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Title: Collaboration Technology in Military Team Operations: Lessons Learned from the Corporate Domain

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Collaboration Technology in Military Team Operations: Lessons Learned from the Corporate Domain

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Abstract

Collaboration technologies used in current military operations, such as email, instant messaging, and desktop conferencing, assist explicit communications between distributed team members. However, research in corporate environments has shown that explicit communication, while an important aspect of collaboration, is often used together with more subtle interactions to help teams communicate and coordinate their joint work. For example, monitoring other team members' on-going task activities help teams integrate related task activities, identify appropriate interruption opportunities, and provide assistance when necessary. When physically distributed, as is often the case in command and control environments, it is difficult to engage in such subtle behaviors because team members' activities are not visibly accessible. Instead, people must resort to explicit methods, such as asking for a status update. These explicit methods require effort from both parties and can be disruptive. To address these issues in corporate work settings, collaboration technologies have been developed to help people remain apprised of remote colleagues' activities, while minimizing disruption. This paper examines the suitability of these corporate technologies for supporting military team interactions, with a focus on identifying aspects of military teamwork that are well supported by these approaches and aspects requiring new methods.

Introduction

Teamwork and collaborative decision making is a critical component both now and in the military's vision of network centric operations (Alberts, Garstka, & Stein, 2000; Alberts & Hayes, 2003). A basic tenet of networked forces is allowing individuals and/or groups the ability to leverage information both locally and globally to reach effective decisions quickly. Collaboration is both a critical element of network-centric operations and of military operations in general. Advances in network capabilities have already increased the connectivity of military operators, and automated sensor and intelligence feeds have increased their access to previously unavailable information. However, the abilities of humans to access this information, filter and understand the information, share it between groups, and come to a consensus all under the added stress of the time-pressure makes collaboration in network-centric operations a likely failure point for overall mission success.

To help operators communicate and exchange information in network-centric environments, remote team members are beginning to rely heavily on popular commercial collaboration technologies such as email, instant messaging (or 'chat'), and video and desktop conferencing applications (Boiney, 2005; Klein & Adelman, 2005). These technologies can be very helpful for conversing and sharing files with remote collaborators. Yet, studies of collaboration in corporate environments have shown that such explicit communication and information sharing, while an important aspect of collaboration, is often accompanied by more subtle group interactions to help people communicate and coordinate during joint work (Gutwin & Greenberg, 2004; Scott, Carpendale, & Inkpen, 2004; Tang, 1991). For example, monitoring other group members' on-going task activities can help a group integrate related task activities, identify appropriate interruption opportunities, and notice when a team member requires assistance (Gutwin & Greenberg, 2004; Pinelle, Gutwin, & Greenberg, 2003).

When physically distributed, it is difficult to engage in subtle group behavior because operators' activities are not visible to their remote team members. Instead, operators must rely on explicit methods, such as asking for the priority of requested information or requesting an update on a team member's current task activities. Explicitly asking for such information requires effort from both parties and can be disruptive. To address these issues in distributed corporate work settings, collaboration technologies have been developed to provide collaborators more sophisticated communication and information sharing mechanisms. These mechanisms help to facilitate overall team performance and to reduce the costs associated with collaborating at a distance. This paper examines the suitability of these corporate technologies for supporting teamwork in military command and control settings.

To provide further context to this investigation, the paper first provides more details about the limitations of collaboration technologies primarily designed to support explicit communication and information sharing. The paper then describes the design approaches and collaboration technologies which have been developed to provide corporate collaborators richer communication and information exchange capabilities. Finally, the paper discusses the feasibility of applying these design approaches and collaboration technologies to military team settings.

Limitations of Explicit Communication Support

Communicating via existing collaboration technologies such as email, instant messaging, and desktop conferencing, lacks the richness of face-to-face interactions, but promises efficient collaborative interaction. For instance, people can send a remote colleague an email or text message to impart information without the obligatory social pressure of further interaction. However, information exchange is only one aspect of collaboration and over time, the lack of support for other types of communication and interaction often results in teams expending considerable time and effort, diminishing any initial time savings and impacting overall team performance (Powell, Piccoli, & Ives, 2004). For example, difficulties often arise because individuals attribute different salience and interpretation to the same written text. Such differences can result in miscommunications, additional time for resolution, and if undetected, can lead to serious communication or coordination breakdowns later in the collaboration (Clark & Brennan, 1993; Powell et al., 2004). This is particularly problematic in instant messaging dialogue which is generally unstructured and informal.

Beyond collaborative explicit information exchanges, research has shown that additional knowledge facilitates collaboration, such as knowing:

- the context of shared information (e.g., How does this information relate to the overall shared activity being performed?) and its source (e.g., Is this person trustworthy? Are they being sarcastic? Are they overwhelmed?) (Powell et al., 2004),
- who else is working on related activities, and their current and future status (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003),
- who is available to offer assistance and when assistance should be offered (Gutwin & Greenberg, 2004; Pinelle et al., 2003; Scott et al., 2004), and
- the shared activity's overall progress, how each team member's actions and communications relate to this shared activity, and the priority of these actions and communications in the context of completing the overall activity (Carroll et al., 2003; Heath & Luff, 1992; Mark, Abrams, & Nassif, 2003).

Much of this information is readily accessible during face-to-face collaboration because team members' actions and the context of these actions are visible. Furthermore, non-verbal communication cues are available, which aid interpretation of people's communications and actions (Short, Williams, & Christie, 1993). In contrast, obtaining this team-related information using existing collaboration technologies introduces significant costs due to the ongoing need to request information from remote colleagues and respond to these requests. Even proactively sharing information requires effort from the provider and may be disruptive to the recipients if it is provided at an inopportune time (e.g., they are activity engaged in critical task activities) (Dabbish & Baker, 2003; Dabbish & Kraut, 2004).

Successful human interaction relies heavily on learned social practices, or social norms, to negotiate efficient and effective interaction (Altman, 1975; Clark & Brennan, 1993; Heath & Luff, 1992; Schmidt, 2002; Scott et al., 2004). Effective use of these social norms depends on perception and interpretation of many relevant cues from collaborators. For example, effective communication occurs because people have learned to negotiate turn-taking required during conversations; most people are adept at interpreting a pause coupled with direct eye contact as an opening to begin a conversational turn. Studies of effective teamwork have also revealed that an essential social practice in collaboration is for team members' to monitor their partners' communications and actions (Clark & Brennan, 1993; Heath & Luff, 1992; Scott et al., 2004). Team members tend also to engage in appropriate 'displays' of information that facilitate this monitoring behavior (Heath & Luff, 1992; Schmidt, 2002). For example, in a study of teams of control operators in the London Underground, Heath and Luff (1992) found that operators verbally announce timetable changes, and repeat and emphasize certain words during telephone conversations knowing that their colleagues will hear this information and, thus, be apprised of these issues. Together, these social practices help teams maintain awareness of the state of each member and their status on overlapping task activities, fostering the overall collaboration process

(Schmidt, 2002). Additionally, these behaviors are typically performed with minimal disruption to other team members' activities.

Unfortunately, the sparseness of information conveyed by typical collaboration technologies restricts people's ability to gather subtle contextual and communication cues or engage in assistive behaviors, such as monitoring and displaying, without disrupting the groups' ongoing activities. This limitation interferes with collaborators' ability to correctly negotiate smooth interaction and is often the cause of miscommunications and coordination breakdowns (Clark & Brennan, 1993; Easterbrook, 1996).

Lack of communication and contextual cues is particularly problematic during synchronous distributed interactions via collaboration technologies, which will become more ubiquitous in network centric operations. In these environments, cues like conversational pauses can be misinterpreted and introduce unwarranted tension or confusion. For example, when someone fails to respond to a text message, the sender of the message may misinterpret this lack of response as annoyance or disagreement with their statement, though it is just as likely that the message receiver has been interrupted by a visitor. In most collaboration technologies, the remote colleague is given no immediate evidence that his or her teammate is unavailable.

The Computer-Supported Cooperative Work (CSCW) research community, which traditionally has focused on understanding and supporting collaboration in corporate office settings, has been designing and investigating collaboration technologies for decades. In recent years, this research community has begun to focus on understanding the limitations of existing collaboration technologies and redesigning them to enable more effective interaction. As discussed above, many of the limitations of these technologies are related to the inherent leanness of the communications enabled by their design and the effort involved in providing more than the minimal amount of information via these media. In order to mitigate these design limitations, enhance interaction between remote collaborators, and ultimately improve the overall effectiveness of distributed collaboration, the CSCW community has begun developing collaboration technologies that provide richer information about a remote team member's overall working context. The following section describes these recent innovations and discusses what aspects of distributed teamwork they support.

Corporate Collaboration Technologies and Design Approaches

A review of the CSCW literature revealed several approaches for enhancing distributed collaboration. The approaches discussed in this paper were selected because they help reduce the user's effort in obtaining or sharing 'additional' information about remote collaborators' communications and actions, beyond what is typically provided during explicit information exchanges. Hence, this discussion focuses on those systems designed to minimize the overhead of remote collaboration which is critical for operators in time pressured environments such as those found in typical command and control settings.

Three main design approaches emerged from reviewing the CSCW literature. The first approach involves, whenever possible, automatically providing information related to remote colleagues' working context. This could include the provision of availability and location information to help remote team members schedule and initiate collaborative interactions. The second approach involves providing non-disruptive communication mechanisms during distributed interactions to reduce the costs of providing remote feedback and backchannel communication, as well as minimizing miscommunications and costly communication repairs. The third approach involves providing better support for the overall shared activity process, and helping collaborators coordinate their related interactions in order to stay apprised of their team members' task activities.

The following sections describe these approaches in more detail, along with examples of corporate collaboration technologies that have been designed using these approaches.

Providing Automatic Contextual Awareness Information

An essential part of collaboration is knowing when and how to communicate with a collaborator. As discussed above, determining whether a remote collaborator is available for interaction can be challenging with current collaboration technologies. This difficulty is due, in part, to the overly simplistic models these technologies use to provide status updates to connected team members. In most instant messaging applications, for example, the availability status of a remote colleague is determined either explicitly by that person actively indicating their availability in the interface or by the system automatically inferring availability status based on whether the person is currently typing. However, neither of these approaches adequately reflects a person's actual availability for remote interaction. People find explicitly updating their own status effortful, distracting and, thus, providing updates are often neglected, especially when people are busy (Begole, 2005; Nagel & Abowd, 2002; Scupelli, Kiesler, Fussell, & Chen, 2005). Furthermore, studies have shown that being physically present does not necessarily correspond to being receptive to interruption (Begole, Tang, Smith, & Yankelovich, 2002; Dabbish & Baker, 2003; Dabbish & Kraut, 2004). Therefore, someone being active on their computer does not necessarily signify that they are available for interaction. In terms of military settings, this person might be performing a critical task operation that would suffer from interruption such as time sensitive targeting.

In order to provide meaningful cues about team members' availability that will enable someone to appropriately determine how and when to interact with that person, CSCW researchers have investigated design approaches that provide more sophisticated and accurate cues about someone's availability and receptiveness to interruption.

Dabbish and Kraut (2004) have explored methods of automatically conveying information about remote colleagues' task activities to help teammates more appropriately judge when to interrupt someone when they require assistance or wish to share information. Their research indicates that providing an abstract view of relevant details of the remote colleague's activities (e.g. showing a running count of the number of on-screen objects a person is controlling in a game) is more effective than providing precise details of that person's activities (e.g. showing the full details of that person's on-screen activities). Both approaches help people determine appropriate times to interrupt a remote team member; yet, providing the full details of that persons' activities tends to be overwhelming and distracting from other task activities (Dabbish & Kraut, 2004). In contrast, providing an up-to-date, abstracted view of remote team members' activities enables people to appropriately determine a colleague's receptiveness for interruption, while minimally distracting from their own task activities, facilitating overall team performance.

While useful for indicating remote team members' computer activities, this approach provides little information regarding their occupation with activities beyond the computer. Someone who is interacting infrequently with their computer may actually be explaining an on-screen diagram to a colleague sitting with them at their computer; hence, they may be quite unreceptive to an interruption that is not of the utmost importance.

To address this issue, Begole et al. (2004) have developed a system, called Lilsys, which uses a combination of technologies to help infer someone's availability for remote interaction. Lilsys aggregates computer-based information (current activity and calendar appointments) with data from a range of sensors located in the environment (audio, motion, and door sensors) in order to infer four probable levels of availability: neutral (probably available), possibly unavailable, probably unavailable, and offline (definitely unavailable). This availability information is then indicated with representative traffic symbol icons in remote colleagues' instant messaging contact lists (see Figure 1). A person's likely location and likely time of return, based on calendar data, is also displayed.

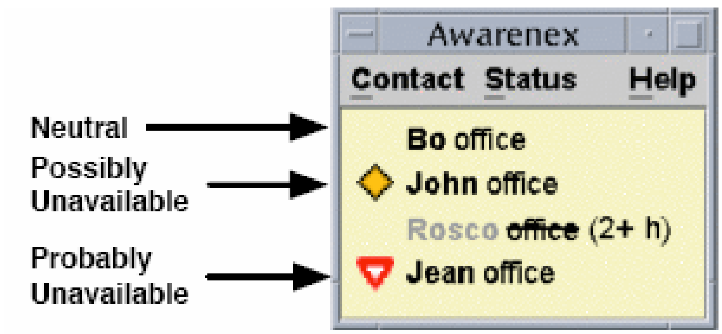

Figure 1. The Lilsys application combines available automation sources to make intelligent inferences regarding the availability of remote collaborators (from Begole et al., 2004).

In summary, using automation to provide relevant contextual cues to remote team members facilitates remote negotiations by improving team members' ability to determine how and when they should contact and interact with their team members. Providing richer context cues other than the standard 'online' or 'away' indicators used in many collaboration technologies enables people to determine the relative priority of their request and choose an appropriate action that most benefits the overall team performance.

Providing Non-Intrusive Communication Mechanisms

Another essential component of collaboration mentioned above is the ability to gather subtle communication and action cues during interactions. Current collaboration technologies typically restrict the ability to provide subtle interaction cues like backchannel cues (e.g., nods of agreement or distracted looks). To mitigate this issue, Yankelovich et al. (2004; 2005) developed an enhanced desktop conferencing system, called Meeting Central, to provide remote colleagues richer, yet non-intrusive forms of communication during distributed meetings. The Meeting Central system includes a combination of user initiated and automated mechanisms to facilitate collaboration. Their system enables participants to subtly indicate their desire to interrupt the current speaker by offering a 'handraising' feature. When a person selects this feature, a number is displayed beside their name in the conference interface (the number serves to distinguish between multiple participants who have raised their hands). Meeting Central also allows people to initiate private text or voice chats with a subset of the remote meeting participants in order to discuss a particular issue without interrupting the entire meeting. This feature is particularly useful for people joining an ongoing meeting or wishing to offer private comments to a colleague whose behavior might unknowingly be disrupting the meeting (e.g., telling someone to stop making background noise or mute their audio) (Yankelovich et al., 2004; Yankelovich et al., 2005).

The Meeting Central system also automatically provides some context information to facilitate smooth interactions. Each meeting participant's current status is automatically indicated in the conferencing interface, including whether they are currently speaking (determined by noise detected on their audio input), whether their audio is currently muted, and whether they are away (see Figure 2). Automatically providing basic status information helps to resolve many of the typical problems encountered during distributed, computer-mediated meetings. For instance, people often forget they have their audio muted and begin talking to the group. By automatically displaying status information to the group, other meeting participants can see that someone is talking while in a muted state and can remind that person that they are muted, quickly resolving the situation. Without this information, the speaker may expend considerable effort talking before they realize the group cannot hear them and will be required to repeat what they have just said. They may even miss their opportunity to speak if the meeting has moved on to other topics.

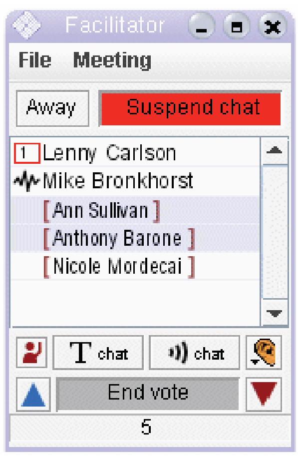

Figure 2. A Facilitator window in the Meeting Central application provides non-intrusive communication mechanisms, such as 'handraising', and automatically updated status information, such as who is speaking and whose audio is muted (from Yankelovich et al., 2005).

In summary, enabling richer, non-disruptive forms of communication during distributed collaboration can provide more opportunities for immediate feedback to help resolve or prevent misunderstandings and miscommunications. This can improve the efficiency of remote interactions since these issues can be handled quickly before problems escalate.

Supporting the Shared Activity Process

Beyond the challenges of conversing with team members via collaboration technologies, remote teams also suffer from the lack of support for the overall collaboration process in these technologies (Carroll et al., 2003; Carroll, Rosson, Convertino, & Ganoe, in press; Mark et al., 2003; Mark & Abrams, 2004; Powell et al., 2004). Teams must expend effort in addition to their ongoing task activities to provide status updates or to interrupt busy team members to ask for assistance. This effort also introduces barriers to team members attempting to provide their teammates assistance. For example, someone who has completed an assigned activity has no unobtrusive way in current collaboration technologies to find out if or how they could assist a teammate who is currently overwhelmed and unlikely to meet an upcoming team deadline.

To mitigate these issues, the CSCW community has begun to develop collaboration technologies that better support the shared activity process (Carroll et al., 2003; Carroll et al., in press; Mark et al., 2003; Mark & Abrams, 2004; Millen, Muller, Geyer, Wilcox, & Brownholtz, 2005; Scupelli et al., 2005). This design approach is aimed at providing collaborators ongoing *activity awareness* information. Carroll et al. (2003) define activity awareness as:

> **“**the awareness of project work that supports group performance in complex tasks. … It involves coordinating and carrying out different types of task components, such as assigning roles, making decisions, negotiating, prioritizing and so forth. … Activity awareness implies an awareness of *other people’s plans and understandings*. Complex, long term, coordinated activity cannot succeed without on-going interpretation of current goals, accurate and continuing assessment of the current situation, and analysis and management of resources (including time) that constrain execution of possible plans.”
>
> (Carroll et al., 2003)

Activity awareness is strongly related to situation awareness, a concept more commonly discussed in the military command and control literature (Endsley & Strater, 2005; Jenkin, 2004; Salerno, Hinman, & Boulware, 2004; Wallenius, 2004). Carroll et al. assert that “the concept of activity awareness subsumes *situation awareness*, defined informally as ‘knowing what is going on around you’” (Carroll et al., 2003, p. 613). While situation awareness and activity awareness are both concerned with “[p]erception, information processing, decision-making, memory, learning, and performance of actions, …the emphasis [in activity awareness] is on aspects of the situation that have consequences for how a group works toward a shared goal over time, rather than one person monitoring a complex information array and making real-time decisions” (Carroll et al., 2003, p. 613).

Though the formal concept of activity awareness is a recent development (Carroll et al., 2003; Carroll et al., in press), several collaboration technologies have already been developed that support the underlying notion of facilitating the shared activity process.

Two essential concepts in these technology designs are ‘visibility of action’ and ‘feedthrough of action’ (Dabbish & Kraut, 2004; Hill & Gutwin, 2003; Scupelli et al., 2005). Within the context of collaboration technologies, these concepts refer to the system playing an active role in the collaboration process by automatically providing some indication of a person’s system actions to their remote collaborators (feedthrough of action) in order to increase the visibility of these actions, thus increasing their collaborators' awareness of these actions. For example, Scupelli et al. (2005) developed an enhanced instant messaging system, called Project View IM, to visually indicate whenever a remote collaborator is currently interacting with a group-related file (see Figure 3). Providing such real-time activity information can help teams coordinate their interactions with shared file resources, as well as keep them apprised of who is working on what, giving them an overall sense of the project status.

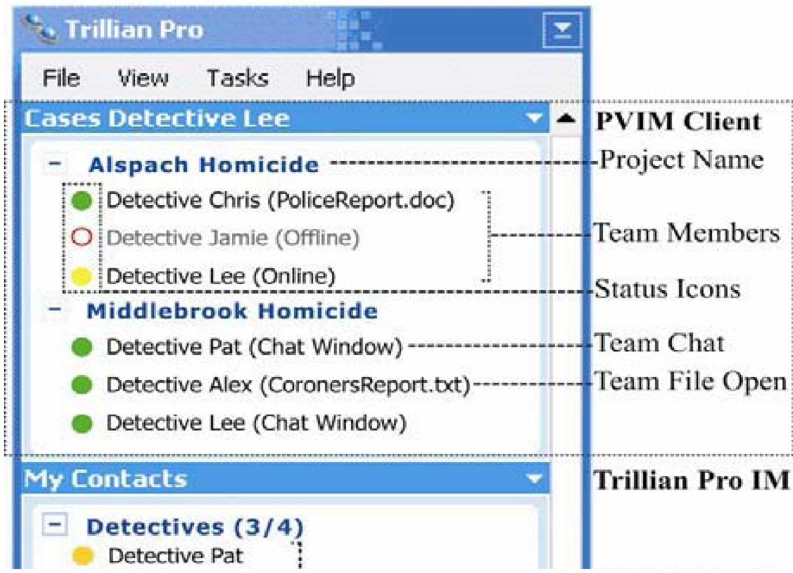

Figure 3. The Project View IM application automatically indicates which shared activity resources remote collaborators are currently interacting with (from Scupelli et al., 2005).

While this approach supports the moment-by-moment awareness of remote team members' relevant activities, it gives little indication of the overall progress and status of the shared activity. Thus, visibility and feedthrough of action alone are insufficient for providing activity awareness. In order to increase collaborators' awareness of the ongoing activity process, Carroll et al. (2003) developed several mechanisms for situating team members' activities within the context of the overall shared activity. In an application developed to assist the joint development of a large science project by groups of students from different schools, called Virtual School, they provided two types of displays to facilitate the shared activity process: a desktop interface for students to perform their individual task activities and a project summary interface, designed for large wall displays located in the separate classrooms.

The desktop interface provides a timeline of recent and ongoing activities of all members of a student's class, or 'team', including upcoming class milestones and overall project deadlines. On the project summary interface, the past and ongoing project activities and deadlines for all students, organized by classes, are shown on a project timeline (see Figure 4). This summary view enables team members to maintain awareness of the current status of the overall shared activity, of which sub-activities are progressing on schedule, and of which sub-activities need more work. This information can help team members' prioritize their own task activities and help the group as a whole delegate task responsibilities. The Virtual School interface provides team members an activity-centric space for organizing their shared virtual resources. Such activity-centric collaboration spaces have been found to help team members coordinate related task activities and to foster opportunistic collaboration (Muller, Geyer, Brownholtz, Wilcox, & Millen, 2004).

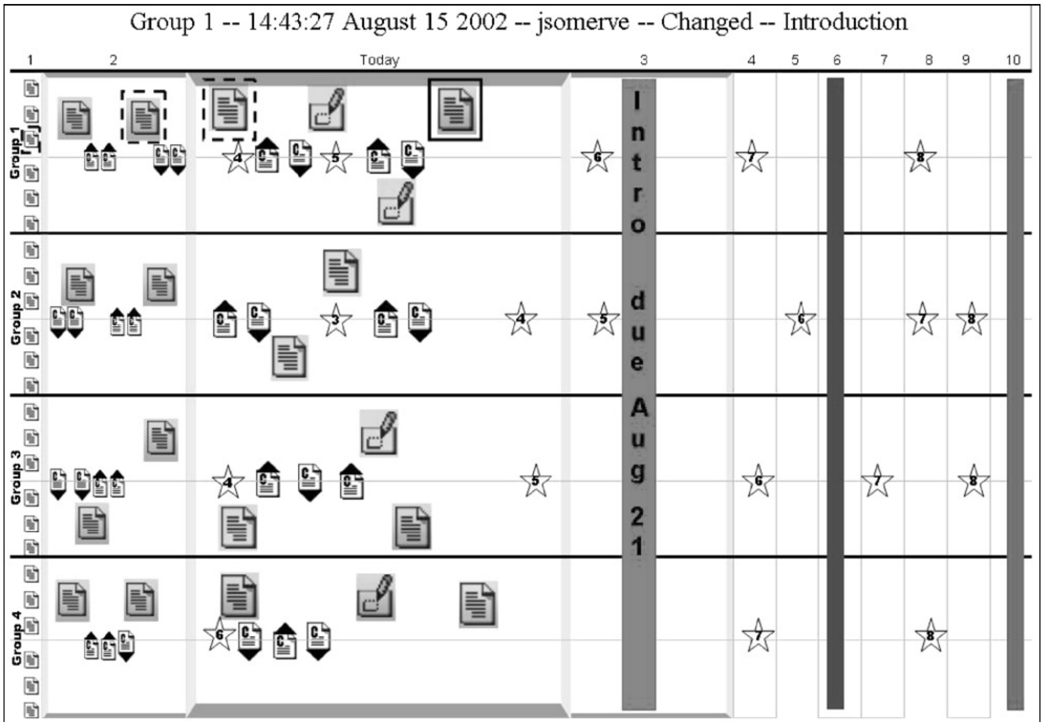

Figure 4. A team summary view in Virtual School provides an overview of the shared activity, indicating ongoing and past contributions from team members and deadlines to be met by the overall team (from Carroll et al., 2003).

In summary, providing feedthrough and visibility of team member's actions within the context of the overall shared activity process enables team members to maintain activity awareness, which can help them interpret remote collaborators' goals and actions, anticipate collaborators' future plans and actions, manage their shared resources, and stay apprised of the overall team situation.

Applying these Approaches to Military Teams

The collaboration technology design approaches discussed above directly apply to some existing military team operations. In particular, they can be used to support teamwork which occurs in office-like settings, outside of the battlefield theater. For instance, many intelligence analysts operate in technical environments very similar to modern corporate offices, using standard desktop computers with always-on network connectivity. Thus, many of the corporate design approaches, such as providing non-intrusive communication mechanisms with desktop conferencing applications like Meeting Central or providing contextual cues of collaborators' availability and receptivity for remote interruptions, could easily be incorporated into these military environments, especially since collaboration technologies are already being used in these environments (Klein & Adelman, 2005).

Enabling better social negotiation of interaction by providing relevant contextual information is particularly important in mission critical military operations. Interrupting someone while they are performing a critical task operation could have dire consequences and could possibly be avoided or minimized if a remote team member has some indication of that person's current task activities and the level of engagement required by these activities.

Similarly, military collaborators who often share documents or presentations would benefit from the corporate approaches for improving activity awareness with activity-centric collaboration technologies like Project View IM (Scupelli et al., 2005) or applications that provide summary views of the overall shared activity. These applications can help enhance team performance by facilitating coordination of related task activities and use of shared resources, providing support for time and project management, and increasing opportunist assistance.

However, the increased time pressures and mission criticality of battlefield operations introduce challenges for directly applying corporate design approaches to technologies in many military command and control team settings. The following section discusses these challenges and highlights areas warranting further investigation to improve collaboration technologies for these complex team environments.

Challenges of Applying these Approaches to the Military Domain

While some military command and control settings resemble teamwork in corporate environments, they are characteristically more chaotic since military operators must make high risk decisions under extreme time pressures, while maintaining continuous operations under rapidly changing operating conditions. These factors limit the ability of corporate collaboration technologies to effectively support teamwork in these dynamic settings.

Mission Criticality Impacts Design Priorities. Corporate collaboration technologies tend to provide fairly low fidelity contextual information of remote colleagues in order to allay privacy concerns of the office workers using these systems. For example, the availability information provided to remote collaborators' using the Lilsys system (Begole et al., 2004) is limited to basic location information (e.g., office, home, conference room) and high-level categories of inferred availability. However, this system gives no indication of *why* the person may be unavailable. Given the potentially dire consequences of collaboration breakdowns during military operations, providing higher fidelity information of team members' availability and task activities may be an appropriate design priority in this context. For example, existing sensor technologies could be used to provide precise location information of a remote teammate, providing further context to help someone infer what a remote team member might currently be doing, where they can be contacted if they are urgently needed, and enabling possible inferences about when they will return to their workstation. This approach is used in Bardram and Hansen's (2004) AwarePhone application to facilitate collaboration among medical staff in a hospital, an environment with similar time and life-critical considerations for technology design.

Providing additional information about *who* else is located with a remote team member may also provide relevant cues about *what* they are doing and how receptive they are to an interruption. In the Lilsys system, when a conversation in the vicinity of the operator's workstation is detected, the system indicates to their remote colleagues that they are 'probably unavailable.' However, the relevance of this inference is highly context-dependent. If the visitor is a fellow team member, a message regarding new mission information might be a highly appropriate interruption. Yet, if the visitor is a four-star general, the remote team member may wish to defer sending the message or choose to send the information via email instead. Providing higher-fidelity contextual information would likely improve someone's ability to determine the most appropriate course of action when they wish to interact with a remote collaborator.

Maintaining Continuity through Dynamic Team Membership and Network Instability. Unlike most corporate environments, military command and control settings often operate continuously during active military conflicts. Round-the-clock operations require constant station manning and, consequently, operator changeover during ongoing activities. Additionally, military personnel are frequently reassigned to different operator duties and locations. Thus, a 'team' in charge of maintaining particular operations must be resilient to operator handoffs during shift changes, as well as changing team membership.

Current military practices are already designed to help address this issue through the use of highly standardized duties and team training that includes practice performing shift changes and performing task duties with a variety of different personnel. Collaboration technologies that support the shared activity process may further address this issue by helping new and returning team members get 'up to speed' when joining an ongoing activity. A study of crew changes in naval operations revealed the need for better situation awareness support for incoming personnel (Endsley & Strater, 2005). However, to effectively support overall crew operations in these and other military operations, operator technologies must be explicitly designed to support fluid team membership and facilitate new team members' understanding of where their task duties fit into the overall shared activity process and of what resources (including available personnel) are available to support their task duties.

Another reality military teams will face in network-centric operations is network instability. Lose of network connectivity may result from a number of factors, including intentional enemy sabotage or unavoidable technical delays or failures in the field. Therefore, to help military teams maintain continuous operations, it will be essential to provide them with collaboration technologies that are robust to network instability. From the operator's perspective, this issue relates strongly to supporting operator changeovers since effective collaboration technologies in an unstable network environment should enable an operator to 'catch up' on past events and ongoing activities of their remote collaborators whenever network connectivity resumes. However, an additional technical requirement will be to enable 'offline' operators to continue as effectively as possible under the circumstances. Providing operators with the last known status of all remote activities and information sources, along with the uncertainty associated with this information (e.g., time elapsed since last updated), should help operators make the best possible decisions under the current operating conditions.

Large-Scale, Time-Sensitive Operations. The increased connectivity of operators in the network-centric paradigm introduces the possibility of large-scale teams and teams of teams. A recent study of a high fidelity network-centric operations exercise revealed that Time-Sensitive Targeting operators actively monitor and engage in large numbers of chat rooms, in which groups of connected operators discuss ongoing activities and intelligence (Boiney, 2005).

Monitoring and participating in numerous ongoing communications, in addition to performing individual task duties, has been shown to be overwhelming both in command and control research and in practice (Cummings, 2004). The addition of time-pressure, often present in military command and control operations, increases the difficulty of effectively communicating and exchanging information with large numbers of remote collaborators (Boiney, 2005).

Given the “overhead” of possible collaborative technologies, providing operators additional information about the activities and availability of their remote collaborators’ could quickly become overwhelming. Thus, a critical design requirement for supporting operator teams in a network-centric environment will be to strike a balance between awareness and information overload. Research from the CSCW community offers some advice on this issue. Dabbish and Kraut (2004) have shown that providing a simplistic, abstract view of someone’s computer activities is quite effective in helping their remote collaborators’ infer when they are likely to be receptive to an interruption. On the other hand, their research has revealed that people find extracting relevant availability information from a full view of a remote collaborator’s computer activities distracting from their own task activities and more time consuming than glancing at an abstracted view of that activity. Carroll et al.’s (2003) work on activity awareness further suggests that the abstract activity information should be integrated into a view of the overall shared activity process to provide relevant context to how these activities relate to each team member’s activities.

Determining the relevant aspects of the shared activity to display to teams will be an essential component to providing effective activity awareness in the military domain. In the corporate world, group activities often center on the production of shared files or other media items; thus, distinct virtual items like files or chat logs can form the basis of activity-centric information displays. Military teamwork, on the other hand, often centers on many inter-related and dynamic real-time activities that support particular mission goals. Technology supporting the overall shared process should reflect these sub-activities, the team’s progress on them, and the team’s current progress on the overall process, especially in the context of temporally constrained activities.

The ultimate design goal that should cut across all technologies designed for distributed military teams is the improvement of overall team and mission performance. Reducing the current overhead and costs of communicating and exchanging information via collaboration technologies would help achieve this design goal because collaborators would have more time to devote to their individual task duties. To facilitate more effective and efficient distributed collaboration in the corporate domain, there has been an increasing trend to integrate intelligent automation into their collaboration technologies. However, given the complexity introduced by continuous, large-scale, time-critical operations of military teamwork, it is likely that making more effective use of intelligent automation to facilitate remote collaboration activities will play an even more critical role in the success of future network-centric operations.

Conclusion

With the increasing trend toward network-centric operations, military personnel will more often find themselves collaborating with people around the world as part of physically distributed teams. While collaboration technologies currently used to facilitate military teamwork enable remote operators to communicate and exchange information, these technologies only support certain aspects of the overall collaboration process. This paper has examined recent innovations in collaboration technology design from the corporate domain in order to draw from their considerable experiences in supporting distributed teamwork. These design approaches appear to offer promise for improving teamwork in military command and control settings. However, this paper has also identified certain challenges to applying these corporate design approaches to military team operations that will require further investigation.

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