets and assign tasks for high-precision reconnaissance.
Player 3: The one with the Satellite sensor assigns high-precision reconnaissance tasks.
Player 3: After that, comparison of assumed targets and strike confirmation.
Player 3: Very easy ;)
Player 4: Very well understood!
Player 3: Alpha 1 / Alpha 2 – confirm!
Player 2: Yes.
Player 1: Yes.
Player 3: Great :D.
Player 4: I guess that will work.
Player 1: How can we reach an agreement on who scans where after the Satellite?
Player 3: The one with the Satellite sensor should make the assignments.

Table A11. Procedural assignments made by an emergent leader

Player 3: Confirm reconnaissance results and then comparison of assumed targets.
Player 1: d8 two hits out of two. E3 two hits out of two. G4 two out of two. F3 one out of two.
Player 4: I confirm i1, j10, with two hits, H3 with no, H4 with one hit.
Player 2: h4 not confirmed, I confirm i6, c5, d1, e3, j10.
Player 1: I assume targets at d8, e3, g4.
Player 2: One hit each.
Player 3: Who else can confirm I1? I have 5/6.
Player 1: i1 two hits out of two with 5%.
Player 4: I1 very likely a target!
Player 4: I report three hits.
Player 4: And three hits at J 10.
Player 3: According to the list, the following targets have been repeatedly confirmed: C5 / D1 / D8 / E3 /G4 /I1 / J 10
Player 3: I suggest that we strike these targets!
Player 2: Ok.
[All players strike]

Table A12. Result integration done by an emergent leader

Player 2: So, Fox 4, do you have all?
Player 2: Have you scanned everything once?
Player 3: I have only scanned at the bottom, what am I supposed to do?
Player 2: Once again in the upper area.
Player 2: Fox4?
Player 4: I have hits at i6 g8 j9, twice red each.
Player 2: Scanned everything once?
Player 3 scans.
Player 4: Will scan twice in the upper area, too. Wait.
Player 2: Ok. Fox 3, does this correspond with your results?
Player 2: Fox3 ?
Player 4 scans.
Player 3: I scanned top and bottom, 2 rounds in sum.

Table A13. Group cohesion maintenance done by an emergent leader

Player 3: e6 definitely … I have six red ones there.
Player 1: Don't strike.
Player 2 scans.
Player 3: I also have B 10 (4 red ones).
Player 1: The question is: who else and with which sensor?
Player 4: b10 is ok, e6 is reliable, too.
Player 4: Somebody with Tornado or something similar, please summarize and provide all data.
Player 2: e6 three red; h2 two red; h4 two red; b10 one red, but with Tornado; a3 one red not sure
Player 1: b10 e5 e6 f3 h2 h4
Player 3: I have three red ones at a3.
Player 4: Yes, a3 is good; I have two red ones there, no green ones.
Player 1: What about j9?
Player 3: Four green ones.

Table A14. Active participation by a proactive followers

Player 1: Echo 1 and 2 wait for what Echo 3 and 4 report.
Player 3: I can report two hits each at G5 and H5.
Player 4 scans (round 4 of 4).
Players 1 and 3 scan.
Player 1: Echo 4, your results?
Player 3: Two hits at J6.
Player 4 strikes.
Players 2 and 3 scan.
Player 4: Echo 1, not understood.
Player 1: Where are your hits?
Player 4: One of us has not finished yet.

Table A15. Example of uncooperative follower

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