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A characterization of distributed teamwork:
Challenges for C2 teams

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Abstract

Rapid changes in the operational environment, globalization, an ever-growing recourse to coalitions and alliances combined with a push towards designing more flexible and versatile organizational structures, has accelerated the need for organizations, including the military, to coordinate work across geographical, functional, intra- and inter-organizational as well as temporal boundaries. Responding to the increasing decentralization and globalization of work processes, many organizations have reacted to their dynamic environments by introducing distributed teams. The environment in which military teams evolve is often characterized by changing conditions, time pressure, uncertainty, and an overwhelming amount of information to process. This report presents an analysis of the literature on distributed teams and highlights issues of potential consequences and interest in the context of adaptive dispersed operations for the Canadian Armed Forces (CAF). The factors that are identified as critical for the success of distributed teams are coordination, communication, shared mental models, trust, and leadership. There is a need for a robust scientific methodology to evaluate tools for collaborative decision making and to verify support decision effectiveness in dynamic, uncertain contexts of operations at the operational and tactical levels.

Résumé

En raison de l'évolution rapide du contexte opérationnel, de la mondialisation, du recours de plus en plus fréquent aux alliances et aux coalitions, ainsi que des récents efforts vers l'établissement de structures organisationnelles plus souples et polyvalentes, les organisations, y compris les organisations militaires, ont un besoin de plus en plus pressant de coordonner leurs activités en repoussant les limites géographiques, fonctionnelles, intra et interorganisationnelles, et temporelles. En réaction à la décentralisation et à la mondialisation graduelles des processus opérationnels, beaucoup d'organisations ont décidé de mettre en place des équipes distribuées. Le contexte dans lequel les équipes militaires évoluent se caractérise souvent par des conditions de travail changeantes, des contraintes temporelles, de l'incertitude ainsi qu'une quantité monumentale d'informations à traiter. Le présent rapport offre une analyse bibliographique sur le sujet des équipes distribuées en plus de mettre en lumière les questions potentiellement dignes d'intérêt et susceptibles d'avoir des effets sur la situation des opérations adaptables et dispersées des Forces armées canadiennes (FAC). Les facteurs qui ont été identifiés comme jouant un rôle important dans le succès des équipes distribuées sont la coordination, la communication, les modèles mentaux communs, la confiance et le leadership. Nous devons nous doter d'une méthode scientifique rigoureuse qui nous permettra d'évaluer les outils d'aide à la prise de décisions et de vérifier l'efficacité de ces décisions dans le contexte dynamique et incertain des opérations aux niveaux opérationnel et tactique.

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Executive summary

A characterization of distributed teamwork: Challenges for C2 teams

Isabelle Turcotte; Marie-Eve Jobidon; Luc Pigeon; Sébastien Tremblay; DRDC Toronto TM 2013-140; Defence R&D Canada – Toronto; May 2014.

Introduction or background: Rapid changes in the operational environment, globalization, an ever-growing recourse to coalitions and alliances combined with a push towards designing more flexible and versatile organizational structures, has accelerated the need for organizations, including the military, to coordinate work across geographical, functional, intra- and inter-organizational as well as temporal boundaries. Responding to the increasing decentralization and globalization of work processes, many organizations have reacted to their dynamic environments by introducing distributed teams. The environment in which military teams evolve is often characterized by changing conditions, time pressure, uncertainty, and an overwhelming amount of information to process.

Results: The key factors that are identified as playing an important role in the success of distributed teams are: coordination, communication, shared mental models, trust, and leadership. Their respective role in the functioning of distributed teams is discussed. A checklist of these factors and how they should be addressed in the context of distributed teams is also presented.

Significance: This report presents an analysis of the literature on distributed teams and highlights issues of potential consequences and interest in the context of adaptive dispersed operations for the Canadian Armed Forces (CAF). Overall, distributed teams seem a promising alternative to collocated teams when required and appropriate. However, distributed teams can face unique and compounded challenges in the ways they evolve and function, which can potentially impact team effectiveness and mission success.

Future plans: The key factors identified in this report should be investigated further in the context of C2 in the CAF. There is a need for a robust scientific methodology to evaluate tools for collaborative decision making and to verify support decision effectiveness in dynamic, uncertain contexts of operations at the operational and tactical levels.

Sommaire

A characterization of distributed teamwork: Challenges for C2 teams

Isabelle Turcotte; Marie-Eve Jobidon; Luc Pigeon; Sébastien Tremblay ; DRDC Toronto TM 2013-140 ; R & D pour la défense Canada – Toronto; mai 2014.

Introduction: En raison de l'évolution rapide du contexte opérationnel, de la mondialisation, du recours de plus en plus fréquent aux alliances et aux coalitions, ainsi que des récents efforts vers l'établissement de structures organisationnelles plus souples et polyvalentes, les organisations, y compris les organisations militaires, ont un besoin de plus en plus pressant de coordonner leurs activités en repoussant les contraintes géographiques, fonctionnelles, intra et interorganisationnelles, et temporelles. En réaction à la décentralisation et à la mondialisation graduelles des processus opérationnels, beaucoup d'organisations ont décidé de mettre en place des équipes distribuées. Le contexte dans lequel les équipes militaires évoluent se caractérise souvent par des conditions de travail changeantes, des contraintes temporelles, de l'incertitude ainsi qu'une quantité monumentale d'informations à traiter.

Résultats : Les principaux facteurs jouant un rôle important dans le succès des équipes distribuées sont les suivants : la coordination, la communication, les modèles mentaux communs, la confiance et le leadership. Dans le présent rapport, nous discutons du rôle de chacun de ces facteurs dans le fonctionnement des équipes distribuées. Nous présentons aussi une liste de contrôle de ces facteurs et nous expliquons comment ceux-ci doivent être abordés dans le contexte d'une équipe distribuée.

Portée : Le présent rapport offre une analyse bibliographique sur le sujet des équipes distribuées en plus de mettre en lumière les questions potentiellement dignes d'intérêt et susceptibles d'avoir des effets sur la situation des opérations adaptables et dispersées des Forces armées canadiennes (FAC). Globalement, les équipes distribuées semblent une voie prometteuse lorsque cela est requis et approprié. Cependant, les équipes distribuées peuvent faire face à des défis uniques et plus complexes que les équipes colocalisées au cours de leur évolution et dans leur façon de fonctionner, ce qui peut potentiellement influencer l'efficacité de l'équipe et le succès de la mission.

Recherches futures : Les principaux facteurs exposés dans le présent rapport devraient être étudiés dans le contexte du C2 dans les FAC. Nous devons nous doter d'une méthode scientifique rigoureuse qui nous permettra d'évaluer les outils d'aide à la prise de décisions et de vérifier l'efficacité de ces décisions dans le contexte dynamique et incertain des opérations aux niveaux opérationnel et tactique.

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1 Introduction and definitions

The complexity of many modern real-world tasks necessitates the involvement of more than one person. Often in settings ranging from military command and control to emergency response or software design, work is accomplished by an interdependent team of individuals who work together to achieve tasks (Swezey & Salas, 1992). In the military as in the civilian world, incentives to use distributed teams continually increase with globalization and technological developments. The objective of this report is to inform a scoping study investigating the feasibility of achieving a dispersed brigade-group headquarters (BGHQ) concept (project 12oz09) by reviewing the existing literature on distributed teams. This effort was carried out as part of the Tracking Agility and Self-Synchronization in Crisis Management (TASSCM) project conducted under the Research Partnership program between the Department of National Defence (DND) and the Natural Sciences and Engineering Research Council of Canada (NSERC). Implementing dispersed headquarters has implications for teamwork because it involves moving from mostly face-to-face teams to distributed or virtual teams. This report presents an analysis of the literature on distributed teams and highlights issues of potential consequences and interest in the context of a scoping study intended to explore the feasibility of achieving a dispersed BGHQ concept within the Canadian Armed Forces (CAF) adaptive dispersed operations (ADO) paradigm, whereby the BGHQ operates in a virtual environment and where HQ branches or elements connect to this environment from a variety of remote locations (Pigeon & Jobidon, 2013).

The scoping study was based on the concerns and constraints expressed in a series of CAF Army documents for the achievement of agile, adaptive, modular, resilient, etc. future capabilities and infrastructures (Vice Chief of Defence Staff [VCDS], 2012; Directorate of Land Concepts Design [DLCD], 2007; Godefroy & Gizewski, 2009; Canadian Army Land Warfare Centre [CALWC], 2012; 1st Canadian Division Headquarters [1 Cdn Div HQ], 2012a; 1 Cdn Div HQ, 2012b). More specifically, this study considered the previous concerns/constraints in the context of the ADO concept (see DLCD, 2007).

The achievement of such BGHQ concept would fulfill two goals. The first would be to better meet the definition of ADO by optimizing dispersal of the CAF HQ components in both the physical and cyber dimensions (human and material). The second goal would be in providing more flexibility to the CAF in their ability to rapidly adapt their HQs based on context changes or mission sets. As validated, this concept could apply to all levels of CAF HQ from the unit level up. In all cases, HQ's human dimension is expressed by teams.

A team can be defined as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership" (Salas, Dickinson, Converse, & Tannenbaum, 1992, p.44). By this definition, a team is a special type of group, one that is interdependent and heterogeneous with respect to individual team member roles. They are, in fact, complex and dynamic systems that affect, and are affected by, a host of individual, task, situational, environmental, and organizational factors that exist both internally and externally to the team.

Teams have been of interest as a mechanism of organization in the workplace for decades. Over this time, literally hundreds of studies have been conducted to study teams and their performance.

The need for a more detailed description of the nature of teams has given rise to several typologies of teams and their work, in recognition of the fact that the nature of the work being completed by teams has an important impact on their functioning. It has also served to organize thinking about teams by highlighting commonalities among the various kinds of teams employed by organizations. Organizations are currently facing important and unprecedented challenges in an increasingly dynamic and complex environment (Rezgui, 2007). Rapid changes in the operational environment, globalization, and an ever-growing recourse to coalitions and alliances combined with a push towards designing more flexible and versatile organizational structures has accelerated the need for organizations, including the military, to coordinate work across geographical, functional, intra- and inter-organizational as well as temporal boundaries (Armstrong & Cole, 1995; Lipnack & Stamps, 1997; Townsend, DeMarie & Hendrickson, 1998). With the rapid progress of electronic information and communication media in the last decades, and advances like cloud computing, distributed work has become much easier, faster, and more efficient (Hertel, Geister, & Konradt, 2005). Responding to the increasing decentralization and globalization of work processes, many organizations have reacted to their dynamic environments by introducing distributed teams.

Although distributed teams have been attributed various labels, including "virtual teams" and "dispersed teams", the term "distributed teams" is used in this report for its clearer connection to the primary components of what constitute this type of team: the distribution of team members interacting over time and space, with communication enabled primarily via technological means (Cascio & Shurygailo, 2003; Connaughton & Daly, 2004).

More specifically, Townsend et al. (1998) define distributed teams as: "groups of geographically and/or organizationally dispersed coworkers [unit members] that are assembled using a combination of telecommunications and information technologies to accomplish an organizational task" (p. 17). The physical separation may range from being located in different buildings within the same city to different countries on different continents. In contrast, members of geographically collocated teams are physically collocated with one another in the same building or site.

It should be pointed out that all distributed teams are not the same. Driskell, Radtke, and Salas (2003) mention that a variety of technologies can support virtual teams, ranging from simple email to audio communications and real-time video. Although some of these technologies provide few of the cues available to face-to-face teams (e.g., non-verbal communication), others provide almost all of the cues available in traditional collocated teams. Researchers are now viewing virtuality as a continuum, arguing that many teams in organizations today are characterized by dimensions of virtuality (Griffith, Sawyer, & Neale, 2003).

Since the definitions of distributed teams include various aspects; the creation of an overall, comprehensive, and valuable classification of virtual teams is needed (Curseu, Schalk, & Wessel, 2008). The integration of all the dimensions could result in a multidimensional and possibly incomprehensible framework that could be challenging to use in practice. However, Martins, Gilson, and Maynard (2004), were able to excerpt some similarities from the different approaches. Indeed, they confirmed that distributed teams are socio-technical systems composed of:

1. two or more persons, who

2. collaborate interactively to reach shared objectives, while

3. at least one of the team members works at a different location, organization, or at a different time, so that

4. communication and coordination are mainly based on electronic communication media (email, fax, phone, video conference, etc.) (Hertel et al., 2005; Martins et al., 2004).

Virtual teams are usually formed in order to benefit from the abilities, local knowledge, skills, experience, resources, and expertise from geographically distributed team members. Innovating, making decisions, taking care of tasks that heavily rely on information processing and solving complex problems are the reasons why organizations value virtual teams. In distributed teams, the interplay between the individual cognitions of team members as well as the team interaction processes guide information processing (Curseu, Schruijer, & Boros, 2007).

1.1 Command and control

BGHQ represents the larger entity of CAF tactical HQ. Brigade or division main headquarters is an entity employed by foreign armed forces and/or international coalitions where CAF personnel and/or units might be deployed. In all cases, this HQ level (as opposed to brigade group, brigade or division) was chosen for both its value (as a target) on theatre, and its physical characteristics of "heaviness" and "statism". In contrast, within a dispersed BGHQ concept, the HQ is not a "single physical entity" anymore: the human beings form the "building blocks" of the BGHQ super-entity or "composite".

Military forces increasingly approach, with new perspectives, highly complex tasks involving a unique division of labour and covering a global terrain of operations coordinated by specialized team members distributed across the landscape. Teamwork in this context entails some specific characteristics due to the nature of command and control (C2) environments and the particularities of military operations. The environment in which military teams evolve is often characterized by changing conditions, time pressure, uncertainty, and an overwhelming amount of information to process. A multitude of stressors may also be identified: multiple information sources; incomplete, conflicting information; rapidly evolving scenarios; performance pressure; time pressure; high work/information load; auditory overload/interference; and threat (Cannon-Bowers & Salas, 1998). Although individuals may be distributed in time and space, distributed teams make decisions, communicate, and share information over an interconnected network. Military operations in this type of environment have been termed network centric or network enabled, such that the battlefield is not only dispersed over geographical terrain but also dispersed over electronic and communication networks (including the Internet). A distributed C2 environment is a complex environment that also requires coordination among a team or teams of heterogeneously skilled operators (i.e., heterogeneous teams). Distributed C2 environments can be conceptualized at different scales, from a relatively small team of three or four to an organization quite large, involving hundreds of operators. Although the use of distributed teams expands organizational flexibility in meeting mission goals, team interaction in distributed environments introduces a number of issues with respect to both individual and team performance, that are distinct from traditional collocated teams. Physically distributed teams face

constraints that may require them to use knowledge and skills differently than collocated teams to achieve and maintain team coordination.

Indeed, coordination and collaboration across distributed teams during planning and execution activities present many challenges to organizations and operations, including military C2. With the increase in spatially and temporally distributed work teams, it is essential to achieve an understanding of how distributed work can be effectively achieved and supported. A critical challenge for the military is supporting the initial development of robust plans, as well as in the adaptation of these plans in the face of continuously evolving and sometimes unanticipated events. Because advances in information and communications technologies are allowing for planning to be accomplished by team members who are geographically and temporally dispersed - for instance by dispersing modules of a command post - it is important to understand how such distributed work can be best supported. The degree to which distributed as opposed to collocated work environments affect team performance and cognition in these settings also has critical implications for Tactics, Techniques and Procedures (TTPs), education/training, and design in support of distributed work. Executing C2 functions is cognitively demanding and engages a variety of cognitive resources or processes such as situation assessment, monitoring, recognition, problem solving, causal learning, search, planning, judgment, and choice (Gonzalez, Vanyukov, & Martin, 2005). Coordinating all those cognitive functions might pose a challenge for distributed teams. In fact, it is the ability to coordinate these cognitive activities under time constraints that is key to the successful exercise of C2. In distributed teams, just like in collocated teams, team-level properties are not directly determined by team-member properties; team interaction processes are a ripe source of variance specific to teams. Because of this unique source of interaction-based variance, approaches that aggregate across the properties of individual team members in order to determine a team-level property (Rentsch & Klimoski 2001) may be insufficient for measuring team-level phenomena (Cooke & Gorman 2006). Little research has examined the effects of distributed mission environments on team performance, process behaviours, or cognition in military settings. The next section presents a review of studies that compare distributed and collocated teams on multiple characteristics in environments such as research and development, product development, and software design. The limited empirical work conducted on distributed teams in C2 environments will be presented in section 3.

2 Differences between collocated and distributed teams

Over the last two decades, researchers have sought to understand the benefits and costs associated with distributed and virtual teams. As a result, a significant body of empirical research has emerged comparing traditional face-to-face teams with computer mediated teams by exploring a number of factors on which the two might differ. This section presents studies on distributed teams organized around key dimensions, including team characteristics, task interdependence, organizational factors, and leadership.

2.1 Team characteristics

Unlike traditional teams, distributed teams "work across space, time, and organizational boundaries with links strengthened by webs of communication technologies" (Lipnack & Stamps, 1997, p. 7). However, many of the successful work processes of distributed teams appear similar to those for traditional teams (Bergiel, Bergiel, & Balsmeie, 2008). For instance, consistent with traditional team research, work on distributed teams most often shows a relatively positive relationship between a team's work processes and its performance (Hause, Last, Almstrum, & Woodroffe, 2001; Knoll & Jarvenpaa, 1998; Lurey & Raisinghani, 2001; Weisband, 2002). Other studies (DeSanctis, Wright, & Jiang 2001; Lurey & Raisinghani, 2001; Piccoli, Powell, & Ives, 2004) reveal that team processes could also be related to satisfaction, and that trust and communication interact to modulate performance (Jarvenpaa, Shaw, & Staples, 2004). Coordination, planning and project management, quality of communication, and cohesion among team members represent factors that are affected by technology and that also influence distributed team performance (Lurey & Raisinghani, 2001; Maznevski & Chudoba, 2000; Kayworth & Leidner, 2000). Hinds and Bailey (2003) noted that in distributed teams, members may have difficulty establishing a shared context. References to objects of interest become challenging to interpret when team members occupy different physical environment (Schober, 1998). Researchers have also mentioned that commitment to the team and team members' satisfaction (Caballer, Gracia, & Peiró, 2005) as well as a healthy team identity development are also related to team processes (Bouas & Arrow, 1996; Fjermestad & Hiltz, 2000). Team beliefs and norm development have also been investigated in a few studies and distributed team members with stronger beliefs in the team's efficacy apparently cooperate more that those with weaker beliefs (Galvin, Ahuja, & Agarwal, 2000; Galvin, McKnight, & Ahuja, 2001). Those with stronger beliefs in the team's efficacy are also more motivated, committed to, and satisfied with their teams (Staples & Cameron, 2004). This pattern of results has also been found in traditional teams. However, it has been shown that distributed teams present more difficulties to develop team norms and conventions (Mark, 2002).

The development of mutual awareness (i.e., members' understanding of other members' situations and their interpretation of events) is influenced by the differences in local physical context, time zones, culture, and language that are present in distributed teams (Olson & Olson, 2000). Distributed teams, especially when working in joint coalition operations (Curseu et al., 2008), can be diverse in directly observable characteristics, such as gender, age, and race, as well as in "hidden" attributes, such as knowledge, skills and abilities, personality, and cultural

background. The differences observed in team member characteristics can also affect team processes and outcomes. The diversity issue observed in distributed teams can bring forth different values, cognitive schemas, and behaviours (Hambrick, Canney Davison, Snell, & Snow, 1998). Gradually apparent diversity usually yields less prejudiced or stereotypical responses than visible diversity (Milliken & Martins, 1996). Indeed, noticeable diversity can elicit labelling that could result in misunderstandings and discord (Swann, Polzer, Seyle, & Ko, 2004; Van der Vegt, Van de Vliert, & Oosterhof, 2003). More specifically, cultural differences have sometimes been linked to coordination difficulties (Kayworth & Leidner, 2000; Maznevski & Chudoba, 2001; Robey et al., 2000) and effective communication can easily be hindered if different languages are spoken (Kayworth & Leidner, 2000; Sarker & Sahay, 2002).

As a team characteristic, team size has traditionally been described as critical to team performance (Steiner, 1972). Researchers have noted that team size may affect distributed teams differently than traditional teams. In fact, technology could moderate the adverse effects of size (such as process losses and production blocking) observed in collocated decision-making or creative teams (Leenders, van Engelen, & Kratzer, 2003; Valacich, Dennis, & Connolly, 1994; Valacich, Dennis, & Nunamaker, 1992). Indeed, distributed teams would generate more ideas when group size is higher comparatively to collocated teams (Gallupe, Dennis, Cooper, Valacich, Bastianutti & Nunamaker, 1992; Valacich et al., 1994). However, the nature of the task and the technology used also come into play when observing the effect of size on distributed teams functioning. For example, Riopelle et al. (2003) studied six globally distributed teams in a field setting and found that it was difficult for participants to interact effectively while using audio-conferencing with an increased team size. Therefore, a bigger team size can become problematic when it comes to certain forms of virtual communications.

Some studies have revealed complications with technology communication in distributed teams. Indeed, computer-mediated communication can handicap the creation of word meaning (Mantovani, 1996). It has also been shown that computer-mediated communication can lead to lengthened decision making comparatively to face-to-face communication (Hedlund, Ilgen, & Hollenbeck, 1998). Unfortunately, these two studies on technology communication did not evaluate the performance of teams working on complex tasks for a prolonged period of time. Indeed, when team members develop a familiarity by working together for an extended length of time, they may present an advantage compared to teams composed of members that are unfamiliar. Some researchers have also found that the better performance associated with higher team member familiarity observed in collocated teams compared to distributed teams, is also influenced by specific group norms (Postmes & Spears, 1998; Postmes, Spears, & Lea, 1998). Since team members in distributed environments must communicate in ways that are less direct (i.e., never or seldom face to face) than collocated teams, they are less likely to be familiar with each other. Furthermore, distributed teams have fewer occasions to coordinate their actions through monitoring behaviour and are therefore exposed to an increased levels of abstraction (i.e., not having a good awareness of each other's concrete tasks and actions), ambiguity, and what Fiore, Salas, Cuevas, and Bowers (2003) labeled team opacity. Team opacity influences such team process behaviours as communication, coordination, and planning. During initial team missions and when workload is high, performance is particularly affected by these team process behaviours (Fiore et al., 2003; Levine & Choi, 2004). In these situations, Fiore et al. (2003) suggest that team members' situation awareness can be limited by the lack of paralinguistic, non-verbal, and other sensory cues. This also suggests that physical separation can hinder the shared mental models of team members' coordination. In accordance with that, Maynard (2004) has

offered that distributed teams would take longer to develop shared mental models. The ability of team members to gain knowledge about the task and/or the team can also be impacted by these factors, with distributed team members having more difficulty in acquiring inter-positional knowledge than collocated teams (i.e., knowledge of each other's roles and tasks). While collocated team members are better able to acquire inter-positional knowledge than distributed team members, the acquisition of a team member's knowledge about the task and/or the team can also be affected (Fiore et al., 2003). However, Espinosa, Slaughter, Kraut, and Herbsleb (2007) argue that familiarity enhances team coordination in a distributed setting, based on their observations that distributed software development teams benefited from team familiarity. A study by Espevik, Johnsen, and Eid (2011) replicates and expands this finding by revealing similar effects for more interdependent and technical tasks. However, it appears that as yet no study has directly compared distributed and collocated teams in regards to shared mental models.

Driskell et al. (2003) proposed communication as one of the four important process variables in distributed teams. The limited cue set in virtual teams is likely to change the nature of effective communication in these teams. In large part, these differences are related to reduced knowledge sharing and feedback (Ashford & Tsui, 1991; Thompson & Coovert, 2002). Recent research efforts, however, suggest that face-to-face teams and distributed teams manifest communication and other teamwork processes in a different way (Priest, Stagl, Klein, Salas, & Burke, 2006; see also Weimann, Hinz, Scott, & Pollock, 2010). Despite the improved accessibility of communication technologies available to distributed team members, consequences from distribution such as less frequent communication and social isolation are often observed (Belanger, Watson-Manheim, & Jordan, 2002). Indeed, the impact of computer-mediated communication on team processes appears a more important issue than the actual physical distance between team members (Bell & Kozlowski, 2002). Research by Baltes, Dickson, Sherman, Bauer, and LaGanke (2002) as well as Bordia (1997), has questioned the suitability of collaboration technologies for enabling distributed team decision making. These studies have demonstrated that these technologies engender diminished information exchange, degraded task efficiency, and reduced problem solving skills. Specifically, Bordia (1997) reviewed 18 studies and came to the conclusion that computer-mediated teams exhibited significantly poorer decision quality, decision speed, and decision satisfaction when compared to face-to-face teams. However, communication patterns usually begin with unidirectional communication and change throughout distributed team stages, to end with mutual communication (Sarker, Lau, & Sahay, 2001). Consequently, the information exchange would be less effective in new distributed teams than in new face-to-face teams (Hightower, Sayeed, Warkentin, & McHaney, 1998).

A second drawback of communication technology is that it makes the development of trust and team identity more difficult. In virtual teams, social and communication cues that individuals use to build trust are more challenging to communicate, such as warmth, attentiveness, and other important interpersonal affections that nurture group cohesion (Jarvenpaa & Leidner, 1999; Jarvenpaa et al., 2004). Team identity is more difficult to develop in virtual teams, leading to low levels of within-team cooperation and team members' commitment to the team, which can have a negative impact on team performance. Both laboratory and field studies have shown that team identity is less developed in distributed teams compared to collocated teams (Bouas & Arrow, 1996; Fjermestad & Hiltz, 2000). Interestingly, other research suggests that differences between face-to-face and distributed teams tend to minimize over time as computer-mediated groups adapt to the technology (Hollingshead, McGrath, & O'Connor, 1993; Walther, 1997). Studying the stages of team development, some researchers have observed that teams develop more effective

communication processes over time (Burke, Aytes, Chidambaram, & Johnson, 1999). Differences observed between face-to-face and distributed teams in cohesion (Burke, Aytes, & Chidambaram, 2001) and centralization of task participation (Berdahl & Craig, 1996) also tend to disappear with time. Given the fact that ongoing distributed teams carry out more task communication than social communication, some scholars even suggested that they could be more effective than face-to-face teams (Hightower et al., 1998). Thus, another advantage of virtual teaming may reside in the fact that the extent of informal exchange of information is limited as distributed teams tend to be more task oriented and exchange less socio-emotional information (Pawar & Sharifi, 1997; Schmidt, Montoya-Weiss & Massey, 2001). Chen, Kang, Xing, Lee, and Tong (2008) note that virtual teaming fosters the mutual sharing of resources and competencies, and that it improves communication and coordination. However, teams that are more widely dispersed face greater challenges to effective communication (McDonough, Kahn, & Barczak, 2001). Collocated teams have the opportunity to discuss day-to-day activities and decisions in informal ways; that is, collocated settings allow for spontaneous communication (e.g., impromptu meetings in hallways or by the coffee machine, informal discussions after meetings) while in distributed environments, the spatial and/or temporal distance greatly limits such informal and spontaneous conversations. Unlike traditional teams, distributed teams do not have easy access to face-to-face communication and thus cannot easily build mutual awareness. A lack of mutual awareness in a team can lead to an absence of contextual information as well as process losses due to misunderstandings and lack of responses (Cramton, 2001). On the other hand, mutual awareness and collective vocabulary help to bond dissimilar knowledge spheres. Teams need to develop a shared vocabulary so that team members can comprehend each other and avoid the possible negative effects produced by the variety of individuals' backgrounds and knowledge.

Shared team identity has also been suggested as critical to the effective functioning of teams due to its influence on cooperation, commitment to decisions, and levels of trust (Kramer & Brewer, 1986). Identity could even be of greater meaning for distributed teams, mostly if the team members expect working together in the future. For example, a study by Walther (1997) found that members of distributed teams with longer lifespan and more tasks to accomplish demonstrate higher affection for their fellow team members than teams with shorter duration and fewer tasks. In two seven-week sessions conducted with students, Bouas and Arrow (1996) found that team identity was initially lower for computer-mediated communication teams than for face-to-face teams. This difference between the two teams diminished over time to become non-significant by the end of the study. Therefore, team 'duration' also relates to other team processes and outcomes. Relational communication can be affected by the anticipation of future interactions in distributed teams (Walther, 1994). Indeed, long team history has been reported as having positive effects on information sharing in both distributed and collocated teams (Hightower et al., 1998).

Prior research focusing on team empowerment in distributed teams has demonstrated a positive relationship with performance (Kirkman & Rosen, 1999). In a study of 35 distributed teams in a field setting, Kirkman, Rosen, Tesluk, and Gibson (2004) found that team empowerment was significantly and positively related to process improvement and customer satisfaction. High-performance teams were differentiated by strong dedication to objectives, identification and emotional bonding between team members, and a balance between unity and respect for individual differences. Additionally, this study found that the number of face-to-face meetings moderated the relationship between team empowerment and process improvement, such that team empowerment was a stronger predictor of process improvement in teams that met face-to-face less often.

The findings for the effects of virtuality on the quality of a team's decisions have been mixed. No difference in performance quality has been found between virtual and face-to-face teams (Cappel & Windsor, 2000; Straus & McGrath, 1994). A study by Hiltz, Johnson, and Turoff (1986) revealed that even if face-to-face teams had higher levels of agreement than did computer-mediated teams, the quality of decisions did not differ between the two types of teams. However, other researchers found that face-to-face teams can outperform distributed teams in some instances (Andres, 2002; McDonough et al., 2001; Straus & McGrath, 1994). A study assessing variability in project management of product development teams revealed that collocated teams reported significantly less difficulty with numerous facets of project management than did distributed teams (McDonough et al., 2001). According to Andres (2002), multiple channels of communication (i.e., "rich" media) are needed to enable better information acquisition, sharing, and integration. However, several researchers have found no difference in performance quality between virtual and face-to-face teams (Cappel & Windsor, 2000; Straus & McGrath, 1994). Using corporate managers performing a desert survival task in a training session, Potter and Balthazard (2002) found that distributed teams were comparable to face-to-face teams in terms of objective performance and process outcomes. On the other hand, better work (Jarvenpaa, Knoll, & Leidner, 1988), more effective decisions (Schmidt et al., 2001), and more distinctive and high-quality ideas (Valacich, George, Nunamaker, & Vogel, 1994) have been attributed to distributed teams. Additionally, some evidence has shown that teams whose members are more critical of one another produce the greatest number of original solutions. However, the same study also revealed that teams with a supportive confederate had the most satisfied members and greater perceived levels of effectiveness (Connolly, Jessup, & Valacich, 1990). Numerous studies also examined the association between performance and team members' attitudes, skills, and abilities. Findings revealed that time management skills are important for success (Larsen & McInerney, 2002) and that interpersonal skills are positively related to team effectiveness (Knoll & Jarvenpaa, 1998; Staples & Cameron, 2004). Furthermore, integrity and a tendency to share are significant predictors of trust (Jarvenpaa et al., 1998) and individuals' communication centrality (the extent to which the individual is linked to other members in the group) relates to their team roles and status (Ahuja, Galletta, & Carley, 1999).

Bowers, Smith, Cannon-Bowers, and Nicholson (2008) noted that team attitudes of trust, collective efficacy, cohesion, and team orientation can be negatively affected by distance. Trust in distributed teams could be reduced by dispersion (Ardichvili, Page, & Wentling, 2003; Staples & Webster, 2008) since mistrust can come from misattributions caused by technological anomalies or decreased cues. Likewise, it is possible that collective efficacy (i.e., the team's shared belief in its ability to accomplish the task) develops differently in distributed teams than it does in collocated teams. Indeed, distributed teams may have trouble experiencing collective success or correctly attributing such success to the team's efforts. Finally, team members in a distributed team may not see themselves as a team in the same way that face-to-face teams do. This may reduce the team members' ability to correctly recognize that teamwork is important and a component of team orientation (Bowers et al., 2008). Team orientation describes the degree to which one team member values teamwork and is willing to engage in teamwork behaviours (e.g., give and take input) (Fiore et al., 2003). Regarding cognitive differences among virtual and collocated teams, Bowers and colleagues (2008) argued that memory processes can be affected by altered information flow, task cues, and communication mechanisms when teams are distributed. For instance, it is likely that workload will be higher in virtual teams because commonly shared visual and auditory cues are not available, and retrieval and prospective memory processes may

be altered due to a lack of robust sets of cues as available in collocated teams (see Fiore, Cuevas, Schooler, & Salas, 2006, for more details).

2.2 Task interdependence

Task interdependence refers to the degree or requirement of task-driven interaction among group members (Shea & Guzzo, 1987) and is also determined when team tasks are designed and defined (Bosch-Sijtsema, Fruchter, Vartiainen, & Ruohomaki, 2011). High task interdependence is created when team members have to synchronize their actions regularly so that the performance of one member strongly affects the work process of other team members (Hertel et al., 2005). The collective bond of team members to task interdependencies and dynamics that provides the capability for teams to self-manage is the team coherence and gives teams the ability to self-manage (Kozlowski, Gully, Salas, & Cannon-Bowers, 1996; Kozlowski & Ilgen, 1996). A number of studies suggest that when team members show a high degree of collective orientation, performance on interdependent tasks can be improved. According to Van der Vegt et al. (2003), interdependent tasks help create a collective identity, and research on team processes suggests that when team members are collectively-oriented, an enhanced performance is usually observed on judgement tasks (Driskell & Salas, 1992). The importance of collective orientation to team performance is supported by a developing body of research; however, its relative influence on distributed teams remains uncertain. Given the distant nature of the interactions involved in a distributed task, it is possible that collective orientation is not as important in these tasks (Fiore et al., 2003). In the long term, interdependent tasks allow teams to develop team norms and ways of working. Some researchers have indicated that distributed teams include the notion that they especially work on interdependent tasks toward a common objective (Martins et al., 2004) and that distributed teams are often used to address complex tasks of substantial significance (Kirkman et al., 2004; Leenders et al., 2003). Additionnaly, the benefits of interdependent tasks among distributed teams have been noted in several studies. Indeed, higher interdependence has been associated with team effectiveness (Hertel, Konradt, & Orlikowski, 2004). However, due to the restrictions of communication technology in supporting tight coupling in a distributed work setting, some studies suggest that distributed work tasks tend to progress into more loosely coupled arrangements (Olson & Teasley, 1996; Ramesh & Dennis, 2002). Task type has been suggested as being critical to the decision-making success and speed in distributed teams (Daly, 1993; El-Shinnawy & Vinze, 1998; Hiltz et al., 1986). For instance, when a team's task is ambiguous, the extent of virtuality may increase the length of time needed to reach a shared goal, but may actually assist in the development of a more focused or better goal (Straus & McGrath, 1994). Hollingshead et al. (1993) even argued that it could be better to focus on the compatibility of the task with distributed teaming instead of looking at task type independently. A study by Andres (2002) also revealed that task type (e.g., decision making or production task) may be a factor in determining the impact of communication technology on distributed work teams.

Interdependent tasks appear to be more appropriate for distributed teamwork; however, research in this area is still limited and the results remain mixed to some degree. It has been suggested that the findings could vary depending upon the length of time members have been working together. In fact, it has been observed that independent tasks (which can be completed without any need for interaction among the different individuals) decrease the necessity for interaction in the early life of a team. However, these tasks do not take advantage of synergies coming from the team's combined abilities. On the other hand, Van der Vegt et al. (2003) reported that interdependent

tasks help to create a collective identity. Over time (and with appropriate technological support), distributed teams should be able to work out processes for handling interdependent tasks. Team members should be assigned interdependent tasks that require them to step outside their comfort zones to develop shared mental models, perspectives, and language with their colleagues as this is how they will learn how to interact (with the aim of reducing process losses). In sum, findings reveal that in the short term, distributed teams may benefit from independent tasks in order to minimize the negative effects of diversity on team processes early in team development. Nevertheless, focusing on interdependent tasks in the long term will allow distributed teams to develop team norms and shared ways of working.

However, research on collocated teams has shown that interdependent tasks have been associated with an increase in conflict among team members. A moderate amount of task conflict has been reported as being beneficial since it would help teams make better decisions by considering more of the members suggested alternatives prior to reaching a decision. Task conflict is "an awareness of differences in viewpoints and opinions relating to the team's task" (Jehn & Mannix, 2001, p. 238). It refers to conflict among team members about ideas and differences of opinion about the task (Amason & Sapienza, 1997). Therefore, the presence of conflicts in a team is not entirely bad since they can also provide more information to complete the task (Dooley & Fryxell, 1999). Mortensen and Hinds (2001) have directly compared the amount of conflict within distributed and collocated teams. They failed to observe a positive relationship between geographic distribution and either affective conflict (typically characterized by negative feelings like anger, frustration, and distrust) or task conflict. However, they did report repeated references to conflict in both distributed teams and collocated teams. The extent and effects of conflict in distributed teams has been found to depend on several contingency factors. Specifically, Polzer, Crisp, Jarvenpaa, and Kim (2006) found that less conflict was generated in completely distributed teams (six members in six locations) as opposed to six-member teams distributed across two or three locations. Indeed, worse conflict has been reported to occur in distributed teams that are split in two or three geographical sub-teams, with a number of members at each location, than in completely distributed or collocated teams. Moreover, Polzer et al. (2006) mentioned that it was especially the case when team members perceived greater homogeneity among the members at another site.

A perceived common team identity would reduce the amount of conflict found in distributed teams (Mortensen & Hinds, 2001). A study by Bazarova and Walther (2009) showed that when there was significant variation across team members behaviours, collocated team members blamed each other more for poor contributions to the team, whereas distributed team members presumed that differences in distant conditions accounted for behavioural discrepancies. A study by Poole, Holmes, and DeSanctis (1991) revealed that the way distributed teams adapted their use of the virtual teaming technology to handle their conflict would have a direct effect on their ability to manage conflict in productive ways. Indeed, the results of this study showed that a group decision support system (GDSS) does not directly determine conflict interaction or outcomes, but that teams' use of the technology will instead mediate its impact. Out of the 13 GDSS teams, six adapted the system in ways that produced impacts that should promote productive conflict management, and seven adapted it in ways that should inhibit productive conflict interaction processes or lead to no net benefit (Poole, Holmes, & DeSanctis, 1991). The effect of distribution on both interpersonal and task conflict can also be alleviated by frequent spontaneous communication (Hinds & Mortensen, 2005). A study by Montoya-Weiss, Massey, and Song (2001) also revealed that successful distributed teams tend to use either a competitive or a collaborative conflict management style in order to cope with internal conflicts. Competitive

interactions typically involve the use of power and domination as one party tries to force its views on the other. Collaboration behaviour is characterized by attempts to identify and achieve outcomes that integrate the interests of all parties involved. Similarly, Paul, Seetharaman, Samarah, and Mykytyn (2004) found that collaborative task conflict management styles positively impacted satisfaction, perceived decision quality, and participation. For collocated teams, task conflict is most valuable at the midpoint of the team's life cycle. High-performing teams show high task conflict close to the midpoint of the team's life cycle when it is key to team functioning, while low-performing teams experience a decline in task conflict at this point but high task conflict right before project deadlines, when this sort of conflict is most destructive (Jehn & Mannix, 2001).

Research on collocated teams proposes that the level of variety in the task should be balanced with the level of team diversity (Jehn, 1995). Indeed, when team members need to dispute and debate opposing standpoints to find appropriate task strategies because the tasks are complex (as compared to routine), information diversity is more likely to increase team performance (Jehn et al., 1999). In other words, when teams with greater diversity are used to perform routine tasks, the costs related to diversity are superior to the benefits gained from diversity. In contrast, non-routine tasks can profit from greater variety and diversity of skills and opinions; when these types of tasks are executed by teams with little diversity, the teams tend to perform sub-optimally.

2.3 Organizational factors

Organizational context variables such as boundary management and organizational support can have a significant effect on team effectiveness (Devine, Clayton, Philips, Dunford, & Melner, 1999; Ilgen, 1999). Even though research has not been conducted yet on this topic with distributed teams, it is possible to hypothesize that the higher the virtuality of a team is, the more important the organizational support and frequent communication with other organizational units will be. The need for effective boundary management to maintain organizational support and resources is increased with teams with high virtuality since they usually work across different organizational units. The cultural and/or reward aspects of organizational context have been examined in a few studies. Consistent with collocated team research, the limited research on distributed teams available on that topic show that a team's environment is a significant contributor to team effectiveness (Rennecker, 2002) and effective knowledge sharing, since it offers structures for the team to work within (Majchrzak, Rice, Malhotra, King, & Ba, 2000). The importance of having a good organizational environment and a supportive culture is reinforced by the notion that trust in the organization is related with team cooperation (Galvin et al., 2001).

Trust among team members is another relational dimension that has been the subject of much research effort in the literature on teams. In fact, trust is cited as a decisive factor in the effectiveness of activities requiring coordinated action (McAllister, 1995). Trust is increasingly recognized as critical in applied team research, particularly because dynamic team tasks require a high level of interdependence (Jones & George 1998). It has also been identified has a key enabler in the military (e.g., Scull, 1990; Shamir, Zakay, Breinin, & Popper, 2000; Shay, 2001). Trust has been considered as mediating two facets of cooperation within the team: coordination and helping (Dirks, 1999). More specifically, the degree to which a team would share and commit to ideas in a decision-making task was mediated by trust just like the degree to which team members cooperated. Precisely, high trust teams exhibited behaviours more consistent with a

collective effort, while low trust teams worked more as individuals and directed their efforts toward one's idiosyncratic goals. According to Jarvenpaa and Leidner (1998, p.809), trust is traditionally considered to be based on "personal relationships and past or future memberships in common social networks that define the shared norms of obligation and responsibility", which may or may not fit the conditions of distributed teamwork. Other researchers have suggested that trust is very important in distributed teams (Handy, 1995; Jarvenpaa, Knoll, & Leidner, 1998; Sarker, Valacich, & Sarker, 2003), as it can reduce the adverse impact that geographic distribution can have on psychological intimacy (Walther, 1994). O'Hara-Devereaux and Johansen (1994) have labelled trust as the "glue of the global workspace". In computer-mediated communication research, trust has been shown to be positively associated with performance (Cascio, 2000; Jarvenpaa et al., 1998), job satisfaction (Morris, Marshall, & Rainer, 2002), improved working relationships (Sharifi & Pawar, 2002), problem and uncertainty resolution, and social information exchange (Jarvenpaa & Leidner, 1998). Finally, the repercussions of trust among team members within distributed teams appear to be in accordance with those evidenced in collocated teams (Driscoll, 1978).

2.4 Leadership

One of the factors related to the development of trust within virtual teams is leadership. A good leader seems essential for teams to perform and to learn adequately from a situation. A key aspect of leadership effectiveness in general, and especially across geographical distance, is communication (Morgeson, DeRue, & Karam, 2010). Previous research has shown differences between collocated and distributed teams in communication, interaction, and leadership (Bell & Kozlowski, 2002; Kirkman et al., 2004). Antonakis and Atwater (2002) write: "Physical distance creates conditions that may not be conducive for leadership because it makes it difficult for leaders and followers to interact with each other" (p. 697). Therefore, effective leadership is more difficult to achieve in virtual teams (Cascio & Shurygailo, 2003; Zigurs, 2003). Distributed team members may need to work more independently than their counterparts in face-to-face teams and be willing to make decisions on their own, given the potential difficulties they may face in trying to reach people quickly. Interestingly, some research has demonstrated that distributed teams work more effectively with one leader per geographical location compared to distributed teams with no leader at all (Kim, Hiltz, & Turoff, 2002). Objective decision quality after six months, the average number of lines per comment, and satisfaction with a decision process were significantly higher in distributed teams with a team leader.

Bell and Kozlowski (2002) argue that a number of substitutes exist for leadership in distributed teams, including the notion that the leadership role itself can be distributed among team members. In fact, distributed teams may engage in shared management, making traditional leadership functions less important or even irrelevant. Other research has found both advantages (Pearce, Yoo, & Alavi, 2004; Piccoli et al., 2004; Ziegert, Klein, & Xiao, 2004) and disadvantages (Alge, Ballinger, & Green, 2004; Crisp, 2002) to shared leadership in distributed teams. For instance, the importance of good virtual team leadership has been reinforced by the findings that in distributed teams, leadership effectiveness relates positively to role clarity, communication effectiveness and satisfaction with team communication (Kayworth & Leidner, 2002). The performance of more dispersed teams relies on leader communication (Cummings, 2006) and leader modeling of appropriate behaviours, such as choosing technologies (Cohen & Gibson, 2003) and helping team members know when to use particular technologies (Kirkman, Rosen, Gibson, Tesluk, &

Mcpherson, 2002). These behaviours are key to the success of distributed teams. Thus, distributed team effectiveness is improved when leaders are modeling appropriate behaviours and communication patterns, enabling training for dispersed team members, and facilitating team members' mutual knowledge of each other's situation and constraints (Kirkman et al., 2002; Weisband, 2002). In another study of designated leaders, Weisband (2002) suggested that effective leaders set the stage for successful future interaction and performance by initiating pressure about task demands and showing awareness and consideration of others early in the project. This differed from teams with leaders that waited until the second half of the project to initiate pressure, which was associated with lower team performance.

In their model of shared leadership in virtual teams, Burke, Shuffler, Salas, and Gelfand (2010) suggest that shared mental models are crucial for successful performance, especially when leadership is shared among multiple individuals in a team. Bowers and colleagues (2008) noted that leadership behaviours are also affected by distance among team members. Specifically, Zhang, Fjermestad, and Tremaine (2005) hypothesized that different leadership behaviours may be needed in distributed teams compared to those of face-to-face teams. However, inconsistencies are found in previous results and suggest the need to investigate more contextual variables. At this point, more research is required to fully understand the possible differences. Leaders of distributed teams face unique challenges when it comes to directing the teams' work, assessing performance, developing and encouraging members (including setting a climate for teamwork), and planning and communicating effective strategies for task accomplishment.

2.5 Shared mental models

Shared mental models are defined as "organized knowledge structures that allow individuals to interact with their environment" (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000, p. 274). Shared mental models help to explain how teams are able to effectively cope with difficult and challenging task conditions (Klimoski & Mohammed, 1994). Shared mental models help team members develop accurate explanations and expectations about the task, and members draw on shared mental models of the team to anticipate the needs of their fellow team members and pass information before it is requested (Espinosa et al., 2002).The establishment of shared mental models is an important aspect in any team, but especially in distributed ones, for in these contexts it may be more difficult to share knowledge due to the reliance on media that are not as rich as face-to-face interaction (Cramton, 2003). Several investigators have observed that accurate mental models are related to better team performance (Cannon-Bowers & Salas, 1998; Cannon-Bowers, Salas, & Converse, 1993; Coury & Terranova 1991; Converse, Cannon-Bowers, & Salas, 1991; Klimoski & Mohammed, 1994; Orasanu, 1993; Orasanu & Salas, 1993; Rouse, Cannon-Bowers, & Salas, 1992; Salas Dickenson, Converse, & Tannenbaum, 1995; Stout & Salas, 1993). However, an extensive literature search revealed that no study has compared distributed teams and collocated directly in regards to shared mental models. Nevertheless, Maynard (2004) posits that distributed teams take longer to develop shared mental models.

3 Distributed versus collocated teams in C2 environments

As mentioned before, C2 tasks are best described as execution tasks, which require team members to extensively collaborate and coordinate in order to achieve mission objectives. While execution tasks account for the largest fraction of time and energy expended by real-world teams, they are underrepresented in the distributed-team performance literature (Baltes et al., 2002; McGrath, 1984). For instance, Kleinman and Serfaty (1989) studied a military-based synthetic task environment that represented a geographically distributed Airborne Warning and Control Systems environment, but there were no direct comparisons of team behaviour, performance, and cognition between this setting and a collocated environment.

Distributed teams were investigated in the context of a simulated coalition Joint Task Force as part of Multinational Experiment 4 (MNE 4). MNE 4 was conducted in 2006 and involved military and civilian participants from multiple nations as well as the North Atlantic Treaty Organization (NATO). Various aspects of teamwork, such as attribution of roles and responsibilities, workload, quality of information, and trust in one's team were assessed through questionnaires. According to Bowman (2007), while participating teams reported a good level of trust, they identified lacks with regards to understanding of roles and responsibilities across teams, quality of information (especially in terms of timeliness and accuracy), effective team processes, as well as unbalanced workload. Although these findings are based on subjective perceptions and were not contrasted with objective measures, they suggest that distributed teams operating in a military context also face multiple challenges, particularly in a multinational context. Interestingly, two thirds of the participants had met face-to-face in the year leading to the execution of the experiment, which may have contributed to the level of trust experienced by participants. Unfortunately, this experiment did not involve a comparison with collocated teams.

An extensive search of the literature revealed one study directly comparing distributed and collocated teams in a C2 military environment. Cooke, Gorman, Duran, and Taylor (2007) compared collocated and distributed teams using the Cognitive Engineering Research on Team Tasks Laboratory UAV-STE task, an abstraction of the US Air Force's Predator UAV ground operations task (Cooke, Rivera, Shope, & Caukwell, 1999). Collocated team members were assigned individual workstations in the same room. They could see each other during missions and they communicated using headsets. Distributed team members and their communication operator were located in separate rooms for the mission planning, and they were separated for the entire experiment by partition walls. This was done to ensure that team members could not see each other. Each member of the team had a unique role and was provided with distinct training and information during the mission. However, they were interdependent and shared some overlapping information. To complete the mission, they needed to effectively coordinate themselves in order to exchange crucial information with one another.

Results showed that collocated teams were more engaged in pre- and post- mission process communication behaviours (adaptation and planning) than distributed teams. Overall, collocated teams spent more time communicating than distributed teams. These kinds of pre- and post-mission process behaviours have been theoretically tied to the building of shared knowledge (e.g., Fiore et al., 2003; Levine & Choi, 2004). The connection between process and knowledge is

supported by the ease that collocated teams had in acquiring knowledge about the task from the perspective of other team members, compared to distributed teams.

On the other hand, Cooke et al. (2007) also found that teams were able to adapt their interactions to these environments to achieve equivalent successful performance, which, in some cases, was better carried out by distributed teams than collocated teams (especially during the switch to high workload). In other words, the collocated teams who displayed more pre- and post- mission process behaviours were less able to adapt to a more intense high-workload task. This shows that teams are able to adjust their behaviours and cognitive activities to the constraints of their environments. This illustrates the principle of equifinality, with different teams attaining qualitatively a similarly successful outcome while taking different routes to achieve it. In a collocated environment, team members can interact more directly and share computer displays, which result in the development of interpositional taskwork knowledge, which, in turn, allows team members to anticipate more correctly the actions or needs of other team members (Entin & Serfaty, 1999; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). This interpositional taskwork knowledge enables team members to appropriately coordinate their activities, and further enhances team process. These results could also partially stem from the possibility that knowledge differences were not critically tied to team performance, but rather they were simply a by-product of different process behaviours. For instance, the development of interpositional knowledge by collocated teams may not produce significant benefits in performance compared with distributed teams when all team members in both settings are allowed to freely communicate, thereby sharing knowledge in real time (Stout, Cannon-Bowers, & Salas, 1996). Given the other extreme, however, in which team members are highly interchangeable, communication restrictions such as requiring team members to communicate by computer messaging or restricting the amount of communication allowed may produce a greater decline in performance for distributed teams compared with collocated teams, who presumably can develop expectations about the needs of other team members. Therefore, in a context of highly specialized division of labour, interpositional knowledge may not always be critical.

An advantage associated with this study comes from the fact that these results suggest that interventions targeting pre- and post- mission process coordination behaviours may benefit distributed teams. Indeed, if interpositional knowledge is necessary in order to adapt to different settings, then an intervention of this type might foster process behaviours that facilitate the development of this sort of knowledge in distributed teams (e.g., through instituting pre- and post-mission planning sessions). However, it is important to keep in mind that various methodological concerns limit the generalization of these results to other task environments. In summary, Cooke et al. (2007) conclude that geographic distribution changes team cognition and team process but apparently has little effect on team performance. The benefits of using distributed teams appear to outweigh any minor costs of geographic distribution in this task. However, when interpositional knowledge is critical and communication is hindered the costs may be significant. Considering the dearth of empirical work directly comparing distributed and collocated teams in C2 environments, more research effort is warranted to investigate the particularities of teamwork in military operations.

4 Extrapolation of parameters

Network-enabled operations promise faster and enhanced decision making with the advantage that an increasing number of tactical players will be enabled to make operational or tactical collaborative decisions. It is expected that these players at the lower echelons will use their shared situation awareness to respond both quickly and appropriately at critical decision points.

The present literature review covering the topic of distributed and collocated teams appear to suggest that beyond technology, success in implementing distributed teams lies with processes and people. Distributed teams can offer many benefits (e.g., allow teamwork across space and/or time) but can also present different challenges (Ebrahim, Ahmed, & Taha, 2009). How can this extensive literature review be applied to military C2 environment characterized by changing conditions, time pressure, uncertainty, and an overwhelming amount of information to process? In this section, we present five different parameters that appear crucial to the development of efficient and effective distributed C2 teams. Even though these parameters are all related to one another, for the sake of clarity we present them separately, focusing on their importance in a military context.

4.1 Coordination

Coordination is critical in distributed teams. It is a complex cognitive activity performed by many team members who work on a common task while being geographically dispersed. These teams often have to deal with challenging coordination problems due to their distributed nature. The synchronization of team members' actions and the progressive integration of these actions are difficult to achieve because members are dispersed across geographical, organizational or even national borders. Therefore, management of distributed teams requires a lot of task and process management involving a great deal of scheduling. Clear mission statements and realistic project timelines are particularly important in order to overcome the ambiguities inherent to the initial phases of team development (Furst, Reeves, Rosen, & Blackburn, 2004). A shared understanding of the commander's intent is crucial among all team members. Therefore, the coordination protocol must encompass process rules and strategies that will be used to facilitate achieving the common goal. The coordination protocol is also primordial for the evaluation of alternatives and solutions, tasks synchronization, as well as monitoring and feedback functions. In teams using computer mediated technology, team processes are constrained, especially planning and coordination. This urges commanders to set clear objectives for the team. Furthermore, structural feedback is needed to monitor activities and to ensure that progress on the task and team performance are transparent all the time. Baltes et al. (2002) completed a meta-analysis of 23 studies comparing face-to-face communication with computer-mediated communication and concluded that computer-mediated communication poses significant challenges to team problem solving and decision making. They noted also that when no time limit was imposed on the team's task and when complete anonymity was maintained for all members, computer-mediated and face-to-face teams performed equally well. This finding is important when considered in the context of future tactical C2 environments, where it is likely that high-stakes tactical decisions will be made by non-anonymous distributed teams under conditions involving time pressure, complexity, risk, and uncertainty. Neville, Fowlkes, Nelson, and Bergondy-Wilhelm (2003) conducted a cognitive task analysis study to examine expertise and experience-related differences

associated with achieving coordination in large, distributed teams. Their findings suggest that team coordination knowledge may be best acquired when learned in the context of responding to mission events, as this would allow that knowledge to be integrated into existing schemas, which seem to be focused around selection of courses of action (Neville et al., 2003). These results may have some important implications concerning coordination training and for planning of future operations with distributed teams. Generally, designers of distributed work systems need to explore technology solutions that support the coordination required in distributed collaborative interactions. Also, because there are clearly situations where synchronous interactions between collaborative partners cannot occur, understanding the requirements for and the design of asynchronous tools must be explored.

A study by Gupta, Mattarelli, Seshasai, and Broschak (2009) revealed the geographic structure of a team (collocated or globally distributed) does not predetermine team outcomes. Both structures are workable models with proper adaptations and neither is inherently superior. The findings also indicated that geographic distribution can be leveraged by taking advantage of the possibility of continuous engagement on tasks across time zones. So it is possible to create a distributed tactical or operational team that would be adapted (and trained beforehand) so that team coordination could be optimal. Given the crucial importance of good coordination among distributed team members, more research focussed on C2 distributed teams in tactical and operational domains is warranted.

Synchronization refers to the process of structuring actions in a temporal dimension to operate in unison (de Greef & Oomes, 2008). An anticipatory behaviour that aids humans in predicting others' behaviours and coordinating their actions is known as implicit coordination. By reducing the need for information exchange, and at the same time minimizing coordination and communication costs (e.g., in time), implicit coordination is crucial for teams that work in dynamic, stressful environments. Training is part of a number of practices that are available to overcome the extra cognitive requirements associated with coordination activities. For example, controlled exercises in which a team member is presented with cues that replicate those found in the actual environment, enable a team to minimize surprises thereby improving the trainee's predictive power. Another example of mitigating additional cognitive burden of distributed teams is seen in explicit and structured communication procedures for instance as used on naval vessels.

4.2 Shared mental model

Shared mental models include the team members' models of the coordinating routines and knowledge within the team. The team is considered the primary cognitive information-processing unit (Artman, 2000). Therefore, the cognitive functioning of shared mental models is vital for how the team collectively assesses the situation. Teams build shared awareness partly through communication; this awareness then drives team coordination (Rosen et al., 2008). Shared mental models allow team members to develop explanations and expectations about the tasks (Cannon-Bowers et al., 1993; Mathieu et al., 2000), and they draw on these models to anticipate the needs of their fellow team members and pass information before it is requested (Espinosa et al., 2002). Through their interactions, team members will develop a shared understanding of the task goals and of their progress. The capabilities of the communication tools are also relevant: They should facilitate frequent interactions and enable the development of a shared understanding of the task and the situation. To take a simple example, one characteristic of many of the military and civil

aviation teams that have been studied is time pressure. Under temporal pressure, when teams have little time to respond or make decisions, they must rely on shared knowledge (or mental models) instead of more deliberate planning. Espevik et al. (2011) carried out a first study to investigate the effect of a shared mental model across team members in distributed teams, in particular whether the shared mental models across team members have an effect on team performance, communication, and physical arousal in two distributed teams in pursuit of a common objective. They used a sample of 15 newly formed navy teams and compared it with a sample of 13 familiar navy teams. The findings showed that when compared to unfamiliar teams, familiar teams presented higher performance levels, faster reaction times, greater accuracy, and greater mission success. Espevik et al. (2011) concluded that the mechanism explaining these findings could be a more developed shared mental model across team members in the familiar teams compared to the unfamiliar teams (see also Cannon-Bowers et al., 1993). Salas, Rosen, Burke, Nicholson, and Howse (2007) suggested a strong connection between monitoring behaviours and shared mental models. According to them, mutual performance monitoring would only occur in teams with adequate shared mental models. Thus, it is possible that the lack of an adequate shared mental model among team members comes from the decrease in monitoring behaviours observed in unfamiliar teams. Therefore, even if separated physically and connected only by verbal communication, shared mental models of team members can enable teams to coordinate activities more effectively and more implicitly. These different studies all seem to point to the importance of developing a shared mental model across team members in order to optimize performance. There must be an optimal information distribution among team members, appropriate briefing, and dissemination of information should be encouraged so that every team member understands clearly every relevant aspect of the operation or task to perform.

4.3 Communication

When designing a distributed team, the communication technology should be designed to enable optimal interactions between the team members, including access to task-relevant knowledge (Curseu et al., 2008). A meta-analysis conducted by Baltes et al., (2002) revealed that when the task is performed under time pressure and it can be characterized as intellective (tasks that involve solving problems with verifiably correct answers) or mixed-motive (tasks that involve resolving conflicts of motive-interest) distributed teams usually perform worse than those using face-to-face communication. Moreover, distributed teams are usually less satisfied compared to those using face-to-face communication in intellective and mixed-motive tasks. Thus, distributed teams are disadvantaged compared to face-to-face teams in this respect. However, distributed teams generally generate a set of realistic and acceptable solutions when faced with a problem, but they often fail to evaluate the alternative solutions properly (Baltes et al., 2002). The evaluation of alternatives is one of the most pertinent communication functions that impact decision quality. This is why using evaluation tools might lead to a higher decision quality. Because the communication environment influences team effectiveness, it is crucial to make sure that the distributed team members know how to use the communication tools. While there are advantages of communication on performance monitoring, there are also disadvantages because communication can disrupt the workflow during high workload periods (Hutchins, 1992). For this reason, officers in naval defence feel that the amount of information exchange in C2 centres is too high and should be restricted to “what is needed” (Rasker, Post, & Schraagen, 2000). Therefore, team and mission success could benefit from team members giving each other feedback on performance monitoring more during low workload periods than high workload periods.

4.4 Trust

As mentioned before, it is more difficult to develop interpersonal relationships in distributed teams because there is little or no face-to-face interaction. As a result, trust and cohesion among team members are not easy to create (Curseu et al., 2008). The quality of the (informal) interpersonal communication between team members represents one of the most important sources of trust, especially in the first stages of team formation. Again, the use of appropriate communication tools is crucial for trust to emerge. The development of trust, cohesion and a strong team identity can be very challenging. Face-to-face interaction plays an important role in this respect and it appears to be especially important in the beginning. Indeed, in the initial phases of the team life, meeting face-to-face will let team members get acquainted with each other. At that moment, it can also be beneficial to set clear objectives for the team and discuss the coordination protocol. This direct contact is essential for the development of trust and cohesion. It is important to have a strong communication network so that team members can sometimes communicate face-to-face in order to build relationships and develop trust in each other (Curseu et al., 2008).

4.5 Leadership

The constraints imposed by the virtual nature of communication processes and information processing in distributed teams can be mitigated by effective leadership. Leaders should encourage team members to develop norms that will guide communication interactions (such as timely information sharing, appropriated responses to electronic communication, etc.). Structured schedules have a positive impact on information integration, as well as on coordination across different time zones. Therefore, team leaders should set clear norms concerning timetables, deadlines and team members' obligations as appropriate (Furst et al., 2004). Bell and Kozlowski (2002) note how leadership factors must differentially address various task complexity factors associated with distributed teams. For instance, implementation of increasingly dispersed teams at the tactical and operational levels might call for further shared leadership. Walker, Stanton, Salmon, and Jenkins (2009) conducted a study to explore whether having the commander remote from his or her planning staff can be, with appropriate facilitation, as effective as having commander and staff collocated. They compared four conditions in which different combinations of voice plus video and/or shared data were recreated (representing progressively degraded versions of remote planning facilitation). One of these conditions, called Collaborative Planning, used voice (telephone), video, and live updateable shared tools (a video and data condition). Findings indicated that in terms of practical implications, the Collaborative Planning condition appeared the best option to facilitate situations in which the commander is remote from his or her team. However, the corollary of this study especially from a technical (specifically bandwidth) point of view, is not altogether favourable. In fact, it is important to note that providing video links similar to those used in this study in military settings would be highly resource (and cost) intensive. Finally, Walker et al. (2009) concluded that with certain caveats attached, it is possible for commanders to remain involved in the planning process while being physically remote from the rest of their team.

5 Conclusion

This study was part of a scoping study aiming to assess the feasibility to achieve dispersed BGHQ. The scoping study itself was based on the acceptance of an ARP proposal on Mobile and Modular Command Post that suggested exploring the dimensions of mobility and modularity as a solution to enable command posts to conduct ADO. The scoping study process led the authors to focus their attention of the intent of enabling command posts to conduct ADO instead of the proposal title that may have suggested a focal attention on mobility and modularity. If these two remained, it is for the sole purpose to ensure flexibility, robustness, and/or security for the conduction of ADO.

In the context of this study, a dispersed BGHQ was seen as a virtual HQ whereby cells and branch members connect and operate within the virtual environment remotely, that is to say from outside the theatre of operations. From a higher level perspective, the achievement of such concept should imply the following science and technology (S&T) themes: cyber-physical-social systems design and engineering, including human factors, human-machine interfaces (HMI), system learning, and the issues of safety, security, and sustainability. It would also involve human collaborative issues such as ergonomics (cognitive, physical), soft and hard information fusion, quality of information, etc. This study assessed the concept of dispersed BGHQ as feasible with regards to distributed teams, and characterized the potential advantages and disadvantages.

With regards to the human aspects of the problem, many studies have compared distributed and collocated teams on multiple characteristics and in various environments. While some differences have been observed between these two types of teams, many of the successful work processes of distributed teams appear to be similar to those of traditional collocated teams. Indeed, just like for collocated team research, work on distributed teams usually reveal a positive association between the team's work processes and its performance. However, distributed teams performance also depends on several other factors whose influence on team effectiveness is compounded by the use of technology (e.g., coordination, project management, quality of communication, cohesion, etc.). The diversity in team member characteristics often present in geographically separate teams can also affect team processes and outcomes. For instance, face-to-face teams and distributed teams manifest communication and other teamwork processes differently. However, other research suggests that differences between collocated and distributed teams tend to decrease over time as computer-mediated teams adapt to the technology and establish ways to work and interact. No differences were observed regarding the quality of decisions between the two types of teams. However, distance between team members appears to have a negative impact with respect to team attitudes, trust, collective efficacy, and team orientation. Some cognitive differences (e.g., memory processes) have also been identified among both types of teams. Although research on type of tasks in distributed teams is limited and the results are somewhat mixed, independent tasks seem to be appropriate for distributed teams in the short term. However, in the long term, interdependent tasks will allow distributed teams to develop team norms and shared ways of working. Homogeneous teams appear more appropriate for routine tasks while heterogeneous teams handle non-routine tasks best. Although comparisons of collocated and distributed with regard to suggest that the two types of teams exhibit similar levels of conflict, research also shows that a "partially" distributed team (with a team being divided in sub-teams) appears to lead to more conflict that a "fully" distributed team where each member is in a different location (a configuration that may not be possible, and arguably desirable, in a military context). The many

benefits associated with the concept of trusting relationships among team members within distributed teams appear to be similar to those evidenced in collocated teams, but establishing trust can prove to be more challenging in distributed teams than collocated teams. Leadership processes might differ among teams that are distributed and those that are collocated but more research is required to fully understand the possible differences.

More research effort is warranted to investigate the particularities of distributed teamwork in military operations in general, and C2 in particular. Distributed teams can offer many benefits but also present different challenges. This extensive literature review allowed the extraction of five different parameters that appear crucial to the development of efficient and effective distributed C2 teams, and which could be the focus of further research and assessment:

- The coordination efficiency and ability to synchronize decisions and actions;
- The development of shared mental models;
- The efficiency and potential breakdowns in communication;
- The level of trust within teams and between distributed teams;
- The presence of leadership and development of shared leadership within and across teams.

Coordination among distributed teams in C2 environment is critical and it must encompass processes and strategies that will be used to facilitate achieving the common goal. Having a shared mental model is also vital for how the distributed team collectively assesses and understands the situation. Under temporal pressure, when teams have little time to respond or make decisions, they must rely on shared knowledge (or mental models) to limit the need for extensive deliberate planning. Also, as the amount of information exchange in C2 environments is often very high, it might be beneficial for team effectiveness and mission success that team members give each other feedback on performance monitoring more during low workload periods than high workload periods. Trust is another crucial concept in distributed teams and one of the most important sources of trust, especially in the first stages of team formation, is the quality of (informal) interpersonal communication between the team members. Effective leadership can help a distributed team to overcome the constraints imposed by the virtual nature of communication processes and information processing in distributed teams. Leaders of distributed teams should encourage team members to develop norms that guide communication and interactions (such as timely information sharing, appropriated responses to electronic communication, etc.) in order to mitigate the challenges from team members being dispersed.

Overall, distributed teams seem a promising alternative to collocated command teams when required and appropriate. The available research suggests that they can function at a level similar to collocated teams in a number of situations. However, one should keep in mind that distributed teams can face unique or compounded challenges in the ways they evolve and function, which can potentially impact team effectiveness and mission success. These challenges and the particularities of C2 distributed teams should be investigated further, and taken into account when implementing distributed teams in future CAF operations.

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Annex A Checklist of key factors for distributed teams

Below is a list of factors that play a significant role in the success of distributed C2 teams, based on the literature review presented in this document.

- **Coordination:** Clear objectives as well as clear coordination guidelines and protocol are needed to support planning, synchronization and scheduling of tasks and team members' actions, monitoring, feedback, etc. Implicit coordination should be supported (e.g., by training) to reduce the need for information exchange and the costs of communication between distributed members (e.g., in time). Distributed teams should have the opportunity to meet face-to-face throughout the team's life, which is particularly important early on.

- **Shared mental models:** Good shared mental models are important in how a team collectively assesses a situation and perform their task. Communication processes and tools should enable the development of a shared understanding of the task and the situation. Shared mental models contribute to better coordination, performance monitoring, and overall performance.

- **Communication:** Communication medium influences team effectiveness. Communication processes and technology should enable optimal and frequent (when relevant and time allows) interactions between team members, as well as the access to task-relevant knowledge. Distributed teams are disadvantaged compared to face-to-face teams in some situations (e.g., early in the team lifecycle or with some type of tasks such as problem solving).

- **Trust:** Trust and cohesion are more difficult to develop in distributed teams because the lack of face-to-face interactions hinders the development of interpersonal relationships among team members. The quality of (informal) interpersonal communication represents one of the most important sources of trust, especially early in the team lifecycle. Thus, meeting face-to-face in this early stage can be very valuable for team trust and cohesion.

- **Leadership:** Effective leadership can mitigate the constraints and drawbacks of distributed teams (e.g., with regards to virtual communication and information exchange). Leaders should encourage the development of norms and guidelines that will guide communication, information integration, and coordination. Distributed leadership (where the leader is remote from the team) can be a worthwhile option with the appropriate technological support (i.e., voice and video communication). However, the cost of such support (e.g., in terms of bandwidth) must be considered.

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List of symbols/abbreviations/acronyms/initialisms

ADO	Adaptive Dispersed Operations
BGHQ	Brigade-group headquarters
C2	Command and control
CALWC	Canadian Army Land Warfare Centre
DLCD	Directorate of Land Concepts Design
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
GDSS	Group decision support system
NSERC	National Sciences and Engineering Research Council of Canada
R&D	Research & Development
S & T	Science and technology
TASSCM	Tracking Agility and Self-Synchronization in Crisis Management
TTP	Tactics, Techniques and Procedures
UAV	Unmanned aerial vehicle
VCDS	Vice Chief of Defence Staff

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Rapid changes in the operational environment, globalization, an ever-growing recourse to coalitions and alliances combined with a push towards designing more flexible and versatile organizational structures, has accelerated the need for organizations, including the military, to coordinate work across geographical, functional, intra- and inter-organizational as well as temporal boundaries. Responding to the increasing decentralization and globalization of work processes, many organizations have reacted to their dynamic environments by introducing distributed teams. The environment in which military teams evolve is often characterized by changing conditions, time pressure, uncertainty, and an overwhelming amount of information to process. This report presents an analysis of the literature on distributed teams and highlights issues of potential consequences and interest in the context of mobile and modular command posts for the Canadian Forces (CF). There is a need for a robust scientific methodology to evaluate tools for collaborative decision making designed to and verify support decision effectiveness in dynamic, uncertain contexts of tactical operation. For instance, military air operations call for precise effects within a highly dynamic environment, requiring collaborative decision making from the strategic to tactical levels.

En raison de l'évolution rapide du contexte opérationnel, de la mondialisation, du recours de plus en plus fréquent aux alliances et aux coalitions, ainsi que des récents efforts vers l'établissement de structures organisationnelles plus souples et polyvalentes, les organisations, y compris les organisations militaires, ont un besoin de plus en plus pressant de coordonner leurs activités en repoussant les limites géographiques, fonctionnelles, intra et interorganisationnelles, et temporelles. En réaction à la décentralisation et à la mondialisation graduelles des processus opérationnels, beaucoup d'organisations ont décidé de mettre en place des équipes décentralisées. Le contexte dans lequel les équipes militaires évoluent se caractérise souvent par des conditions de travail changeantes, des contraintes temporelles, de l'incertitude ainsi qu'une quantité monumentale d'informations à traiter. Le présent rapport offre une analyse bibliographique sur le sujet des équipes décentralisées en plus de mettre en lumière les questions potentiellement dignes d'intérêt et susceptibles d'avoir des effets sur la situation des postes de commandement mobiles et modulaires des Forces canadiennes (FC). Nous devons nous doter d'une méthode scientifique rigoureuse qui nous permettra d'évaluer les outils d'aide à la prise de décisions et de vérifier l'efficacité de ces décisions dans le contexte dynamique et incertain des opérations tactiques. Par exemple, les opérations militaires aériennes visent à produire des effets précis dans un environnement hautement dynamique, ce qui nécessite une prise de décisions stratégiques et tactiques axée sur la collaboration.

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Teamwork; distributed teams; C2; coordination; communication; leadership; trust; shared mental models

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