Coordination in virtual teams

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Chapter 1

Introduction and theoretical framework

Introduction

Imagine an infantry platoon that is searching a village for weapons or materials that can be used for making Improvised Explosive Devices (IEDs). When the platoon enters the village, it will not be clear if there are people with hostile intentions among the civilians. The platoon splits up into four squads in order to search the village. While one squad is talking to local police officers, other squads are searching houses and other buildings. The squads are able to coordinate their actions because they use radio and digital information tools to communicate and share information with each other. This makes it possible for squads to make effective use of information that is obtained from police officers or civilians, deliberate possible courses of action with the platoon commander, or ask for assistance in case they encounter hostilities. Communication media help dispersed squads in these situations to accomplish their tasks effectively, and enable them to anticipate on the actions and needs of other squads.

This example clearly shows that distributed military teams have to operate decentralized. This means that teams have the authority to adapt their actions in response to emerging situations, for instance to respond to the hostile acts of the enemy by returning fire. Teams are allowed to respond to situational changes without direct supervision from higher organizational levels. Theoretical foundation of decentralization is sought in systems theory and complexity science (see, for example, Moffat, 2003), and theorists refer to the concepts of emergence and self-synchronization (Alberts & Hayes, 2003; 2006; Atkinson & Moffat, 2005; Kaufman, 2004). Emergence refers to bottom-up processes in which behaviours of individuals are amplified by interactions with others, and lead to collective action. Self-synchronization is used in theory on modern military operations to describe the alignment of actions of teams without direct control from the higher level.

Military operations have a strong focus on establishing coordinated action. Coordination is needed when dispersed units have to collaborate in complex and dynamic environments where actions have to be adapted to emerging conditions. Military operations are ‘tight’ by nature, as the activities of one unit directly affect the activities of other units. Therefore, coordination of actions by several units is necessary. The coordination of actions of different units is intended to create a synergetic effect on combat power, leading to competitive advantage in military operations (Alberts, Gartska, & Stein, 1999). This creation of synergy, called synchronization, has become an essential part of military doctrine (Alberts & Hayes, 2006; Kirin, 1996; United Kingdom Joint Warfare Publication, 3-63, 2003). Synchronization refers to the arrangement of actions in time and space, where ‘space’ does not only refer to the physical domain but also to the alignment of actions in information, cognitive, and social domains (Albert et al., 1999). Synchronization of the contributions of dispersed teams is aimed at speeding up decision-making processes, the effective use of resources, and ultimately increasing the effectiveness of military operations.

Similar to other organizations, military organizations seek to exploit the benefits that advanced information and communication technology offers for synchronizing the actions of different teams. Networking the contributions of dispersed teams, by timely coupling their capabilities, competencies and resources, affects command and control processes. These processes can be more flexible and adaptive by using information and communication technology. Military operations in which information and communication technology is used for the synchronization of the actions of teams or units are labelled *networked military operations*. Networked military operations draw heavily on the ability of teams to coordinate their actions without direct control from higher organizational levels.

The use of information and communication technology by teams has become commonplace in organizations, because this technology offers new possibilities to team members to communicate and share information with other team members (e.g., Gibson & Cohen, 2002; Kanawattanachai & Yoo, 2002). Teams that primarily rely on information and communication media for team member interactions are called *virtual teams* (Kirkman & Mathieu, 2005; Martins, Gilson, & Maynard, 2004). However, it is not clear how effective coordination in virtual teams can be established. Two important questions that still have to be addressed are related to specific characteristics of electronic communication media and virtual team leadership. First, media characteristics influence coordination processes in virtual teams, such as the extent to which communication media are capable of facilitating synchronous interactions between team members and the transfer of relevant social context cues (e,g, Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002; Bordia, 1997; Curşeu, Schalk, & Wessel, 2008). Media theories that consider specific characteristics of electronic communication media have been proposed, and empirical support for these theories is emerging (Dennis, Fuller, & Valacich, 2008). Second, it is not clear which leadership style is best for establishing effective coordination in virtual teams. Theories on virtual team leadership have been proposed (e.g., Bell & Kozlowski, 2002; Zaccaro, Ardison, & Orvis, 2004), and empirical support for these theories is beginning to emerge (e.g., Hambley, O’Neill, & Kline, 2007; Kahai, Sosik, & Avolio, 2004). The aim of the present research is to examine how virtual teams coordinate their actions and which factors foster effective coordination in virtual teams. The central research questions are formulated as:

Research question 1: How do team members in virtual teams coordinate their actions with those of other team members during team performance?

Research question 2: What factors foster the effective coordination of team member contributions in virtual teams?

Virtual teams

An important reason for organizing work in teams is the potential variety and flexible employment of skills and knowledge that are needed for meeting the demands of operating in complex and dynamic environments. Complex and dynamic environments may be described as "*situations where cause and effect are subtle, and where the effects over time of interventions are not obvious*" (Senge, 1992, pp. 71-72). Teams that are confronted with ambiguity and equivocality, have to make sense of 'what is going on' in order to accomplish their goals (Weick, 1995). Teams operating in complex and dynamic environments have to develop a dynamic understanding of the environment. To achieve this, they have to interact with the environment, interpret information, take action, and evaluate the effects of actions in order to create meaning. A team is better suited for complex and dynamic environments than single individuals, provided that the team consists of persons with different competencies, capabilities, resources, and expertise, and that the team members interact dynamically. Team members use their individual and shared resources to operate in dynamic, complex environments by communicating and effectively coordinating team member contributions (LePine, 2005; Burke, Stagl, Salas, Pierce, & Kendall, 2006).

Information and communication technology offer some extraordinary benefits in permitting collaborative work to virtual teams. First, virtual teams can accomplish their tasks when team members are not collocated, because team members can communicate and share information regardless of their physical location. Second, members of virtual teams can be located in different time zones ('global virtual teams'; Jarvenpaa, Knoll, & Leidner, 1998; Lipnack & Stamps, 2000). This 'working around the clock' is for instance observed in software development teams, where engineers in different time zones work on the same project. This makes it possible for organizations to speed up organizational processes. Third, the use of technology for facilitating team member interactions leads to cost reduction, because members of teams do not have to travel to meet each other. Teams that use information and communication technology in these situations can share information and communicate in order to establish and maintain coordinated action. Fourth, team members can be selected for their specific expertise or capabilities (e.g. Bell & Kozlowski, 2002). This enables organizations to select 'the best man for the job'. Fifth, virtual teams can be formed ad hoc in response to changing task demands (Bell & Kozlowski, 2002;

Townsend, DeMarie, & Hendrickson, 1998). This is particularly important for teams that operate in complex and dynamic environments, where sudden and unexpected changes affect team progress. Finally, team membership can be flexible in virtual teams, which means that team members can enter or leave the team depending on task demands. For instance, individuals with specific expertise can be invited to enter a team in response to changing tasks (e.g., Bell & Kozlowski, 2002). This allows a precise division of labour in virtual teams, which makes it possible to make effective use of resources. The ad hoc formation of teams offers the flexibility that organizations in complex and dynamic environments seek, and technology is an important enabler for this flexibility.

There has been a proliferation of definitions of virtual teams since the emergence of information and communication technology at the end of the last century. Many definitions have focused on the use of technology for enabling teams to overcome locational, temporal, and relational boundaries. Research in this domain has focused on the first four benefits described above, and featured teams that crossed locational, temporal, and/or relational boundaries (e.g., Hinds & Bailey, 2003; Jarvenpaa, Knoll, & Leidner, 1999; Lipnack & Stamps, 1997; Montoya-Weiss, Massey & Song, 2001). Other research has focused on the flexibility that virtual teams offer in terms of team membership, which was described in the latter two benefits of virtual teams. Research is focused on flexible team membership, temporary teams, and the lifecycle of virtual teams (e.g., Alge, Wiethoff, & Klein, 2003; Bell & Kozlowski, 2002; Furst, Reeves, Rosen, & Blackburn, 2004).

Research on virtual teams generally took the approach of comparing collocated or face-to-face teams and virtual teams, where virtual teams used technology for information sharing and communication, and, additionally, featured other characteristics that made teams virtual. The popularity of information and communications technology in modern organizations means that the complexity and diversity of teams in organizations has increased. Research has indicated that the majority of employees of large companies now work in teams that can be characterized by some level of virtuality (e.g., Bell & Kozlowski, 2002; Kanawattanachai & Yoo, 2002). Teams that use technology for working together differ on a wide range of factors, including reliance on technology, spatial distance, extent to which organizational boundaries are crossed, lifecycle, and type of task. Because of the widespread use of information and communication technology in organizations, theorists recently started to move away from the dichotomous conceptualization of virtual teams that is typically investigated by means of comparing face-to-face teams and virtual teams (Gibson & Gibbs, 2006; Martins et al., 2004). Instead, team virtuality is considered to be a multidimensional concept that potentially characterizes all teams (e.g., Cohen & Gibson, 2003; Griffith & Neale, 2001; Kirkman & Mathieu, 2005). In attempts to develop integrative theories on team virtuality, several frameworks have been proposed. First, Griffith and Neale (2001) distinguished between two dimensions: time that team members spend together, and the extent to which technological support is employed by the team. These dimensions lead to a classification of ‘pure’ traditional and ‘pure’ virtual teams, and hybrid teams that use a mix of face-to-face communication and computer-mediated communication. This conceptualization of virtual teams holds an important issue, as it is not explicated what proportion of team member interactions has to run via electronic communication media in order to be virtual. This means that all teams that use technology in some way for communicating and sharing information can be characterized by some level of virtuality. Second, Cohen and Gibson (2003) introduced a framework that featured ‘electronic dependence’ as one of two dimensions that define team virtuality. Electronic dependence ranges from low electronic dependence (face-to-face communication) to high electronic dependence (computer-mediated communication). The second dimension was geographical distance. The advantage of this framework is that team virtuality is treated as a variable, and teams are not classified in different categories.

On top of that, Kirkman and Mathieu (2005) pointed out in their framework on team virtuality that teams in modern organizations may not only use technology to overcome boundaries, but teams *choose* to use technology to interact when this offers benefits to them. This means that members of virtual teams may work for the same organization, and may even be located in the same office, but choose to interact via technology when this helps them to accomplish their tasks more effectively. Kirkman and Mathieu (2005) distinguished three dimensions of team virtuality: (1) extent of reliance on virtual tools, (2) the informational value of these tools, and (3) synchronicity of team member interactions. The first dimension is similar to Cohen and Gibson’s (2003) concept of electronic dependency. The second dimension refers to the extent to which media can transfer information in a way that is relevant for task execution. The third dimension encompasses to what extent team members can communicate synchronously, as some media facilitate synchronous interactions between team members (e.g., videoconferencing, chat), while others do not (e.g., fax, voicemail). According to Kirkman and Mathieu (2005), the crossing of locational, temporal, and relational boundaries will always be an important reason to organize work in virtual teams, but this is not a factor that contributes to the extent to which teams are virtual.

The present research is focused on teams that communicate and share information via electronic communication media, and does not consider face-to-face communication. This research strategy is chosen for the following reasons. First, the goal of the research was to develop a better understanding of team coordination in the context of networked military operations. In these types of operations, team members often operate in distributed settings, and exclusively rely on technology for team member interactions during task execution. Second, it was emphasized by Kirkman and Mathieu (2005) that teams that are collocated may intensively use technology as well.

It was discussed above that teams that use technology in addition to face to-face communication can be characterized by some level of virtuality. This has raised a discussion on what proportion of communication must run via electronic communication media for teams to be virtual (Martins et al., 2004). This debate is ongoing, which means that only those teams in which all communication between team members is mediated by electronic information and communication media are unquestionably virtual teams. In this thesis we studied teams that only used information and communication technology for communication. An important consequence of the focus on virtual teams is that the present research does not feature face-to-face teams as control groups, and research outcomes only apply to virtual teams.

Team coordination

When teams perform complex, interdependent tasks, team members have different roles, responsibilities, competencies, and resources. Team coordination refers to the effective management of mutual dependencies that result from the differences between members of the team. Team coordination may be defined as *"the process of orchestrating the sequence and timing of interdependent actions"* (Marks, Mathieu, & Zaccaro, 2001: pp. 367–368).

Team coordination processes can either be explicit or implicit (see Espinosa, Lerch, & Kraut, 2004). Explicit coordination processes can be defined as processes that are purposefully employed by teams in order to manage dependencies (Espinosa et al., 2004). Examples of explicit coordination processes are division of labour, schedules, plans, and tools. Explicit coordination is effective when tasks have many routine aspects and when there are no changes in the task or in the environment that interfere with the routines of teams. In these situations, explicit coordination processes are effective ways for team members to coordinate their efforts (Espinosa et al., 2004). Another important explicit coordination process is communication, for example, when team members provide mutual feedback. Coordination through communication can take many forms, depending on factors such as the number of team members that are involved and the context in which communication takes place (formal or informal). Teams use communication when routines no longer apply to the task, or when dependencies between team members can no longer be managed by the existing coordination processes.

Implicit coordination in teams may be defined as "*synchronization of member actions based on unspoken assumptions about what others in the group are likely to do*" (Wittenbaum & Stasser 1996: p. 3). The concept of implicit coordination was originally developed to describe the capacity of teams to maintain performance levels under conditions of high workload. It was observed that teams notably reduced the communication within the team, while performance levels did not decrease (e.g.; Kleinman & Serfaty, 1989; Orasanu, 1990; Serfaty, Entin, & Volpe, 1993). Typical behaviours for teams that are able to maintain performance levels while reducing communication are: proactively sharing information or feedback, sharing workload by helping other team members, monitoring progress and the activities of other team members, and adjusting own behaviour to the expected actions of other members of the team (e.g., Entin & Serfaty, 1999; Rico et al., 2008; Wittembaum & Stasser, 1996).

Research on team cognition suggests that when team members interact with each other and become experienced in a task, team members develop shared knowledge of the team and the task. This shared knowledge enables members of a team to anticipate on the needs and actions of others and adjust their behaviour accordingly without having to communicate directly with each other or plan the activity of coordinating (e.g., Converse, Cannon-Bowers, & Salas, 1991; Entin & Serfaty, 1999; Kleinman & Serfaty, 1989; Rico, Sánchez-Manzanares, Gil, and Gibson, 2008). Implicit coordination refers to coordination processes that are the result of shared knowledge and are not consciously employed for the purpose of coordinating (Espinosa et al., 2004). An important benefit of implicit coordination processes is that they generally cost less time and effort once they are established. Implicit coordination is based on the expectations of team members regarding the task and the actions of other team members. These expectations in turn are based on the individual knowledge structures of team members regarding the task and the team. This knowledge is shared among team members through team member interactions. These knowledge structures are referred to as team mental models, describing the mental representations of team members regarding the team (e.g., roles, responsibilities, distribution of expertise) and the task (e.g., typical task strategies). Team mental models contain stable knowledge about the task and the team (see Cooke, Kiekel, Salas, Stout, Bowers, & Cannon-Bowers, 2003; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000).

More recently, researchers have emphasized the importance of contextual information for the development of implicit coordination (Cooke et al., 2003; Cooke, Salas, Cannon-Bowers, Stout, 2000; Rico et al., 2008). Team situation models are the mental representations that are associated with a dynamic understanding of the current situation. Team situation models thus contain dynamic information rather than the stable information that is captured in team mental models. Team situation models evolve during task performance and cannot be established beforehand (Cooke et al., 2000). The importance of team situation models for implicit coordination is based on the logic that implicit coordination itself is dynamic and situation dependent and contextual information such as team situation models is closely linked to team processes that are dependent on the context (Rico et al., 2008).

Teams will often manage their dependencies using a mix of explicit and implicit coordination processes (Espinosa et al., 2004). For instance, team members may have formal roles and responsibilities, but experienced team members may help team members that are less experienced in situations of high workload by giving feedback or performing subtasks of less experienced team members without begin asked to. The mix of explicit and implicit coordination processes that is employed by the team is influenced by factors that are related to the team (e.g. task experience, team tenure), the task (e.g., level of specialization, possibilities to arrange dependencies), or to the context in which the task is accomplish (e.g., technological mediation, geographical dispersion). This means that a particular coordination process may be more effective for different types of tasks (Espinosa et al., 2004). Further, the mix of coordination processes on a single task may change over time because explicit coordination processes may be substituted by implicit coordination processes (e.g., Rasker, 2002; Van der Kleij, Schraagen, Werkhoven, & De Dreu, 2009). Following the input-process-output models that are used by many for the study of teams (McGrath 1991, McGrath & Hollingshead 1994), differences on any of the factors will affect team coordination processes in teams, and ultimately influence team performance.

Coordination in virtual teams

Considerable research has been conducted on the effects of technology on team processes and performance (see reviews by Curşeu et al., 2008, and Martins et al., 2004; and meta-analyses by Bordia, 1997, and Baltes et al., 2002). The general conclusion of this research is that technology affects both explicit and implicit coordination processes in virtual teams, which perform complex, interdependent tasks. Both positive and negative effects have been described.

Regarding explicit coordination processes, the revolution in information and communication technology has created a wide variety of software and internet-based tools that can be used for the planning and coordination of team member contributions. These applications have been specifically designed for scheduling meetings and assigning tasks to members of the team. Additionally, the popularity of mobile phones made it easier to communicate with other team members. However, virtual teams often use typed messages to communicate with each other, and this may negatively affect team coordination. McGrath and Hollingshead (1994) compared teams with face-to-face communication with teams that communicated via text-based messages. They concluded that teams using typed messages spent more time and effort on communication with team members, which negatively affected team coordination processes: for instance, because team members reduce the amount of informal and non-task related communication in virtual teams (see Baltes et al., 2002). Further, restrictions in communication between team members during task execution have been shown to limit the sharing of task-related and situational information, which in turn negatively affects implicit coordination and team performance on complex tasks (Rasker, 2002; Rasker, Post, & Schraagen, 2000).

The emergence of implicit coordination hinges on team members’ shared knowledge about the team, the task, and the environment. Because communication is an important mean for sharing information on these topics, virtual teams experience difficulties when it comes to establishing interpersonal relationships and maintaining work flow and a shared context (Cramton, 2001). Researchers have concluded that virtual team members need high communication and media competencies to overcome the negative effects of technological mediation (see Cornelius & Boos, 2003; Driskell et al., 2003). Further, virtual teams have been shown to adapt to media over time. Rasker (2002) found that communication is important in a phase when teams are developing team mental models and team situation models, but communication becomes less important once mental models have been established. In these circumstances, communication is aimed at maintaining mental models, and using media that are high in virtuality may be sufficient for this. In line with this finding, researchers have shown that virtual teams may adapt to media over time (Van der Kleij, et al., 2009; Van der Kleij, Paashuis, & Schraagen, 2005; Van der Kleij, Paashuis, Langefeld, & Schraagen, 2004).

Another way in which the technology may affect implicit coordination in virtual teams is the reduced number of social context cues in computer-mediated communication. Social context cues are geographic, organizational, and situation variables that influence the content of interactions among persons (Sproull & Kiesler, 1986) The loss of social context cues, such as facial expressions and tone of voice, lead to difficulties on a range of team processes that are important for establishing shared knowledge, including difficulties of virtual team members to get to know each other (McGrath & Hollingshead, 1994), developing trust (e.g. Cascio, 1999), establishing a unified sense of purpose (Blackburn, Furst, & Rosen, 2003), and establishing effective communication (Thompson & Coovert, 2003).

When team members are not able to communicate verbally during task execution, for instance when members of virtual teams are not collocated, media characteristics will determine the extent to which team members can share and discuss task-relevant information. The capacity of electronic communication media to enable synchronous communication between team members is crucial for this, because media that are high in synchronicity enable team members to interact with each other without time delays. Media synchronicity is therefore considered to be crucial for effective coordination in virtual teams (Dennis & Valacich, 1998; Dennis, Valacich, & Fuller, 2008).

Team coordination processes in the present study

The present research was aimed at gaining more insight in team coordination processes in virtual teams and the factors that foster effective coordination in virtual teams. Five aspects of team coordination are considered. The following processes are related to implicit coordination: (1) team information processing, (2) transactive memory systems (TMS), (3) team situation models, and (4) self-synchronization. Explicit coordination is studied by means of communication (see also figure 1.1). These processes were selected because they are regarded to play a key role in coordination in virtual teams. Further, these processes are not only related to stable team- and task-related information, but also consider situation-dependent information (see Rico et al., 2008).

Team information processing was studied because team coordination processes are based on the extent to which team members share information with each other. Team members not only need to be aware of each others' roles, responsibilities, competencies, and resources, but the sharing of situational information is also important for teams that operate in complex and dynamic environments. It is expected that input factors affect team information processing, because team members cannot process all information that is present on the task and in the environment (Hinsz, Tindale, & Vollrath, 1997). For instance, leadership style is expected to influence what information is used in task execution.

TMS were studied because they contain stable knowledge on the distribution of task, roles, and responsibilities among member of the team. These models are important for teams that operate in complex and dynamic environments. This was also the reason to study team situation models. Team situation models are particularly important for teams that operate in environments that can change unexpectedly, as team coordination will depend on the extent to which team members have accurate and shared perceptions of the operational situation. Self-synchronization was studied because of the emphasis that theory on networked military operations has placed on implicit coordination in teams that are distributed and networked through technology. Finally, explicit coordination was studied by means of communication because teams that operate in complex and dynamic environments will rely on communication for coordinating team member contributions, rather than on other explicit coordination processes. The five team coordination processes are discussed below, and specific attention is given to the application of the concepts in virtual teams.

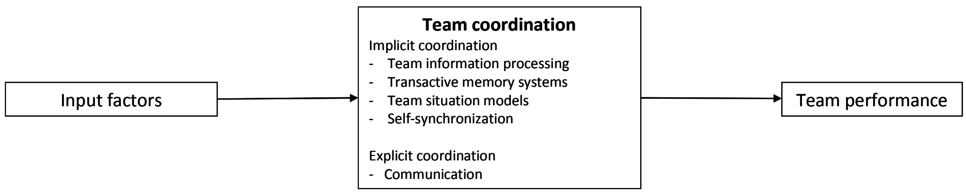

Figure 1.1: A framework for research on coordination in virtual teams

Team information processing. Much like individuals, groups process information when performing cognitive, intellectual tasks such as problem solving, decision making, and designing solutions or products (see Cooke, Salas, Kiekel, & Bell, 2004; Hinsz et al., 1997). Information processing at the group level is defined as: "*the degree to which information, ideas, or cognitive processes are shared, and are being shared, among the group members and how this sharing of information affects both individual- and group-*

level outcomes." (p. 43). The group information processing model of Hinsz and colleagues (1997) provides a general framework for information processing in groups.

According to the model of Hinsz et al. (1997), team members acquire information when they interact with the environment. The goals of team members provide a context for information processing, and therefore influence the attention, encoding, storage, and retrieval of information. Selection of information is crucial in complex, interdependent tasks, because team members will not be able to attend to all the information in these tasks. Information from the environment is integrated with information that team members have brought to the task, such as knowledge about the team and the task, and individual expertise. The integration of these two types of information occurs in what Hinsz et al. (1997) labelled the "processing work space". Information processing occurs on the basis of rules, beliefs, and procedures. Team information processing leads to the development of a response in the form of actions, decisions, or judgments. The responses of team members are evaluated by other team members in the form of feedback. Team information processing is influenced by the following factors, which may be task-related, (e.g., distribution of information), team-related (e.g., team composition, tenure, leadership), or related to the environment (e.g., high levels of ambiguity or equivocality).

Since team information processing is driven by team goals, this process is susceptible to many biases and errors (for an overview, see Curşeu et al., 2008). One of the most important biases in team information processing is selective use of information,, which may be described as the failure of teams to consider all relevant information (see Hinsz et al., 1997).

Curşeu and colleagues (2008) indicated that the use of information and communication technology facilitates information processing in teams. The benefits of information processing in virtual teams result from the reduced number of social cues in virtual teams. Although the reduced number of social cues makes it more difficult to establish trust and mutual knowledge, it may lower the team members' experience of social pressure. As a consequence, team members may be less susceptible to biases resulting from social processes, such as compliance with dominant views (Curşeu et al., 2008; Dennis, 1996). Another advantage of the reduced number of social cues is that ideas of members of virtual teams are evaluated on their merit rather than on the status of the team member who proposed the ideas (Baltes et al., 2002). Another benefit of the reduced number of social cues is that the negative effects of team member heterogeneity are mitigated when interacting through technology. Virtual teams are often characterized by higher levels of team member heterogeneity because team members may come from different organizations and cultures (Potter & Balthazard, 2002; Bell & Kozlowski, 2002). Since interacting through electronic communication media makes the differences between team members less prominent, virtual teams can profit from the diversity of team members in terms of different perspectives, whereas the negative aspects (e.g., stereotyping) may be limited.

In sum, the literature suggests that the extent to which information and communication technology is capable of transferring social context cues in team member interactions may affect team information processing in virtual teams. Unlike other team processes that will be discussed below, reduced numbers of social cues are considered to be a potential benefit for team information processing in virtual teams.

Transactive memory systems. Team members have their own specific knowledge, expertise, and capabilities, which they bring to the task. As was argued above, this applies particularly to virtual teams, where team members are selected for their expertise and skills that make them valuable to the team (Bell & Kozlowski, 2002). Given these differences, between team members, team performance largely depends on how well teams manage to integrate the expertise of individual team members. Transactive memory refers to team members' knowledge about the distribution of expertise, capabilities, and knowledge among members of the team, and how this knowledge has to be integrated. Similar to the group information processing model of Hinsz et al. (1997), TMS are group-level memory systems that are used for encoding, storing, retrieving, and communicating group knowledge (Hollingshead, 1998; 2001; Lewis, Lange, & Gillis, 2005).

TMS consist of team members' knowledge on specialization, credibility, and task coordination (Liang et al., 1995; Moreland & Myaskovsky, 2000). Specialization refers to knowledge of the diversification and distribution of expertise over the team members and who is responsible for what knowledge domain. Credibility consists of team members' beliefs on the reliability of expertise of other team members. Coordination refers to knowledge of team members on how the contributions of team members should be integrated. TMS help teams to perform tasks efficiently because they allow team members to have quick and coordinated access to the specialized knowledge of other team members. In this way the team makes optimal use of the task-relevant knowledge that is present in the team (Lewis, 2004). Further, TMS are positively related to team coordination because the knowledge in TMS help members of teams to develop expectations on the needs and actions of other team members (e.g., Liang et al., 1995; Moreland, 1999).

Driskell and colleagues (2003) and Cornelius and Boos (2003) argued that establishing and maintaining mutual team knowledge is more difficult for virtual teams than for face-to-face teams. These differences result from changes in team composition, limited life span, and limited knowledge about virtual team members. These difficulties make it hard for virtual teams to establish common ground, and therefore can lead to problems in the coordination of team member activities (Oshri, Van Fenema, & Kotlarsky, 2008). Methods have been suggested to overcome the negative influence of electronic mediation, such as task-specific training (Cornelius & Boos, 2003; Kamphuis, et al., 2009b; Lewis et al., 2005), standardization of work processes, and meeting face-to-face (Oshri et al., 2008).

In sum, literature suggests that certain aspects of virtual teams (e.g., technology-mediated communication, flexible membership) may make it difficult to establish TMS virtual teams. It will be investigated in the present research to what extent virtual teams are able to establish TMS on complex, interdependent task, and examine the roles of two media characteristics for this.

Team situation models. Cooke and colleagues developed the concept of team situation models to describe coordination in teams that operate in dynamic environments (see Cooke et al., 2003; Cooke et al., 2001). These investigators define team situation as the team's understanding of a specific situation at any one point in time (Cooke et al., 2001). Team situation models represent team member's dynamic understanding of the situation, and contain information on the team, the task, and the environment. Team situation models are expected to be positively related to team performance because a shared understanding of the situation will lead to congruent actions of individual team members.

Thus, the understanding of a specific situation at the team level thus is the product of situation assessment at the individual level and the aggregation of individual situation models to the team level. The dynamic understanding of situations at the individual level is known as situation awareness (SA). Endsley (1988) defined SA as "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*" (p. 97). In other words, it derives from the integration of individual knowledge with information from the environment in order to understand, explain, and predict in this context (Endsley, 1988).

Rico and colleagues (2008) indicated that team situation models may be difficult to establish in virtual teams, because virtual teams may use media that are low in synchronicity, and team members may lack a shared workspace. This would make it also difficult to develop implicit modes of coordination in virtual teams. At the same time, virtual teams that succeed in developing similar and accurate team situation models will also profit the most from this, as implicit coordination is particularly important for teams that communicate asynchronously and where the transmission of information takes relatively much effort.

There has been little empirical research on team situation models in virtual teams. Two important contributions from Rasker (2002) and Rasker et al. (2000) studied the effects of situational assessment on coordination and performance in teams. They found that the sharing and discussing of situational information facilitated the development of similar team situation models and team performance on a complex, interdependent task. Importantly, teams that could only communicate via standardized email messages experienced more difficulties in the development of team situation models than teams that could communicate face-to-face.

Self-synchronization. This concept was developed to describe implicit coordination processes in teams that participate in networked military operations (Alberts & Hayes, 1999; 2003; 2006). Self-synchronization has the following characteristics: horizontal integration, vertical integration, event handling, and initiative taking.

Self-synchronization encompasses the alignment of actions of team members with those of other team members. Self-synchronization is necessary in situations where different, highly interdependent but distributed entities are working on the same goal. This means that these entities have to align their actions with other entities in order to complete the task effectively. Team members have to integrate their actions along the horizontal dimension of organizations (at the same level of decision-making power). Horizontal integration is observed when team members share information or help other team members without being asked.

When there is a person or a team who is leading the mission, or when there are multiple organizational levels involved in the operation, teams should also integrate their actions along the vertical dimension of organizations. This dimension differentiates organizational entities for the level of decision-making power. Integration at the vertical dimension refers to alignment of actions with the overall goals of the task or mission, which means that teams complete the task as was intended. Both dimensions (horizontal and vertical integration) can be considered important aspects of self-synchronization because they imply that team members perform the task as was intended, and anticipate the needs and actions of other team members.

There are two other aspects of self-synchronization that reflect the dynamic adjustment of behaviour to changes in the environment that virtual teams have to deal with. *Event handling* describes the ability of teams to adapt collectively to unpredicted changes in the environment that (potentially) influences the progress of the team to achieve its goals. Event handling is closely related to team adaptation, which refers to the adjustment in the team's system of member roles in reaction to unpredicted change (LePine, 2003; 2005). This means that teams have to be flexible when it comes to the division of labour and the use of resources (e.g., Burke et al., 2006; LePine, 2005). It may be difficult for virtual teams to handle events because reconsidering roles, responsibilities, division of workload, and communication patterns *in situ* may be difficult when team members are mediated by technology.

The other aspect of self-synchronization is initiative taking, which refers to the dynamic adjustment of behaviour in line with the needs and actions of other team members. This aspect reflects the importance that is given to delegation of authority and emphasizes the active role of team members in decision-making. The required active role of team members is determined by range of factors, including the level of specialized knowledge of team members.

Communication. Teams can coordinate their actions explicitly by means of coordination mechanisms such as planning or schedules, or by communicating with each other. As an explicit coordination process, communication is referred to as 'coordination by feedback' (March & Simon, 1958). Teams use communication for explicit coordination when other coordination mechanisms are less effective, such as when major incidents suddenly occur and directions should be given or the changed situation should be discussed on a short notice. In these situations, communication enables team members to deal with change because team members can interact and try to find a solution (Espinosa et al., 2004). Espinosa and colleagues (2004) emphasized that many teams use a mix of explicit and implicit coordination processes when performing their tasks, and that this mix depends on task-related factors (e.g. complexity, changes) and team-related factors (e.g., team tenure, group composition). Because other explicit coordination mechanisms lack the flexibility that is required to deal with change, communication is important for teams that operate in complex and dynamic environments.

Communication in virtual teams is usually done by team members sending typed messages by email, chat, or text messages. Walther (1995) demonstrated that typing text takes more time than communicating face-to-face (see also McGrath & Hollingshead, 1994). Other research has demonstrated that members of virtual teams learn how to make effective use of electronic communication media over time. Van der Kleij and colleagues demonstrated that virtual teams learned to make effective use of video-mediated communication over time (Van der Kleij et al., 2005; 2009). The initial differences between face-to-face teams and teams that used video-mediated communication disappeared over a series of four sessions. These results indicate that virtual teams have the capacity to adapt to new media, but at the same time it should be noted that video-mediated communication is a medium that is high in richness , and that less is known to what extent media that are low in richness, such as email and shared digital workspaces, can be as effective as face-to-face communication.

Factors affecting coordination in virtual teams

The present research was designed to gain more insight in coordination processes in virtual teams, and identify what factors foster effective coordination in virtual teams. Five factors that were expected to affect coordination processes in virtual teams are investigated: level of authority, experience to work together, leadership style, media synchronicity, and distribution of information. As was discussed above, team coordination can be influenced by the following three categories of factors. Factors can be related to the task, the team, or the context in which teams perform their tasks (see Espinosa et al., 2004). The context of the research largely shaped the development of the set of factors, and it was decided to study a set of factors that was related to all three categories. The factors that are studied in the present research are described below.

An important aspect of networked military operations is the use of information and communication technology. Technological factors are related to the context in which teams perform their tasks. Two media characteristics appeared to be relevant for virtual teams that operate in complex and dynamic environments. First, the extent to which communication media facilitate synchronous interactions between team members (media synchronicity) is important in situations that can change unexpectedly. These environments require teams to search the operational situation for new information, make sense of the information, and establish coordinated action with other team members in response to unexpected change. It was expected that media synchronicity is relevant for team coordination in these environments. Further, information and communication technology offer increased possibilities to share information with other team members (e.g. data links, shared workspaces). Second, the increased levels of distribution of information are expected to be positively related to the establishment of coordinated action in theories on networked military operations (e.g., Alberts & Hayes, 2003; 2006). This expectation seems to be consistent with literature on information sharing in teams, where it has been shown that team members find it easier to discuss information that is held by other team members than to discuss information that is held by only one team member (Hinsz et al., 1997; Stasser & Titus, 2987; Van Ginkel & Knippenberg, 2007). Taken together, it was decided to study in what ways distribution of information affect team coordination in virtual teams.

However, technology will also change the way in which military operations are designed as well. This means that organizational factors should also be considered. It was discussed that networked military operations are associated with decentralization, which at the team level means that teams will have higher levels of authority. This means that teams have more freedom to decide how the team will perform its task. For this reason, level of authority is related to the task in the framework of Espinosa et al. (2004). It was decided to study this factor because increasing authority levels of teams that are located at the edge of organizations is a central assumption of theory on networked military operations, but it remains unclear to what extent these assumption is warranted (Alberts & Hayes, 2003; 2006),

Factors that are related to the team are leadership style and level of experience. First, it is investigated in what ways leaders of virtual teams could foster effective coordination between the decisions and actions of team members. It will be discussed below that both theory on networked military operations and theory on virtual team leadership associate virtual teams with participative leadership styles. At the same time, empirical research on this topic is emerging (e.g., Hambley et al., 2007). It was decided to investigate to what extent leadership style of team leaders affect team coordination in virtual teams. Second, level of experience was studied because working in similar environments has been shown to be positively related to the development of shared knowledge in command-and-control teams (Cooke, Gorman, Duran, & Taylor, 2007). Prior experience on a task expands the knowledge that team members bring to the task (Kraiger & Wenzel, 1997; Cannon-Bowers, Salas, & Converse, 1993). This means that prior experience in working with others in a networked environment was expected to be relevant for coordination in virtual teams.

In conclusion, the research that is presented in this thesis not only considers technological factors (context-related factors) that influence team coordination processes and performance, but also considers factors that are related to the team itself (team-related factors), and to the organization in which teams perform their tasks (task-related factor). See Figure 1.2 (p. 26) for an overview of the factors and the team coordination processes under study.

Level of authority. Although it is expected that high levels of authority facilitate team processes, regardless of team structure, this factor has hardly been addressed in theories on networked military operations. Great emphasis is placed on decentralization of the command structure (Alberts & Hayes, 2003; 2006; Atkinson & Moffat, 2005), but empirical support for the effects of decentralization at the team level has received less attention (Van Bezooijen, Essens, & Vogelaar, 2006; Warne, Ali, Bopping, Hart, & Pascoe, 2004). In networked military operations, decentralization or delegation of authority to teams or individuals that are located at the edge of organizations are expected to allow teams to adapt their actions in response to emerging situations, without first consulting higher organizational levels. Freedom to act, that is, the permission to take initiatives to adapt to the operational conditions are expected to lead to more flexible and adaptive decision making, and speeding up the decision making process (Alberts et al., 1999; Alberts & Hayes, 2003; 2006). Research suggests that teams with decentralized structures were faster and more accurate on difficult complex, interdependent tasks when compared to team with centralized structures, and that they also shared more knowledge on these tasks (Schraagen, Huis in ‘t Veld, & De Koning, 2010).

As was discussed in the beginning of the chapter, military operations are ‘tight’ by nature. This implies that increased authority levels require teams that are given the authority to coordinate more with others that work on the same task. This means that teams will communicate less with the higher level, and communicate more with the same level. In sum, it is expected that increasing the level of authority of teams that located at the edge of organizations is positively related to coordination processes, because team members have more opportunities to coordinate their actions without direct supervision from higher organizational levels.

Experience. Experience to work together is expected to facilitate the coordination in virtual teams. The positive impact of experience on coordination and team performance can be explained by the role of shared knowledge, because prior experience increases the long-term background knowledge that team members bring to the task (e.g., Cooke et al., 2007). This knowledge of team members can be shared with other team members during task performance. This stable knowledge of team members is stored in shared mental models that are related to the team (e.g., distribution of roles and responsibilities) and the task (e.g., task strategies). The importance of shared knowledge for team performance is demonstrated by various studies (e.g., Lim & Klein, 2006; Mathieu et al., 2000). Experience with working with others in similar settings is expected to affect team members’ shared knowledge, effective communication, the development of team situation models, and self-synchronization. Further, teams with higher levels of experience to work together are expected to apply their knowledge to make effective use of the extra decision-making authority given to them. In other words, experience to work together is expected to be positively related to coordination processes in virtual teams.

Leadership style. The use of technology to share information and communicate with each other is expected to impact the way in which team leaders perform their functions (Bell & Kozlowski, 2002; Kahai, Sosik, & Avolio, 1997; 2004; Zaccaro, Ardison, & Orvis, 2004; Hambley, O'Neill, & Kline, 2007). Virtual team leadership may be defined as: "*a social influence process mediated by advanced information technologies to produce changes in attitudes, feelings, thinking, behaviour, and/or performance of individuals, groups, and/or organizations*" (Avolio, Kahai, & Dodge, 2001: p. 617). It will be argued that participative leadership styles are positively related to effective team coordination in virtual teams. Two aspects of leadership will be discussed: (1) The way in which the use of technology affects the behaviour of team leaders, and (2) whether participative leadership styles help team leaders to coordinate the actions of team members more effectively.

When it comes to the way in which technology affects the behaviour of team leaders, the ability of virtual teams to cross locational, temporal, and relational boundaries has implications for virtual team leadership in three ways. First, due to the widespread use of technology, virtual teams have become increasingly complex (Zaccaro et al., 2004). We propose that this increased complexity results from two sources: (1) members of virtual teams may have different backgrounds, because they may come from different cultures and organizations. This holds for so-called global virtual teams (e.g., Lipnack & Stamps, 1997), but differences in cultures are also likely to be found between different types of organizations and between services. (2) Team composition may change during task execution because of flexible team membership (e.g., Bell & Kozlowski, 2002). The complex forms of virtual teams affect leaders of these teams, when they are faced with challenges for effectively coordinating team member contributions into coherent decisions and actions at the team level (Kirkman et al., 2004; Zaccaro et al., 2004).

Second, the benefits of virtual teams particularly apply to the performance of complex, interdependent tasks (e.g., Bell & Koslowski, 2002; Townsend et al., 1998). Compared to less complex tasks, complex tasks are characterized by reciprocal and intensive workflow arrangements (Thompson, 1967, Van de Ven, Delbecq, & Koenig, 1976). An important determinant of the complex workflow results from the high level of specialization of team members (Bell & Kozlowski, 2002). Since the effective integration of team member contributions is crucial on these types of tasks, it is important that team members can share information and communicate with other team members. This enables team members to monitor the activities of other team members and deliberate on the integration of contributions. Therefore, complex, interdependent tasks demand more of team leaders in terms of pacing of activities and integrating contributions than simple tasks.

Third, complex, interdependent tasks generally have tight external linkages with the environment or with other parties (e.g., Cohen & Bailey, 1997). This means that teams have to deal with all sorts of changes that potentially influence team processes and progress. Teams will be faced with high levels of ambiguity and equivocality in these environments, because the implications of situational changes will often not be immediately clear. Team members will need time to find solutions to problems, use their knowledge, expertise, and capabilities, and generate idiosyncratic solutions in these dynamic, complex environments (Sherif & Sherif, 1969; Van de Ven et al., 1976). Leaders of virtual teams will thus have to find ways to facilitate this type of problem solving, and effectively integrate the contributions of team members at the team level.

Another characteristic of virtual teams that has implications for team leaders is technological mediation between the team leader and team members (Kirkman et al., 2004). Building on earlier work of Zaccaro, Rittman, and Marks (2001), Zaccaro and colleagues (2004) have proposed a framework of virtual team leadership. This framework distinguishes between cognitive, affective, motivational, and coordinative team processes, and it is proposed that team leadership directly affects all categories of team processes. The framework generally holds that technology influences team processes because of loss of social context cues in mediated communication. This makes it more difficult for team leaders to control motivational processes, such as the development and maintenance trust, team cohesion, team member satisfaction, and team efficacy. Further, it is proposed that the loss of social context cues makes it more difficult to manage affective processes, such as failure to detect emotions, increased likelihood of misinterpretations, and limitations in the possibilities of team leaders to deal with stress of team members. Likewise, technological mediation may negatively affect cognitive processes, including the collective information processing, development of mental models and TMS.

We propose that participative, delegative leadership styles are commensurate with the demands of leading virtual teams that perform complex, interdependent tasks in complex and dynamic environments. Participative, delegating, and directive leadership styles differ in the extent to which team members have influence on team processes and decision-making (see Yukl, 2006: pp.82-83). Participative leadership is defined as the sharing of problem solving with followers by consulting them before making a decision (Bass, 1990). The sharing of problem solving by consulting team members can take many forms, including considering the opinions of team members when making decisions or making decisions together with team members. Moreover, team leaders can delegate authority to team members. This means that team leaders give more autonomy to team members and do not closely supervise the decision-making on the delegated (sub)tasks (Kahai et al., 1997). A mix of participative and delegating leadership styles is observed when team members have the authority to take action or implement decisions on a specific (sub)task, and when team members participate in decisions that teams have to make. Directive leadership styles are characterized by little participation of team members in decision-making, and team leaders do not delegate authority to team members.

The most important argument for participative, delegative leadership styles in virtual teams is based on the high levels of specialization of team members in virtual teams. When team members are selected for their individual knowledge or expertise, this means that there is less need to monitor team members (Bell & Kozlowski, 2002). Team members will be able to carry out their own subtasks, and often may be capable of managing their dependencies with other team members without interference of the team leader. Moreover, team members with high levels of individual expertise may also have ideas on how the contributions of team members could be integrated effectively, for instance because of prior experience in other virtual teams. Participation of team members in problem solving enables more thorough understanding of relevant aspects of the problem (Kahai, Sosik, & Avolio, 2004). While directive leadership styles may be beneficial on structured problems, because it keeps team members focused on a limited range of possible solutions, participative, delegative leadership styles may be beneficial on complex, interdependent tasks since the team profits from the solutions and contributions that are proposed by team members, or because team members have solved the problem that was delegated to them.

In conclusion, virtual team leadership is demanding because of the increased complexity of teams and technological mediation. Virtual team leaders may deal with the challenges in a number of ways. Participation of team members in team processes and decision-making and delegation of (sub)tasks to team members have been proposed as a means for effective leadership in virtual teams (Bell & Kozlowski, 2002; Zaccaro et al., 2004). Participation of team members (e.g., about pacing of activities, development of courses of action), may help team leaders to focus on the leadership functions in which participation of team members may be less effective (e.g., performance management). Delegation of (sub)tasks to team members is expected to be beneficial for virtual teams for a similar reason. When team members perform (sub)tasks and do not have to be monitored, this will reduce the need for coordination. Team leaders can focus on the execution of leadership functions that can not be carried out by team members. Ultimately, members of virtual teams may come from different organizations and are invited to the team because of their specific knowledge or competencies. This makes directive leadership less appropriate in virtual teams. Since we are focused on coordination in virtual teams that perform complex, interdependent tasks in complex and dynamic environments, we expect that participation of team members is positively related to coordination processes in virtual teams.

Media synchronicity. Media synchronicity is assumed to play a critical role in the performance of virtual teams (Espinosa et al., 2004; Kirkman & Mathieu, 2005; Dennis et al., 2008). In particular in tasks in complex and dynamic environments, team members have to interact intensively in order to develop shared understanding of the situation, decide how they are going to accomplish their goals, and to establish coordinated action. It is proposed in the Media Synchronicity theory (MST; Dennis & Valacich, 1999; Dennis et al., 2008) poses that synchronous interactions are important for teams in these situations. Media synchronicity refers to the capacities of electronic communication media to facilitate interactions without time lags (Dennis & Valacich, 1999; Dennis et al., 2008).

Emails or postings on company message boards are low in media synchronicity, because team members will not respond directly to emails or postings. Electronic communication media such as chat or videoconferencing are high in synchronicity, as communication is direct and there are no time lags between messages and responses. The present research is intended to test the expected positive effects of media synchronicity on team coordination and performance.

Distribution of information. Distribution of information refers to the extent to which team members have common or unique information. Hinsz et al. (1997) referred to this as the commonality-uniqueness dimension of information, which is defined as the "*variability in how many group members have access to a piece of information*" (p. 54). Unique information refers to information that is held by only one member of the team, whereas shared information refers to information that can be accessed by all members of the team. Importantly, distribution of information is not the same as the sharing of information during task performance through team members interactions, which may be described as the openness or willingness of team members to share information (Mesmer-Magnus & DeChurch, 2009).

Information and communication technology is effective for exchanging information with others, and it is investigated if higher levels of shared information positively affect team coordination processes and performance of virtual teams. The reason to study this factor resulted from research on distribution of information, which maintains that teams are more likely to consider shared information than unique information. The rationale for this is that it is easier to discuss information that is held by all team members (shared information) than it is to discuss information that is new to other team members (unique information; Stasser and Titus, 1987; Van Ginkel & Van Knippenberg, 2009; and Mesmer-Magnus & DeChurch, 2009). Information and communication technology provides excellent ways for distribution of information to other members of the team in the form of attachments to emails or shared network drives. It is expected that distribution of information is positively related to team coordination in virtual teams, because the utilization of shared information will help virtual teams to develop TMS, similar team situation models, and foster self-synchronization.

Outline of the thesis

In this chapter we have described the context of the research, the team processes that will be studied, and the factors that are expected to affect team coordination processes in virtual teams. Before turning to the outline of the study, we will discuss some conditions regarding the research that has been conducted. These conditions are related to the type of tasks that were used in the research and the consequences of our focus on virtual teams.

Virtual teams in the present research performed tasks that were complex, and team members depended on each other for their expertise, capabilities, and resources. Complex, interdependent tasks require team members to share information with other team members, attach meaning to information, and collectively decide on how the team responds to this information (Lim & Klein, 2001; Baltes et al., 2002). These team processes are important for teams in (military) organizations, and can be studied in controlled research environments.

This context of the research influenced the choice of tasks that featured high levels of unpredictability. Operating in highly complex and dynamic environments means that teams have to develop a shared understanding of the situation in order to accomplish their goals. For this reason, it is important that experimental tasks have high levels of unpredictability, so that team members have to assess the situation and attach meaning to information in order to perform well. This means that teams in this research were confronted continually with new information during task execution, team members had to make sense of this information, and act upon the meaning that they attached to the information.

A consequence of our focus on virtual teams is that the present research does not consider face-to-face communication, and does not feature 'traditional' teams as control groups. It was discussed above that teams in networked military operations often are geographically dispersed, and therefore all communication is mediated by electronic communication media. Further, many teams that are collocated exclusively rely on communication media as well. Good examples are air defence command teams. Although team members of air defence command teams are located in a single operations room, all communication between team members is mediated by technology. Our focus on virtual teams means that the conclusions are formulated for virtual teams only, and conclusions do not apply to teams that have lower levels of team virtuality.

Finally, it should be noted that teams in the present research differed in the extent to which team members knew each other. Teams that are studied in Chapter 2 were existing teams, which means that team members had worked with each other before the study started, and would continue to work together after the study ended. Alternatively, teams that participated in the experiments that are presented in Chapter 3 and Chapter 4 were so-called short-term teams.

The following three chapters describe the experiments that were conducted in order to answer the research questions (see Figure 1.2 for an outline of the thesis). Not all team coordination processes could be studied in all chapters. For instance, it was only possible to study team situation models in Chapter 3 and 4 because the assessment of team situation models did not apply to the realistic environment of the research that is presented in Chapter 2. The outline of the thesis is discussed below.

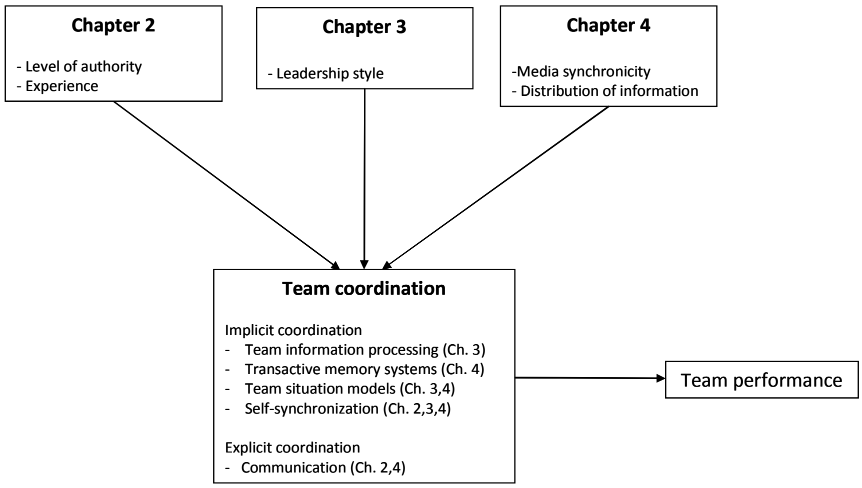

Figure 1.2: Outline of the thesis

Chapter 2 describes an explorative experiment (Experiment 1) that was conducted in order to gain more insight in coordination processes in virtual teams, and to determine the effects of decentralization of the command structure and experience. This was done by studying the effects of level of authority and experience to work together on coordination in virtual teams in a realistic environment. It was investigated in what ways increased levels of authority influenced coordination processes and team performance. Further, it was investigated in what ways joint experience helped teams to make effective use of the extra authority. The experiment was conducted in a simulated, but realistic environment in which existing air defence command teams engaged in a joint air defence task. Because the rapid and accurate detection and handling of incidents is of the highest importance in air defence, the research was focused on communication within the air defence teams and the communication between the air defence command team and other units in the network, and self- synchronization. Four air defence teams from two nations completed two joint air defence scenarios. A mix of self-report data, log file data, expert observations, and group discussions was used to determine the effects of level of authority and experience on team coordination and performance.

Chapter 3 describes an experiment (Experiment 2) in which the effects of leadership style on team coordination processes were investigated by comparing two types of leadership: participative, delegating leadership versus directive leadership. Participants were civilians that volunteered to take part in the experiment. Participants were recruited from a pool of one of the research institutes and were arrayed in three-person teams. Teams completed a complex planning task where team members have different roles and responsibilities. Team leaders were assigned randomly and were trained for either a participative or a directive leadership style. Self-report (team information processing, self-synchronization) and log file data (team situation models) were used to determine the effect of leadership style of virtual team leaders on team coordination (information processing, team situation models, self-synchronization), and team performance.

Chapter 4 describes an experiment (Experiment 3) which focused on the effects of two factors that are related to information and communication technology. A complex planning task was used to determine the effects of media synchronicity and distribution of information on coordination processes and team performance. Participants were cadets from the Netherlands Defence Academy. The planning task was adjusted in order to manipulate media synchronicity, which may be described as the level to which electronic communication media facilitate synchronous interactions between members of the team. The second factor that was manipulated in this study was distribution of information, which may be described as the extent to which members of the team have unique information (information is held by single team members) or shared information (information is held by all team members). A mix of self-report (TMS, self-synchronization) and log file data (team situation models, communication) was used to assess the effects of these two factors on team coordination and team performance.

Chapter 5 is the synthesis of the research results. This chapter consists of an overview of the main findings of the present research, and theoretical and practical implications are formulated. Subsequently, strengths and limitations of the present research are discussed. The chapter also provides suggestions for further research.

Chapter 2

Effects of level of authority and joint experience on coordination in virtual teams

Introduction

Today's military operations are characterized by a multinational, multiservice, and multiagency approach (combined, joint, and comprehensive operations, respectively), in which diverse parties coordinate and collaborate to establish secure and stable conditions for reconstruction and development. In these operations the military have to deal with high levels of organizational and operational complexity, because ad hoc collectives of parties with different backgrounds, experience, and goals have to interact in order to synchronize their efforts. Operations take place in environments that are characterized by high levels of equivocality, such as when adversaries operate amongst the civilian population aiming at destabilisation (asymmetric warfare). Organizations are faced with unpredictable changes in these environments, such as attacks or ambushes. Operating in these environments requires organizations to be flexible and adaptive.

In response to these developments and the new opportunities that information and communications technology offer, networked military operations are designed to facilitate flexible and adaptive decision-making. Theory on networked military operations is focused on transforming the military into a flexible and adaptive ('*agile*') organization in which decision making power is located at the edge of organizations (Alberts & Hayes, 2003; UK Ministry of Defence, 2009). Teams that are located at the edge of organizations are teams that interact with the environment of organizations, such as patrol or intelligence units of the Army. The decentralization of decision-making authority to the edge of organizations is intended to enable military teams to respond effectively to unpredictable change by giving teams sufficient authority to handle situations without direct control from higher levels.

An important consequence that has been associated with higher levels of authority for teams at the edge of organizations is that the speed of decision-making processes may be increased (e.g., Alberts & Hayes, 2003, 2006: Perrow, 1999). Teams do not have to interact with higher levels for discussing the operational situation and obtaining permission to act. Decentralized organization structures therefore lower the need for communication between organizational levels, which increases the accuracy and the speed of the decision-making process (see Hollenbeck et al., 2002). This promotes the flexibility and adaptability that is needed for operating in complex and dynamic environments.

Higher levels of authority in networked military operations typically include the authority of teams to interact and collaborate with other teams, whereas in traditional command structures the coordination between the actions of different teams is carried out at higher organizational levels. Teams that have higher levels of authority are expected to be able to directly synchronize their efforts with other teams that are present in the operational arena (Alberts & Hayes, 2003, 2006). An example of an ad hoc collaboration between military teams is close air support, where a land-based military team is supported by an air element, such as a fighter helicopter team, for instance when the land-based team is under attack. The fighter helicopter can locate adversaries and use its weapons. These teams coordinate their actions via information systems and radio, which enables flexible and adaptive decision-making. In such operational situations, collaboration is not planned in detail beforehand, but emerges when teams share workload, capabilities, or assets with other teams in order to accomplish their goals.

Increasing the levels of authority of teams that are located at the edge of organizations, means that these teams are confronted with changing task demands in terms of coordination. When teams that are located at the edge of organizations are given higher levels of authority, it means that these teams coordinate less with higher levels, and establish decisions without direct supervision from higher organizational levels. Higher levels of authority also increase the need for coordination among the team members and with other networked teams that work on the same task or mission. Whereas team actions are coordinated at higher levels in traditional command structures, decentralized command structures increase the need for teams that are located at the edge of organizations to establish coordinated action with other teams on their own. Taken together, decentralization of the command structure means for teams at the edge of organizations that they have more freedom to act without direct control from higher levels, but at the same time are faced with changed task demands regarding decision making, and communicating within their team as well as with other teams. The research that is presented in this chapter was aimed at testing in what ways increasing levels of authority of teams that are located at the edge of organizations affect their coordination processes and performance. In order to determine in what ways decentralization of the command structure affects coordination in virtual teams, we were not only interested in coordination processes that take place within these teams, but on top of that we also focused on the extent to which teams were able to establish coordinated action with other networked teams. For this reason, moving beyond team boundaries was necessary for gaining more insight in coordination processes in virtual teams and identifying in what ways decentralization of the command structure affects teams. A trilateral research programme on command and control in networked military operations offered good opportunities to study existing virtual teams as part of a larger organizational network in a realistic environment. This research programme allowed us to study coordination processes not only within virtual teams, but also focus on coordination processes between members of virtual teams with other networked teams. Conducting research in a high-fidelity simulation environment enabled us to study coordination processes while establishing some level of control over the environment. This made it possible to systematically vary level of authority (by adjusting the command structure) and examine the effect of level of authority on coordination processes in virtual teams.

A factor that may be positively related to the extent to which team members can make effective use of the increased freedom to interact and establish coordinated action with other teams is prior experience in working with other teams in similar environments. In the context of joint military operations, this refers to experience with working with teams from other services. This will be referred to as *joint experience*. We propose that joint experience may help military teams to make effective use of the increased levels of authority, because team members who are experienced in joint operations will have knowledge on the roles, responsibilities, goals, and resources of teams from other services. We expect that this knowledge helps team members to coordinate effectively with other networked teams.

The knowledge of team members about teams from other services is stored in mental models, which result from either experience or knowledge acquisition (Cannon-Bowers, Salas, and Blickensderfer, 1999; Cooke, Salas, Cannon-Bowers, & Stout, 2000). Focusing on the role of experience, we expect that joint experience increases the body of knowledge that is relevant to the task in terms of task strategies and when they apply. This expectation is based on research on command-and-control teams in which prior experience on a task led to performance benefits over inexperienced teams on similar command-and-control tasks (Cooke, Gorman, Duran, & Taylor, 2007). Teams that consisted of team members with high levels of experience profited from knowledge of team members by the sharing of knowledge via team member interactions. In this way, teams profited from prior experience not only in the execution of individual subtasks, but moreover by making knowledge available to other team members through interactions. For this reason, it is important that command-and-control teams can communicate unrestrictedly during the execution of complex command-and-control tasks (Rasker, 2002; Rasker et al., 2000). Given that team members in the present research have excellent opportunities for communication with other team members, we expect that members of teams who are experienced in joint operations can make effective use of their knowledge about teams from other services, and that this leads to better communication, coordination, and team performance.

Research approach

In order to investigate in what ways level of authority and joint experience affect coordination processes and team performance of virtual teams, it was decided to study existing teams in a realistic environment. Studying existing teams in a realistic environment would give us the advantage of gaining more insight in team coordination processes in virtual teams. This means that teams had to be studied that exclusively relied on technology-mediated communication for team member interactions. Another condition was that coordination processes and team performance of teams had to be assessed in detail in the research environment. Further, some level of control over the environment had to be established in order to be able to study team coordination processes effectively. Establishing some level of control was important for investigating the effects of level of authority and joint experience on team coordination processes and team performance. In all, we conducted an explorative experiment in which we explored coordination processes in existing virtual teams in a realistic environment, while establishing some level of control over the environment in order to examine the effects of two factors that were expected to be important for coordination in these teams.

A trilateral research programme (Netherlands, Sweden, and Canada) that was conducted at TNO Defence, Security, and Safety[1] offered the possibilities to meet all of the conditions that were described above. Three research institutes that are affiliated with the Ministries of Defence in these nations combined their efforts to investigate the effects of decentralization on command and control processes in networked military operations. Importantly, this research programme made it possible to study existing teams in a semi-controlled research environment. The research team of the Netherlands was leading the research programme. The research team consisted of researchers from TNO and the Netherlands Defence Academy, and subject matter experts from TNO and the Royal Netherlands Air Force (RNLAF).

The research was conducted in the context of joint air defence. There are four reasons underlying this choice. First, air defence command teams are accustomed to use information and communication technology for coordinating interactions with other teams and organizational levels as well as within the team. Because air defence command teams only use technology-mediated communication, conducting research in the context of air defence is consistent with our focus on virtual teams. Second, joint air defence teams could be studied in a realistic environment. Air defence teams perform their tasks in air operations command centres, and it was possible to create a similar working environment in a research facility of TNO. Third, it was possible to manipulate the command structure in line with the research objectives. Air defence command teams are located at the edge of the organization, because they form the link between decision making and the execution of decisions. At the same time, these teams have a good overview on the mission area. Fourth, it was possible to invite teams with different levels of joint experience to participate in the study. Teams from two different nations were invited to take part in the study. These nations differ in their level of joint experience because of their strategic military orientation. Differences in level

[1] TNO is the Netherlands Organization for Applied Scientific Research. Other institutions that were involved were Totalförsvarets Forskningsinstitut (FOI) from Sweden and Defence Research and Technology Canada (DRDC).

of authority of air defence command teams were expected to affect the way in which teams performed their tasks, but decentralization of the command structure was not expected to influence the structure of air defence command teams. This meant that the effects of decentralization of the command structure were not studied in terms of what team structure would be best for performing a complex, interdependent team task (see Hollenbeck et al., 2002; Schraagen et al., 2010), or to what extent teams can adapt to new team structures (see Moon et al., 2002; Entin, 1999), but rather the study was aimed at identifying in what ways level of authority and joint experience influence team coordination processes and team performance in a realistic operational situation.

Some level of control was established by using realistic joint air defence scenarios and by manipulating the two factors that were under study. The scenarios were realistic for air defence command teams because they were based on exercises that are used for training teams to operate effectively in joint operations. Two scenarios were developed that were equally demanding for the teams. Scenarios were equal for the amount of air traffic and the number of critical incidents. Also, teams were given a higher level of authority when they performed the second scenario. Further, teams had different levels of joint experience. Another factor that contributed to the establishment of some level of control resulted from the so-called ‘white cell’, which consisted of a set of military personnel that played the roles of other teams in the network and other organizational levels. These role-players were aware of the research objectives and actions were supervised by subject matter experts on joint air defence from the research team. These measures were intended to allow us to make precise comparisons for the team processes that were under study.

When one studies an object or phenomenon in-depth, this calls for a diverse set of data sources, so that outcomes of different sources can be combined in the formulation of conclusions. This is considered to substantiate the conclusions of the research (Yin, 2009). The research that is presented in this chapter featured a mix of data sources, including self-report data, observer data, and behavioural data. The diversity of data sources is particularly important when case studies have relatively few data points, which is the case for the research that is presented in this chapter. Four three-person air defence command teams participated in the case study. They each participated in two runs. By precisely measuring how teams performed on the joint air defence task, combining the outcomes of measures made it possible to gain more insight in the effects of decentralization and joint experience on communication and coordination processes of virtual teams.

Conducting research in realistic environments is often accompanied with methodological challenges, and the present case study was no exception in this respect. Below we discuss the complexity of the research design, and the design of team performance protocols for decentralized command and control structures.

The first methodological challenge was to study the effects of two factors in a single study. The number of air defence teams is limited, and therefore it was unique to study four complete, existing air defence teams during two experimental weeks. At the same time, this made the research design complex. Level of authority was studied using a repeated-measures design for all four teams (teams performed air defence tasks with different levels of authority, while the effects of joint experience were studied in a between-subjects design (comparing teams from two nations). Potential methodological issues in this research design are learning effects, confounding of learning effects and the manipulation of level of authority, and observer biases. It will be discussed in the method section in what ways we attempted to deal with these methodological issues.

Another methodological challenge was the development of best practices for team performance for the handling of critical incidents in the command structure where teams were given a higher level of authority. Because there are no guidelines for the way that critical incidents should be handled in decentralized command structures, the research team and the team of expert observers from the Royal Netherlands Air Force (RNLAF) and the North Atlantic Treaty Organization (NATO) jointly developed best practices for all incidents. The development of best practices will also be discussed in the method section.

In conclusion, the case study research approach enabled us to gain more insight in team coordination processes in virtual teams in a realistic environment. All communication is mediated by technology in air defence command teams, which makes it possible to formulate conclusions that apply to virtual teams. Finally, studying teams in a semi-controlled environment enabled us to investigate the effects of level of authority and joint experience on team coordination processes and performance. A brief description of joint air defence is provided below in order to formulate hypotheses.

Joint air defence

Joint air defence is based on the notion that control of the air is important to the success of joint operations, because controlling the air space means that units on the ground or at sea have freedom of action. Having control over the air space is not an end in itself, but an enabler to achieve joint campaign objectives (see United Kingdom Joint Warfare Publication 3-63, 2003). The Joint Forces Commander (JFC) controls two components (Figure 2.1). The air component comprises an air component commander (ACC) and a Combined Air Operations Centre (CAOC). Decision making for air operations takes place at these levels. The ACC and the CAOC give guidance to the Control and Reporting Centre (CRC), which consists of an air defence command team and fighter controllers, who directly communicate with the pilots of fighter aircraft. The CRC executes the decisions of the higher levels. The maritime component has a similar structure. Decision-making is carried out by the Maritime Component Commander (MCC) and Commander Task Group (CTG), and the Anti-Air Warfare Commander (AAWC) controls the sea-based units such as frigates and patrol vessels. These units have capabilities for air defence, such as personnel, ship-based radars, missiles, and helicopters. The present research is focused on the CRC, specifically the air defence command team. The air defence command team is the link between higher level decision making and coordination and the operational environment where they control the actions of the fighter aircraft. In this sense the air defence command team is located at the edge of the organization.

CRCs have their own Areas of Responsibility (AORs), which defines the airspace that the CRC controls. Traditionally, air defence command teams are authorized to apply protocols to standard situations, but when incidents occur the authority is handed back to the higher level, such as in the case of an aircraft that leaves the planned route or an unidentified aircraft that enters the AOR[2]. When it comes to integrating the actions of different services, the JFC is responsible for coordinating the actions of the joint units. Joint air defence is aimed at deconfliction, meaning that actions of different services do not interfere with one another. When actions of different services are intended to coincide, the integration of actions is regulated by protocols at the level of the CAOC and higher.

Increasing authority levels of air defence command teams. When air defence command teams are given the authority to handle incidents themselves and to collaborate with teams from other services without direct control from the higher level, this would lead to a command structure where the roles of the CAOC and higher levels are limited.

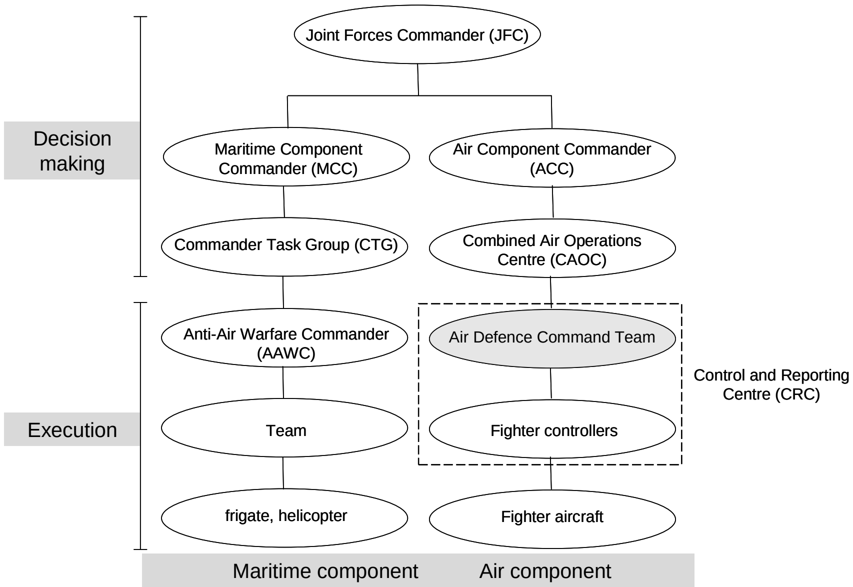

Figure 2.1: Joint air defence command structure

[2] See http://www.infowars.com/nato-jets-shadow-russian-bombers-over-arctic-atlantic/ for the description of an incident on December 18th, 2009 in which fighter aircraft of the Royal Netherlands Air Force (RNLAF) took action.

Increasing authority levels of air defence command teams makes it necessary to provide air defence command teams with information of all units that are present in the AOR, because the air defence command team has to know what units are present in the area, what are the goals of the teams, what capabilities could be shared, and how the actions of teams could be synchronized. This information is not relevant for air defence command teams in traditional command structures, and thus a *Joint Common Operational Picture (JCOP)* has to be created.

In the present research, extra authority was delegated to the teams in the high level of authority condition in terms of incident handling and ad hoc collaborations with the maritime component. The JCOP provided relevant information to the air defence command teams when the teams were preparing for the experiment, by integrating the information on the maritime component in the operational picture of the air defence command teams, and by facilitating communications between all units that were present in the AOR. These changes are consistent with theory on networked military operations and made it possible to assess in what ways higher levels of authority affect the team coordination processes and team performance of air defence command teams.

In sum, the decentralization of the joint air defence command structure influenced the teams because extra information was presented in the JCOP, extra authority was given to teams to handle incidents and to collaborate with teams from other services without interference of higher organizational levels. These changes faced joint air defence teams with changed task demands, because there was less need to communicate with higher organizational levels, but at the same time teams had to process more information, consider more alternatives, and communicate more when they had more authority. We expected that the changed task demands would affect the ability of teams to deal with environmental change such as incidents and unpredicted events. Hypotheses on the effects of level of authority and joint experience on air defence command teams are formulated below.

Formulation of hypotheses

The present research was intended to gain more insight in coordination processes in virtual teams, and to determine to what extent level of authority and joint experience foster effective coordination in virtual teams. Both factors were manipulated in the present research.

Level of authority

The research focused on the effects of level of authority on team coordination processes in air defence command teams. In the context of joint air defence, higher levels of authority for air defence command teams means that teams have the authority to handle incidents and collaborate with other teams that are present in the AOR without direct control of higher levels. It is expected that the level of authority affects communication of teams both within the air defence command teams and communication with other networked teams. Further, it was expected that higher levels of authority would affect synchronization of team members' own actions with those of other team members in the air defence command teams, as well as synchronization with other teams. Finally, it was expected that a higher level of authority would affect team performance.

Effects of level of authority on communication. Higher authority levels of air defence command teams imply that less communication is expected between the higher levels (JFC, MCC, CAOC) and the air defence command team, while at the same time more communication is expected between the air defence command team and other teams that have capabilities for air defence (e.g. frigates, helicopters). Regarding the communication between the higher level and the air defence command team, the reduction in the amount of communication along the vertical dimension of organizations results from the air defence command team not having to obtain authorization for their actions from the higher level. This means that teams do not have to describe the situation at hand and suggest courses of action.

When vertical communication is reduced, this enables air defence command teams to focus on the situation and to communicate with other teams that have capabilities for air defence, such as the AAWC or directly with command teams on platforms such as frigates. This is communication along the horizontal dimension of organizations. Typical examples of collaboration with other teams in air defence are sharing information (such as sharing information of radars via data links), and sharing of workload (such as the identification of enemy aircraft). Increased levels of authority enable air defence command teams to communicate more with other teams in the AOR for developing adaptive responses to incidents. In sum, it is tested in the present research to what extent the assumption of level of authority regarding reduced communication along the vertical dimension and increased communication along the horizontal dimension of organizations is warranted in a joint air defence operation (hypothesis 1a).

Level of authority is also expected to affect team communication within air defence command teams. Making effective use of the extra authorities requires teams to process more information, discussing courses of actions, and making decisions. For this reason, a higher level of authority was expected to influence communication within air defence command teams by increasing the amount of communication between all team members (hypothesis 1b).

Effects of level of authority on self-synchronization. It was described in Chapter 1 that self-synchronization consists of four aspects: vertical integration, horizontal integration, event handling, and initiative taking. Vertical integration refers to the integration of decisions and actions with the overall intentions of the task or mission. In the present research, the air defence command teams had to align their behaviour with the intentions of CAOC. Within the air defence command team, team members had to align their decisions on their individual tasks with the intentions of the team leader on how to accomplish the task and team goals. When air defence command teams were given more authority, this made it possible for the team to synchronize their actions with the overall intent of the mission without direct control of higher levels (vertical integration). It was therefore expected that higher levels of authority for air defence command teams would positively influence vertical integration. Horizontal integration was described as the integration of decisions and actions with other team members and other teams that work on the same task, for instance by providing information to team members or other networked teams without being asked to. We expected that higher levels of delegated authority facilitated the horizontal integration of actions because the team could orchestrate their actions with the actions of other networked teams without interference of other organizational levels.

The third aspect of self-synchronization was event handling. We expected that teams were better able to respond to unpredicted events when teams had extra authority, since team members could be more flexible in sharing workload and resources with other members of the team or other networked teams. We also expected that higher levels of delegated authority would facilitate the initiative taking, because teams now have the freedom to act and to collaborate with other networked teams. In sum, we expected that level of authority would lead to better synchronization of actions within the air defence command teams and between the air defence command teams and other teams in the network (hypothesis 1c).

Performance. Level of authority was expected to enable air defence command teams to perform better on a realistic joint air defence task. Performance measures were handling of critical incidents and overall team performance (hypothesis 1d). The hypotheses are formulated below:

Hypothesis 1a: A higher level of authority for air defence command teams enables team members of these teams to communicate less with the higher level and more with other networked teams that have capabilities for air defence.

Hypothesis 1b: A higher level of authority for air defence command teams increases the amount of communication between all team members of air defence command teams.

Hypothesis 1c: A higher level of authority for air defence command teams enables team members of these teams to better synchronize their actions with the actions of other team members and other networked teams.

Hypothesis 1d: A higher level of authority for air defence command teams enables team members of these teams to perform better in terms of handling critical incidents, and overall team performance.

Joint experience

Another factor that is important for establishing effective coordination in complex and dynamic environments is experience with working in similar environments (Cooke et al., 2007). Teams profit from experience of team members, because prior experiences of team members expand the pool of task-relevant knowledge that teams can use during task performance (e.g., Kraiger & Wenzel, 1997; Cannon-Bowers, Salas, & Converse, 1993). Research has shown that knowledge of a task can be transferred to other similar tasks (Cooke, Kiekel, & Helm, 2001). Further, research has demonstrated that teams benefit from experience of team members not only because experienced team members have more task-relevant knowledge when executing their individual subtasks, but experience also helps team members to communicate and coordinate effectively. In other words, experience helps teams to master the ‘rules of coordination’ (Cooke et al., 2007). Further, when team members are able to communicate effectively, this positively affects the development of shared mental models of the task and the team (Rasker et al., 2000). For instance, team members are better aware of the relations between activities of different team members.

Regarding joint air defence, prior experience in working in joint operations is expected to increase team members’ knowledge on command and control processes of other services and the integration of actions of different teams and units. We expect that this will help team members communicate and coordinate effectively with other team members and, particularly, networked teams.

Having more knowledge about command and control processes and capabilities of teams and units from other services is expected to help team members of air defence command teams to anticipate on the actions and needs of other units in the AOR and to make effective use of opportunities to work together. Joint experience is expected to be important for air defence command teams for developing better understanding of operations of other services and how the actions of different services have to be integrated to accomplish shared goals. In sum, joint experience is expected to positively affect team coordination processes (communication and self-synchronization) and performance on a joint air defence task.

Effects of joint experience on communication. When team members are able to anticipate on the expected actions of other team members and other networked teams, members of these teams use less communication than teams that coordinate their actions using explicit modes of coordination. Indeed, teams have been shown to have lower coordination/communication ratios when team members were experienced (Cooke et al., 2007). For this reason, joint experience is expected to lead to less communication between members of teams. In the present research, this means that less communication was expected between the air defence command team and the higher level, between the air defence command team and other teams that have capabilities for air defence, and between members of the air defence command team (hypotheses 2a, 2b).

Effects of joint experience on self-synchronization. Self-synchronization is a team coordination process that consists of anticipating the actions of others (team members, other networked teams) and dynamic adjustment of own behaviour. It is expected that joint experience helps teams to develop mutual expectancies, and it is thus expected that experience enables team members to synchronize their actions accordingly. In this research, we expected that teams that have higher levels of joint experience are better able to synchronize their actions with those of other team members and those of other networked teams.

Joint experience will positively affect the ability of team members to integrate their actions on both the vertical and the horizontal dimensions of organizations, because higher levels of experience will help team members to develop accurate expectancies and predictions on the actions of other team members and other networked teams. It is expected that joint experience leads to better synchronization of actions with other networked teams. In sum, higher levels of team members' joint experience is expected to enable team members of air defence command teams to synchronize their actions with other team members and other networked teams (Hypothesis 2c).

Team performance. The positive effects of joint experience were expected to positively affect team performance levels. Therefore, teams with higher levels of joint experience were expected to be better at handling critical incidents and perform better overall on joint air defence tasks (hypothesis 2d).

Interaction. It was hypothesized that joint experience helps teams to make effective use of the possibilities that higher levels of authority offer to them. It was discussed above that higher levels of authority inevitably place extra demands on the team regarding communication, coordination, and decision making. It was therefore proposed that teams that have more joint experience will be better able to utilize the increased levels of authority. For the current research, this means that extra decision making authority will increase team performance, particularly for those teams that have higher levels of joint experience. It was expected that teams that are less experienced in joint operations will benefit less from having extra decision making authority. This interaction between the effects of level of authority and joint experience is formulated in hypothesis 3.

> *Hypothesis 2a*: Team members of air defence command teams that have higher levels of joint experience communicate less with higher levels and other networked teams than team members of air defence command teams that have lower levels of joint experience.

Hypothesis 2b: Team members of air defence command teams that have higher levels of joint experience communicate less with other team members than team members of air defence command teams that have lower levels of joint experience.

Hypothesis 2c: Team members of air defence command teams that have higher levels of joint experience are better able to synchronize their actions with other team members and other networked teams than team members of air defence command teams that have lower levels of joint experience.

Hypothesis 2d: Air defence command teams that consist of team members with higher levels of joint experience perform better in terms of handling critical incidents and overall team performance.

Hypothesis 3: The positive effects of higher levels of authority on performance will be larger for team members of air defence command teams that have higher levels of experience in joint air defence than for team members of air defence command teams that have lower levels of joint experience.

Method

The research was conducted in the context of air defence, where all communication between team members and with other teams is mediated by technology. It was possible to precisely study coordination processes in existing military teams with some level of control. Further, it was possible to study the effects of delegation of authority and joint experience by manipulating the command structure and by inviting teams with different levels of joint experience.

A mix of qualitative techniques (semi-structured group discussions) and quantitative measures (log file data, expert observer ratings, and self-report questionnaires) was applied in order to gain insight in the effects of level of authority and joint experience on team coordination processes (communication, self-synchronization), and team performance. The effects of delegation of authority and joint experience were identified by integrating the findings of qualitative and quantitative techniques, and different data sources.

The setup of the study was as follows. The study consisted of two sessions. The first session represented the current organization and command structure. Air defence command teams engaged in an operational, complex scenario, where three critical incidents had to be dealt with. The command structure was different for the second scenario. Here, air defence command teams were given more authority. The manipulation will be discussed in detail below. Team member scores were compared between scenarios in order to establish the effects of level of authority (within-subjects design). Joint air defence was studied by inviting teams with different levels of joint experience. Scores were compared between members of air defence command teams that varied in their level of joint experience (between-subjects design)[3].

Procedure

Participants. Four air defence teams were invited at the TNO Advanced Concept Development & Experimentation (ACE) research environment in The Hague, The Netherlands (Figure 2.2). Each team consisted of three participants. Teams consisted of a team leader (Master Controller; MC), and two team members. First, the Track Production Officer (TPO) is responsible for identification of all aircraft that are present in the AOR. These aircraft can be commercial aircraft, or military aircraft from nations that are involved in the operations or aircraft from adversaries. Second, the Fighter Allocator (FA) controls the aircraft of own forces by assigning tasks to fighter aircraft and monitoring the aircraft (e.g. time left in the air before refuelling is needed). The team leader has to integrate the actions of the team members, and is responsible for the communication with higher levels, and the maritime component.

Two teams were from the Swedish Air Force (SAF), and two teams were from the RNLAF. All participants were qualified for and experienced in their specific function. The teams were composed of participants who performed tasks that corresponded with their everyday jobs.

Figure 2.2: The ACE research environment at TNO Defence, Security and Safety, The Hague

[3] Quantitative data were obtained at the individual level. Data were not aggregated to the team level because the low number of teams that participated in the study.

Task. The teams completed two scenarios during two experimental weeks. In the first week, the RNLAF air defence command teams played the scenarios, the SAF air defence command teams two weeks later. Each scenario was part of a five-hour session that consisted of an introduction by the researchers, team preparation and team leader briefing, the actual two-hour scenario run, followed by group discussions with the team, the observers, and the researchers.

Scenario. The scenarios were based on two exercises that are used for the training of air defence command teams in the RNLAF. None of the participants had been involved in these training exercises within a year before the experiment. Each scenario contained three critical incidents, which varied in the operational response that was required from the team. The critical incidents required a creative response from the team, because incidents were non-routine incidents and teams had limited experience with these types of incidents in their everyday jobs. More importantly, the critical incident was best resolved with the involvement of the maritime component. This potential for the sharing of information, assets, and workload differed across the critical incidents, building up to the final critical incident which in fact could entirely be handled by the maritime component.

Three critical incidents took place during the scenarios: a hijack/renegade incident, a defecting aircraft incident, and a hostile combined air operation. The critical incidents required different responses of the air defence command team. A hijack means that an aircraft was hijacked by passengers, which means that air defence teams had to discover what the intentions of the hijackers are. A defecting aircraft is an aircraft that leaves its original route. Air defence command teams had to find out whether this occurred accidentally or on purpose. Air defence command teams therefore had to establish communication with the aircraft or had fighter aircraft escorting the aircraft before it could pose a threat on important locations in the AOR. A hostile combined air operation consisted of an attack by enemy aircraft. Air defence command teams had to make sense of the intentions of the adversary and develop adaptive responses to the attacks.

The type of incidents was similar on both sessions, but the critical incidents were placed in a different order and the incidents differed between sessions. For example, the defecting aircraft was a small private jet during the first session, and a military aircraft of own forces that deserted in the second session. In this way, the sessions differed from each other while task demands were the same.

An important methodological issue in repeated-measures studies are learning effects. When individuals or teams perform a task more than once, it is likely that individuals perform better the second time because of task-specific knowledge that participants have obtained on the first run. Learning effects can occur regarding the tasks or roles that participants perform and regarding the task itself. Below a series of measures is described that was taken to limit the possibility that learning effects occurred. Importantly however, no empirical evidence can be presented that learning effects were indeed successfully prevented.

The first argument regarding learning effects results from the context of the research. All participants were members of air defence command teams in real life, and therefore were qualified for, and experienced in, their individual roles. Further, team members knew each other beforehand, and would be working together after the research. These characteristics of existing air defence command teams differentiates these teams from student-teams that are often used in experimental team research. The high levels of experience of team members with the tasks and roles that they performed in the research and the familiarity of team members with each other were expected to help to limit learning effects regarding individual tasks and roles of participants between the two sessions.

The second argument that is related to learning effects regarding the individual tasks and roles of participants is that participants were accustomed to be involved in training programs and exercises. Air defence is an aspect of military operations where errors and mistakes can easily lead to severe consequences (e.g., failure to identify a friendly/neutral/hostile aircraft, failure to identify the intentions of the adversary on time). This means that there is a strong focus on training and participating in exercises in air defence, and members of air defence command teams continue to participate regularly in exercises throughout their careers. This means that team members of air defence command teams are used to work in different environments, such as training facilities and deployed command centres. Likewise, team members were all used to the presence of observers, and often function as observers themselves in the training of servicemen. This means that the effects of working in a different environment and the presence of observers will have been limited. In other words, the high levels of experience of participants with working in different environments and training/research scenarios were expected to limit learning effects with regard to individual tasks and roles that participants performed. Again, this differentiates teams in the present research from short-term student teams that are often used in experimental team research.

The third argument regarding individual roles is related to the research environment in which the case study took place. The design of the operations room, the working stations, and the communication tools were largely similar to the working environments of air defence command teams in their daily jobs. Before the experiment started, all participants took the opportunity to engage in a ‘familiarization session’ in which they could acquaint themselves with the apparatus. In sum, these arguments hold that participants were well-prepared for the individual roles and tasks that they performed in the case study, and this was intended to reduce the likelihood that learning effects occurred the second time that participants completed the second scenario regarding individual roles and responsibilities.

Further, it was discussed above that learning effects can also result from the task itself. Two different scenarios were developed in order to reduce the possibility that learning effects would occur. The scenarios were equally demanding for participants, because the scenarios were similar for the number and type of incidents, and in both scenarios the demands of the incidents for teams increased in the same way throughout the scenario. This was done to allow precise comparisons between scenarios. However, it is possible that learning effects resulted from this. It could be argued that team members would have anticipated that the incidents would increase in the same way on the second scenario. Because it was crucial to assess team coordination processes and team performance precisely in order to test hypotheses, it was decided that possible learning effects on this point would have to be accepted.

The above argumentation was set up to discuss possible confounding of the manipulation of level of authority and learning effects, because the level of authority for all air defence command teams was higher in the second session than in the first session. All teams were given a higher level of authority in the second session in order to allow precise comparisons between teams. It was decided that creating a baseline for team performance in a traditional command structure was important for team members of air defence command teams. Furthermore, introducing the relatively new command structure of delegating authority to air defence command teams on the first session, and then ask them to perform as usual in the second session seemed awkward, because team members would have learned how to work differentially with each other and with other networked teams. For these reasons, it was attempted to reduce the possibility that learning effects (and thus confounding of learning effects and the manipulation of level of authority) occurred, as was explained above.

When learning effects had occurred, this would mean that teams had a performance benefit the second time that they performed the scenario. In the light of the measures that have been described above, we believe that all measures were taken that could reduce the possibility that learning effects, and thus confounding of learning effects and the manipulation of level of authority, did occur. Importantly however, no empirical evidence can be presented that confounding did not occur.

Team leader briefing. Team leaders were asked to prepare a briefing for the teams before the first session started, which is the standard procedure in operations. The team leader had to provide the team with clear tasks, roles, and responsibilities, and describe the way that he would be leading the team. The preparation for the team leader briefings for the second session was done by the Track Production Officer, the Fighter Allocator, and Master Controller together. Here, the team leaders were instructed separately to specifically address how the team should coordinate with the maritime component. This was done to make sure that all team members actively explored in what ways the new authorities would influence their individual tasks and responsibilities in the second session.

White cell. The command structures of the air component and the maritime component (e.g., CAOC, fighter pilots, AAWC), and the platforms and other units that appeared in the scenarios (e.g., frigates, helicopters, land-based air defence locations) were simulated by the so-called white cell. These roles were played by personnel of the RNLAF and Netherlands Maritime Force (NLMARFOR), who were qualified for and experienced in their roles. All individuals in the white cell were experienced in role playing during training programmes and regular exercises. Moreover, the actions in the operations room (air defence command team and fighter allocators) and the white-cell were coordinated by two researchers that were subject matter experts in joint air defence. These researchers also designed the scenario. All individuals who were involved in the quasi-experiment could communicate via a local digital radio network. In this way the white cell could play the scenario in line with the research objectives.

Expert observers. Team performance scores (handling of critical incidents, overall team performance) were derived from the evaluations of a team of expert observers. The team of observers consisted of four observers. All observers were experienced in the function that he or she evaluated, because they performed that function earlier in their careers. One observer evaluated the team as a whole. All observers were experienced in observing air defence command teams for purposes of training and/or qualification of personnel. Observers were given a headset, so that they could hear the communication of the team member that he or she evaluated. Observers were given performance protocols for the evaluation of team member performance. These protocols are discussed below in the measures section.

Observers are not blind to conditions. Because observers are not used to the delegation of authority condition, this could potentially affect their judgments, for instance because it is not clear to them in what ways the higher level of authority affects the roles and responsibilities of team members. Two measures were taken to reduce the possibility that observers were biased in their evaluations. First, all observers were experienced in the specific functions that they evaluated, and moreover observers were experienced in observing air defence command teams during formal training and (international) exercises. As command structures are somewhat different at the national level, and the NATO command and control structure that is used in international missions differs from most national command structures, the observers can be expected to be able to evaluate team performance in a new command structure. Another point in this respect is that observers were involved in the development of the team performance protocols for the decentralized command structure. This means that they were familiar with the protocols beforehand. The second measure that was intended to reduce the likelihood of observer biases was the development of so-called best practices. Best practices had been developed for all critical incidents, which functioned as a point of reference for observers for evaluating team members' performance. In line with these best practices, the protocols for the handling of critical incidents were developed separately for all six critical incidents (three per scenario). However, it is important to note that no empirical evidence can be presented that observer biases did not occur.

Manipulation of delegation of authority. The decision making authority was laid down in the command structure. The command structure in the first session in the experiment was identical to the current way of working in the RNLAF and the North Atlantic Treaty Organization (NATO), with CAOC in command. The roles of CAOC and the MC are somewhat different in Sweden, but all Swedish participants were experienced in working in the NATO setting. The command structure in the second session was adjusted to provide air defence command teams with extra authority by delegating the rules of engagement and interactions between different services to the air defence command teams. All decision making authority was located at the air defence command team throughout the whole scenario of the second session. In this command structure, the air defence command teams were able to handle incidents without direct control of the CAOC, and could collaborate with teams from the maritime component, which has a (limited) air defence capability.

Although the behaviour of participants may be influenced by learning effects in repeated-measures research designs, another methodological issue can emerge when new command and control approaches are explored in repeated-measures designs. Entin (1999; 2000) has demonstrated that when participants are not adequately prepared for the non-traditional command structure, this may negatively influence process and performance measures because the benefits of the new structure are not well understood by participants.

The present research featured a short instruction on so-called *Networked Enabled Capabilities* (NEC) in order to prepare participants for operating in the decentralized command structure. NEC refers to the new possibilities that networked military operations offer in terms to flexible and adaptive command and control. The NEC training consisted of two presentations. In the first presentation, a member of the research team explained theory on networked military operations. It was described in what ways decentralized command structures can foster flexible and adaptive decision making, and the importance of ad-hoc collaborations between teams without direct control from higher levels. The second presentation focused on the implications of decentralized command and control for joint air defence. These presentations were intended to make team members of air defence command teams aware that delegation of authority offered new possibilities to them, and that this may affect the way in which team members perform their tasks.

Manipulation of joint experience. All teams were fully qualified in air defence operations. However, the teams differed in their experience with working in joint environments, reflecting the national strategic military orientations. The SAF teams were less experienced in joint operations compared to the RNLAF teams, who train regularly with the maritime component.

Measures

Communication, self-synchronization, handling of critical incidents, and overall team performance were assessed.

Communication. Communication ran via digital local radio networks. All working stations were equipped with two-channel headsets and a touch screen, which enabled individuals on all positions to contact others (point-to-point communication), or to all other working stations simultaneously (a ‘broadcast’). The use of such headsets is common in air defence, where headsets are used simultaneously for interacting with others and listening to the broadcasts of others.

Log files were used for the analysis of communication in terms of the number of interactions between members of the air defence command team and between members of the air defence command team and other networked units. The number of interactions was used as the measure for communication. Each interaction was coded for sender and receiver. This resulted in a dataset in which communication of the air command teams could be analysed.

Self-synchronization. The self-synchronization questionnaire (Van Bezooijen & Essens, 2007) consisted of twenty five-point Likert-type items, ranging from 1 (“*strongly disagree*”) to 5 (“*strongly agree*”). Participants filled out the questionnaires directly after task completion. The questionnaire contained items on four aspects of self-synchronization: vertical integration (six items, Cronbach’s alpha = .72), horizontal integration (six items, Cronbach’s alpha = .74), event handling, (five items, Cronbach’s alpha = .43) and initiative taking (three items, Cronbach’s alpha = .63). Examples of items of each subscale were: *“I knew what I had to do to meet the overall mission objectives”* (vertical integration); *“The tasks and responsibilities of other units were clear to me”* (horizontal integration); *“When incidents happened, I knew what I had to do”* (event handling); and *“During incidents, I stimulated team members to take initiatives”* (initiative taking). Reliability reached .70 for the overall scale, indicating adequate levels of internal consistency. Because of the small number of teams that participated in the present study, responses of individual team members were not aggregated to the team level.

Performance. Four expert observers rated the overall performance and the way that members of the air defence command teams handled the critical incidents. Each participant in the air defence command team was observed by one observer, who had performed that specific function earlier in his or her career. Additionally, there was one observer for the team as a whole. Observers were the same for both sessions. Overall team performance was scored on a twenty-seven item observer protocol that was based on the protocol for the qualification of air defence personnel in the RNLAF. The protocol considers command and control, communication within the team and with other networked units, control of the airspace (air surveillance), and the way in which teams dealt with actions of the adversary (air battle management). Examples of items are: *“Did the <function> develop a strategy to achieve objectives?”* and *“Were enemy actions, and other factors taken into account when making tactical decisions?”* Consistent with the RNLAF-protocol, the response categories ranged from one to four, using the labels “*unsatisfactory*”, "*marginal*", "*satisfactory*", and "*excellent*". Scores at the individual level were not aggregated to the team level because of the low number of teams in the research.

Furthermore, the handling of the critical incidents was scored by the observers using an eight-item protocol which was specifically designed for each of the critical incidents. The protocol included items on situation awareness, use of information, and showing knowledge on roles and responsibilities. The items were developed by the researchers and personnel from the RNLAF. Examples of items are: *"The <function> based decisions exclusively on own information"* and *"The <function> did not correctly interpret available information"* (reversed item). All items in the observer protocols were eight-point Likert-type items, ranging from 1 ("*Strongly disagree*") to 8 ("*Strongly agree*").

Best practices were developed for all critical incidents in the study (three critical incidents per scenario). The best practices described in what ways team members could respond to the incidents. For instance, it was described for the incidents in the decentralized command structure at what point it would be beneficial for team members of the air defence command teams to collaborate with teams from the maritime components. This enabled observers to indicate the quality of team members' behaviour. Best practices were used in this way for the assessment of team members' performance.

Qualitative data. Semi-structured group discussions with the air defence command teams were conducted after team members had completed the self-synchronization questionnaire. Members of the research team walked the members of the air defence command teams and the team of observers from the operations room to another room at the research facility. Both team members of the air defence command team and observers participated in the forty-minute group discussion. The group discussions started with team members, who reflected on their performance. Observers were subsequently asked to discuss the performance of teams. Two researchers were discussion leaders, and made sure that all team performance criteria that were described in the overall performance protocol were discussed. Another member of the research team took notes. The empirical findings and the outcomes of the group discussions are described in the results section below.

Results

Level of authority

The hypotheses on level of authority were investigated in a within-subjects design and tested in a series of paired-samples *t*-test procedures. Four three-person teams participated in the study. The effects of level of authority were assessed for team coordination processes and team performance. Log files were used for the analysis of communication, questionnaires were used for self-synchronization, and a team of expert observers rated the quality of team performance. Scores were analysed at the individual level because of the limited number of teams that participated in the study. Hypotheses on communication and self-synchronization were tested using eleven degrees of freedom, because there were two levels and twelve participants (formula for degrees of freedom in repeated measures design is $(k - 1)(n - 1)$; e.g., Field, 2005). Regarding team performance, four observers rated the performance of members. This resulted in sixteen scores per condition (four teams and four observers per team). The degrees of freedom differed across the analyses for team performance, because not all observers scored all items on the performance protocols for the handling of the critical incidents and overall team performance.

Communication. It was expected that when team members of air defence command teams were given a higher level of authority, team members would communicate less with the higher level and more with other networked teams that had capabilities for air defence (hypothesis 1a).

Results of a series of paired-samples *t*-tests were consistent with our expectations, as team members of air defence command teams communicated less with the higher level when team members had a higher level of authority (M = 22.67, SD = 14.39) than when team members had a lower level of authority (M = 34.42, SD = 19.96, $t(11)$ = 2.42, p = .03, d =.68). Further, team members communicated more with other teams that had capabilities for air defence when they had a higher level of authority (M = 66.00, SD = 39.48) in comparison to the command structure where they had a lower level of authority (M = 38.75, SD = 21.29, $t(11)$ = 1.99, p = .07, d = .86; see Table 2.1). These results fully support hypothesis 1a.

It was further expected that team members of air defence command teams would communicate more with each other when teams had extra authority (hypothesis 1b). The mean difference was consistent with this expectation, but the result of the paired-samples *t*-test did not reach significance (Table 2.2). Hypotheses 1b was not supported.

Table 2.1: Mean scores, standard deviations, and *t*-test results for communication between members of the air defence command team and other networked teams

	Level of authority							
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Members of command teams to higher level	34.42	19.96	22.67	14.39	2.42	11	.03**	.68
Members of command teams to other teams	38.75	21.29	66.00	39.48	1.99	11	.07*	.86

** $p < .05$, two-tailed * $p < .10$, two-tailed

Table 2.2: Mean scores, standard deviations, and *t*-test results for communication within the command team

	Level of authority							
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Communication to other team members	70.25	20.58	94.17	44.11	1.56	11	.14	.69

Self-synchronization. Team members of the air defence command teams filled out the self-synchronization questionnaire directly after task completion. Team leaders were also asked to fill out the questionnaire, because the effects of higher levels of authority were also expected to influence the way that they synchronized their actions with other team members and other networked teams. The expected positive effects of level of authority on self-synchronization were formulated in hypothesis 1c and tested in a series of paired-samples *t*-tests, because assumptions regarding normal distribution of data and homogeneity of variance were met. Data were analysed using *t*-tests since data were normally distributed and variances did not differ across conditions.

Results showed that team members of the air defence command teams reported higher scores for self-synchronization when team members were given more decision-making authority, $M = 4.37$, $SD = .33$, in comparison to the command structure where team members had lower levels of authority, $M = 3.91$, $SD = .43$, $t(11) = 4.24$, $p < .01$, $d = 1.20$ (Table 2.3). This indicates that team members better synchronized their decisions and actions when they were given more authority. Team members who were given a higher level of authority reported higher scores for vertical integration, $M = 4.21$, $SD = .36$, than when team members had a lower level of authority, $M = 3.74$, $SD = .39$, $t(11) = 3.09$, $p < .01$, $d = 1.25$. Additionally, team members who were given higher levels of authority reported higher scores for horizontal integration, $M = 4.17$, $SD = .53$, in comparison to the command structure where team members had a lower level of authority, $M = 3.53$, $SD = .57$, $t(11) = 2.84$, $p < .01$, $d = 1.17$. Although mean differences were in line with our expectations, no significant differences were found for event handling and initiative taking. The score on the subscale initiative taking was already very high in the command structure where team members had a lower level of authority ($M = 4.48$). Therefore, it would have been hard to improve this score substantially. The results provide substantial support for hypothesis 1c.

Table 2.3: Mean scores, standard deviations, and *t*-test results for self-synchronization

	Level of authority							
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Overall (scores 1-5)	3.91	.43	4.37	.33	4.24	11	<.01**	1.20
Vertical	3.74	.39	4.21	.36	3.09	11	<.01**	1.25
Horizontal	3.53	.57	4.17	.53	2.84	11	<.01**	1.17
Event handling	3.56	.65	4.25	1.37	1.57	11	.15	.64
Initiative taking	4.48	.62	4.73	.52	1.08	11	.30	.44

** $p < .05$, two-tailed

Performance. Hypothesis 1d predicted that level of authority would positively affect team performance. Four observers rated the performance of members of the team for eight aspects per event. The scores on these eight aspects were averaged into single scores for the handling of each of the three critical incidents. Judgments of the observers for the way that team members handled critical incidents resulted in sixteen scores per condition (four teams and four observers per team). The degrees of freedom differed across the three incidents because not all observers rated all items on the performance protocols. Likewise, observers judged the overall performance of team members using a 27-item observer protocol. The scores were averaged into scores for five aspects of team performance (see Table 2.4). Again, the degrees of freedom differ across overall performance aspects because not all observers rated all items on the performance protocols.

Increasing level of authority did positively affect incident handling, as observers rated the handling of the critical incidents higher when team members had a higher level of authority, $M = 5.10$, $SD = .89$, in comparison to the command structure where team members had a lower level of authority, $M = 4.34$, $SD = 1.30$, $t(14) = 3.21$, $p < .01$, $d = .68$ (Table 2.4). Similar results were obtained for overall team performance, as team members who were given a higher level of authority, $M = 2.64$, $SD = .53$, performed better than in the command structure where team members had a lower level of decision-making authority, $M = 2.35$, $SD = .80$, $t(8) = 1.85$, $p = .05$, $d = .43$. These results fully supported hypothesis 1d.

Table 2.4: Mean scores, standard deviations, and *t*-test results for team performance

	Level of authority							
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
(scores 1-8)								
Incident handling	4.34	1.30	5.10	.89	3.21	14	<.01**	.68
Incident 1	4.80	1.06	5.50	.79	2.91	12	.01**	.75
Incident 2	4.16	1.47	5.00	1.05	2.63	13	.01**	.66
Incident 3	4.05	1.38	4.81	1.10	1.53	11	.07*	.56
(scores 1-4)								
Overall performance	2.35	.80	2.64	.53	1.85	8	.05*	.43
Command and control	2.28	.76	2.50	.76	1.17	13	.13	.29
Communication	2.58	.67	2.89	.51	2.06	14	.03**	.52
Air Battle Management	2.34	.79	2.40	.63	.30	14	.39	.08
Air Surveillance/ Track production	2.43	.90	2.73	.54	1.49	9	.09*	.40
Air Surveillance/ Identification	2.26	.85	2.78	.60	1.73	8	.06*	.71

Note: the degrees of freedom differ across performance criteria because observers did not score all items on the protocol at all times

** $p < .05$, two-tailed * $p < .10$, two-tailed

Joint experience

The hypotheses on joint experience were analysed in a between-subjects design and tested in a series of independent-samples *t*-test procedures. Two teams had lower levels of joint experience, and two teams had higher levels of joint experience. Scores were analysed at the individual level because of the limited number of teams that participated in the study. Analyses were performed separately for the two levels of authority because otherwise the assumption of independent samples would be violated because of the repeated-measures design of level of authority. The analyses on self-synchronization and communication were performed with ten degrees of freedom, since the degrees of freedom for independent samples *t*-tests are calculated by adding the two sample sizes and subtracting the number of samples ($df = 6 + 6 - 2 = 10$, e.g. Field, 2005). Finally, the number of the degrees of freedom for team performance scores differed because not all observers scored all items on the performance protocols.

Communication. It was expected that joint expertise would help team members to communicate less with the higher levels, and with other networked units that had capabilities for air defence (hypothesis 2a). Results provided us with no support for this hypothesis. Team members with higher levels of joint expertise communicated even *more* with other networked teams, M = 51.33, SD = 19.17, than team members with lower levels of joint experience, M = 26.17, SD = 17.14, $t(10) = 2.48$, $p = .03$, d = 1.38, in the command structure where team members had a lower level of authority (Table 2.5). No significant differences were found for communication with the higher level. Hypothesis 2a was rejected.

Regarding communication between members of the air defence command team, it was hypothesized that joint experience enabled teams to communicate less with other team members (hypothesis 2b). No significant differences were found between teams that consisted of team members with higher levels of joint experience and teams that consisted of team members with lower levels of joint experience (Table 2.6). No evidence was obtained that experience influenced communication between team members of the air defence command team, providing no support for hypothesis 2b.

Table 2.5: Mean scores, standard deviations, and *t*-test results for communication between members of the air defence command team and other networked teams

	Level of joint experience							
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Condition: low level of authority								
Members of command teams to higher level	26.33	20.53	42.50	17.25	1.48	10	.17	.85
Members of command teams to other teams	26.17	17.14	51.33	19.17	2.48	10	.03**	1.38
Condition: high level of authority								
Members of command teams to higher level	20.67	13.62	24.67	16.15	.46	10	.65	.27
Members of command teams to other teams	74.33	13.62	57.67	31.35	.72	10	.49	.70

** $p < .05$, two-tailed

Table 2.6: Mean scores, standard deviations, and *t*-test results for communication within the command team

	Level of joint experience							
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Condition: high level of authority								
Communication								
to other team members	69.17	19.48	71.33	23.44	.17	10	.86	.10
Condition: high level of authority								
Communication								
to other team members	89.17	37.51	99.17	53.04	.38	10	.71	.22

Self-synchronization. It was hypothesized that higher levels of joint experience would help teams to better synchronize their actions (hypothesis 2c). Hypotheses were tested separately for the two levels of authority. Two series of independent samples *t*-tests were conducted because assumptions regarding normal distribution of data and homogeneity of variance were met.

Results indicated that joint experience did affect self-synchronization, but only when teams had lower levels of authority (Table 2.7.1, and Table 2.7.2). Team members of teams with higher levels of joint experience, $M = 4.07$, $SD = .37$, synchronized their actions better with other team members and other networked units than team members of teams with lower levels of joint experience, $M = 3.51$, $SD = .27$, $t(10) = 2.94$, $p = .02$, $d = 1.73$) under lower levels of authority. Follow-up *t*-tests (see Table 2.7.1) revealed that teams with higher levels of experience reported higher scores for integrating their actions on the vertical dimension, $M = 4.03$, $SD = .25$, than teams with lower levels of joint experience, $M = 3.44$, $SD = .26$, $t(10) = 4.07$, $p = .01$, $d = 1.91$. Teams with higher levels of experience also reported higher scores for integrating their actions on the horizontal dimension, $M = 3.83$, $SD = .56$, than teams with lower levels of joint experience, $M = 3.22$, $SD = .42$, $t(10) = 2.15$, $p = .06$, $d = 1.23$. Finally, teams with higher levels of experience also reported higher scores for the handling of critical events, $M = 3.92$, $SD = .66$, than teams with lower levels of joint experience, $M = 3.21$, $SD = .43$, $t(10) = 2.19$, $p = .05$, $d = 1.27$. Importantly, no effect was found for self-synchronization in the command structure where team members had a higher level of authority (Table 2.7.2). In this command structure, team members with a higher level of joint experience, $M = 4.41$, $SD = .27$, did not report significantly higher scores for self-synchronization than team members with a lower level of joint experience, $M = 4.20$, $SD = .38$, $t(10) = 1.15$, $p = .28$, $d = .64$).

In sum, the results indicated that joint experience influenced self-synchronization, but only when teams had a lower level of authority. These results partially support hypothesis 2c.

Table 2.7.1: Mean scores, standard deviations, and *t*-test results for self-synchronization (condition: low level of authority)

	Level of joint experience				Condition: low level of authority			
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Overall (scores 1-5)	3.51	.27	4.07	.37	2.94	10	.02**	1.73
Vertical	3.44	.26	4.03	.25	4.07	10	.01**	1.91
Horizontal	3.22	.42	3.83	.56	2.15	10	.06*	1.23
Event handling	3.21	.43	3.92	.66	2.19	10	.05*	1.27
Initiative taking	4.33	.61	4.63	.64	.81	10	.44	.41

** $p < .05$, two-tailed * $p < .10$, two-tailed

Table 2.7.2: Mean scores, standard deviations, and *t*-test results for self-synchronization (condition: high level of authority)

	Level of joint experience				Condition: high level of authority			
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Overall (scores 1-5)	4.20	.38	4.41	.27	1.15	10	.28	.64
Vertical	4.00	.33	4.42	.27	2.37	10	.04**	1.39
Horizontal	3.92	.23	4.42	.65	1.78	10	.11	1.02
Event handling	4.50	1.98	4.00	.22	.61	10	.55	.35
Initiative taking	4.63	.54	4.83	.52	.68	10	.51	.38

** $p < .05$, two-tailed * $p < .10$, two-tailed

Team performance. As can be seen in Table 2.8.1 and Table 2.8.2., joint experience did not influence team performance in terms of handling of critical incidents. Team members of air defence command teams with higher levels of joint experience, $M = 4.91$, $SD = 1.14$, did not handle critical incidents significantly better than team members of air defence command teams with lower levels of joint experience, $M = 3.84$, $SD = 1.29$, $t(13) = 1.68$, $p = .12$, $d = .88$, under the conditions of lower level of authority. There seemed to be a trend that team with higher levels of joint experience were better in handling critical incidents, but this trend did not reach significance. Similar results were obtained under conditions of high levels of authority, because team members of air defence command teams with higher levels of joint experience, *M* = 5.39, *SD* = .72, did not handle critical incidents significantly better than team members of air defence command teams with lower levels of joint experience, *M* = 4.83, *SD* = .95, *t*(14) = 1.33, *p* = .21, *d* = .66.

Table 2.8.1: Mean scores, standard deviations, and *t*-test results for team performance (condition: low level of authority)

	Level of joint experience				Condition: low level of authority			
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
(scores 1-8)								
Incident handling	3.84	1.29	4.91	1.14	1.68	13	.12	.88
Incident 1	4.03	1.54	4.91	1.04	1.27	13	.23	.67
Incident 2	3.73	1.25	4.27	1.66	1.28	12	.23	.37
Incident 3	3.82	1.53	5.10	.77	1.70	10	.12	1.06
Overall performance	2.12	.65	3.00	.56	2.26	9	.05*	1.45
Command and control	2.00	.73	2.67	.69	1.74	12	.11	.94
Communication	2.25	.61	2.95	.56	2.31	13	.04**	1.20
Air Battle Management	1.83	.61	2.93	.51	3.74	13	.00**	1.99
Air Surveillance/ Track production	2.14	.84	3.07	.55	2.15	10	.06*	1.31
Air Surveillance/ Identification	2.00	.77	2.83	.46	2.31	11	.04**	1.32

Note: the degrees of freedom differ across performance criteria because observers did not score all items on the protocol at all times

** $p < .05$, two-tailed * $p < .10$, two-tailed

Joint experience did influence overall team performance, as team members with higher levels of joint experience, *M* = 3.00, *SD* = .56, performed better than team members with lower levels of joint experience, *M* = 2.12, *SD* = .65, *t*(9) = 2.26, *p* = .05, *d* = 1.45 in the command structure where team members had a low level of authority. Importantly, this result was obtained only in the situations where teams had a low level of authority. Inspections of Table 2.8.1 and Table 2.8.2 teach us that the lack of results may be attributed to performance differences between teams with similar levels of joint experience. In sum, the results provide partial support for hypothesis 2d.

Table 2.8.2: Mean scores, standard deviations, and *t*-test results for team performance (condition: high level of authority)

	Level of joint experience				Condition: high level of authority			
	Low		High					
	M	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
(scores 1-8)								
Incident handling	4.83	.95	5.39	.72	1.33	14	.21	.66
Incident 1	5.23	.79	5.72	.72	1.20	12	.25	.65
Incident 2	4.52	1.12	5.59	.68	2.33	14	.04**	1.15
Incident 3	5.15	1.15	4.84	1.17	.54	14	.60	.26
Overall performance	2.33	.42	2.78	.57	1.48	9	.17	.90
Command and control	2.38	.85	2.67	.66	.69	12	.50	.38
Communication	2.75	.43	3.12	.64	1.53	14	.15	.68
Air Battle Management	2.40	.75	2.42	.50	.07	14	.95	.03
Air Surveillance/ Track production	2.56	.62	2.81	.54	.80	11	.45	.43
Air Surveillance/ Identification	2.80	.73	2.83	.40	.10	9	.93	.05

Note: the degrees of freedom differ across performance criteria because observers did not score all items on the protocol at all times

** $p < .05$, two-tailed * $p < .10$, two-tailed

Interaction effect. In the present research we combined a within-subjects design and a between-subjects design. The effects of the factors were addressed separately when testing the hypotheses on level of authority and joint experience, but the effects can also be tested in a ‘between-within subjects analysis of variance’ (Tabachnik & Fidell, 1996). A 2 x 2 General Linear Model (GLM) repeated measures design was used to analyze the data, with level of authority as within-subjects variable and joint experience as between-subjects variable. It was expected that the effects of level of authority on performance would be larger for team members of joint air defence teams with higher levels of joint experience than for team members of joint air defence teams with lower levels of joint experience (hypothesis 3). Results of the analyses are presented in Table 2.9.

No interaction effect of level of authority and joint experience was found in the handling of critical incidents ($F(1,9) = 1.79$, $p = ns$, $\eta^2 = .16$). Alternatively, an interaction effect of level of authority and joint experience was found regarding overall team performance ($F(1,9) = 4.88$, $p = .04$, $\eta^2 = .41$). An inspection of Tables 2.9, 2.8.1, and 2.8.2 revealed that the team members with a lower level of joint experience profited more from the extra authority than team members with higher levels of joint experience. Hypothesis 3 was rejected.

Table 2.9: Mean scores, standard deviations, and repeated-measures ANOVA results for level of authority and joint experience

	Level of authority Low (n = 12)		High (n = 12)		Effects
	Low level of of joint experience	High level of joint experience	Low level of joint experience	High level joint experience	
Handling of critical incidents					
M	3.84	4.91	4.83	5.39	a*
SD	1.29	1.14	.95	.72	
Overall team performance					
M	2.12	3.00	2.33	2.78	a*,c*
SD	.65	.56	.42	.57	

Note: a = main effect level of authority; b = main effect of joint experience, c = interaction effect level of authority x joint experience

* $p < .10$, two-tailed

Qualitative results

The results of the group discussions with the air defence command teams and the observers are described below[4]. The protocol for the group discussions were based on the team performance protocol that observers used for scoring the overall performance of the air defence command teams. As was discussed above, the protocol considered command and control, communication between members of the team and with other networked units, air surveillance, and way in which teams dealt with actions of the adversary. The group discussions started ten minutes after the scenario had ended. The group discussions took forty minutes. Two members of the research teams were discussion leaders and made sure

[4] The majority of participants and observers were male. In order to describe qualitative results anonymously, all responses are described using ‘he’, ‘his’, etcetera.

that all performance criteria were discussed, and that all team members reflected on the non-traditional command structure after the second scenario. Another member of the research team took notes. The outcomes of the group discussions are described below for level of authority and joint experience.

Level of authority. Team members of the air defence command teams reported that they had to get used to the new command structure in the second session. Team members remarked that they needed some time to work out how they could make use of the higher level of authority, but that this became clear to them by the time the critical incidents happened. Teams had different opinions regarding the effects of higher level of authority. Some team members and team leaders reported that they were fully occupied when performing their tasks in the traditional setting, and therefore they could make no effective use of the higher level of authority. Other teams reported that the higher level of authority helped the team to play a more active role in controlling the air space. The comments of the observers in the second group discussion indicated that the team leader was important for this, because not all team leaders provided information to team members about how the extra authority could help the team members to perform their tasks.

Team leaders instructed their teams in the team leader briefing about the way they intended to operate. In the briefing the team leader addressed how the team should make use of the extra authority. Observers noted that although most team leaders did address this issue at the team level, they did *not* specify how this affected individual roles of the TPO and the FA. Only one team leader addressed the possibility for collaboration with the maritime component by discussing the capabilities of the frigates (e.g., personnel, radar capabilities, weapons). Further, he promoted initiative taking by stating that “If you want assets from them, look at the AAWC and the MC”. This means that some team leaders addressed the higher levels of authority at the team level, but did not work out how this affected the roles and responsibilities of team members subsequently. This made it hard for team members to make effective use of the higher level of authority, such as taking initiatives with other networked teams without consulting team leaders or higher organizational levels first.

Further, observers indicated that not specifying individual roles and the potential of maritime component units in advance made adaptation during operations difficult, because teams were quite overloaded when handling critical incidents. During critical incidents, task demands simply exceeded the capabilities of team leaders, leading to impaired information sharing and, more importantly, members of the command team had to wait to get approval for taking action. In other words, if the team is not working well, networked interactions will be reduced. One participant commented: “*The team had to complete the whole OODA-loop*[5]*, while in the traditional command structure the orient and*

[5] The OODA-loop is a decision-making loop that is used in the military for decision making at the strategic level. It consists of four phases: observe, orient, decide, and act. See http://en.wikipedia.org/wiki/OODA_Loop for a description of the loop.

decide were done by the CAOC". This comment indicated that higher levels of authority influenced the roles and responsibilities of air defence command teams in terms of information processing, communicating, and coordination with other team members and other networked teams. As a consequence, the new roles and responsibilities may have prohibited air command teams to develop collaborations with the maritime component on time. These teams worked "*behind the power curve*", as another participant remarked. This participant commented that *"more decision power means more freedom, but also more thinking"*. Nevertheless, participants reported that the extra authority enabled them to synchronize their decisions with regard to the maritime component and that this helped them to handle the critical incidents better. Participants and observers agreed that, when the new roles and responsibilities are clear to the members of the teams, the higher levels of authority enabled air defence command teams to respond more effectively to critical incidents. Teams could establish coordinated action with teams from the maritime component more quickly, which made it possible to deal with critical incidents at an early stage.

Experience. Joint experience affected some aspects of team coordination processes and team performance according to the observers, but differences between teams that had similar levels of joint experience were also noticed. This made it difficult to interpret the results on joint experience. For instance, observers and members of air defence command teams indicated that the impact of working with different equipment and in a slightly different command structure did seem to primarily affect teams with lower levels of joint experience. At the same time, a team leader that had little joint experience did provide his team with clear roles and responsibilities, and this team responded well to incidents and taking initiatives toward the maritime component.

The collaborations of the air defence command teams with the maritime component in the second session were very diverse. One team was hesitant to let the maritime component help in handling incidents, while another team already initiated collaboration with the maritime component when the incident was merely building up. This team let the maritime component handle the incident with their own assets. Again, differences were observed for both teams with higher levels of joint experience as well as teams with lower levels of experience, and there was no indication that differences in level of joint experience affected the effective utilization of higher levels of authority.

Discussion

The goal of the present research was to gain a deeper understanding of team coordination in virtual teams and to investigate in what ways level of authority and experience on similar tasks would affect coordination processes in virtual teams. A research programme at TNO offered the possibility to study existing air defence command teams in a realistic research environment. It was decided to study air defence command teams because all communication in these teams is mediated by technology. Some level of control over the environment could be established because the study was conducted in a high-fidelity simulation environment. Establishing some level of control made it possible to systematically manipulate level of authority (by adjusting the command structure) and level of experience (by inviting teams with different levels of joint experience). Since air defence command teams have to coordinate their actions not only with other team members, but also with other teams (e.g. higher organizational level, platforms), we also studied coordination with other teams in the this study. It was decided to apply a mix of qualitative and quantitative techniques, and different sources of data. This research approach was conducted because the number of data points was limited in the present research. Four air defence teams performed two similar joint air defence tasks, and team coordination processes and team performance were assessed.

The results of level of authority generally supported the benefits of delegating authority to teams at the edge of organizations. The analysis of communication log files revealed that there was less vertical communication in the decentralized command structure, which would mean that air defence command teams had more time to interact with other networked teams that had capabilities for air defence. The amount of communication with other networked teams indeed increased when teams had a higher level of authority. The results of self-synchronization supported this view, as air defence command teams that were given higher levels of authority synchronized their actions better with those of other team members and with other networked units. Ultimately, air defence command teams in the decentralized command structure performed better when it came to handling of critical incidents and overall team performance.

In all, the quantitative results indicated that higher levels of authority enable teams to perform better in complex and dynamic environments where dealing with unpredicted change is the key to operational success.

The outcomes of the group discussions indicated that the role of team leaders is highly important for the way in which teams utilize the higher level of authority. When authority is delegated to air defence teams, team leaders can either share authority with members of the team, or ‘absorb’ the extra authorities. Team leaders who absorbed the extra authority in fact extended the number of tasks that they had to perform in this way. Observers indicated in the group discussions that absorption of the extra authority was not an effective approach, because team leaders became overloaded when critical incidents occurred. While teams may have performed better in the decentralized command structure, the performance increases could have been greater if team leaders would have delegated some of the extra authority to team members. The outcomes of the group discussions indicated that team leaders differed in this respect, and that the team leader briefing is an important indicator for this. When team leaders did not specify in what ways the extra authority would affect the tasks and responsibilities of team members, it appeared to be hard for team members to make effective use of the extra authority in the decentralized command structure. Observers indicated that the capacity of teams to change the roles and responsibilities of team members *during* task execution was limited.

In conclusion, the findings of the present research indicate that increasing levels of authority for teams that are located at the edge of organizations positively affects team coordination and team performance. Team members of air defence command teams were able to make effective use of the new possibilities that a higher level of authority offered them in terms of flexible, adaptive decision making. The findings on the self-synchronization questionnaire imply that team members were better able to synchronize their efforts with other team members and other networked teams.

The outcomes of the group discussions indicate that the positive effects of higher levels of authority hinge on the extent to which team leaders delegate some of the authority to team members. Team members indicated that when the team leader had not addressed how the extra authority affected the roles and responsibilities of team members, team leaders were not able to do this during task execution. The importance of leadership style became apparent during critical incidents, as team leaders who did not delegate some of the extra authority to team members were so occupied with dealing with the incident that team members had to wait to get information or approval for suggested actions.

Results on the effects of joint experience were less consistent. Teams that consisted of team members with higher levels of joint experience reported higher scores for three aspects of self-synchronization (vertical and horizontal integration, and event handling) than teams that consisted of team members with lower levels of joint experience, but only under conditions of lower levels of authority. Teams that consisted of experienced team members also had a performance benefit over teams that consisted of inexperienced team members. However, also these differences disappeared when teams were given a higher level of authority. Analysis of the communication log files revealed that the amount of communication between team members of the air defence command teams and between these teams and other networked units did not differ between groups. Further, team performance scores indicated that there was no interaction between level of authority and joint experience in the expected direction. This means that teams with higher levels of joint experience were not able to make more effective use of higher levels of authority than teams with lower levels of joint experience. Taken together, the quantitative results indicated that joint experience may help teams to perform better on a similar task and to communicate better, but that this may not help teams to adapt to higher levels of authority.

A possible explanation for the results on self-synchronization and the interaction between level of authority and joint experience on team performance may result from ceiling effects. Inspections of Tables 2.7.1., 2.7.2., 2.8.1, and 2.8.2. showed that scores for self-synchronization and performance of team members with higher levels of authority were already high in the first session. This may have made it difficult for team members with high levels of experience to improve their scores on the second scenario.

Finally, it is important to note that teams with similar levels of joint performance differed considerably on various team performance scores. This makes that the role of joint experience on coordination in air defence command teams remains unclear.

A final remark should be made regarding possible learning effects and confounding of learning effects and the manipulation of level of authority. A considerable set of measures was taken to prevent learning effects (and thus confounding of learning effects and the manipulation of level of authority). Additionally, Cooke et al. (2007) found that experienced command and control teams may have a performance advantage over inexperienced teams on a command and control task, but not a learning advantage. They found that prior experience on a command-and-control task did benefit experienced teams in terms of performance, but both experienced teams and inexperienced teams showed similar performance improvements in a series of five sessions on a complex command and control task. Although we had no indication that learning effects did occur, no empirical support can be presented that learning effects were indeed successfully prevented. Likewise, there is no empirical evidence that our measures regarding potential observer biases were effective. These limitations temper the interpretation of the results.

Theoretical and practical implications

The present research was intended to gain a deeper understanding of team coordination in virtual teams and to identify in what ways level of authority and experience on similar tasks would affect coordination processes in virtual teams. Results indicated that higher levels of authority affected virtual teams in line with our expectations. Higher levels of authority reduced communication on the vertical dimension of organizations, increased communication at the horizontal dimension, and teams better synchronized their actions with regard to other team members and other networked teams. Ultimately, teams performed better in the second session in terms of handling unexpected incidents and overall team performance.

The most important theoretical implication is, however, that these effects hinge on the way that team leaders utilize the extra authority. Higher levels of authority at the team level also requires teams to reconsider the way that they perform their tasks in terms of leadership style, sharing workload, and a more active role in the development of adaptive responses to unpredicted change. Importantly, the relocation of decision-making authority towards the team level will not lead to better performance per se, as team leaders may absorb these extra authorities and become overloaded when unpredicted changes occur. The importance of preparing team leaders to whom extra authorities *are delegated to* is not incorporated in theory on networked military operations. Results of the present study indicate that higher levels of authority offer new opportunities to teams, but that these opportunities face teams with additional task demands. Therefore, team leaders have to reconsider their activities and explore in what way authority can be shared with team members.

A practical implication is that team leaders will have to be prepared for making effective use of higher levels of authority in networked environments. The preparation of team leaders should be focused on how teams can leverage the opportunities for effectively integrating the actions of different team members as well as sharing workload and resources with other teams.

Another practical implication is that teams have to be prepared for working with higher levels of authority before task execution. Team members indicated that when incidents are building up, there is no time left to explore the capabilities of other teams or platforms in the network, so this has to be done before the start of a mission (e.g., Dalenberg, Vogelaar, & Beersma, 2009). Results suggest that it may be important for teams to find out what other teams are present in the network beforehand, and how workload or resources may be shared with other teams. We propose that this would enable teams to take initiatives during task execution and, subsequently, to respond effectively to unpredicted change.

Results on joint experience did lead to inconsistent results, since joint experience did not affect self-synchronization, communication, and team performance under conditions of high authority. The inconsistencies between outcomes on team coordination processes and team performance suggest that the relation between joint experience and team performance is also influenced by other factors than team coordination. Possible factors are motivational (e.g. collective efficacy, team empowerment) or affective (team cohesion, emotional distress; see Zaccaro, Rittman, & Marks, 2001).

Strengths, limitations, and directions for further research

The research was aimed to study the benefits of decentralization of the command structure in a realistic command and control environment. A strength of the present research is that air defence command teams performed a complex air defence scenario in a realistic working environment. Further, the creation of a JCOP and the decentralization of the command structure were in line with theory on networked military operations. This means that the results of the present research contribute to theory on networked military operations for determining effects of levels of authority to teams that are located at the edge of military organizations.

Limitations of the present research result from limited levels of experimental control and a limited number of available teams. Although some level of control was established by means of working with scenarios, role players and a white cell, multiple data sources, and protocols, teams nevertheless differed in multiple respects, such as the way in which team leaders prepared themselves for the experiment. These differences are typical for team research in which existing teams participate, and can only be minimized by increasing the number of teams and establishing high levels of experimental control. The low number of teams that participated in the study means that generalizability may be limited. Further, the military context of the research that was conducted makes that the findings have limited value in other environments.

The results of this study lead to clear suggestions for future research. The crucial role of leaders of air defence command teams advocates further research on leadership style in teams that are networked through information and communication technology and operate in complex and dynamic environments.

Conclusion

The present research was conducted to study the effects of level of authority in a realistic command-and-control setting. Further, the study was aimed at determining the role of experience in joint operations regarding the ability of teams to make effective use of the extra authority. The study had a case study research approach and was carried out in a semi-controlled research environment. Four air command teams completed two scenarios. In the second scenario, the command structure was altered by increasing the level of decision making authority of air defence command teams.

The present research demonstrated that increasing the level of authority for teams at the edge of organizations is positively related to operational effectiveness. Air defence command teams handled incidents better and performed better overall when decision-making authority was delegated to them. At the same time, more authority also meant that teams faced additional demands in terms of decision making and synchronization of own actions with those of other teams. Team leaders played a key role in this process, as team leaders determined how the extra authority was applied. Team leaders differed in the way in which they utilized the extra authority. Some team leaders 'absorbed' the extra authority and the higher levels of authority did not affect the way in which team members performed their individual tasks. Alternatively, other team leaders shared authority with team members. These teams could share the workload that resulted from the increased task demands. Sharing authority appeared to be an effective way to make use of extra authorities.

In sum, this study showed that increasing the level of authority of teams that are located at the edge of organizations affects team coordination processes and performance. The findings also indicate that extra information can hamper team processes when teams are not trained to handle extra information and authority. Decentralization of the command structure potentially enables flexible, adaptive decision making, but at the same time it puts additional demands on particularly the leaders of air defence command teams.

Chapter 3

Effects of leadership style on coordination in virtual teams

Introduction

Organizations increasingly operate in complex and dynamic environments that require adaptive action. In these environments organizations rely on teams that can adapt to changes ‘on the fly’ by flexibly applying their capacities, expertise, and resources (Burke, Stagl, Salas, Pierce, & Kendall, 2006; LePine, 2005). Team members’ actions have to be coordinated in order to achieve a commonly shared goal (Entin & Serfaty 1999; Van de Ven, Delbecq, & Koenig, 1976; Zaccaro, Rittman, & Marks, 2001).

Team coordination is defined as “*the process of orchestrating the sequence and timing of interdependent actions*” (Marks, Mathieu, & Zaccaro, 2001: pp. 367–368). Coordination processes in teams are either explicit or implicit. Examples of explicit coordination are planning processes and overt communication. Implicit coordination is observed when team members anticipate on other team members’ needs and actions and adjust their own behaviour accordingly (Entin & Serfay, 1999; Serfaty & Kleinman, 1990; Rico, Sánchez- Manzanares, Gil, & Gibson, 2008). For instance, when making decisions in military operations, military teams have to process large amounts of information about the different aspects of operations. As it would be impossible for all team members to process and interpret all information, team members have assumptions about who will process what information. These assumptions are based on roles, responsibilities, knowledge about information distribution, and past experiences. By anticipating what other team members will do and by adjusting own behaviour accordingly, the team is able to processes the information without using explicit coordination.

The most important benefit of implicit coordination is that it requires less effort of team members than explicit coordination processes. This makes implicit coordination particularly useful in high workload conditions due to stress or complexity of the task (Burke et al., 2006; Entin & Serfaty, 1999; Entin, Serfaty, & Volpe, 1993). Teams rely on routines and stable work distribution and interrelation patterns in high workload conditions for establishing implicit coordination processes. Teams must further have shared and accurate perceptions of the situation at hand in order to align their behaviour without using explicit communication (Rico et al., 2008; Weick & Roberts, 1993). Establishing implicit coordination processes is difficult for teams that share the same physical location, but is even harder for members of virtual teams because of the dispersion by time, distance, and/or technology (Bell & Kozlowski, 2002; Rico et al., 2008; Zaccaro, Ardison, & Orvis, 2004).

So how can implicit coordination in virtual teams be fostered? Team leaders play a key role in team coordination processes, as they are responsible for a number of relevant team coordination processes, such as matching roles and team members, offering strategies to complete the task, and providing feedback. (Kozlowski, Gully, Salas, & Cannon-Bowers, 1996; Zaccaro et al., 2001). Virtual team leaders, however, also face obstacles due to dispersion that are likely to affect their abilities to perform leadership functions such as mentoring and coaching team members, and monitoring team processes. The main difference between leaders of collocated teams and leaders of virtual teams is that virtual team leaders have less or no opportunities for face-to-face communication when executing their leadership functions due to dislocation. Since team leaders cannot perform all leadership functions in virtual teams because of locational, temporal, and relational boundaries, virtual teams will profit from participation of team members (Bell & Kozlowski, 2002; Kahai, Sosik, & Avolio, 2004). Team leaders can consult team members before making a decision, or team members can take over some of the leadership functions of team leaders (e.g. managing material resources, information searching). Team leaders can also share workload with team members by delegating authority to team members for taking actions or implement decision on specific (sub)tasks. For these reasons, participative and delegating leadership styles are important issues for virtual teams.

Participative and directive leadership styles in virtual teams

A classification of leadership styles that differentiated leaders has been made in 1939 by Lewin, Lippitt, and White. These authors used the labels autocratic, democratic, and laissez-faire leaders. The latter label has become less popular, because it describes leaders who give team members complete freedom and no guidance or feedback on how to complete the task unless asked to. This passive role of team leaders is incommensurate with the tasks and environments in which teams function today. The other two styles refer to leadership in terms of team member participation. They range from leadership styles that do not include participation of team members (autocratic or directive leadership) to leadership styles where team members participate in decision making and/or where responsibilities are shared across members of the team (participative and democratic leadership).

Directive leaders limit team member participation in decision making by controlling team decision making and interaction processes or by dominating the selection of a specific outcome (Peterson, 1997). The key characteristic of directive leaders is that these leaders control team member actions by providing directions and seeking compliance of team members (Bass, Valenzi, Farrow, & Salomon, 1975; Durham, Knight, & Locke, 1997; Kahai, Sosik, & Avolio, 1997). Here, team leaders centralize the decision making process. Directive leadership occurs when leaders closely control how a task is done (see Sagie, Zaidman, Amichai-Hamburger, Te’eni, & Schwartz, 2002).

Regarding participative leadership styles, participation of team members can take many forms, such as asking the opinions of team members before making a decision or team leader and team members deciding together (Yukl, 2006). Team leaders may consult team members for various reasons, such as making optimal use of the available knowledge in the team or making a decision that is favoured by the majority of team members. Alternatively, delegating authority to team members means that team leaders share their power with team members by giving team members authority or responsibility to take action or to implement decisions without direct control of the team leader. Team leaders may delegate authority to team members when task demands exceed the capabilities of team leaders to perform their functions, such as when workload is high because of timelines or when team leaders have no expertise in a relevant domain. Therefore, participation and delegation are separate categories of managerial behaviour (Leana, 1987; Yukl, 2006).

Virtual teams call for a mix of participative leadership and delegation of authority to team members for several reasons. First, members of virtual teams are typically selected for their individual expertise, perform their tasks from different locations, and may come from different organizations (e.g., Bell & Kozlowski, 2002). Team leaders have limited possibilities to control team member actions in these situations, and therefore team leaders will have to delegate authorities to team members. This enables team members to accomplish their tasks in the way that they think is best, and team leaders can focus on the leadership functions that can be performed at a distance, such as setting time lines or managing team progress. Second, delegating authority to team members means that less coordination is needed between team leaders and team members. Reducing the coordination needs of teams makes that team members can focus on other activities that contribute to team performance, such as performing individual tasks.

Participation of team members offers benefits to virtual teams when making decisions. Here, team leaders will consult team members for their opinions in order to come to the best decision. Participation of team members helps team leaders to make optimal use of all available knowledge. Another reason for participation may be that decisions have to be acceptable to all team members. This may be particularly important for virtual teams that consist of members from different organizations (or organizational parts), whose team membership is based on expected positive outcomes for all stakeholders. Now that the differences between delegation of responsibilities to team members and participation of team members in decision making have been addressed, the mix of delegation and participation in virtual teams will be referred to as participative leadership in the remainder of this thesis.

In sum, it can be concluded that participation of team members is important for virtual teams to make optimal use of the expertise of team members, reduce the need for coordination, and to increase the quality of team performance. Team leaders play a crucial role here, as leadership style does not only determine in what way team members participate in decision making, but also influence team coordination processes.

Team coordination processes in virtual teams

The effects of team leadership style are considered to directly affect team processes in virtual teams (Zaccaro & Bader, 2002; Zaccaro et al., 2004). The present research is focused on identifying the importance of team member participation on implicit coordination in virtual teams. The team processes that were studied were team information processing, team situation models, and self-synchronization (see Figure 3.1). Team information processing was studied because it describes the sharing of information, ideas, or cognitive processes in teams (Hinsz, Tindale, & Vollrath (1997). Team information processing concerns the selection of information from the environment and the retrieval of information from the collective memories of members of the team in the light of the team goals. Team situation models convey team members' mental representations of the operational situation (Cooke, Stout, & Salas, 2001; Rico et al., 2008). Team situation models represent the dynamic understanding of the situation of team members, and contain information on the team, the task, and the environment. Self-synchronization refers to implicit coordination in virtual teams, and concerns the predictions and expectations of team members about the actions of other team members and task states. Further, self-synchronization describes the dynamic adjustment of the behaviour of team members that follows from these predictions.

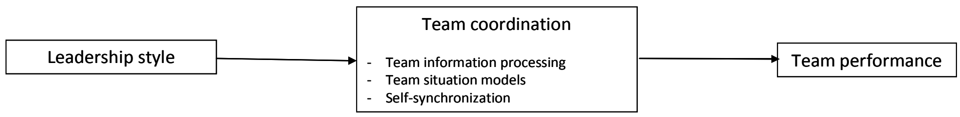

Figure 3.1: Research model

Team information processing

Team information processing is a crucial team process that influences team coordination and performance when teams are confronted with problems (Zaccaro et al., 2001). The model of Hinsz et al. (1997) provides a general framework for information processing in teams. The framework was described in Chapter 1. Team information processing describes the activities of team members to obtain information from the environment. Information from the environment is processed in the processing work space, where information is combined with knowledge that is retrieved from the memories of team members. The integration of information occurs on the basis of beliefs and rules, which ultimately leads to actions in the form of judgments or decisions.

Participation of team members in team information processing is possible when team members are capable and experienced with respect to their task (Kozlowski, 1998; Kozlowski et al., 1996). Team member participation is beneficial for teams because leadership functions such as searching, structuring, and utilizing information can be transferred to team members (Zaccaro et al., 2001). The effects of leadership style on team information processing have been addressed by Kahai, Sosik, and Avolio (1997), who found that participation is positively related to the generation of problem solutions and productivity on moderately structured tasks. In line with this finding, Larson, Foster-Fishman, and Franz (1998) found that participative leadership leads to more information sharing between team members. Information processing and sharing are important determinants of team effectiveness for complex tasks where team members are interdependent (Jehn & Shah, 1997; Mesmer-Magnus & DeChurch, 2009). It is expected that the benefits of team member participation also hold for information processing in virtual teams. It is hypothesized that virtual teams with participative leaders have higher levels of information sharing than virtual teams with directive leaders. The importance of participation of team members in virtual teams is based on characteristics of virtual teams, such as high levels of individual expertise and the crossing of locational and relational boundaries by members of the team. These characteristics call for participation of team members because team leaders may not have expertise in all relevant domains.

Leadership style is expected to affect how team members deal with information, as participative leaders do not control how team members perform their information processing and information sharing activities. When team members can individually decide how they perform these activities and coordinate these activities with other team members, teams make optimal use of their cognitive capacities. In sum, it is expected that participative leadership is positively related to team information processing.

> *Hypothesis 1:* Virtual teams with leaders who use a participative leadership style will have higher levels of information processing than virtual teams with leaders who use a directive leadership style.

Team situation models

Mental models have been identified as the cognitive mechanisms through which individuals perceive, interpret, and explain the environment. Mental models are also used to make predictions about the future state of the environment (Rouse & Morris, 1986). Mental models can be shared across team members by sharing information and communication. These shared mental models in teams contain either information on the task (task mental models) or on the team (team mental models). The similarity of mental models across members of a team is an important determinant of team performance, and the accuracy of team mental models is also predictive of team performance (Lim & Klein, 2006).

The relation between leadership style and task and team mental models has been studied by Marks, Zaccaro, and Mathieu (2000), who focused on the relation between team leader communication, mental models, and team performance. When team leader communication contained more information on the link between environmental changes and team responses, team leader communication was positively related to mental model similarity, which in turn was related to increased team performance levels (Marks et al., 2000). Differences in communication between the team leader and team members are indicators of leadership style. Team mental models contain stable longer-term knowledge on the team and the task. The mental representations of changes in the environment develop *in situ*, and therefore differ from team mental models. The mental models that contain situational information are labelled team situation models (Cooke et al., 2001). Team situation models are particularly relevant for coordination processes as these models guide situation assessment, determining the strategy, assessing how the team is proceeding, predicting team members' actions, and selection of behaviours (Cooke et al., 2001). When it comes to understanding the relation between mental models and team coordination processes and team performance, it is argued in the team literature that researchers should focus on team situation models rather than on team- and task mental models (Cooke, Kiekel, Salas, Stout, Bowers, & Cannon-Bowers, 2003; Cooke, Salas, Cannon-Bowers, & Stout, 2000; Rico et al., 2008).

Directive leaders provide their team members with task-relevant directions and instructions, and closely control team decision making. Therefore, team leaders with a directive leadership style will be the only members of the team to interact with the environment (Ancona & Caldwell, 1992; Zaccaro et al., 2001). As information on environmental changes are only relevant for team leaders in this way, team members will only receive instructions on how to deal with the consequences of changes in the environment. In teams with leaders who use a participative leadership style, on the other hand, team members are expected to interact with the environment, contribute to the information processing and decision making processes (Kahai et al., 2004).

In sum, we expect that participative leadership is positively related to the similarity of team situation models because team members interact with the environment and share information with team members, whereas teams with directive leaders are only confronted with information that is relevant for their individual task:

> *Hypothesis 2:* Virtual teams with leaders who use a participative leadership style have more similarity in their team situation models than virtual teams with leaders who use a directive leadership style.

Self-synchronization.

Coordination refers to the integration of the actions of team members in order to achieve team goals. Participation of team members in coordination processes has been shown to positively affect the quality of tactics in teams that complete a complex task (Durham et al., 1997). There are two aspects of team coordination processes that influence team performance according to Hinsz et al. (1997, p.56): “(a) the identification and application of the important contributions (resources, skills, abilities, and knowledge) group members bring with them to group interaction and the task and (b) the processes involved in the way these various contributions are combined (aggregated, pooled, or transformed) to produce group-level outcomes”. Because the distribution of resources and knowledge was instructed in the complex planning task that was used in the present research, the focus is on the integration of team member actions at the team level.

The present research was aimed to gain more insight in implicit coordination processes in virtual teams. Specifically, the research was focused on self-synchronization, which may be described as team members’ expectations on the actions of other team members and future task states, and the adjustment of own behaviour in line with these expectations. Self-synchronization includes the following aspects: (a) integration of actions within the team; (b) dealing with unexpected events that are inherent to operating in dynamic environments, and (c) initiative taking by team members. These three aspects of self-synchronization are discussed below.

First, it was discussed in Chapter 1 that establishing implicit coordination is considered to be both more beneficial and more difficult in virtual teams. Implicit coordination between team members is especially valuable for virtual teams because explicit coordination via electronic media is more demanding than it is for collocated teams to interact face-to-face. Virtual teams therefore profit more from implicit coordination once it is established. Implicit coordination is, however, more difficult to establish for virtual teams because the ongoing and interpersonal interactions that are important to reach common ground are restricted by interacting via electronic communication media (Bell & Kozlowski, 2002; Driskell, Radtke, & Salas, 2003; Espinosa, Lerch, & Kraut, 2004; Rico et al., 2008). Anticipating the needs and actions of other team members and dynamic adjustment of behaviour in virtual teams is similar to implicit coordination in collocated teams as described by Rico et al. (2008). Typical implicit coordination behaviours (such as actively sharing task-relevant information and adapting behaviour to expected behaviour of other team members) are also important for virtual teams (Rico et al., 2008). As these processes are based on shared knowledge of the task, the team, and the environment, participation of team members helps team members to develop accurate predictions on the behaviour of other team members. This facilitates horizontal integration of actions of team members in virtual teams.

The second aspect of self-synchronization is the handling of unpredictable events. This aspect refers to the handling of unpredictable events that are relevant for the completion of the task or assignment by virtual teams. This adaptive behaviour of team members requires reconsideration of current beliefs or approaches (Burke et al., 2006; LePine, 2005). Team leaders of virtual teams will rely on the input of team members, because it will be difficult for team leaders to consider the implications of unpredictable events for team members that are geographically distributed. Therefore, participation of team members in decision-making and the implementation of decisions will help virtual teams to adapt to unpredictable events.

The final aspect of self-synchronization, initiative taking, directly reflects the ‘self’ of self-synchronization. The team’s capability to stimulate initiative taking and being able to implement decisions are considered to be important for self-synchronization. In sum, we expect a positive relation between participative leadership style and self-synchronization:

> *Hypothesis 3:* Virtual teams with leaders who use a participative leadership style are better able to synchronize their actions than virtual teams with leaders who use a directive leadership style.

Team performance

The input-process-output (I-P-O) framework (e.g., Hackman & Morris, 1975) is the dominant framework for assessing the effects of input variables on team processes and outcomes in team research (LePine, Piccolo, Jackson, Mathieu, & Saul, 2008). Input factors define the starting conditions of the team, processes are the dynamic interactions between members of a team, and output represents the results of the functioning of the team (Martins et al., 2004). The I-P-O framework has been criticized for not conveying the interplay between team processes (see Ilgen, Hollenbeck, Johnson, & Jundt, 2005), but the framework is well-suited for precisely studying the relations between input, process, and outcome variables of (virtual) teams in controlled research environments (Driskell et al., 2003; Martins, Gilson, & Maynard, 2004).

Central to our research model is the proposition that leadership style influences the performance of virtual teams on complex tasks. By affecting team information processing, team situation model similarity, and self-synchronization, leadership style stimulates teams to develop better decisions and actions.

> *Hypothesis 4a:* Virtual teams with leaders who use a participative leadership style perform better than virtual teams with leaders who use a directive leadership style.

Hypothesis 4b: Team performance in virtual teams is influenced by leadership style through its effects on the team coordination processes team information processing, team situation models, and self-synchronization.

Method

Participants and design

A total of one hundred and seventy-seven participants (74 men and 103 women; mean age 25.2 years; *SD* = 6.93) were assigned to three-person teams. Each participant was assigned to one of 59 teams, leaving us with 29 teams with directive leaders and 30 teams with participative leaders. Participants were recruited from the participant pool of the Netherlands Organization for Applied Scientific Research (TNO). Participants were either students or had completed higher education, and were less than forty years old to ensure adequate levels of experience with working on computers and using email. Participants received 40 Euros for taking part in a three-hour study on team performance. Additionally, 50 Euros were rewarded to members of the team that performed best on the task in either condition.

Task

The complex planning and problem-solving task for teams called PLATT (PLAnning Task for Teams) was chosen as the experimental task (see Kamphuis, Essens, Houttuin, & Gaillard, in press; Kamphuis & Houttuin, 2007). PLATT is designed for studying distributed team processes and performance in a dynamic complex task environment. It is a software platform that consists of generic software architecture and scenarios.

PLATT is a complex planning task for teams, in which three or more team members with interdependent roles have to share information, communicate, and coordinate their actions in order to construct a planning. Participants communicate with each other using email and share information with each other using a shared digital workspace. Participants complete the scenario using information from written task materials, email messages, and by retrieving information from a series of web sites that are accessible from the computers. The actions and messages of participants are recorded in log files, which are used for the creation of behavioural measures. The PLATT task enables researchers to study team processes in a controlled research environment because of the use of scenarios and individual working spaces, and by logging communication and behavioural data.

Dynamic complexity was created by entering extra information in the task during task execution. This means that teams are confronted with several new task developments, offering new opportunities or prohibiting particular solutions. The extra information is entered by sending programmed emails to the team members and altering the content of the web sites during the scenario. The role of extra information and the creation of a dynamic, complex task environment will be addressed in the study setup section.

For the current research, individual working places with networked computers and test materials were created side by side using room dividers, ensuring that there was only computer-mediated interaction between participants during the task. All working stations were directed towards a central display on which the digital shared workspace was projected. The shared workspace contained a map of the operational area and featured tools such as text fields, symbols, and a pen to enter information in the map.

Scenario

Teams completed a forty-five minute evacuation scenario in which a group of people had to be transported from a hostile city to a city that is safe. The scenario was oriented at the military domain as teams had to employ military units for transportation (transport unit), making dangerous roads safe (infantry unit), and repairing broken or otherwise obstructed roads (engineering unit). The time that was needed for the evacuation depended on the location and employment of the units, distances between cities, and the speed at which the units could travel. Speed depended on characteristics of the road (flat or mountainous). Teams were instructed to construct a planning for the evacuation using information from written task materials, which contained tables on distance and speed. The information from these tables had to be combined in order to determine how long it would take units to travel between cities. The team leader had to integrate the information into a planning, which had to be filled out on a standardized planning form.

During the scenario, teams were confronted with extra information on road conditions and deployment of units. This information was sent to members of the team by email or could be obtained from a series of web sites that were accessible from the computer. This extra information affected the planning activities of teams as it made some routes faster (“The hostilities on the road to city X have ended, which means that the road does no longer have to be secured by the infantry unit”) or slower (“There has been a landslide on the road to city Y. It will take the engineering unit eighty minutes to get the road reopened”). The scenario did not require specific knowledge of military operations.

Roles

A team consisted of a team leader and two team members. Task interdependence was created by designing different roles with varying tasks, responsibilities, information, and expertise. Team members interacted real-time during the session, which meant that team members had to maintain situational awareness, send relevant information to one another, and thereby depended on each other's actions and output. When team members must diagnose, solve problems, and/or collaborate simultaneously to accomplish the common goal, there is intensive interdependence between team members (Van de Ven et al., 1976). This intensive interdependence was constructed between all roles.

Analogous to military teams, three roles were distinguished in the scenario: operations, logistics, and intelligence. The role of the team leader (operations) was to process information given to him or her by the programmed emails and by the emails of team members, to monitor the activities of the team members, and to integrate the input of all three into a comprehensive situational picture in the digital shared workspace. For this reason, the shared workspace could only be accessed from the computer of the team leader. Team leaders further had to complete the standardized planning form at the end of the scenario, in which he or she had to write down which route was the fastest, where the units were located and how they had to be deployed in the evacuation. Teams further had to calculate the amount of time that was needed for the evacuation.

Team members were responsible for either logistics or intelligence. Logistics concerned transportation issues such as condition of the roads and availability of vehicles. Intelligence focused on obtaining information on the adversary, such as identification of threats, locating hostile acts and determining which roads are safe. Both team members had to process information from the emails, and retrieve information from the web sites that were accessible from their computers and from written task materials. Written task materials contained information on distances and road conditions for the logistics role and information on trustworthiness of information sources for the intelligence role. Team members had to provide the team leader with adequate information to work out the fastest route. It was emphasized in the task instruction that all information and expertise in the task was unique for each role, so that it was important to process and communicate all information.

Procedure

Participants arrived at the reception of the research facility in groups of three. The experiment leader made sure that the participants did not know each other prior to the session. The experiment leader welcomed participants and guided them to the experimental rooms of the facility. Roles were assigned randomly to participants. It was explained to the participants that the session consisted of two parts (task instruction and experimental session) and that there would be two experiment leaders, each monitoring one part of the experiment. The experiment was carried out by two experiment leaders, who switched roles daily.

Task instruction. A seventy-minute training module was developed for training the task and the roles. The training consisted of an instruction video (20 minutes), a power-point presentation (15 minutes), studying written task materials (20 minutes), and a practice session (15 minutes). Participants first watched the instruction video which described the nature of the task, the roles, and use of software applications for email, intranet, and the shared digital workspace. Next, the experimenter gave a presentation that focused on the uniqueness of the information for each role and the corresponding interdependence of the roles in the scenario. Third, the teams were instructed to study the written task materials and the role sheets. Finally, the participants completed a fifteen-minute practice scenario. Participants were encouraged to ask questions during the practice scenario. The experiment leader monitored the session actively, making sure that the team used all applications and filled out the standardized planning forms correctly.

Experimental session. After finishing the training module, the experiment leader walked the team to another room at the research facility where the team was handed over to the second experiment leader. The second experiment leader made sure that participants were seated on the working places that corresponded with the roles that were assigned to the participants. The experiment leader then left the room and started the scenario from the central research computer. All team members were asked to indicate three times during the scenario what route they thought was the fastest.

After forty-five minutes, the team leader had ten extra minutes to complete the standardized planning form. He or she had to describe the route using the names of the cities on the route, specify the starting positions of the units, describe how each of the units had to be employed, and how long it would take to evacuate the group. Team leaders had to complete the form with information from the emails and information that was present in the shared workspace at the end of the scenario. Team members meanwhile filled out the final questionnaire. Team leaders had to fill out the final questionnaire after they completed the planning form. When all participants had completed the final questionnaire, the experiment leader debriefed the participants about the leadership instruction of the team leader, and offered the possibility to withdraw their data. None of the participants withdrew their data. When data collection was completed, participants received a written debriefing at their home addresses in which the winning teams were announced.

Manipulation

Method. In the experiment two leadership styles were compared with contrasting effects on the team processes that were under study. In this experiment team leaders were instructed by studying role sheets (see Durham et al., 1997) to make the instructions on leadership style different from the videotaped instructions on the task and the roles. Team leaders were assigned randomly to the role of directive or participative team leader and received instructions on their role prior to the experiment.

Procedure. During task instruction, all participants had twenty minutes to study individually the role sheets and other task materials. At this point, the experiment leader escorted the team leader to another room. Team members were told that this was because the role of the team leader was 'best explained verbally, as it was somewhat more complicated'. The other two team members were instructed to study their roles and task materials until the team leader returned.

Team leaders were given a brief leadership instruction. It consisted of a verbal instruction by the experiment leader (three minutes), studying a set of role sheets (fifteen minutes), and the possibility to ask questions to the experiment leader (two minutes). Finally, team leaders had to fill out the manipulation check questionnaire. Team leaders were instructed not to discuss details on their role with team members, and they were informed that the instructions on their role would be addressed in the debriefing at the end of the session.

Design. The instruction focused on communication, coordination, and participation of team members in decision making. Directive team leaders were trained to keep the decision making process centralized, which meant instructing team members what route they should work on, closely monitoring their activities, and deciding which route is the fastest without consulting team members for their opinions. Participative team leaders were trained to decentralize decision making by emphasizing the importance of participation, and initiative taking, by letting team members decide for themselves how to complete their tasks, and consulting team members regularly for their opinion on the fastest route.

On the role sheets, the participants found either the label *team coordinator* (participative leadership) or *team commander* (directive leadership). This is consistent with the research by Durham et al. (1997), who successfully manipulated leadership style prior to the experimental task in a military simulation. These researchers used these labels for leadership styles that varied in team member participation. The same labels were used by Bliss & Fallon (2003) who manipulated autocratic and participative leadership styles by giving team leaders instructions like: "As commander, tell your group how to answer this" (instruction for directive leadership style). As we also used a task with a military orientation, we decided to use these labels team commander and team coordinator for the manipulation of leadership style.

Measures

Self-report data were used for the measurement of the effect of the manipulation, information processing and self-synchronization. Log file data were used for the measurement of team situation models and team performance.

Manipulation checks

Three manipulation checks were used to assess the functioning of the team leader. Two were administered to the team leader, and one manipulation check was filled out by the other team members.

*Team leader***.** Team leaders completed a six-item questionnaire directly after the leadership manipulation. The scale consistent of seven-point Likert-type items ranging from 1 ("*strongly disagree"*) to 7 ("s*trongly agree"*). Examples of items are: "*During the task, I am going to consult my team members before making a decision*" and "*I am going to tell my team members that I only want to receive information on the route that I specified*" (reversed item). The functioning of the team leader was also assessed in the final questionnaire after task completion. Team leaders responded to ten items on leadership such as: "*When making important decision, I consulted my team members*" and "*Team members only had little influence on the planning"* (reversed item).

Team members. Team members were also asked to evaluate their team leader in the final questionnaire. The scale consisted of five 7-point Likert-type items ranging from 1 ("*strongly disagree"*) to 7 ("s*trongly agree"*). Examples of items were: "*The team leader carried out my suggestions in practice*" and "*I noticed that I had little influence on the planning*" (reversed item).

Team information processing

Team information processing was assessed using three variables: information sharing, lack of overview, and tunnel vision. The three measures all assessed different aspects of team information processing. Information sharing was assessed to indicate how well team members communicated task-relevant information with each other. The degree to which team members experienced lack of overview indicated the inverse of the degree to which team members (excluding team leaders) were able to process the information that was present in the task. Tunnel vision, subsequently, indicated the inverse of the degree to which team members were able to utilize the information for considering different routes. Team members scored each item on a seven-point Likert-type scale ranging from ("*strongly disagree"*) to 7 ("s*trongly agree"*).

Information sharing. The questionnaire concerning information sharing consisted of a scale of eight items that was developed by Kamphuis, Gaillard, and Vogelaar (2009a).

The items were designed to assess the level to which team members shared information with other team members (e.g, "*I frequently provided my team members with information without being asked to*"; and "*I received information from other team members timely*"). However, the items on information sharing did not reach sufficient reliability levels, as Cronbach's alpha was .53 for eight items (N = 118). Based on reliability statistics, we removed two items that had low item-total correlations. Cronbach's alpha was .63 for the remaining six items. Individual responses can be aggregated to the team level when team members hold similar perceptions of the team processes that are assessed. The mean interrater agreement (r_{wg}; James, Demaree, & Wolf, 1984; 1993) was .85 for this scale, which indicates high within-team agreement. Responses were analyzed at the group level (N = 59) by averaging the responses of team members (team leaders not included).

Lack of overview. Team members indicated to what degree they were able to process all information that was present in the task and detect changes in the environment. The lack of overview scale of Kamphuis *et al.* (2009a, 2009b) was used to assess to what degree team members had experienced lack of overview during the task. Examples of items are: *"We made the planning using all information in the task"* (reversed item); and *"It was hard to keep track of all the information in the task"*. Higher scores on this scale indicated that participants experienced lack of overview during the task. The scale consisted of four items (Cronbach's alpha = .76). Responses of team members were analyzed at the group level (N = 59) by averaging the responses of team members (team leaders not included).. The r_{wg} was .69 for this scale.

Tunnel vision. We used items based on the scale of Kamphuis et al. (2009a; 2009b) on tunnel vision. Examples of items are: *"When working on a route, we did not consider alternatives anymore"*; and *"I searched for information that would undermine the choice for the route that we were working on"* (reversed item). Higher scores on this scale indicate that team members experienced tunnel vision. Cronbach's alpha was .71 for these four items. Responses were analyzed at the group level (N = 59) by averaging the responses of team members (team leaders not included). The r_{wg} was .75 for this scale.

Team situation models

During task execution, both the team leader and the team members were asked on three occasions which route they thought would be the fastest. Participants responded to this single-question electronic questionnaire by entering the route in a text field using the format: "Town A – Town B – Town X" and so on. Data from all team members were used for measuring team situation model similarity. Team situation model similarity was determined by scoring the correspondence between the responses at the team level for the route as a whole, ranging from 0 (no similar routes were entered), 1 (one similarity between team members was observed), and 2 (two similarities were observed; all three participants entered the same route).

Development of self-synchronization questionnaire

Self-synchronization was operationalized by a twenty-item questionnaire. We originally developed items on four dimensions of self-synchronization: horizontal integration (six items), vertical integration[1] (six items), event handling (five items), and initiative taking (three items). Examples of items are: *"Considering my tasks, I knew what my team members expected of me"* (horizontal integration); *"I knew what I had to do, even when I had no specific instructions of the team leader"* (vertical integration); "*I was able to determine what the consequences of new developments were*" (event handling); "*I felt uncomfortable when other team members came up with initiatives*" (initiative taking; reversed item). Since the present study was focused on the effects of leadership style on virtual teams, the items were completed by only the team members (N = 118; team leaders not included). Team members scored each item on a seven-point Likert-type scale ranging from 1 ("*strongly disagree"*) to 7 ("s*trongly agree"*). Two reversed items in the scale were deleted based on reliability statistics.

A principal component analysis (PCA) was performed on the eighteen remaining items, which showed that there were only three factors with an eigenvalue higher than 1. Component 1 ($\text{eigenvalue}_{1\,=}$ 6.799) explained 37.8% of the variance. The other components had eigenvalues of 2.182 (explained variance is 12.1%) and 1.316 (explained variance is 7.2%) respectively. Studying the component matrix, it was concluded that the items on horizontal and vertical integration loaded substantially on component 1. This result was consistent with the high correlation that was obtained between these two dimensions (r .= .68), and led to the conclusion that the dimensions could not be distinguished from each other well in the current data. Further, three items of this scale loaded on another factor than the rest of the items of that subscale. These three items were omitted from the data.

Based on these outcomes, we ran another PCA on the grouped items of vertical and horizontal integration (new label ‘integration; nine items), event handling (four items), and initiative taking (two items). Again, we obtained three components with an eigenvalue of more than one (eigenvalue_1 = 5.588, explained variance 37.3%; eigenvalue_2 = 2.137, explained variance 14.3%; eigenvalue_3 = 1.143, explained variance 7.6%).

In sum, the final questionnaire on self-synchronization consisted of the subscales integration (nine items, Cronbach's alpha .87), event handling (five items, Cronbach's alpha .80), and initiative taking (two items, Cronbach's alpha .56). Correlations between

[1] Vertical coordination refers to the alignment of decisions and actions on the vertical dimension of organizations, which differentiates people in terms of authority of power (Katz & Kahn, 1978; p. 76). Differences in power are also present in teams, as team leaders are responsible for team performance and team development (see Kozlowski et al., 1996). This is known as vertical leadership (Ensley, Hmieleski, & Pearce, 2006; Pearce, 2004).

dimensions ranged from .47 to .31. Mean within-group agreement index scores demonstrated sufficient levels of agreement for integration (r_{wg} = .80), event handling (r_{wg} = .72), and initiative taking (r_{wg} = .71), so responses of team members (team leaders not included) were aggregated to the team level.

Team performance

The team leader had to complete the standardized planning form individually, based on the information that he or she received from the other team members. The measures that were derived from the planning form therefore represented the whole team in the analysis. Team performance was determined by the rank score of routes and by scoring the faults in the planning form. As there were eighteen possible routes, rank scores of the routes ranged from 1 (best route) to 18 (worst route). Lower scores on this scale reflected better team performance.

The second measure for team performance was the quality of the planning. The planning form was scored on: (a) faults in the deployment of units regarding the evacuation (scoring range 0-2); (b) other faults regarding units, such as starting locations (scoring range 0-2); (c) faults in transportation of the group (scoring range 0-1); and (d) faults in calculations (scoring range 0-3). Therefore, scores could range between zero and eight. The scores were discrete and depended on the impact of a fault on the planning. Minor fault scores (score = .33) were given to miscalculations or faults that had marginal impact on the planning. Medium fault scores (score is .50 or .66, depending on variable) were given to faults that had moderate impact on the planning, such as mistakes in the starting locations of units and miscalculations that affected the planning. Major faults (score = 1.00) were given for severe miscalculations, major faults in the employment of units, or missing relevant information. The faults were summed into one variable, where a lower fault score represents better team performance levels.

Results

Manipulation checks

Team leader. The effects of the leadership manipulation were checked directly after the leadership instruction of the team leader. The effects were analyzed by a *t*-test with leadership style as between-subjects variable (Table 3.1). Results showed that participative leaders were planning to involve their team members more in decision making than directive leaders ($t(57) = 14.82$, $p < .01$, $d = 3.82$). The functioning of the team leaders was also assessed in the final questionnaire after task completion. Results indicated that participative team leaders stimulated team members to participate more than directive leaders ($t(57) = 9.11$, $p < .01$, $d = 2.36$).

Team members. Team members were also asked to evaluate their team leader in the final questionnaire. Consistent with the results of the team leader manipulation checks, results indicated that participative leaders indeed involved team members in decision making ($t(116) = 4.50$, $p < .01$, $d = .83$). It was concluded that the leadership manipulation had the desired effect.

Table 3.1: Mean scores, standard deviations, and t-test results of the manipulation checks at the team level of analysis ($N = 59$)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Team leader/instruction							
Directive	29	2.32	.72	14.82	57	<.01**	3.82
Participative	30	4.64	.47				
Team leader after task completion							
Directive	29	3.39	.96	9.11	57	<.01**	2.36
Participative	30	5.47	.79				
Team members after task completion							
Directive	29	4.87	.71	4.50	116	<.01**	.83
Participative	30	5.51	.83				

Note: p-values are one-sided
** p < .05

Team information processing

A one-way multivariate test of variance (MANOVA) was performed to determine the effects of leadership style on the set of measures indicating team information processing. The analysis was carried out with leadership style as independent variable and three scales on information sharing, lack of overview, and tunnel vision as dependent variables. A main effect of leadership style was obtained (Hotelling's $T^2 = .24$, Wilk's lambda = .81; $F(1,55) = 4.38$, $p < .01$, $\eta_p^2 = .19$), indicating that leadership did affect team information processing. Three follow-up t-tests were used to determine what aspects of team information processing were affected by leadership style (see Table 3.2).

Information sharing. It was expected that information sharing in participative teams would be higher than in directive teams. Participative teams reported higher levels of information sharing than directive teams, which supported expectations ($t(57) = 1.79$, $p = .04$, $d = .47$).

Lack of overview. Team members were asked to what degree they were able to process all information and detect changes in the operational environment. The items were directed at experiencing lack of overview, so higher scores indicated higher levels of lack of overview. The results of a t-test indicated that participative teams and directive teams did not differ for lack of overview ($t(57) = .93$, $p = .18$, $d = .23$), providing no support for expectations.

Tunnel vision. It was assumed that participative teams would consider more alternatives than directive teams, as team members are supported to take initiatives and find out for themselves what seems to be the best solution to the task. Items were directed at experiencing tunnel vision, so lower scores indicate lower levels of tunnel vision. A t-test showed that participative teams experienced less tunnel vision than directive teams ($t(57) = -2.17$, $p = .02$, $d = .56$), which is consistent with expectations.

In sum, the main effect showed that leadership style did affect team information processes, providing support for hypothesis 1. The results of information sharing and tunnel vision supported expectations, but the results of lack of overview did not.

Table 3.2: Mean scores, standard deviations, and t-test results for team information processing at the team level of analysis ($N = 59$)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Information sharing							
Directive	29	5.50	.55	1.79	57	.04**	.47
Participative	30	5.74	.47				
Lack of overview							
Directive	29	2.99	.77	.93	57	.18	.23
Participative	30	3.19	.93				
Tunnel vision							
Directive	29	2.79	.93	-2.17	57	.02**	.56
Participative	30	2.29	.84				

Note: p-values are one-sided
** $p < .05$

Team situation models

Team situation models were assessed three times during the scenario (Table 3.3). Hypothesis 2 predicted that participative leadership style had a positive effect on team situation model similarity, as team members were expected to coordinate better when teams had participative leaders. A one-way multivariate analysis of variance (MANOVA) was performed to test hypothesis 2. No significant effect of leadership style was found on the three assessments of team situation model similarity (Hotelling's T^2 = .08; Wilk's lambda .93; F(2, 56) = 2.17, p = .12, η_p^2 = .07), which provided no support for hypothesis 2.

As can be seen in Table 3.3, team situation model similarity was relatively high for the first assessment, but seemed to decrease rapidly after the first assessment. A repeated-measures ANOVA was performed to test team situation model similarity throughout task execution. The results show that team situation model similarity decreased significantly during the experiment (Hotelling's T^2 = .99; Wilk's lambda .50; F(2, 56) = 27.82 p < .01, η_p^2 = .50). These results indicate that teams experienced difficulties to maintain team situation model similarity during task execution. This accounts even more for the participative leadership condition.

Table 3.3: Descriptive values for team situation model similarity at the team level of analysis (N = 59)

	Directive Leadership (*n = 29)*		Participative leadership (*n = 30)*		Overall *(n = 59)*	
	M	*SD*	*M*	*SD*	*M*	*SD*
Assessment 1	1.61	.57	1.71	.64	1.66	.61
Assessment 2	.96	.79	1.13	.67	1.05	.73
Assessment 3	1.11	.83	.77	.76	.94	.80
Overall	1.23	.73	1.20	.69		

Self-synchronization

The effect of leadership on self-synchronization was tested using a multivariate test of variance (MANOVA) procedure with leadership style as independent variable and the three subscales of self-synchronization (integration, event handling, and initiative taking) as dependent variables. A main multivariate effect of leadership style on self-synchronization was obtained, indicating that leadership style did affect self-synchronization (Hotelling's T^2 = .19; Wilk's lambda .84, F(1,55) = 3.59, p < .02, η_p^2 = .16). Three follow-up t-tests showed the results for the three different aspects of self-synchronization (Table 3.4).

The hypothesized difference for integration in distributed teams was obtained as participative teams reported higher scores for their coordination activities than directive teams (t(57) = 1.79, p = .04, d = .47). Leadership style was expected to affect event handling in distributed teams. It was proposed that participation in decision making would have a positive effect on event handling. This effect was not found, as there was no difference (t(57) = -1.24, p = .11, d = .23) between teams with participative leaders and teams with directive leaders. It was further expected that team members with participative team leaders would take more initiative in decision making than members of teams with directive leaders. Results of the t-test did confirm our expectations as participative teams showed higher levels of initiative than directive teams ($t(57) = 1.71$, $p = .04$, $d = .43$). The results provided support for hypothesis 3, as there was a main effect and the expected effects of leadership on coordination and initiative taking were obtained. No differences were found for event handling.

Table 3.4: Mean scores, standard deviations, and t-test results for self-synchronization at the team level of analysis ($N = 59$)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Integration							
Directive	29	5.90	.58	1.79	57	.04**	.47
Participation	30	6.14	.44				
Event handling							
Directive	29	4.70	.74	-1.24	57	.11	.23
Participative	30	4.44	.85				
Initiative taking							
Directive	29	4.60	.66	1.71	57	.04**	.43
Participative	30	5.02	1.13				

Note: p-values are one-sided
** $p < .05$

Team performance

Two aspects of the planning that determine team performance were measured: the quality of the planning and rank score of the route. It was hypothesized that participative leadership positively influences team performance. Leadership was expected to influence team performance through its effects on the three aspects of team information processing (information sharing, lack of overview, and tunnel vision), team situation model similarity, and the three aspects of self-synchronization (integration, event handling, and initiative taking). The hypotheses were tested separately for quality of the planning and rank score of the route, as the scores of the latter measure are ordinal.

Quality of the planning. Virtual teams with directive leaders did not differ from virtual teams with participative leaders when it comes to the quality of the planning. The groups did not differ in the number of faults in the planning ($t(57) = 1.14$, $p = .26$, $d = .74$), providing no support for hypothesis 4a. Descriptive values and correlations between team process variables and quality of the planning (sum of fault scores) are presented in Table

3.5. Lower fault scores indicate better team performance levels. Information sharing and team situation models (measured at the end of the scenario) were the only variables that were related significantly to team performance, so mediation analyses could only be performed for these variables.

To examine the mediating role of information sharing and team mental model similarity, three steps have to be performed following the approach of Baron and Kenny (1986). First, there have to be relationships between antecedent and consequence, that is, between leadership style and team performance in the current research. Second, the relationships between antecedent and mediator, and the relationship between mediator and consequence have to be demonstrated. Third, mediation is observed when the strength of the relationship between antecedent and consequence decreases when the mediator is entered into the model. Mediation can be determined here using hierarchical regression analysis.

The relationship between leadership style and quality of the planning was not observed (β = -.15, p = *ns*), which makes mediation by information sharing and team interaction model similarity impossible.

In sum, leadership style did not affect team quality of the planning, providing no support for hypothesis 4a. Virtual teams with participative leaders did not differ in their quality of the planning from directive leaders. The effects of leadership on team performance through its effects on coordination processes (hypotheses 4b) mirror the results of hypothesis 4a. No support was obtained for the mediating effects of any of the team processes.

Rank score of the route. The second measure for team performance was rank score of the route (see table 3.5 for descriptive values and Spearman's rank correlations). No direct effect of leadership on rank score of the route was found. Teams with directive leaders (*Mean rank* = 29.95, *sum of square ranks* = 928.50) did not differ from teams with participative leaders (*Mean rank* = 30.05, *sum of square ranks* = 841.50; U = 423.50, $p <$ .98, *ns*), providing no support for hypothesis 4b.

Similar to quality of the route, information sharing and team situation model similarity at the third assessment were the only variables that were statistically related to the rank score of the route, so only these team processes could mediate the relationship between leadership style and team performance. Again, no support was obtained for any of the dimensions of self-synchronization. Ordinal data cannot be used in hierarchical regression analysis because the assumption of normal distribution is violated. Mediation could therefore not be computed using hierarchical regression analysis.

In sum, leadership did not influence team performance in the present study. Mirroring these results, no mediation was found for any of the team processes. No support was obtained for hypotheses 4a and 4b.

Table 3.5: Correlations between dependent variables at the team level of analysis (*N* = 59)

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11
Team information processing													
1. Information sharing	5.63	.52	-	-.36**	-.12	.11	.09	-.05	.54**	.31*	.40**	-.38**	-.29*
2. Lack of overview	3.10	.85		-	-.25	-.04	-.07	.07	-.54**	-.56**	-.45**	.04	.01
3. Tunnel vision	2.54	.83			-	.05	.18	.02	-.23	-.05	-.04	.09	.13
Team situation models													
4. Assessment 1	1.66	.60				-	.24	.24	-.05	-.08	.07	-.04	-.08
5. Assessment 2	1.05	.73					-	.07	.01	.02	.19	-.12	-.11
6. Assessment 3	.93	.80						-	-.15*	-.09	.08	-.29*	-.28*
Self-synchonization													
7. Integration	6.03	.52							-	.31*	.47**	-.16	-.14
8. Event handling	4.56	.80								-	.44**	-.06	.01
9. Intiative taking	4.82	.95									-	-.01	-.06
Team performance													
10. Quality of the planning	2.09	1.07										-	.11
11. Rank score route	2.00 (*Mdn*)	.00 – 4.50 (*range*)											-

Note: Column 11 contains Spearman's rank correlations

* $p < .05$ ** $p < .01$

Discussion

The present research was focused on coordination in virtual teams and did not feature face-to-face teams as control groups. As a consequence, conclusions and implications are formulated for teams that rely on teams that exclusively use electronic communication media for communication and information sharing between members of the team.

Effects of leadership style on team processes

Team information processing. The predicted effects of participative leadership on team information processing were obtained for information sharing and tunnel vision, but no effect was found for lack of overview. The findings indicate that virtual teams with participative leaders are better at sharing task-relevant information, but that leadership style does not necessarily help teams to develop a better view on the operational situation. These results are commensurate with the findings of Kahai et al. (2004), who conducted a similar experiment. These authors found that when virtual teams have to perform a creativity task, participative leadership does lead to more participation of team members in terms of idea generation, but that participative leadership was negatively related to team member satisfaction. This finding was attributed to the difficulties that teams experienced when they had to reduce the set of alternatives during the task using electronic communication media. The findings of the current research and Kahai et al. (2004) suggest that participation of team members helps virtual team members to execute their tasks at the individual level (differential effects of participation on sharing information with other team members, number of alternatives on creativity task), but that participation does not help in converging individual actions at the team level (no effect of participative leadership on experiencing a better overview). These outcomes suggest that virtual teams have difficulty to profit from the initial benefits of team member participation. The outcomes of the current study underline the importance of participative leadership in virtual teams, and at the same time stress the challenges that virtual team leaders face for integrating the actions of team members at the team level.

Team situation models. Similarity of team situation models did not differ between groups, so the results of the study provided no support for the expected effects of leadership style on team members' perceptions of the operational situation in virtual teams. This finding suggests that leadership style has limited effect on how individual team members of virtual teams perceive the operational situation.

The reason why team coordination processes are not affected by leadership style may be that team members of virtual teams have difficulty to establish and maintain similar team situation models. Virtual teams often perform cognitive tasks such as planning tasks or decision-making tasks in which team members have different expertise that has to be integrated. Team members of virtual teams thus perform individual subtasks, and integrate the outcomes with those of other team members. When team members are focused on performing their individual tasks, team members may focus less on the development of team situation models. Repeated-measures analysis revealed that when new information was added during task performance, this negatively affected team situation model similarity. Similarity decreased during task execution on both groups, indicating that virtual teams performing complex, interdependent tasks developed increasingly limited shared perceptions of the situation. A trend was observed that virtual teams with directive leaders seemed to have higher levels of team mental model similarity at the end of the task in the present study. This was not expected, but the trend might have resulted from the higher level of guidance of directive leaders. When team leaders instruct team members to work out a specific route, this may in fact help team members to develop similar perceptions of the operational situation. In sum, it may be concluded that virtual teams find it hard to develop and maintain similar team situation models, and that leadership style of team leaders did not influence team situation model similarity in the present research.

Self-synchronization. It was predicted that virtual teams with participative leaders are better able to synchronize their actions than virtual teams with directive leaders. The effects of team member participation were expected on all aspects of self-synchronization. The results supported our expectations largely, as there was a main effect of leadership style on integration and initiative taking. However, the groups did not differ in the way they handled events. It is therefore concluded that team member participation does stimulate team members of virtual teams to synchronize their own decisions and actions with other members of the team without being asked to, but that this does not affect how well teams deal with unexpected events.

Team performance. Team performance was measured in terms of quality of the planning and rank score of the route. The expected effects of leadership on team performance were based on previous research in which leadership positively predicted outcomes in collocated teams (see Salas, Sims, & Burke's (2005) teamwork taxonomy) and in virtual teams (Kahai et al., 2003; 2004). First, leadership was expected to positively affect team performance. However, no differences were obtained for the two performance measures. Second, the relations between team processes and team performance were also not significant, except for information sharing and team situation models at the third assessment. Interestingly, the effect of information sharing on team performance resulted from better information sharing in teams with participative leaders, whereas the effect of team situation models on team performance may be attributed to the effects of directive leadership, since teams with directive leaders had higher scores for team situation model similarity at the third assessment.

It is concluded that both directive and participative leadership styles affect different aspects of team coordination in virtual teams. First, participative leadership enhances team information processing in virtual teams, but this does not automatically lead to increased convergence of team members' interpretations of the operational environment. Second, team situation model similarity seemed to be stimulated by directive leadership of teams, and furthermore was positively related to team performance. Consistent with the conclusions of Kahai et al. (2004) on leadership style in virtual teams, the findings of the present study indicate that participative and directive leadership styles affect different team processes of teams that perform complex, interdependent tasks. Therefore, the effects of leadership style on team coordination will depend on team-related factors such as team size and team tenure, and task factors such as type of task and complexity.

Another possible explanation for the obtained results may be that the present study was exclusively focused on team coordination processes. According to Zaccaro et al. (2001), team leadership is considered to influence team performance through four sets of processes: cognitive, motivational, affective, and coordination. While the present study was focused on coordination processes in virtual teams, the other sets of team processes potentially influenced the way in which teams performed the task. Teams possibly differed in the level to which team members experienced team cohesion or collective efficacy, and some team members may have experienced conflicts. Although the relation between team processes and team performance in general is well-established (see Hinsz et al., 1997; Mathieu et al., 2000), the link is not always obtained from the data that are collected in controlled research settings (e.g. Cooke et al., 2003; Hambley, O'Neill, & Kline, 2007).

Theoretical and practical implications

As was pointed out by Zaccaro et al. (2004), research on virtual team leadership is still in its infancy compared to leadership in collocated teams. Empirical studies of virtual team leadership were primarily focused on the effects of leadership on team cohesion, social loafing, and satisfaction (see Potter & Balthazard , 2002; Hambley et al., 2007; Kahai et al., 2003; 2004). As these processes are team motivational and affective processes, this means that the effects of virtual team leadership on team cognitive and coordination processes are largely unknown. The major contribution of this study then is its examination of its effects of leadership style on team cognitive processes (team information processing and team situation models) and team coordination processes (self-synchronization).

While one should be cautious in formulating practical implications based on research on teams that performed their task in a laboratory setting, the positive effects of adopting participative leadership styles do indicate that participation of team members can indeed be beneficial to virtual teams. The results of the current research are in line with Bell and Kozlowski (2002), who state that virtual teams face additional challenges in early stages of team development. The findings of the current research indicate that increased levels of information sharing were not accompanied by a better overview, and that increased levels of self-synchronization could not be related to team performance.

Limitations

The current study was performed in a controlled research environment, in which teams consisted of individuals who did not know each other before the experiment and had no intentions for future collaboration. While this is definitely a limitation for generalizing the findings to existing teams, many virtual teams in organizations are also ad hoc teams characterized by short lifecycles. Hambley et al. (2007) pointed out that the findings of laboratory studies on virtual teams therefore may be generalizable to existing virtual teams that are formed to complete a single task and are abandoned afterwards.

The manipulation of leadership also poses constraints for generalizing the findings to settings outside the laboratory. Although the manipulation check demonstrates that team leaders executed their leadership functions as was instructed, the way in which team leaders were instructed to lead the team potentially differed from the personal leadership style of that participant. As was pointed out by Hambley et al. (2007), team members therefore may have experienced leadership that was not as realistic or convincing as in real-life teams. Moreover, most team leaders have a leadership style that is intermediate between a directive and a participative leadership style. The effects of these intermediate leadership styles have not been considered in this study. In sum, it was concluded that the manipulation check demonstrated that team members experienced the leadership styles as intended, but that studying effects of leadership in teams in controlled research environments inherently means that there will be differences between team leadership in laboratory settings and ad hoc teams that are formed in the real world.

Future research.

The results of the present research indicate that leadership style does not affect all team coordination processes that take place in virtual teams. Since the present research was focused on virtual teams and did not consider teams with lower levels of virtuality, it remains unknown to what extent media characteristics influence the relation between leadership style and, for instance, the development of team situation model similarity. More specifically, future research should address how communication media can help virtual team leaders with this, as there is a wide range of electronic media that are available to team leaders for communicating with virtual team members. Studying the combined effects of leadership and communication media was done in research by Kahai et al. (2003, 2004) and Hambley et al. (2007), but these studies did not consider participation as an input variable and focused primarily on team motivation processes.

Second, developing more insight in the role of team member participation in virtual team cognitive processes and self-synchronization is needed for optimizing team processes. The need for better understanding of team interaction processes is particularly relevant for teams that operate in uncertain and demanding situations (see Stachowski, Kaplan, & Waller, 2009). As both team adaptation and organizing in virtual teams are unmistakably key characteristics of effective teams *and* both build on increased team member participation, empirical research in this area is needed to develop these teams.

Conclusion

The limited understanding of leadership in virtual teams (see Bell & Kozlowski, 2002; Hambley et al., 2007; Zaccaro, et al., 2004) was the driver for the current research. The present research contributes to team research by providing more insight in the relation between leadership and coordination processes in virtual teams that are confronted with complexity of their task and their environment.

This study suggests that leadership styles affect information processing and self-synchronization processes in virtual teams that perform complex tasks. Compared to directive leadership, participative leadership facilitates better information sharing and helps teams to avoid information overload. Moreover, when team members participate in team decision making, they are better able to synchronize their decisions and actions with those of the other members. The present results suggest that participative leadership improves the quality of team members' actions to the task, but that virtual team leaders face major challenges to integrate these actions. The initial benefits of team member participation will diminish when leaders of virtual teams are not able to meet these challenges.

Chapter 4

Effects of media synchronicity and distribution of information on coordination in virtual teams

Introduction

Many teams use electronic communication media in order to share information, communicate, and coordinate activities of team members. This holds for teams that are geographically dispersed, such as software design teams that are distributed across the globe and work around the clock, but collocated teams also use electronic communication media for sharing documents or data. Joint air defence teams, for example, sit side-by-side and exclusively rely on electronic communication media for sharing information on aircraft and coordinating courses of action. These teams are virtual teams because team member interactions run via electronic communication media.

An important characteristic of electronic communication media is the extent to which media enable synchronous interactions between members of the team. Media synchronicity refers to the extent to which media facilitate team members interactions without time lags (Dennis, Fuller, & Valacich, 2008; Montoya-Weiss, Massey, & Song, 2001). For example, when a team member posts a message on a message board, he or she does not know when other team members will respond, whereas team members who use chat expect other team members to respond immediately. Synchronous interactions are particularly important for teams that perform complex interdependent tasks in complex and dynamic environments. Team members have different responsibilities and capabilities that have to be integrated quickly in order to accomplish tasks effectively in these situations. In joint air defence, for example, unidentified aircraft requires rapid and efficient interactions between team members, because the team has to detect, interpret, decide, and act within minutes. In these situations, team leaders make decisions based on information that comes from other team members, namely a team member that retrieves information from the radar and a team member that interacts with fighter pilots that are on patrol in the air. Synchronous communication is crucial in these situations for integrating contributions into coherent team actions timely (see Bell & Kozlowski, 2002; Dennis et al., 2008; Kirkman & Mathieu, 2005).

Another important characteristic of electronic communication media is the ease with which information can be distributed to other team members (distribution of information). Electronic communication media are excellent for distributing documents, information, or data. This means that all members of the team have the same information when working on a joint task. The possibilities that electronic communication media offer for distributing information across all members of the team will affect the use of information when performing complex interdependent tasks. One the most important issues in this respect is the selective use of information by teams that perform complex tasks (Stasser & Titus, 1987; but see Wittenbaum, Hollingshead, & Botero, 2004). Selective use of information occurs when teams do not use all information that is relevant to the task. One of the most important factors that affect selective use of information in teams is distribution of information, since teams tend to be focused more on information that can be accessed by all team members than on information that is held by only one member of the team (Curşeu, Schalk, & Wessel, 2008; Wittenbaum et al., 2004). Distribution of information refers to the extent to which all team members have access to a piece of information. Hinsz and colleagues (1997, p. 54) referred to distribution of information as the 'commonality-uniqueness' dimension. This dimension differentiates teams where all team members hold unshared or *unique* information from teams where more than one team member (or all team members) have access to a piece of information (*shared* information; e.g. Winquist & Larson, 1998; Stasser & Titus, 1987; Van Ginkel & Van Knippenberg, 2009). Distribution of information affects team processes because teams are more likely to use shared information during task performance than unique information. First, team members are more reluctant to share information that is unknown to other team members than to share information that other team members also have. Second, information that has been shared by team members is more likely to be used in decision-making because team members have seen the information before and therefore information has become salient (Stasser & Titus, 1987; but see Wittenbaum et al., 2004). Therefore, shared information is more likely to be discussed in team member interactions than unique information, and teams that have higher levels of unique information may not use all information that is relevant to the task. The capacity of electronic communication media to share information with other team members thus will help teams to use all relevant information when performing complex interdependent tasks.

The purpose of the present research is to investigate in what ways media synchronicity and distribution of information affect team coordination processes in virtual teams that perform complex interdependent tasks. The link between media synchronicity and team coordination processes is made in two media theories that are discussed below. These theories are used for the formulation of hypotheses on synchronicity. Hypotheses on distribution of information are formulated subsequently.

Matching teams and electronic communication media

A variety of electronic communication media are available to virtual teams, including videoconferencing, chat sessions, or shared digital workspaces. The main criterion for using a particular type of media is that it is capable of transferring team members' contributions in terms of text, voice, data, or any other type of information that is valuable for completing the task that the team is working on. The link between communication media and tasks is described in the Media Richness Theory (MRT; Daft & Lengel, 1984; 1986). MRT has been widely applied to describe the differences between communication media with respect to the richness of information that can be transmitted via that medium. MRT is rooted in social presence theory (Short, Williams & Christie, 1976), which states that communication media differ in the extent to which a medium allows for psychologically close, interpersonal communication. Social presence theory describes communication as a multifaceted process that includes both verbal and nonverbal components. Media that are high in social presence facilitate 'rich' communication, in which individuals experience less ambiguity about the other person than media that are low in social presence. Richness of information refers to "the ability of information to change understanding within a time interval" (Daft & Lengel, 1986, p. 560). The capacity of media to transmit rich information is determined by four criteria: (a) the ability for immediate feedback; (b) the number of cues and channels that can be used; (c) the ability to convey natural language; and (d) the personal focus of the medium (Daft & Lengel, 1986).

The underlying logic of MRT is that communication in organizations is intended to reduce equivocality (Daft & Lengel, 1986). Equivocality is described as "*the existence of multiple and conflicting interpretations about an organizational situation*" (Daft & Lengel, 1986, p. 556; Weick, 1979). In other words, equivocality is the problem of dealing with multiple and contradictory meanings (Daft & Weick, 1984; but see Kramer, 2007). At the team level, this means that there is no shared framework that can be used for the interpretation of information. Reducing equivocality in teams therefore requires negotiation and ultimately reaching consensus on one interpretation (Dennis & Valacich, 1999). MRT thus proposes that richer media (e.g., face-to-face, videoconferencing) are better suited than lean media (e.g., email, text messages) for dealing with equivocality.

So how can media characteristics help teams to deal with equivocality? The central assertion of MRT is that for routine tasks, media of lower richness are sufficient to transmit task-relevant information between team members. When tasks get more complex and when team members are interdependent, though, teams are faced with equivocality and therefore need to transmit rich information. This means that face-to-face communication is considered to be superior to mediate communication on complex tasks, as face-to-face communication is the richest way of communicating.

Although MRT has been widely used for selection and use of communication media, researchers have identified two major shortcomings of MRT: the hierarchical ranking of media and difficulties to consider the qualities of electronic communication media. These arguments are discussed below.

The major criticism against MRT is that the characteristics of media are considered to be absolute, so that some types of media are inherently better than other types. Theorists have criticized that this ranking of communication media is invalid, as the capabilities of communication media are not invariant to the way in which media are used (see Walther, 1992). Teams, for instance, adapt to the technology that they use over time. Adaptive structuration theory (AST) considers mutual influence of technology and social processes (DeSanctis & Poole 1994), and states that group interaction processes are important determinants for group outcomes and for mediating the effects of technology. The structure of the relations between members of a group and the task at hand is not permanent according to AST, but rather evolves over time into a stable set of interaction patterns. AST thus proposes that the way in which a technology is used by a group is determined by the interaction between team factors and technological characteristics. In other words, teams learn how to use a particular medium over time and overcome technological limitations (Dennis et al., 2008; DeSanctis & Poole 1994; Olson & Olson, 2000; Van der Kleij, Paashuis, Langeveld, & Schraagen, 2004; Van der Kleij, Paashuis, & Schraagen, 2005; Van der Kleij, Schraagen, Werkhoven, & De Dreu, 2009). Moreover, teams have been shown to adapt their structure in order to exploit the benefits that a medium offers (Majchrzak, Rice, Malhotra, & King, 2000). These findings indicate that the relation between a task and the communication media is not as rigid as proposed in MRT.

In line with this argument, it is argued by other researchers that MRT does not capture the unique characteristics of virtual media adequately. Dennis and colleagues (Dennis et al., 2008; Dennis & Valacich, 1999) proposed that the characteristics of new media are not solid, as new media are interconnected and therefore the capabilities of media are flexible. For instance, mobile devices facilitate email and give access to the internet, where all kinds of tools and services are available for working together. Therefore, Dennis and colleagues focus on capabilities of media to transfer and process information rather than considering characteristics of specific media. These media capabilities are described below.

Dennis and colleagues emphasized that the effectiveness of using a particular medium is not only determined by fit between communication media and the task, but the level to which communication media are commensurate with the communication processes of teams. Dennis and colleagues proposed that, rather than considering task type, team tasks should be described in terms of the communication processes that are required to accomplish a task (Dennis et al., 2008; Dennis & Valacich, 1999). These authors distinguished between two types of communication processes: conveyance and convergence. Conveyance describes the processing and transmission of information by single team members, and convergence describes the discussion of processed information at the team level. Regarding conveyance, team members process information in order to create meaning. Team members analyze information, interpret information, and integrate information into their mental models. Subsequently, information is shared with other team members. Regarding convergence, team members discuss processed information in order to reach a common understanding on the meaning of information at the team level. As complex interdependent tasks require individual information processing and information sharing, as well as establishing coordinated action, this means that complex interdependent team tasks involve both types of communication processes. So rather than relating media capabilities to task characteristics in MRT, the Media Synchronicity Theory (MST; Dennis et al., 2008; Dennis & Valacich, 1999) is based on the assertion that the effectiveness of media results from the extent to which media are commensurate with communication processes that go on in teams.

Five characteristics are proposed in MST that determine the capacity of media to facilitate conveyance and convergence: transmission velocity; parallelism; symbol variety; rehearsability; and reprocessability. First, transmission velocity is defined as the speed at which a medium delivers messages to recipients. High transmission velocity means that messages are delivered without time lags, facilitating rapid feedback and conversations. Second, parallelism refers to the number of simultaneous transmissions that a medium can support. Parallelism describes the extent to which multiple users can use the medium at the same time. Third, symbol variety refers to the number of ways in which a medium facilitates the encoding of information. Analogous to Daft and Lengel's (1986) multiplicity of cues, symbol variety is focused on the use of (multiple) symbol sets that can be transmitted. Fourth, rehearsability refers to whether a medium allows users to rehearse or fine-tune messages before sending. Fifth, reprocessability is the extent to which contributions can be changed or updated in the light of new events (Dennis et al., 2008).

The present research is focused on virtual teams that perform complex interdependent tasks. In these tasks, teams are confronted with information of which the meaning is not immediately clear. MST proposes that synchronous interactions are important in these situations, because team members have to interact in order to establish meaning. Team member interactions in these situations take the form of discussions or feedback, and therefore require media that are high in synchronicity. For this reason, media synchronicity is important for virtual teams that operate in dynamic complex environments. The relation between team coordination processes and media synchronicity is discussed below.

Media synchronicity

It was argued above that overcoming equivocality in a short period of time is a main challenge for teams that perform complex, interdependent tasks. In these situations, it is not feasible to use asynchronous communication media because "(…) *the assumption that all potential receivers have in fact read and understood a given message within a short span of time is not likely to be warranted*" (McGrath & Hollingshead, 1994; p.21). The importance of synchronous interactions between team members has been emphasized most profoundly in MST (Dennis et al., 2008; Dennis & Valacich, 1999).

As was discussed above, MST distinguishes between two types of communication processes. Conveyance and convergence differ in the way in which team members communicate with each other. Because conveyance requires team members to individually process information and share information with others, communication is aimed primarily at transmitting information to other team members. This means that there is little need for facilitating synchronous team member interactions, as information sharing does not require feedback or other communication loops. A typical example of conveyance is sending an email with a document or database attached to the email.

Convergence between team members within a small amount of time requires a reciprocal process. In order to establish coordinated action, teams need to converge their interpretations on complex interdependent tasks. Convergence requires team members to discuss the meaning of information in the light of the team's goals. In order to reach consensus, team member interactions are focused on the coordination and verification of team members' interpretations of the situation. This means that it is crucial that electronic communication media enable synchronous interactions in terms of feedback and discussions. As synchronous interactions facilitate rapid interactions between team members, convergence processes benefit from higher levels of synchronicity (Dennis et al., 2008; Graetz, Boyle, Kimble, Thompson, & Garloch, 1998). Dennis et al. (2008) underline the importance of media synchronicity as follows: "*Generally speaking, convergence processes benefit from the use of media that facilitate synchronicity, the ability to support individuals working together at the same time with a shared pattern of coordinated behaviour*" (p.576). Typical examples of convergence are discussions or chats.

The importance of synchronicity of interactions has also been emphasized by Kirkman and Mathieu (2005) in their framework of team virtuality. Synchronicity of interactions is a key determinant of team virtuality, together with informational value and the use of virtual tools. Kirkman and Mathieu (2005) pointed out that the importance of synchronicity of interactions depends on the activities of team members. Asynchronous interactions allow team members to work without being disturbed, and enable team members to consult background information or information of other team members. Asynchronous interactions also help teams to overcome the effects of time and distance, such as in virtual teams whose members are distributed around the globe. Synchronous interactions, on the other hand, are most fruitful when teams have to determine their goals, analyze their previous actions, and formulate their strategy. Similar to MST, Kirkman and Mathieu (2005) emphasized that communication needs can vary throughout task execution.

Based on the above, media synchronicity is expected to be important for virtual teams that perform complex interdependent tasks. Media synchronicity is expected to lead to better team coordination processes (H1-H4) and is expected to positively affect team performance directly (H5a) and through its effects on team coordination processes (H5b-H5e). The research model is depicted in Figure 4.1. It was described in Chapter 1 that team coordination processes can be explicit and implicit. Three implicit team coordination processes are studied. First, knowledge about the distribution of expertise and capabilities across members of the team helps team members to make optimal use of the team's resources, and is positively related to team performance. This knowledge is embedded in transactive memory systems (TMS; e.g., Moreland & Myaskovsky, 2000; Wegner, 1987). Second, team situation models are important for team coordination on complex, interdependent team tasks because the information in these models is used for selection of behaviour on these tasks (Dalenberg, Vogelaar, & Beersma, 2009; Rico et al., 2008). Third, team members have to anticipate the decisions and actions of other team members and the future task states in order to establish coordinated action. The anticipation of expected actions of other team members and future task states, and the dynamic adjustment of own behaviour that results from these expectations was labelled self-synchronization. The present study considers explicit coordination by means of communication. Communication is important for teams to converge team members' perceptions on the team, the task, and the environment into coordinated actions at the team level.

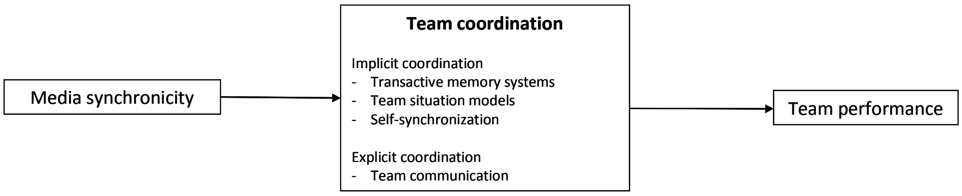

Figure 4.1: Research model for effects of media synchronicity on team coordination and team performance

Transactive memory systems. Teams, virtual or not, need to have knowledge about the distribution of knowledge, expertise, and capabilities within the team when performing complex, interdependent tasks. Mutual knowledge may be defined as knowledge that team members share and know they share (Krauss & Fussell, 1990). Mutual knowledge refers to stable, longer term knowledge about the distribution of knowledge across members of the team. This knowledge on 'who knows what' in the team is embedded in TMS.

TMS are group-level memory systems that are used for encoding, storing, retrieving, and communicating of group knowledge (Hollingshead, 1998; Lewis, Lange, & Gillis, 2005). TMS structures can be observed in teams where team members have developed specialized knowledge on task-relevant domains, rely on other team members for knowledge on other domains, and integrate their knowledge when completing a task. Specialization reduces the cognitive workload of team members individually and the amount of redundant knowledge at the team level, while all team members have access to the pool of information that the group as a whole possesses (Majchrzak, Jarvenpaa, & Hollingshead, 2007). TMS consist of three elements: specialization, credibility, and coordination (see Lewis, 2003). Specialization is the tendency to specialize and delegate responsibility of knowledge domains, credibility consists of team members' beliefs about the reliability of expertise of other team members, and coordination refers to the ability of team members to coordinate their contributions effectively. TMS have been used in team research to describe the utilization and integration of distributed expertise in teams. Research has largely focused on how the development and utilization of TMS can be stimulated by training and how TMS can be maintained (see Hollingshead & Fraidin, 2003; Lewis et al., 2004; Moreland & Myaskovsky, 2000), and how TMS can be measured (see Moreland, 1999; Lewis, 2003).

Laboratory studies have been performed to examine how TMS affect team coordination processes and performance. These studies have demonstrated that teams that develop TMS structures are better in using task-relevant knowledge and better integrate the contributions of team members. This ultimately results in better team performance levels (Kamphuis, Gaillard, & Vogelaar, 2009a; 2009b; Moreland, 1999; Moreland & Myaskovsky, 2000).

It was argued by Driskell, Radtke, and Salas (2003) and Cornelius & Boos (2003) that establishing and maintaining mutual knowledge is difficult for virtual teams. Virtual teams are considered to be faced with difficulties in developing and maintaining TMS because of changes in team composition, limited life span, and limited knowledge about distributed team members (for a detailed discussion, see Bell & Kozlowski, 2002). These difficulties make it hard for virtual teams to establish common ground, and lead to problems in the coordination of team member activities (see Oshri, Van Fenema, & Kotlarsky, 2008). Methods have been suggested to overcome the negative influence of electronic mediation, such as task-specific training (Cornelius & Boos, 2003; Kamphuis et al., 2009a; 2009b; Lewis et al., 2004), standardization of work processes, and meeting face-to-face (Oshri et al., 2008).

The development of TMS means that team members have to discover who-knows-what in the team. This means that, as no large quantities of information have to be processed, the establishment of TMS requires team members to converge their mental models on the distribution of capabilities and expertise that are represented in the team. The convergence of mental models will evolve through team member interactions such as discussion and feedback. For this reason, it is expected that media that are high in synchronicity lead to better developed TMS than media that are low in synchronicity:

> *Hypothesis 1:* Team members in virtual teams that use electronic communication media that are high in synchronicity have better TMS than team members in virtual teams that use electronic communication media that are low in synchronicity.

Team situation models. Team situation models have been described as team members' mental models on situation-dependent information, which differentiates these models from team- and task-related models that contain more stable knowledge (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Rico, Sánchez-Manzanares, Gil, and Gibson, 2008). Team situation models have been linked positively to team performance, as these models guide situation assessment, determining the strategy, assessing how the team is proceeding, and predicting team members' actions, and selection of behaviours (Dalenberg et al., 2009). Team situation models are considered to be important for virtual teams, as virtual teams typically are employed in environments where changes in the environment affect task execution (Rico et al., 2008). Importantly, changes often cannot be anticipated and the similarity of team situation models largely determines the way that a team will respond to these changes.

The development of team situation models is driven by convergence, as changes in the environment are typically small in volume, but directly affect team progress (e.g., identification of hostile entity, changes that disrupt the planning that was created). This means that convergence of team situation models benefits from synchronous interactions, as adapting to change requires teams to discuss their interpretations of the situation rather than processing large quantities of information. It is thus proposed that virtual teams that use electronic communication media that are high in synchronicity develop more similar team situation models than teams that use media that are low in synchronicity:

> *Hypothesis 2:* Team members in virtual teams that use electronic communication media that are high in synchronicity have more similar team situation models than team members in virtual teams that use electronic communication media that are low in synchronicity.

Self-synchronization. Self-synchronization describes implicit coordination in virtual teams, emphasizing the active role that team members have in integrating their efforts with those of other team members in order to accomplish team goals. In Chapter 1 we described three aspects of self-synchronization: integration, event handling, and initiative taking. An important aspect of self-synchronization is that team members form expectations and predictions about the actions of other team members and future task states, and adjust their behaviour accordingly. Therefore, team members do not transfer or process much information, and team interactions can be short. Media that are high in synchronicity are good for facilitating these interactions, and higher levels of media synchronicity will lead to better self-synchronization.

> *Hypothesis 3:* Team members in virtual teams that use electronic communication media that are high in synchronicity are better able to synchronize their actions than team members in virtual teams that use electronic communication media that are low in synchronicity.

Team communication. The main challenges for teams that complete complex, interdependent tasks are overcoming equivocality and collectively developing adaptive responses to unpredicted change. Adapting via explicit coordination processes would take teams too long to function effectively in these environments. Implicit coordination enables teams to improve their performance on complex interdependent tasks while reducing the amount of explicit coordination (Entin & Serfay, 1999; Rico et al., 2008).

For virtual teams, communication generally means typing text in the form of emails or chat messages. Typing text is an extensive form of communication, even for skilled typists. This makes communication very slow when compared to other forms of explicit coordination such as face-to-face communication or telephone conversations. In a similar fashion, the reception and transmission of messages also takes more time using electronic communication media. Therefore, team members may fall behind in reading all messages when all team interactions evolve via typed messages. This will negatively affect team coordination. (McGrath & Hollingshead, 1994). This means that the sharing of information in other ways than typing messages is important for virtual teams. Two media capabilities that were described in MST are relevant for this: the parallel use of multiple channels and the use of symbol sets. First, when team members can use multiple channels this means that coordination processes can evolve more quickly than when teams have a single channel for sharing information and communicating. For instance, team members in virtual teams that only use email have to type messages when interacting with each other, while team members in virtual teams that use both email and a shared workspace can share task-relevant information by entering information in the shared workspace, and only use email messages for team coordination processes and decision-making. Second, the use of symbol sets will help teams to reduce the amount of communication of virtual teams. Symbol sets refers to the possibilities of team members to encode information. For instance, when teams perform a planning task, having a map of the operational area and symbols for roadblocks and hostile incidents can be used for sharing information and attaching meaning to information without using typed messages. Virtual teams that use media that are high in synchronicity therefore will use less communication than virtual teams that use media that are low in synchronicity:

> *Hypothesis 4:* Team members in virtual teams that use electronic communication media that are high in synchronicity use less communication than team members

> of virtual teams that use electronic communication media that are low in synchronicity.

Team performance. Following the I-P-O approach (e.g., Hackman & Morris, 1975), the effects of using synchronous or asynchronous electronic communication media should resonate in the team coordination processes that are under study, which in turn are expected to affect team outcomes. Consistent with the hypotheses described above, it is expected that the benefits of using electronic communication media that are high in synchronicity are reflected in performance levels. Teams that use electronic communication media that are high in synchronicity are expected to perform better on complex interdependent tasks than teams that use electronic communication media that are low in synchronicity. Media synchronicity is expected to influence team performance directly, and through its effects on the team coordination processes that are under study:

> *Hypothesis 5a:* Virtual teams that use electronic communication media that are high in synchronicity perform better on a complex interdependent team task than virtual teams that use electronic communication media that are low in synchronicity.

> *Hypotheses 5b, 5c, 5d, 5e:* Team performance of virtual teams is positively affected by the use of electronic communication media that are high in synchronicity through its effects on TMS (H5b); team situation models (H5c); self-synchronization (H5d); and team communication (H5e).

Distribution of information

An important benefit of organizing work in virtual teams is that electronic communication media make it easy to share information within the team. Sharing information via shared digital workspace or storing documents on a network drive or the internet requires little effort of team members, and rapidly expands the pool of information that is available to the team. Following the group information processing model of Hinsz et al., (1997), having more task-relevant information available means that more information can be processed and therefore can be utilized in the creation of responses.

According to the group information processing model of Hinsz et al. (1997), team members acquire information when they interact with the environment. The goals and objectives of team members provide a context for information processing, and therefore influence the attention, storage, and retrieval of information. Selection of information is crucial for team performance levels on complex interdependent tasks, as team members will not be able to attend to all the information on complex tasks (Hinsz et al., 1997; Mesmer-Magnus & DeChurch, 2009; Winquist & Larson, 1998).

How teams direct their attention depends on a number of social and cognitive factors, such as the distribution of information among team members (Hinsz et al., 1997). The present research is focused on the effects of distribution of information, which was described as the "*variability of how many group members have access to a piece of information*" (Hinsz et al., 1997, p.54). At this point, it is important to note that distribution of information and information sharing are different processes. Whereas distribution of information refers to way in which information is distributed across members of the team prior to task performance, information sharing (or: openness to share information) refers to the discussing of information in team member interactions during task performance (see Mesmer-Magnus & DeChurch, 2009). In line with theory on distribution of information, 'unique' and 'shared' information refer to distribution of information (or: redundancy of information), whereas the sharing, exchanging, or discussing of information refer to team members' openness to share information during task performance (e.g., Van Ginkel & Van Knippenberg, 2009; Mesmer-Magnus & DeChurch, 2009).

Research on shared information demonstrated that teams are more likely to be focused on shared information, and that shared information is exchanged more often than unique information during task performance. The Information Sampling Model of Stasser and Titus (1985; 1987) describes that there is a positive relation between the level to which information is shared and the likelihood that information is exchanged during team interactions (Stasser & Titus, 1985; 1987). The rationale is that it is easier to discuss information that is already known to other team members. The tendency of teams to be focused on shared information is considered as a bias, as it negatively influences team performance. The tendency to be focused on shared information makes that information that is unique tends to be overlooked by the team, meaning that the team is not able to take advantage of all knowledge and expertise that was available to the team (e.g., Larson, Foster-Fishman, & Keys, 1994; Stasser & Titus, 1987; Wittenbaum et al., 2004). In other words, although more information should help teams to accomplish complex interdependent tasks because there is more information available to the team, teams only profit from unique information when overcoming the bias to be focused on information that was pooled. Hypotheses are formulated for the effects of distribution of information on team processes (H6-H9), and the effects of distribution of information on team performance (H10a-H10e; see Figure 4.2).

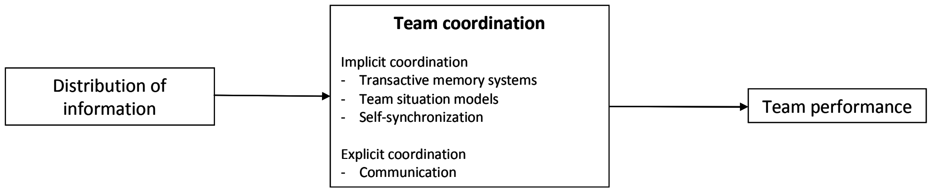

Figure 4.2: Research model for effects of distribution of information on team coordination

Transactive memory systems. Shared information is expected to lead to better development of TMS. Prior research on TMS demonstrated that team members learn about each other's knowledge when they are interacting. For this reason, teams where team members know each other well or are used to work together have better developed TMS than ad hoc formed teams (e.g. Lewis, 2004). Similarly, studies have shown that team training positively affects the development of TMS (Liang, Moreland, & Argote, 1995; Moreland, 1999). Nonetheless, TMS can also be developed even when there is no communication between team members. Training individual team members for a team task and subsequently providing information on the knowledge of other team members has been shown to positively affect the development of TMS. These teams performed equally well on a complex interdependent team task as teams whose members were trained together (e.g., Moreland & Myaskovsky, 2000).

As Moreland and Myaskovsky (2000) demonstrated, neither communication nor collective training are prerequisites for the development of TMS. These authors concluded that TMS can emerge when individual team members are trained for their task, have information on the knowledge of others, and know how this knowledge has to be combined for task completion. In sum, having accurate and similar perceptions of team member interdependence and having information on the knowledge of other team members should be sufficient to develop TMS in virtual teams. Shared information will help teams to develop accurate and similar perceptions on who-knows-what and how this information should be combined during task performance. The expected effect of distribution of information is formulated in hypothesis 6:

> *Hypothesis 6:* Team members in virtual teams that have shared information have better TMS than team members in virtual teams that have unique information.

Team situation models. As was discussed in the formulation of hypothesis 2, team situation models are team members' mental models with a dynamic understanding of the current situation. It has been proposed that when team members hold similar team situation models, team members are better able to anticipate on the actions of other team members and adjust behaviour accordingly (e.g., Dalenberg et al., 2009; Rico et al., 2008). Team situation models are considered to be important for virtual teams, as virtual teams in complex and dynamic environments, where teams have to deal with unpredictable change (Rico et al., 2008).

For teams that are faced with unpredictable change, effectively responding in the first place means recognizing changes and attaching meaning to what is going on. However, situation assessment is a team activity that is driven by the existing knowledge and beliefs that are collectively held by teams, and "*habitual routines work against the recognition of such cues*", according to Burke, Stagl, Salas, Pierce, and Kendall (2006; p. 1193). Burke et al.'s remark illustrates that teams -similar to selective information processing- tend to focus on information that is shared and may overlook unique information that is relevant for the task. Building on the importance of prior knowledge for the creation and adjustment of team situation models, it is expected that shared information helps teams to develop similar mental representations of the situation:

> *Hypothesis 7:* Team members in virtual teams that have shared information have more similar team situation models team members in teams that have unique information.

Self-synchronization. Distribution of information is expected to influence self-synchronization in virtual teams because sharing information will help teams to coordinate team member contributions, deal with unexpected events, and foster initiative taking. First, it is proposed that shared information helps virtual team members to integrate their actions. Implicit coordination mechanisms describe the behaviours of team members to align their actions by predicting and anticipating the needs of the task and other team members without explicit coordination. Providing task-relevant information or knowledge to team members without being asked is a typical implicit coordination behaviour (e.g., Entin & Serfaty, 1999; Rico et al., 2008). It is expected that shared information helps team members to develop accurate expectations on the actions of others and future task states. Second, shared information is expected to help teams to handle unexpected events. When team members are confronted with environmental changes, teams that are able to adapt to these changes are able to use information from the task environment to adjust the team's strategy. This adaptation to unexpected events occurs through compensatory behaviours and reallocation of team resources (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995). It is proposed that when task-relevant information is shared and can be accessed by all members of a team, it becomes easier for team members to assess the needs of other team members to anticipate to these needs and to adjust behaviours accordingly. Third, closely related to the identification and anticipation of the needs of other team members, shared information is considered to influence self-synchronization by fostering initiative taking in virtual teams.

> *Hypothesis 8:* Team members in virtual teams that have shared information are better able to synchronize their actions than team members in virtual teams that have unique information.

Team communication. Distribution of information is expected to influence the amount of communication in virtual teams. Miranda and Saunders (2003) emphasized that the key outcome of communication is the establishment of shared understanding on information. Members of teams have information on the team, the task, and the environment, and therefore communication will be focused on establishing shared understanding with regard to the distribution of expertise (TMS), the situation at hand (team mental models), future task states, and the actions of other team members (self-synchronization). Shared information is expected to positively influence the establishment of shared understanding in these domains, because team members can for instance verify information, check background information or work out alternative interpretations without having to ask other team members to provide information. These activities will help teams to reduce the amount of information, and therefore distribution of information will lead to less communication in virtual teams:

> *Hypothesis 9:* Team members in virtual teams that have shared information use less communication than team members in virtual teams that have unique information.

Team performance. The hypotheses 6 through 9 expressed the expected positive effects of pooling information on the team coordination processes that are under study. Virtual teams that work with pooled information are expected to perform better on a complex interdependent task. The effects of pooling information are expected to affect team performance directly, and through its effects on the team coordination processes that are under study:

> *Hypothesis 10a:* Team members in virtual teams that have shared information perform better on a complex interdependent task than team members in virtual teams that have unique information.

> *Hypotheses 10b, 10c, 10d, 10e:* Performance of team members in virtual teams is positively affected by distribution of information through its effects on TMS (H10b), team situation models (H10c), self-synchronization (H10d), and team communication (H10e).

Method

Participants and design

Data were collected from hundred and fifty (126 men and 24 women; mean age 21.3 years; *SD* = 1.79) cadets of the Royal Netherlands Military Academy (RNMA), who were arrayed in 50 three-person teams. Cadets of the RNMA take part in a military-scientific program which lasts 4.5 years. Participants were in their second year or higher. Teams consisted of participants who were in their same year, and teams were all single-sex. Participants had no experience in military operations. Subjects received no initial financial reward for participating in the study, but 50 Euros were rewarded to the members of the team that performed best on the task in all three conditions to stimulate participants to perform at their best.

We took a design in which the hypotheses on media synchronicity (asynchronous communication media vs. synchronous communication media) and hypotheses on distribution of distribution of information (unique information vs. shared information) were tested separately. There were three conditions. The effects of media synchronicity were tested by varying media synchronicity while giving teams in both conditions unique information. The effects of distribution of information were tested by varying the distribution of information while teams in both conditions worked with synchronous media. This means that the condition in which teams communicated via synchronous media and were given unique information was used for testing the effects of media synchronicity and for testing the effects of distribution of information. Teams were randomly assigned to one of the three conditions. The numbers of teams in the conditions were 18 (unique, asynchronous), 15 (unique, synchronous), and 17 (shared, synchronous).

Task

The PLAnning Task for Teams (PLATT; Kamphuis & Houttuin, 2007; Kamphuis, Essens, Houttuin, & Gaillard, in press) was used as the experimental task environment. As was described in the previous chapter, PLATT can be used to study distributed teams in complex and dynamic environments. Team members had to construct a planning for the evacuation of a group of people by sharing information and resources (military units), and by communicating and coordinating their actions. Teams interacted via email and, in two conditions, by using a digital shared workspace. Team members also had to use written task materials which contained information on distances and the speed at which the units could drive between cities. The task did not require specific knowledge on military operations or command and control, so no differences were expected between participants who were in different years of their study.

Three individual working spaces with networked computers were created using room dividers. Team members worked on personal computers which were equipped with software for sending and receiving emails and which, in two conditions, gave access to the digital shared workspace. The workspace contained a map of the operational area and tools to work in the map, such as a pen, text fields, and a tool to delete information from the map. The map was empty throughout the whole session in the condition where teams had to complete the task using email only. The data of the electronic questionnaires and the communication between team members were logged on the central research computer. The log files were used for the analysis of team communication.

Scenario

Teams completed a forty-minute scenario in which they had to construct a planning for the evacuation of a group of people from a hostile city to a city that is safe. Teams had to employ military units for transporting the group of people (transport units), making dangerous roads safe (infantry units), and repairing broken roads or vehicles (engineering units). During task execution, teams were confronted with extra information on the condition and safety of the roads and information regarding the operational readiness of some of the units by email. The speed at which the units could travel on the roads had to be determined by combining information from different tables in the written task materials. This information consisted of distances, road conditions, and time tables.

Adjustments to the task. The task was the same as described in Chapter 3. However, some changes have been introduced, which we will be described in this section. First, individual tasks were not designed from a functional perspective (operations – logistics – intelligence roles), but all three members of a team had the same function. Team members all were commanders of their own ‘area of responsibility’ (AOR). Consistent with military operations, the AORs were named Alpha, Bravo, and Charlie. All team members had their own units for transporting the group of people (transport units), making dangerous roads safe (infantry units), and repairing broken roads or vehicles (engineering units). As it was allowed to employ units in other AORs than the AOR where a unit was located, this meant that the team could employ nine units for the evacuation of the group of people. This is different from the task in the previous chapter, where teams had three units available for the evacuation. This flexible employment of resources increased team member interdependence, as team members now not only had to share information on their AORs, but also had to share resources to complete the task. Moreover, the new role structure meant that there was no team leader in this task structure. All team members were equal with regard to task completion, as they all had the same number of cities, roads, and military units. This was specifically addressed in the task instruction.

All AORs were equal for task completion. This means that the number of roads, cities, incidents, and units were identical for the AORs. The group of people that had to be evacuated was located at the city of Bukhara in AOR Alpha and had to be evacuated to the city of Dihok, which was located in AOR Charlie (Figure 4.3). The task contained routes that went directly from AOR Alfa to AOR Charlie and routes that went through AOR Bravo. The number of possible routes was equal for all AORs in this respect.

The second difference in the scenario was that information sharing was made easier in two conditions by allowing all team members to work in the digital shared workspace rather than allowing this to only one member of the team. This enabled teams to share information directly, as team members did no longer have to email information to the team member who had access to the shared workspace, who subsequently had to enter all information in the workspace. Team members could enter information in the shared workspace by adding text fields or symbols in the map or delete information from the map. Team members were instructed to work only in their own AOR, and use emails for communication and coordination of routes and actions. This means that team interaction processes still went exclusively by email and therefore could be used for analysis of communication.

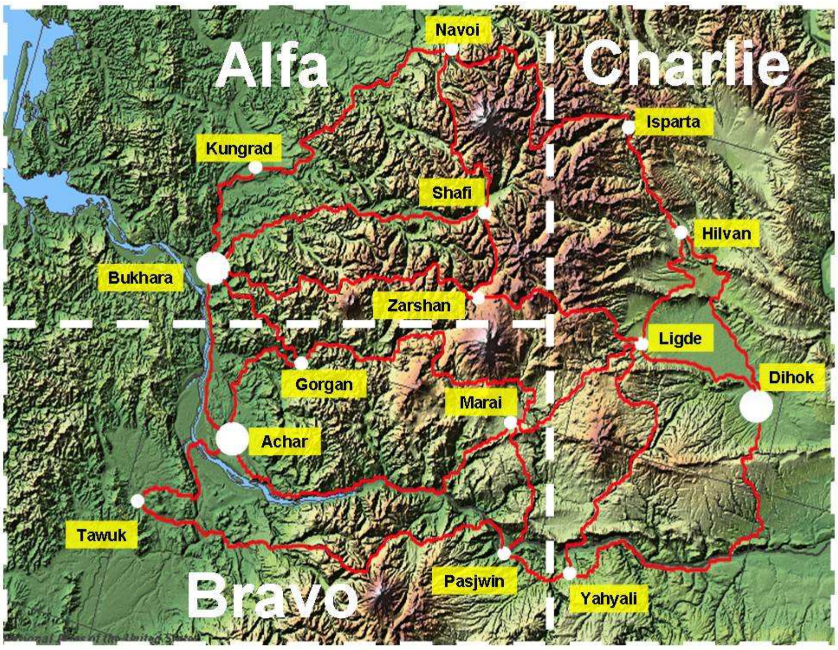

Figure 4.3: Map of the operational area

Third, the emails of the scenario were sent to all team members. This adjustment was made to facilitate the manipulation of information distribution. The email messages all had an indication in the title for which AOR the email was intended, so it was clear to team members which emails they had to read to stay informed on their own AOR without opening the emails. The information in the emails only became relevant for task execution when combined with the information in the written task materials, such as the tables with distances and speed. For example, the consequences of hostile events on a particular road only became relevant when combined with information on how long it would take to use this road in comparison with other roads. These comparisons with other roads where no incidents were reported could only be made using information that could only be obtained from the written task materials. In this way, the written task materials formed the key to the manipulation of information distribution. The manipulation and the role of the emails will be discussed below in the manipulation section.

The fourth change of the experimental task was that all team members had to complete a standardized planning form at the end of the scenario. Here, team members had to specify which route was the fastest, the amount of time that was needed for the evacuation, where units were located, and how they had to be employed. This change enabled us to study not only the similarity of team situation models at the end of the scenario, but to assess in detail the team members’ understanding of the evacuation. The second advantage of combining the individual performances is that the measure of team performance reflects the team better than when the team leader completed the planning form individually.

The changes to the task were made to increase team member interdependence and to facilitate team coordination. When compared to the functional role structure in the previous chapter, the AOR role structure meant that team members had more opportunities to engage in team coordination processes such as sharing workload, demonstrating backup behaviours, or detecting faults in other team members’ contributions. The increased team member interdependence resulting from the flexible employment of resources further meant that the need for coordinating individual contributions was increased.

Roles. Teams consisted of three team members, who were responsible for the AORs Alpha, Bravo, and Charlie. All AORs had an equal workload, as they had the same number of roads, cities, incidents, and possibilities to travel to other AORs. The team members had to process information from emails and from written task materials and enter information in the shared digital workspace. They also had to share information and communicate with other team members by email to work out what was the fastest route to evacuate the group of people. Ultimately, team members had to coordinate the employment of their units on the route that they thought would be the fastest. This means that team members had to suggest a route to other team members and propose which units would have to be employed to carry out the evacuation. It was emphasized in the instruction that there was no team leader and all team members were equal in the decision making process.

All team members had to fill out a standardized planning form, in which they had to specify the evacuation route, which units were to be employed, and how long it would take to complete the evacuation.

Procedure

Participants enrolled in an experiment which consisted of two sessions. Teams were identical across the two sessions. The first session consisted of instructions about the PLATT task and the software for emailing and the shared digital workspace, and an experimental session that was not related to the current research.

The experimental session took eighty-five minutes. The session consisted of an introduction and task instruction by the experiment leader (twenty minutes), filling out a questionnaire on personal information (five minutes), running the scenario (forty minutes), completing the standardized planning form (ten minutes), and filling out the final questionnaire that contained the self-report dependent measures (ten minutes). After the planning forms were collected, the experiment leader announced that teams would receive a written debriefing on both sessions when data collection was completed, in which the winning teams would also be announced.

Manipulation

The experiment contained two manipulations. First, we assessed the effects of two configurations of electronic communication media that differed for the level to which they facilitated synchronous interactions between team members, addressing hypotheses 1 through 5. Second, we compared two levels of information distribution for their effects on team processes and performance, addressing hypotheses 6 through 10. The effects of media synchronicity were tested by comparing two conditions where teams did not differ for distribution of information. Teams in both conditions completed their task using unique information. The effects of distribution of information, alternatively, were tested by comparing teams who all worked with media that were high in synchronicity.

Media synchronicity. Teams completed the planning task using a media configuration that was low in synchronicity or a media configuration that was high in synchronicity. Teams used email in both conditions, but teams in the synchronous condition could also use a shared digital workspace for information sharing. As directly sharing information through a digital operational picture is easier than sharing information by typing messages, adding a communication modality that is high in synchronicity was expected to affect team communication and coordination processes positively. In the remainder of this thesis, the media configuration that only featured email is considered to be low in media synchronicity, whereas the configuration that featured both email and a shared digital workspace is considered to be high in media synchronicity.

The shared digital workspace contained a digital map of the operational area, featured a pen and text fields to enter information, and contained symbols. The shared digital workspace facilitated information sharing and helped team members to converge their interpretations on the route and use of resources. First, information sharing was made easier in this configuration because information could be entered directly in the map, so team members did not have to compose email messages. Second, the shared digital workspace served as a tool to develop shared understanding during task execution, because team members could directly integrate information into a single operational picture. This made the interpretation of the situation easier than in the asynchronous configuration, where team members had to develop shared understanding individually by creating their own operational map using paper and a pen. The manipulation of media synchronicity was straightforward, as teams that used the configuration that was low in media synchronicity could switch between the screens of the email program and the shared workspace, whereas the shared digital workspace was not available to the teams that worked with the configuration that was low in media synchronicity. Switching between the email software and the shared digital workspace was done by clicking on a button in the taskbar.

The media configuration that was high in synchronicity differed from the media configuration that was low in media synchronicity for two media characteristics (parallelism and symbol variety) that Dennis et al. (2008) described. First, teams could use email and the shared digital workspace at the same time (e.g., one team member was working in the shared workspace, two team members were typing and reading emails). This means that teams could use both email and the shared workspace during task performance, which means that parallelism was higher in the synchronous condition. Regarding symbol variety, the use of multiple symbol sets differed across the conditions, as the shared digital workspace featured a set of symbols and tools that offered additional ways of sharing information. Information on hostile events or road conditions, for example, could be shared through text in email messages or by symbols in the shared workspace. Participants received an instruction on the use of the shared digital workspace, so that the meaning of signs and symbols was clear to all. Therefore, the shared digital workspace could be used for sharing information that was already processed.

Distribution of information. Distribution of information was manipulated by giving team members written task materials on either their own AOR (unshared condition) or on all AORs (shared condition). Team members in both conditions were instructed to process information on their own AOR first before considering information on other AORs. The experiment leader monitored this process as he could see all the screens of the team members on the central research computer. The effects of shared information were expected to become visible when the teams were confronted with extra information from the scenario, which affected the fastest routes of the scenario at that point. The extra information was sent to team members by emails. Here, team members in the shared information condition could help other team members by sharing workload and checking the accuracy of information of other team members, whereas in the unshared condition possibilities were limited, depending on the information that was exchanged via email.

Measures

Transactive memory systems. TMS were assessed by using Lewis's (2003) scale on TMS, which consists of the subscales specialization, credibility, and coordination. Team members scored each item on a five-point Likert-type scale ranging from 1 ("*strongly disagree"*) to 5 ("*strongly agree"*). As specialization was affected by the manipulation of information distribution, we did not include this scale as dependent variable. We used items of the credibility scale (Cronbach's alpha .66; five items) and the coordination scale (Cronbach's alpha .82; five items) to measure TMS. See Table 4.1 for the descriptive values. The r_{wg} values of the subscales were .90 and .81 respectively, and we aggregated individual responses to the team level by means of averaging. The reliability of the overall scale reached .80.

Team situation models. Members of the team were asked three times during task execution what they thought would be the fastest route. Team members completed a short electronic questionnaire in which they entered the route in a text field by stating the first letter of the cities on the route. Team situation model similarity was determined by scoring the number of similarities between routes at the team level. Scores ranged from 0 (no similarities; all team members entered different routes) to 2 (two similarities; all team members entered the same route).

Self-synchronization. Self-synchronization was assessed after task completion using a nine-item questionnaire. Adjustments to the questionnaire were made based on the outcomes of the previous chapter. The scale now consisted of the subscales integration (four items), event handling (three items); and initiative taking (two items). Team members scored each item on a five-point Likert-type scale ranging from 1 ("*strongly disagree"*) to 5 ("*strongly agree"*). Examples of items are for integration "*I was able to work out the best solution together with the other team members"; event handling* "*When unexpected events happened, I was able to determine the consequences for other parties*"; and initiative taking "*I did not like it when other team members came up with other plans*" (reversed item). Reliability of the subscales ranged from .43 to .74. The correlations between the subscales ranged from .43 to .73 (p <.01 for all correlations). The reliability of the self-synchronization questionnaire reached .77 (see Table 4.1). The r_{wg} values for the subscales were .68 or higher, and individual scores were aggregated to the team level by means of averaging the individual responses.

Team communication. Log files were used for the analysis of team communication. The log files contained data on email communication and use of the digital shared workspace. Data on email communication consisted of the number of: (a) received email messages; (b) opened email messages; (c) sent email messages; (d) replied email messages on received email messages. The email program of the PLATT environment differed from regular email software in that the content of email messages only became visible after opening the emails in the inbox. This was done to ensure that information from emails could only be processed when team members read the text of the email message. Two variables were constructed from these data. The variable team communication (sum of sent and replied email messages) describes the amount of communication between team members, thereby excluding the programmed emails from the scenario. Although no hypothesis was formulated, the use of the shared workspace was measured as well. As teams were expected to intensively use the shared workspace for sharing information, knowledge about the use of the workspace is interesting when interpreting the results on team communication. The measure for use of the shared digital workspace was the number of times that team members switched between the email screen and the workspace screen on their computers. All data were collected at the team level.

Team performance. Two measures were used for team performance: rank score of the route and quality of the planning. The rank scores of the route ranged from one to eight. Lower rank scores indicated better team performance. The quality of the planning was determined by scoring (a) deployment of units and (b) accuracy of the calculations. For the deployment of units, team members received one point for each unit that was correctly deployed, and one point was subtracted for each unit that was deployed incorrectly. The accuracy of the calculation was determined scoring the nominal deviation between the correct number of minutes of the route and number of minutes that was filled out on the planning form. The individual scores were averaged for the team level scores.

Manipulation check. Two items of the specialization subscale of Lewis's (2003) questionnaire on TMS were used to check whether the manipulation of information distribution had the desired effect. The items were "*Each team member has specialized knowledge of some aspect of our project*", and "*I have knowledge about an aspect of the project that no other team member has*" (Cronbach's alpha .82 for the two items). We expected that there would be no differences on these items between teams in the two conditions where there was only information given to team member's own AORs. Results of a *t*-test confirmed this expectation (p = .27). Conversely, we expected that teams who that information on all AORs differed from teams who had only information on their own AOR. This expectation was also confirmed (p < .01). Descriptive values and test results are presented in Table 4.2.

Table 4.1: Descriptive values for TMS and self-synchronization at the individual level of analysis (N = 150)

	Number of items	*M*	*SD*	*Cronbach's alpha*	r_{wg}
TMS					
Overall scale	10	3.73	.57	.80	.94
Credibility	5	4.08	.57	.66	.90
Coordination	5	3.38	.78	.82	.81
Self-synchronization					
Overall scale	9	3.86	.55	.77	.95
Coordination	4	3.85	.60	.55	.88
Event handling	3	3.61	.67	.74	.68
Initiative taking	2	4.09	.79	.43	.91

Table 4.2: Mean scores, standard deviations, and *t*-test results for manipulation checks at the team level for teams in all conditions ($N_{overall}$ = 50)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Unique information, low synchronicity	18	3.16	.76	1.13	31	.27	.40
Unique information, high synchronicity	15	2.87	.70	3.63	30	$.01^{**}$	1.26
Shared information, high synchronicity	17	2.08	.52				

Note: p-values are one-sided

** p < .05

Results

Media synchronicity

Hypotheses 1 through 5e predicted that media synchronicity would positively affect team processes (TMS, team situation models, self-synchronization, and communication), and that media synchronicity would positively affect team performance directly and through its effects on team processes. The hypotheses were tested using multivariate analysis of variance procedures (MANOVAs) and follow-up *t*-tests. As the rank score of the routes are ordinal, Mann-Whitney tests were used to test the effect of synchronicity of interactions on this outcome variable. Table 4.3 presents means, standard deviations, and Pearson correlations between all variables of interest. Spearman's rank correlations were computed between the rank scores of the route and the other variables.

Transactive memory systems. A one-way MANOVA procedure was conducted with media synchronicity as independent variable and the two subscales of TMS as dependent variables. Results showed that media synchronicity did not affect TMS (Hotelling's trace .20; Wilk's lambda .84; $F(2,30) = -2.95$; $p = .07$; $\eta^2 = .16$). Follow-up *t*-tests demonstrated that media synchronicity did not differ for coordination ($p = .41$), and did negatively affect credibility ($p = .02$) perceptions in virtual teams (see Table 4.4). Hypothesis 1 was not supported.

Team situation models. Similarity of team situation models was assessed three times during the scenario. A MANOVA procedure was used to determine the effects of media synchronicity on team situation model similarity. Results showed media synchronicity did not affect team situation model similarity ($M_{asynchronous} = 1.11$, $SD_{asynchronous} = .47$, $M_{synchronous} = 0.82$, $SD_{synchronous} = .32$, Hotelling's trace = .21; Wilk's lambda = .83; $F(3,29) = 2.06$; $p = .13$, $\eta^2 = .18$). Although the overall difference was non-significant, the direction of the differences of the teams contradicted our expectations. We therefore conducted separate *t*-tests for the three times that team situation model similarity was measured.

The results on the *t*-tests (Table 4.5) show that there are no differences regarding team situation model similarity on the first two measurements ($p_1 = 21$; $p_2 = .22$), but teams differed at the third measurement ($p_3 = .02$). Here, teams that used the media configuration that was high in synchronicity showed *less* similarity in their team situation models than teams that used the media configuration that was low in synchronicity. Reflecting the results of the MANOVA, this outcome contradicted the hypothesis. Hypothesis 2 was not supported.

Self-synchronization. A one-way MANOVA procedure was performed with media synchronicity as independent variable and the three subscales of self-synchronization as dependent variables. No multivariate effect was found (Hotelling's trace = .13; Wilk's lambda = .89; $F(3,29) = 1.21$; $p < .32$; $\eta^2 = .11$). Follow-up *t*-tests indicated that integration ($p = .37$) and event handling ($p = .22$) were not affected by media synchronicity, but that media synchronicity did negatively influence initiative taking ($p = .04$), as teams that used media that were high in synchronicity reported less initiative taking than teams that used media that were low in synchronicity (Table 4.6). This outcome contradicted our expectations. In all, the results provided no support for hypothesis 3.

Team communication. The variable team communication consists of the number of emails that team members sent to each other during the session. It was hypothesized that the availability of media that were high in synchronicity would decrease team communication via email, because information could be shared directly with team members. The expected differences were not observed, as teams in both conditions did not differ significantly for the amount of emails that were sent by team members (see Table 4.7, p = .19). Media synchronicity did not affect team communication. Hypothesis 4 was rejected.

Team performance. Team performance was assessed using three indicators for team performance: rank score of the route, correct employment of units, and deviation from correct end time. Regarding the rank score of the route, a Mann-Whitney test revealed that teams that used media that were high in synchronicity did not differ significantly from teams that used media that were low in synchronicity (M = 17.87; U = 122.000, p = .62). Two t-tests were conducted to test the differences of media synchronicity on unit deployment and deviation from end time measures (Table 4.8). Results of the Mann-Whitney U-test and the t-tests indicated that media synchronicity did not affect team performance, providing no support for hypothesis 5a. Hypotheses 5b through 5e predicted that the team processes that were under study would mediate the effects of media synchronicity on team performance (see Table 4.3 for descriptive values and correlations). As no main effects of media synchronicity was obtained on any of these processes (see above), these hypotheses were rejected.

Table 4.3: Descriptive values and correlations between team process and team performance variables at the team level of analysis (N = 33 for media synchronicity)

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
TMS														
1. Credibility	3.34	.53	-	.43*	-.01	-.20	.27	.59**	.51**	.76**	.03	-.05	.15	.02
2. Coordination	4.15	.32		-	-.13	.21	.00	.75**	.54**	.50**	.16	-.15	.45	-.09
Team situation models														
3. Assessment 1	.91	.70			-	.33	-.11	.00	-.07	.03	.06	-.29	.22	.09
4. Assessment 2	1.18	.77				-	.13	.12	.28	-.06	.45*	-.42*	.34	-.31
5. Assessment 3	.83	.57					-	.03	.27	.22	.09	.15	.01	.09
Self-Synchronization														
6. Integration	3.84	.45						-	.73**	.43**	.02	-.05	.31	-.01
7. Event handling	3.62	.39							-	.38**	.32	-.08	.15	-.15
8. Initiative taking	4.12	.57								-	-.14	-.07	.15	.03
Team Communication														
9. Team communication	40.64	10.56									-	-.16	.17	-.13
Team performance														
10. Deviation end time	68.23	47.45										-	-.54*	.33
11. Unit deployment	1.77	1.71											-	.03
12. Rank score route	4.12 (*Mdn*)	1.00 – 8.00 (*range*)												-

Note: Column 12 contains Spearman's rank correlations

** $p < .01$. * $p < .05$

Table 4.4: Mean scores, standard deviations, and *t*-test results for TMS (*N* = 33 for media synchronicity)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Coordination							
Low synchronicity	18	3.40	.67	.22	31	.41	.07
High synchronicity	15	3.44	.39				
Credibility							
Low synchronicity	18	4.27	.29	- 2.06	31	.02**	.70
High synchronicity	15	4.04	.36				

Note: p-values are one-sided
** $p < .05$

Table 4.5: Mean scores, standard deviations, and *t*-test results for team situation model similarity (*N* = 33 for media synchronicity)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Assessment 1							
Low synchronicity	18	1.00	.69	-.84	31	.21	.29
High synchronicity	15	0.80	.70				
Assessment 2							
Low synchronicity	18	1.28	.83	-.78	31	.22	.27
High synchronicity	15	1.07	.70				
Assessment 3							
Low synchronicity	18	1.06	.54	-2.23	31	.02**	.81
High synchronicity	15	0.60	.60				

Note: p-values are one-sided
** $p < .05$

Table 4.6: Mean scores, standard deviations, and t-test results for self-synchronization (*N* = 33 for media synchronicity)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Integration							
Low synchronicity	18	3.86	.50	-.35	31	.37	.11
High synchronicity	15	3.81	.39				
Event handling							
Low synchronicity	18	3.67	.45	-.79	31	.22	.28
High synchronicity	15	3.56	.31				
Initiative taking							
Low synchronicity	18	4.27	.46	-.1.80	31	.04**	.64
High synchronicity	15	3.93	.60				

Note: p-values are one-sided

** $p < .05$

Table 4.7: Mean scores, standard deviations, and *t*-test results for team communication (*N* = 33 for media synchronicity)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Team communication							
Low synchronicity	18	42.28	9.68	-.90	31	.19	.31
High synchronicity	15	39.00	11.26				

Note: p-value is one-sided

Table 4.8: Mean scores, standard deviations, and *t*-test results for team performance (*N* = 33 for media synchronicity)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Unit deployment							
Low synchronicity	18	1.66	1.65	.33	31	.28	.13
High synchronicity	15	1.88	1.76				
Deviation from end time							
Low synchronicity	18	79.62	56.76	1.29	31	.11	.47
High synchronicity	15	56.83	38.14				

Note: p-values are one-sided

Distribution of information

Hypotheses 6 through 10e predicted that distribution of information was positively related to the team processes under study (TMS, team situation models, self-synchronization, communication). It was further hypothesized that distribution of information would positively affect team performance directly and through its effects on these team processes. Similar to hypothesis testing on media synchronicity, hypotheses were tested using MANOVAs and follow-up *t*-tests. As the variable rank score of the routes was ordinal, Mann-Whitney tests were used to test the effect of the distribution of information on this variable. Table 4.9 presents means, standard deviations, and correlations between all variables of interest. Spearman's rank correlations were computed between the rank scores of the route and the other variables.

Transactive memory systems. The availability of information about other team members' AORs was hypothesized to influence the development of TMS. The effects of distribution of information on TMS were tested using a MANOVA-procedure. The results of the MANOVA are presented in Table 4.10. The results show that team coordination processes were not affected by distribution of information. Because of the small *F*-values no follow-up *t*-tests were performed. No support was obtained for hypotheses 6.

Team situation models. It was expected that teams with shared information have more similarity in their team situation models. Testing the differences in a MANOVA procedure showed that there were no differences regarding team situation model similarity ($M_{unshared}$ = 0.82, $SD_{unshared}$ = .66 M_{shared} = 0.84, SD_{shared} = .63; Wilk's lambda .96; Hotelling's trace .04; $F(3,28) = .37$; $p = .77$, partial $\eta^2 = .04$). As the results on team situation model similarity differed across three measurements when testing hypothesis 1, we computed three separate *t*-tests to assess whether the measurements differed for distribution of information. Table 4.11 shows that teams in the unique information condition did not differ from teams in the pooled information condition on any of the assessments, providing no support for hypothesis 7. A repeated-measures ANOVA was performed to test team situation model similarity throughout task execution. The results show that team situation model similarity decreased significantly during the experiment (Hotelling's trace = .23; Wilk's lambda .81; $F(2, 29) = 3.38$ $p = .05$, $\eta_p^2 = .19$). These results indicate that both groups experienced difficulties for maintaining team situation model similarity.

Table 4.9: Descriptive values and correlations between team process and team performance variables at the team level of analysis (*N* = 32 for distribution of information)

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
TMS														
1. Credibility	3.21	.71	-	$.68^{**}$	-.15	-.07	.02	$.64^{**}$	$.49^{**}$	$.51^{**}$	-.20	.08	-.04	-.03
2. Coordination	3.37	.54		-	-.06	.14	.13	$.78^{**}$	$.74^{**}$	$.63^{**}$	-.20	-.04	.20	.01
Team situation models														
3. Assessment 1	.94	.66			-	.15	.02	.03	-.25	.07	.01	.05	.13	-.27
4. Assessment 2	1.03	.74				-	.10	.06	.01	.03	.03	-.21	.25	-.09
5. Assessment 3	.60	.66					-	.20	.34	.06	.23	-.08	$.42^{*}$	-.08
Self-Synchronization														
6. Integration	3.86	.41						-	$.64^{**}$	$.69^{**}$	-.29	-.09	.17	.10
7. Event handling	3.59	.46							-	$.45^{**}$	.10	.03	.08	-.29
8. Initiative taking	4.00	.55								-	$-.45^{**}$	-.13	-.02	-.30
Team Communication														
9. Team communication	37.06	10.94									-	-.03	.23	-.14
Team performance														
10. Deviation end time	55.88	42.24										-	-.29	-.33
11. Unit deployment	1.73	1.47											-	-.03
12. Rank score route	5.00 (*Mdn*)	1.00-9.00 (*range*)												-

Note: Column 12 contains Spearman's rank correlations

** $p < .01$. * $p < .05$

Table 4.10: Mean scores, standard deviations, and *t*-test results for TMS (*N* = 32 for distribution of information)

	n	*M*	*SD*	*F*	*df*	*p*	η^2
TMS							
Unique information	15	3.73	.33	-.92	30	.35	.03
Shared information	17	3.58	.52				

Note: p-value is one-sided

Table 4.11: Mean scores, standard deviations, and *t*-test results for team situation model similarity (*N* = 32 for distribution of information)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Assessment 1							
Unique information	15	0.80	.67	-.88	30	.20	.31
Shared information	17	1.00	.61				
Assessment 2							
Unique information	15	1.07	.70	-.56	30	.29	.21
Shared information	17	0.94	.56				
Assessment 3							
Unique information	15	0.60	.63	-.04	30	.58	.03
Shared information	17	0.58	.71				

Note: p-values are one-sided

Self-synchronization. Shared information did not affect self-synchronization (Table 4.12). The small *F*-ratio indicates that differences within groups were larger than between groups, so no additional *t*-tests were performed. Hypothesis 8 was not supported.

C*ommunication*. Hypothesis 9 predicted that shared information helps virtual teams to limit the amount of communication. The number of email messages that were sent within the team expressed the amount of communication. The result of a t-test demonstrated that there is no reduction in the number of messages ($p < .25$; Table 4.13). No support was obtained for hypothesis 9. Although no hypothesis was formulated for the use of the digital shared workspace, a second *t*-test was performed to test the effects of distribution of information on the use of the shared workspace. The results indicated that team members in both groups intensively used the shared workspace, regardless of distribution of information ($p < .48$).

Table 4.12: Main effects of information distribution on self-synchronization (*N* = 32 for distribution of information)

	n	*M*	*SD*	*F*	*df*	*p*	η^2
Self-synchronization							
Unique information	15	3.67	.24	-.71	30	.41	.02
Shared information	17	3.57	.41				

Table 4.13: Mean scores, standard deviations, and *t*-test results for communication (*N* = 32 for distribution of information)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Team communication							
Unique information	15	39.00	11.26	.68	30	.25	.24
Shared information	17	36.41	10.22				
Use of digital shared workspace							
Unique information	15	147.47	58.74	.19	30	.48	.06
Shared information	17	150.76	41.07				

Note: p-values are one-sided

Team performance. Hypothesis 10a predicted a main effect of information distribution on team performance. This hypothesis was tested in a Mann-Whitney procedure, where the rank scores of the quality of the routes were compared for teams that used unique information with teams that used shared information. Results show that teams with unique information (*M* = 18.27) did not differ from teams that worked with shared information (*M* = 14.94; *U* = 101.00, *p* = .30). The second measure for team performance was the employment of units. A *t*-test revealed that teams with unique information did not differ from teams with shared information (*p* = .33). The third measure for team performance was the deviation from the correct end time of the chosen route. The results of a *t*-test indicated that teams did not differ on this variable (*p* = .48). Results are presented in Table 4.14.These results provide no support for hypothesis 10a.

Reflecting the absence of support for hypotheses 6 through 9, team processes could not be related to team performance. This means that there is no mediation by these processes. The hypotheses on the mediating role of team processes (H10b through 10e) are rejected.

Table 4.14: Mean scores, standard deviations, and *t*-test results for team performance (*N* = 32 for distribution of information)

	n	*M*	*SD*	*t*	*df*	*p*	*d*
Unit deployment							
Unique information	15	1.88	1.76	.46	30	.33	.18
Shared information	17	1.61	1.24				
Deviation from end time							
Unique information	15	56.83	38.41	.07	30	.48	.04
Shared information	17	57.84	46.00				

Note: p-values are one-sided

Discussion

This study examined the effects of media synchronicity and distribution of information on virtual teams that perform complex, interdependent tasks. Following MST (Dennis et al., 2008; Dennis & Valacich, 1999), it was tested to what extent synchronous media helped virtual teams to perform better on complex interdependent tasks. Results of the present study are not in line with MST, as team coordination processes were not affected by media synchronicity and teams did not differ with respect to team performance levels. Moreover, the present research demonstrated that media that are high in synchronicity *negatively* affected team situation model similarity, perceptions of team member credibility, and initiative taking. A possible explanation for these contradictory results is that teams that used media that were high in synchronicity simultaneously used email and a digital shared workspace for team member interactions, a possibility that has not been considered in MST. Further, no differences were obtained between teams that had unique information and teams that worked with shared information. The effects of media synchronicity and distribution of information are discussed in detail below.

Transactive memory systems. Research on TMS has demonstrated that the encoding, storing, and retrieval of information about distribution of expertise within the team helps teams to perform better on complex, interdependent tasks (e.g., Lewis, 2004; Liang, Moreland, & Argote, 1995; Moreland & Myaskovsky, 2000). Team members need to develop mutual and accurate expectations on the expertise of other team members. The development of TMS through team member interactions results from knowledge about other team members, prior experience to work together, or training at the individual or group level (e.g., Lewis, 2004; Kamphuis et al., 2009b). The development of TMS means that team members have to interact with each other to acquire this information. For this reason, TMS were expected to be positively affected by media synchronicity. It was also expected that distributing all task-relevant information among all team members would positively affect the development of TMS. Results provided us with no support for these expectations.

A possible explanation for the lack of results is that team members may have found it difficult to learn how to make effective use of the shared digital workspace. Cornelius and Boos (2003) argued that short-term virtual teams (virtual teams that are composed of strangers that have no intentions to work together in the future) may experience difficulties when they have to learn how to work with electronic communication media. These authors proposed that media that are low in synchronicity often have features that foster *intermessage connectedness*, such as threads or previous messages being displayed in an email conversation. As media that are high in synchronicity typically lack these features, adapting to synchronous media may be more difficult than working with media that are low in synchronicity for short-term virtual teams. Indeed, the digital shared workspace that was used in this research did not have such features, and this research was conducted with short-term teams.

Another possible explanation for the lack of results is that team members' perceptions of the credibility of other team members was affected by media synchronicity. Teams in the synchronous condition rated their fellow team members as *less* credible than in the asynchronous condition. This finding is attributed to the use of the shared digital workspace, albeit in the opposite direction of our expectations. It is proposed that for teams that worked with media that are high in synchronicity, team members were confronted with errors and mistakes of other team members when working in the shared workspace, such as sharing incorrect information or forgetting to enter relevant information in the shared workspace. In this way, higher levels of media synchronicity may have led to *lower* perceptions of credibility of other team members in the present research.

Team situation models. Following MST, it was expected that media synchronicity would help teams to develop similar team situation models. Findings indicated that media synchronicity did not affect team situation model similarity in the present study. In fact, virtual teams that could use both email and a digital shared workspace had *less* similar team situation models on one of the assessments than virtual teams that used only email. This finding may be attributed to the use of the shared digital workspace. Teams used email and the shared digital workspace in the condition where media synchronicity was high. As will be discussed below, interacting via two electronic communication media did not reduce the amount of typed messages that team members sent to each other. In other words, teams in the synchronous conditions did not only spend time and cognitive resources on sharing information in the shared digital workspace, but on top of that team members sent each other typed messages. We propose that this may have led to a reduced focus on developing accurate perceptions on the operational situation. Importantly, this explanation could not be tested empirically.

Further, teams with shared information were expected to have more similar team situation models than teams with unique information. Results indicated that distribution of information did not affect similarity of these models

Self-synchronization. Self-synchronization was expected to be positively affected by media synchronicity, because coordination, event handling, and initiative taking typically require negotiation and feedback between team members, interactions that require media that are high in synchronicity (Dennis et al., 2008). However, the expected effects of self-synchronization were not obtained. Additional analyses revealed that teams did not differ on the integration and event handling subscale, but that teams that used media that were high in synchronicity reported *lower* scores on the subscale initiative taking. These results may be related to the aforementioned result on team member perceptions of credibility. Credibility refers to the extent to which teams members judge the reliability of the expertise of other team members (see Lewis, 2003). When team members rate the reliability of other team members' expertise lower, team members will be less likely to take initiatives that involve other team members.

Communication. Following MST, team communication was expected to decrease when teams could use both email messages and share information via the shared digital workspace. Entering information in the shared workspace rather than typing email messages was expected to reduce the amount of communication in virtual teams. The reduction of the average amount of email messages per participant (participants sent on average three messages less per session; see Table 4.7) did however not reach significance.

The finding that teams did not limit their communication via email is attributed to the redundant use of media in the condition where teams worked with both email and the shared workspace. The log files showed that team members made intensive use of the shared workspace in the synchronous condition (on average participants accessed the workspace 49 times per session; see Table 4.13), while team members in both conditions also sent over forty email messages (see Table 4.7). This outcome indicates that teams that used both email and the shared digital workspace attempted to communicate and share information via *both* types of media simultaneously, rather than *switching* between media. Studying the text of the messages revealed that, indeed, team members did use email for sharing information (travel times, reporting incidents) and subsequently entered this information in the shared workspace and vice versa.

This redundant use of media was not expected. Dennis and colleagues (2008) introduced the term 'media appropriation' to describe the level to which users use a communication medium the way that it is intended (e.g., users can choose to send email back and forth in such a tempo that the medium in fact functions as instant messaging or chat). Dennis et al. (2008) emphasized that media are designed to function in a specific way, and thereby inherently facilitate and constrain the behaviour of users (cf. McGrath & Hollingshead, 1994). The absence of differences in the use of email between conditions indicated that participants did not use the media as it was intended (email for discussing the best alternative, information sharing via the shared workspace). By comparing the content of the electronic maps with the text of email messages, teams used the shared workspace for sharing information, but teams sent the same information via email as well. These results imply that the benefits that were associated with the shared workspace were not warranted, because sharing information via email messages was not substituted by sharing information via the shared digital workspace. As was discussed above, it remains unclear to what extent this finding can be attributed to the use of short-term teams in the present research.

Team performance. The three measures for team performance assessed different aspects of team performance. There was a hierarchy of routes, and rank scores indicated how well teams completed the scenario. Moreover, the correct employment of units and the errors in the calculation of the end-time focused on the accuracy of the planning. No effects of media synchronicity of interactions and shared information on team performance were found.

The aforementioned changes to the task as used in Experiment 2 were designed in order to get a more thorough understanding of the quality of team members' efforts. The absence of relations between team processes and team performance that were described in Chapter 3 were attributed to the fact that the construction of the planning was carried out by the team leader. This might not have been a good representation of the performance of the team as a whole. For this reason, all team members were now asked to fill out a planning form from which all team performance scores were derived. Again, only few relations were found between team processes and outcome measures. The absence of direct effects of input factors on performance measures, as well as the absence of significant relations between team processes and performance measures, indicate that the performance measures did not function adequately.

Another possible explanation for the lack of results regarding distribution of information is the type of task that was used in the present research. The majority of research on distribution of information features so-called hidden-profile tasks. This type of tasks requires team members to share and discuss information in order to select the best alternative (i.e. information on a set of persons that apply for a job). This task type features a 'hidden profile' in that some important piece of information is known to one or more team members. This information is crucial for selecting the best alternative. The present research did not feature a hidden profile, and all information in the task was relevant for determining the best route. For this reason, the consequences of not sharing a particular piece of information were less dramatic on the planning task than on a hidden profile task.

The present task did not feature a hidden profile because this was considered not to be representative for the distribution of information in modern (military) organizations. It was decided that the main criterion for team performance should be the amount of information that was processed and shared with other team members. Importantly, the relation between distribution of information, information sharing, and team performance was made less dramatic than in hidden profile tasks. As distribution of information did not affect coordination processes and performance in the present research, adjustment of the experimental task may be important for investigating the effects of distribution of information in virtual teams.

Theoretical implications

The present study indicated that media synchronicity and distribution of information did not affect coordination processes and performance in virtual teams. It was proposed that the simultaneous use of different electronic communication media could explain these outcomes. In an attempt to deduct the implications for theory on coordination in virtual teams, we propose that the simultaneous use of electronic communication media may influence the functioning and performance of virtual teams in two ways. First, the simultaneous use of electronic communication media may distract the team from the task, as the team devotes considerable time and effort to sharing and discussing information on complex, interdependent tasks. This holds particularly for virtual teams that are not used to use different media simultaneously. For this reason, teams may have less attention for other activities, such as detecting changes in the environment or performing individual subtasks. For teams that operate in dynamic environments, this may negatively affect the teams' capacity to adapt. Second, redundant information sharing on complex, interdependent tasks in complex and dynamic environments is prey to inconsistencies and errors. The current research suggests that this may affect team members' perceptions on the credibility of other team members. As a result of this, the simultaneous use of electronic communication media may negatively affect team processes such as complicating the discussion of shared information and initiative taking. As many teams in business and the military use more than one communication medium, it is proposed that future research is needed to address the effects of redundant information sharing in virtual teams.

The finding that members of virtual teams intensively use both types of media regardless of the level to which information is distributed implies that virtual teams find it difficult to reduce the amount of communication and establish implicit modes of coordination when performing complex tasks. The findings imply that offering alternative ways for sharing and integrating information to teams may not positively affect team performance.

Regarding team situation models, Rico et al. (2008) emphasized that the team itself forms the context in which team members operate. Driven by team member interactions, individual situation models are expected to converge and lead to commonly held situation models. Findings of the current study suggest that virtual teams find it hard to establish similar team situation models, as team members differed for their ideas on the best route in a large majority of teams. It is not possible to determine to what extent these difficulties result from interaction via electronic communication media, as the present research did not consider face-to-face teams as control groups. Further, it is not clear to what extent short-term teams differ from teams that are used to work together in this respect. Given the dynamic aspect of team situation models, it is suggested that establishing similar team situation models is more difficult than establishing similar team- and task-related models, which contain more stable knowledge. This topic has not been discussed in mental model literature so far.

Limitations and future research

The present study was conducted in a laboratory setting, where teams that were formed ad hoc completed a complex experimental task. This setting is typical for experimental (virtual) team research, as it allows researchers to study in detail the effects of input factors on team processes and team performance (LePine, Piccolo, Jackson, Mathieu, & Saul, 2008; Martins et al., 2004). This approach is known as the input-process-output approach (e.g., Hackman & Morris, 1975). Important drawbacks of the IPO approach are that the relations between input factors, process factors, and output factors are more complex and dynamic outside the laboratory and that team processes that evolve over time cannot be studied (Ilgen, Hollenbeck, Johnson, & Jundt, 2005). For these reasons, results of experimental team research have limited value for application outside the laboratory.

The finding that media synchronicity can negatively affect the perceptions of team members on the credibility of other team members call for further research in this area, since these perceptions were related to initiative taking in this study (see Table 4.3). This suggests that the effects of media synchronicity work in two ways: media synchronicity can lead to convergence in teams that work together well, but media synchronicity may also negatively influence team coordination processes when team members notice that other team members perform less well, such as reduced initiative taking. This potential downside of media synchronicity should be addressed in further research.

The expectations on the effects of synchronicity of interactions and distribution of information were driven by the MST (Dennis et al., 2008; Dennis & Valacich, 1999). The present study was focused on the ability of electronic communication media to foster the convergence of cognitive structures and behaviour in virtual teams. A major limitation of the present study was that the expectations and methodology were not designed to distinguish between conveyance and convergence, since the present study was aimed at team coordination processes rather than communication processes. Future research should differentiate these processes, for instance by providing electronic documents and applications to participants rather than printed task materials. In this way, the processing and transferring of information can be distinguished, which makes it possible to relate these processes to conveyance and convergence.

Another limitation results from the use of the questionnaire on self-synchronization. The adjustments that were made to the questionnaire after Experiment 1 did not turn out well, as the reliability scores of two subscales decreased substantially. The low reliability score indicates that the questionnaire did not satisfactorily assess two aspects of self-synchronization in the present research. Future research should address the use of multiple communication media by virtual teams, because data suggest that the simultaneous availability of different types of media is relevant for coordination processes in virtual teams. This research should differentiate between conveyance and convergence processes, and specify the appropriation of different types of electronic media for these processes.

Conclusion

Many teams in business and the military are virtual in the sense that teams rely on electronic communication media for team member interactions. These media differ considerably to the extent to which media enable team members to interact synchronously and to the extent to which media can be used to distribute information among members of the team. The present research investigated to what extent virtual teams benefit from synchronous interactions and distribution of information when performing complex interdependent tasks.

The findings of the study largely contradicted expectations. Both synchronicity of interactions and distribution of information did not have major effects on team cognitive processes or team performance. In some cases, the results had to be attributed to methodological issues. However, other results led to theoretical questions. First, results indicated that the simultaneous use of synchronous and asynchronous communication media lead to higher communication overhead, because team members share information via both types of media rather than switch between media when sharing information and discussing shared information in the light of the team goals. As results suggested that this may negatively affect the perceptions of credibility of team members, it is possible that the parallel use of different types of media can affect virtual teams. For this reason, comparing different media configurations (rather than different media) could be helpful for addressing this issue in further research. Second, team cognition literature has focused on the similarity of team members' perceptions of the team (e.g., expertise, capabilities), the task (e.g., interdependency, equivocality), and the situation (e.g., opportunities, threats). While similarity of stable team- and task-related knowledge is well-established (see Lim & Klein, 2006), less is known about the importance of holding similar knowledge on the situation (Rico et al., 2008). The results of the present research suggest that virtual teams experience difficulties to establish and maintain similar team situation models.

Chapter 5

General discussion

Introduction

The present research was intended to develop a better understanding of coordination in virtual teams and to determine which factors foster effective coordination. This chapter discusses the theoretical and practical implications of the findings, and the strengths and limitations of the research.

All teams in the present research exclusively relied on technology for communicating and sharing information with other team members during task execution. Three empirical studies have been presented in three subsequent chapters. Experiment 1 was an explorative experiment in which we studied existing military teams in a simulated, but realistic environment. Teams in Experiment 1 used voice communication, messaging, and visual images. Experiments 2 and 3 were laboratory experiments in which teams performed a complex planning task. Teams in Experiments 2 and 3 used email and, in some conditions, a shared digital workspace. The extent to which teams rely on technology for team member interactions is one of the determinants of team virtuality in the framework of Kirkman and Rosen (2005). This means that all teams in the present research were virtual teams. It was decided to focus exclusively on virtual teams rather than comparing virtual and face-to-face teams. Conclusions therefore apply to virtual teams that exclusively rely on information and communication technology for team member interactions during task execution.

Experiment 1 investigated in which way level of authority and joint experience affected coordination in air defence command teams. These teams engaged in a realistic joint air defence task in a high-fidelity simulation environment of TNO. Level of authority and experience with multi-service operations (‘joint’) were studied for their expected influence on communication, self-synchronization, and team performance. Level of authority was manipulated by giving the teams more authority in handling incidents without direct supervision from the higher command level. In this condition, teams had the freedom to collaborate directly with other-service teams that worked in the same mission. Joint experience was studied by comparing teams with different levels of joint experience.

Experiment 2 investigated the effects of leadership style on coordination processes in virtual teams by comparing a participative with a directive leadership style. Leadership style was manipulated by giving team leaders a leadership training before executing the planning task. Coordination processes that were studied in this experiment were team information processing, team situation models, and self-synchronization. This study was conducted at a research facility of TNO.

Experiment 3 investigated the effects of media synchronicity and distribution of information on coordination processes and team performance of virtual teams. Media synchronicity and distribution of information are two factors that are related to information and communication technology. Media synchronicity refers to the extent to which media allow synchronous interactions between team members. Media synchronicity was manipulated in this experiment by adjusting the configuration of media. A team performed the planning task either using only email, or using both email and a shared digital workspace. The second factor was distribution of information, which refers to the extent to which all team members have access to the same information. Distribution of information was manipulated by giving team members either unique information or giving team members shared information. Coordination processes studied were team situation models, self-synchronization, and communication. This experiment was conducted at the NLDA.

Findings and theoretical implications

This section discusses first the results that were found regarding coordination processes and after that the focus is on the factors that have been manipulated in the three studies.

Coordination processes in virtual teams

The implicit coordination processes studied were team information processing, team situation models, transactive memory systems (TMS), and self-synchronization. Explicit coordination was studied by analyzing the communication between team members.

Team information processing. Team information processing involves the sharing of information, ideas, or cognitive processes among team members and how this helps teams to accomplish their goals (see Hinsz, Tindale, & Vollrath, 1997). Team information processing was assessed using Likert-scales for information sharing, lack of overview, and tunnel vision. Results indicated that a participative and delegating leadership style positively affected team information processing in virtual teams. Teams that had leaders with a participative, delegating leadership style reported that they were better able to share information with other team members and experienced less tunnel vision when compared to teams that had leaders with a directive leadership style. These outcomes are consistent with theories on virtual teams that participation of team members positively affects team information processing (Curşeu, Schalk, & Wessel, 2008; Kahai,Sosik, & Avolio, 1997; 2004). Further, this finding provides empirical support for the view that team leadership style plays an important role in team information processing in virtual teams (Bell & Kozlowski, 2002; Cascio & Shurygailo, 2003; Zaccaro, Rittman, & Marks, 2001).

Further, sharing information was positively related to self-synchronization, and lack of overview was negatively related to self-synchronization. Since team members have to process information in order to make decisions on complex, interdependent tasks, these correlations suggest that team information processing is related to the ability of team members to synchronize their decisions and actions with other team members. This finding shows that a participative leadership style is positively related to information processing at the individual level, and suggests that a participative leadership style enables team members to synchronize their decisions and actions with other team members. These findings are consistent with theories on virtual team leadership that team leaders have a major impact on coordination processes in virtual teams (Bell & Kozlowski, 2002; Zaccaro, Ardison, & Orvis, 2004).

In sum, the outcomes are consistent with theory on virtual teams that participation of team members positively affects team information processing, and that team leaders play an important role in establishing effective coordination in virtual teams (Bell & Kozlowski, 2002; Hambley, O'Neill, & Kline, 2007; Kahai, Sosik, & Avolio, 1997; 2004). This means that for virtual teams that perform complex, interdependent tasks in dynamic environments, may profit from participation of team members for the selection and utilization of information on the task.

Transactive memory systems. TMS were expected to positively affect team coordination processes and team performance, because knowledge about the distribution of expertise within the teams is assumed to help teams to perform better on complex, interdependent tasks (e.g., Liang, Moreland, & Argote, 1995; Moreland & Myaskovsky, 2000). TMS were assessed by Lewis' scale of TMS (2003). Two factors were studied for their effects on TMS.

First, media synchronicity did not affect the development of TMS and did not positively affect team performance. This outcome suggests that media synchronicity is not important for virtual teams to develop their TMS. This finding is contradictory to theories on TMS that providing opportunities to team members to learn about other team members' roles and expertise is important for the development of TMS (e.g., Liang et al., 1995). On the other hand, previous research has shown that providing team members with information about other team members' roles and expertise can also facilitate development of TMS (Moreland & Myaskovski, 2000). It is possible that team members relied on information from the instruction for the development of TMS, and that they did not improve their TMS during task execution, which means that higher levels of media synchronicity provided little advantage for this.

Interestingly, media synchronicity negatively affected team members' perceptions regarding the credibility of the expertise of other team members, one of the aspects of TMS. This outcome is contradictory to theories on TMS, where better opportunities to learn about the roles and expertise of other team members are positively related to perceptions of the credibility of the expertise of other team members (e.g., Liang, 1995; Kamphuis, Gaillard, & Vogelaar, 2009b). The negative effect of media synchronicity on the perceptions of the credibility of the expertise of other team members may be explained by an unexpected effect of media synchronicity. When team members use media that are high in synchronicity, they continually can see the actions of other team members (e.g. entering information in a shared digital workspace), which can negatively affect the perceptions of the credibility of other team members. The findings have implications for theories on TMS in that it appears that the development does not require synchronous information and communication technology when team members already have information on the roles and expertise of other team members.

Second, the distribution of information did not affect the development of TMS in virtual teams, and did not affect team performance. Apparently, working with shared information did not help team members to gain more knowledge on the distribution of expertise within the team and how this expertise had to be integrated. It was expected that teams could profit from higher levels of shared information for the development of TMS (Mohammed & Dumville, 2001). The results provided no support for this expectation. Again, it is possible that team members developed their TMSs using information from the instruction, and that shared information offered little benefits for this during task execution.

In sum, the manipulations of media synchronicity and distribution of information did not affect the development of TMS, which suggests that neither of these technological factors seems to be important for the development of TMS in virtual teams. A possible explanation of this finding is that virtual teams seem to be capable to develop a good TMS when they are given information on the roles and expertise of other team members beforehand. A downside of the lack of effects is that this makes it hard to draw solid conclusions on the importance of technological factors on TMS building in virtual teams.

Team situation models. Cooke, Stout, and Salas (2001) and Rico, Sánchez-Manzanares, Gil, and Gibson (2008) proposed that situation-dependent information is important for teams to develop a dynamic understanding of the environment. Rico et al. (2008) proposed that team situation model similarity is particularly important for establishing effective coordination in virtual teams, because team members lack the ongoing interpersonal communications that characterize face-to-face teams. Therefore, it may be particularly important for virtual teams to establish similar team situation models.

Log files were used for the analysis of team situation model similarity. None of the factors that were studied in this thesis helped teams to improve the similarity of their situation models. No evidence was obtained that the development of team situation model similarity was affected by leadership style or factors related to information and communication technology. Also, no relations were obtained between team situation model similarity and other team coordination processes. In contrast, research by Rasker and colleagues (Rasker, 2002; Rasker, Post, & Schraagen, 2000) showed that communication between team members during task execution helps teams to establish similar team situation models. This may be explained by differences in the design of the studies. Rasker and colleagues manipulated communication by comparing teams that could only send standardized email messages and teams that could send standardized email messages *and* could communicate verbally, whereas all communication in the present research was mediated by technology. It is likely that establishing similar team situation models may be more difficult when team members can only communicate via typed messages and a shared digital workspace, than via verbal communication (face-to-face, by telephone, or videoconferencing).

Another finding was that the similarity of team situation models decreased over time. This indicated that virtual teams have problems to maintain similar team situation models when situations get more complex. This is consistent with the argument of Rico et al. (2008) that team members need ongoing interpersonal communication in order to develop a shared understanding of the situation. Future research should be focused what media characteristics are related to the development and maintenance of team situation model similarity in virtual teams that perform complex tasks (see Dennis, Valacich, & Fuller, 2008).

In sum, the findings on team situation models indicate that virtual teams find it hard to establish similar team situation models, since the scores for team situation model similarity were low in Experiments 2 and 3. This suggests that maintaining or increasing team situation model similarity may require richer media than were used in the present research. This issue should be addressed in further research.

Self-synchronization. The concept self-synchronization was introduced to describe how virtual teams anticipate on the actions of other team members and adjust their own behaviour accordingly. The concept was developed to underline the consequences of computer-mediated communication for implicit coordination in teams. Self-synchronization was measured by a self-report scale that was developed in this research (see Experiment 2).

Self-synchronization was affected by three factors: level of authority, joint experience (under conditions of low levels of authority), and leadership style. The findings are consistent with theories on implicit coordination that describe that team-related factors (leadership style, experience) and organizational factors (level of authority) affect implicit coordination in teams (e.g., Espinosa, Lerch, & Kraut, 2004). The outcomes of the experiments show that this also holds for virtual teams, since self-synchronization was improved by enhancing authority levels and by the participative leadership style of team leaders. However, the lack of effects of technological factors is inconsistent with theories on implicit coordination. Our findings provide no support for theories that propose that media synchronicity is important for effective coordination in virtual teams, which is proposed in MST (Dennis & Valacich, 1999; Dennis, Valacich, & Fuller, 2008). Further, no evidence was obtained that shared information is important for effective coordination in teams, as was proposed by MacMillan, Entin, and Serfaty (2004).

The findings of the present research have implications for current models of team coordination in virtual teams by demonstrating that self-synchronization can be enhanced by organizational and team-related factors, but no evidence was obtained that technological factors affect self-synchronization.

Communication. Log files were used for the analysis of communication. Results indicated that level of authority affected communication. In Experiment 1 teams communicated less with higher organizational levels and more with other units working in the same mission, which positively influenced self-synchronization and performance. Level of authority did not affect communication between team members. Further, indications were observed in Experiment 3 that media synchronicity enabled teams to communicate less, but this trend did not reach significance. It was concluded that overlap in the capabilities of media to share information may lead to redundant use of media, which therefore did not reduce the amount of communication between members of the team.

Communication is important for coordination in teams because team members need to exchange information, discuss information, find solutions, and provide feedback to other team members. Communication is considered to be affected by the use of information and communication technology since communicating may take more time and cognitive resources (McGrath & Hollingshead, 1994). Consistent with this view, the findings of Rasker, Post, and Schraagen (2000) demonstrated that restrictions in communication because of the use of information and communication technology negatively affect coordination and performance.

The findings of Experiment 1 generally support the view that the use of technology influences communication, but there were no effects of media synchronicity and distribution on information on communication in Experiment 3. The findings in Experiment 3 may be caused by differences between the media used in these experiments. While teams used voice communication, messaging, and visual images in Experiment 1, teams used typed messages in Experiment 3. According to the framework of Kirkman and Rosen (2005), communication is positively related to coordination processes and performance in teams that are low in virtuality (e.g., videoconferencing teams), (see Martins, Maynard, & Gilson, 2004). Alternatively, teams that are high in virtuality (e.g., teams that use email) experience difficulties to make effective use of media (e.g., Cornelius & Boos, 2003). The lack of results in Experiment 3 is attributed to the ineffective use of the synchronous media configuration, which indicate that further research on the role of communication in virtual teams for different levels of virtuality is needed to address this issue, and to what extent virtual teams can adapt to media over time (see Van der Kleij et al., 2004; 2005; 2009).

S*elf-report and log file data.* All experiments featured a mix of self-report (questionnaires) and log file data. It was observed that correlations between these types of measures were low. A possible explanation for this finding is that team members' perceptions of the coordination between them differed from their behaviour. For instance, it is possible that team members entered a different route on the planning form (team performance), while team members were convinced that they all worked on the same route (self-synchronization). These differences between perceptions of team processes and behaviour are also found in other research (e.g., Kamphuis, Gaillard, & Vogelaar, 2009a). For the present research, the low correlations indicate that team members' behaviour was also affected by other team processes, such as motivational (i.e., group cohesion, collective efficacy) and affective processes (i.e., team composition). This suggests that research on coordination processes will profit from a mix of data sources and measures for other team processes that may influence team members' behaviour. Further, measuring coordination processes via multiple methods may increase our understanding of coordination processes in teams.

Factors affecting coordination in virtual teams

Level of authority. Experiment 1 showed that level of authority did affect coordination processes and team performance. A higher level of authority for the air defence command teams positively affected explicit coordination. With higher levels of authority the air defence command teams communicated more with other units that had capabilities relevant to the task. Contrary to our expectations, level of authority did not affect communication within the team. Of the processes determining implicit coordination, only self-synchronization was affected by the level of authority. Higher levels of authority enhanced both horizontal and vertical integration of the actions of team members, which means that team members were better able to integrate their actions with the overall team goals (vertical integration) and with other team members and other networked units (horizontal integration). However, level of authority did not affect the other two aspects of self-synchronization, event handling and initiative taking. Results demonstrated that with decentralization critical incidents were better handled and overall team performance was increased.

The results of the group discussions indicated that the team leaders played an important role in making effective use of the increased levels of authority. Team performance did only improve when team leaders reconsidered the new roles and responsibilities of team members and gave instructions to team members to make optimal use of the new possibilities. Further, team members indicated that some team leaders were fully occupied with processing information themselves during critical incidents, which negatively affected the execution of subtasks by team members. For instance, these team leaders did not provide team members with information on time or did not give permission to act on time. This finding indicates that the effectiveness of delegation of authority depends on the way that team leaders make use of increased level of authority.

In sum, the findings of Experiment 1 imply that higher levels of authority positively affect coordination processes and performance. However, team members seemed to profit only when team leaders encouraged them to do so. These results are consistent with the research of Schraagen et al. (2010), who investigated the effect of authority by comparing hierarchical and networked teams. These authors found that higher levels of authority in networked teams (decision rights, availability of information, information sharing, and task division) positively affect team performance on difficult tasks. The present results indicate that increasing the authority level is beneficial for virtual teams that perform difficult tasks when team leaders encourage team members to participate in decision making, or delegate some authority to team members. In line with other research on leadership, the findings of the present study imply that team leaders have to be trained to meet the demands of leading virtual teams in decentralized organization structures (e.g. Zaccaro et al., 2004; Hambley et al., 2007).

Joint experience. Experience was the second factor that was investigated in Experiment 1. Joint experience was operationalized as the experience team members with working with teams from other services. Based on prior research on the role of experience in command and control teams (e.g., Cooke et al., 2007) and the theory on networked military operations, it was expected that joint experience would help air defence command teams to enhance team coordination and enable teams to make effective use of their extra authority to collaborate with other networked units.

Results showed that joint experience facilitated self-synchronization, but only when teams had a low level of authority. Further, joint experience positively affected overall team performance. Again, this difference was only observed in the condition in which teams had a low level of authority. These results provide us with no support for the positive effects of joint experience in decentralized command structures. Interestingly, our findings relate to those of Cooke et al. (2007), who found that experienced teams are able to transfer previous command and control experience to different tasks, but that this is only a performance benefit. Contrary to their expectations, command and control teams did not learn how to perform different command and control tasks better than inexperienced teams. Cooke et al. (2007) concluded that prior experience gave teams a performance benefit, but not a learning benefit. The expected learning benefit was also not found in the present research. As the teams were used to work in the centralized command structure, here we found the same performance benefit that Cooke et al. (2007) reported. As the decentralized command structure was new for the teams, there was no indication that experience working together in a command and control setting transferred to this new setting.

Leadership style. It is emphasized in the literature on virtual team leadership that leaders are important for coordinating the actions of members of virtual teams, who may be working across locational, temporal, and relational boundaries (Zaccaro et al., 2004; Hambley et al., 2007). As was discussed under level of authority, the results of Experiment 1 supported the importance of team leaders in virtual teams. The extent to which teams made effective use of extra authority depended on the actions of team leaders to let team members participate in coordination processes and to delegate (sub)tasks to team members.

Experiment 2 examined in which way leadership style affected coordination processes and performance. Results confirmed expectations that a participative leadership style positively affected team information processing and self-synchronization, but it did not positively affect team situation model similarity or team performance. Further, team situation model similarity decreased during task execution under both leadership styles.

The absence of differences between teams with participative and directive leaders regarding team situation model similarity suggests that leaders may have had limited possibilities to enhance the similarity of situation models between members of the team. This finding converges with the decrease in the similarity between team situation models in both conditions, indicating that members of virtual teams have increasingly different understandings of the situation during task performance. It appears that virtual teams suffer from the lack of ongoing, interpersonal communication in developing a shared understanding of the environment, as was proposed by Rico et al. (2008). Further, it was demonstrated by Rasker and colleagues (Rasker, 2002; Rasker et al., 2000) that restrictions in communication negatively affect the development of situational knowledge. Taken together, it appears that virtual teams experience difficulties in developing similar team situation models. Nonetheless, it is important for virtual teams to establish similar situation models in order to establish coordinated action. This clearly calls for future research on the possibilities of team leaders to influence coordination processes that involve situational information.

In summary, the findings of Experiment 2 indicate that a participative, leadership style may help team members to process more effectively task-relevant information and to synchronize their actions. This finding is consistent with theories on virtual team leadership that characteristics of virtual teams (e.g., working across locational, temporal, and relational boundaries, flexible membership) call for participative, delegating leadership styles (Bell & Kozlowski, 2002; Cascio & Shurygailo, 2003; Zaccaro et al., 2004). However, it appears that it is difficult for team leaders to influence the coordination processes involving situational information. This outcome contributes to theories on virtual team leadership (Zaccaro et al., 2004; Hambley et al., 2007) that it may be more difficult for virtual team leaders to influence coordination processes that involve situational information.

Media synchronicity. Media synchronicity was described as the extent to which media enable synchronous interactions between members of virtual teams (see Dennis, Fuller, & Valacich, 2008).

Results demonstrated that media synchronicity did not affect coordination processes and performance. No main effects were found for TMS, team situation models, self-synchronization, communication, and performance. Additional analyses revealed that some aspects of coordination were affected. Contrary to expectations, media synchronicity *negatively* affected perceptions of team member credibility (a subscale of TMS), team situation model similarity at the end of the task, and initiative taking (a subscale of self-synchronization). These results may be explained by assuming that in the synchronous media configuration, team members could observe the actions of other team members in the shared workspace (e.g., entering or altering information), which may have negatively affected perceptions of team member credibility. For instance if team members noticed that other team members performed their task slowly or poorly, this may have negatively affected team member credibility. Although this explanation could not be tested, the outcomes suggest that media synchronicity can potentially lead to negative perceptions of coordination in virtual teams that perform complex, interdependent tasks.

In contrast with expectations, teams using a synchronous media configuration did not differ from teams that used an asynchronous media configuration for the amount of communication. A strong reduction in the use of email was expected here, because there was no need to share information through email messages when information could be shared via a digital workspace. However, teams that used asynchronous media did not differ in their use of email from teams that used synchronous media. It was concluded that virtual teams may find it difficult to switch between different types of media for sharing information and discussing information to accomplish the task. The way in which teams used electronic communication media for sharing information and communication may explain why team performance did not profit from media synchronicity. Dennis and colleagues used the concept of *media appropriation* to describe the extent to which individuals use media as intended (Dennis & Reinicke, 2004; Dennis et al., 2008). The redundant use of email and the shared workspace in the synchronous condition suggests that team members did not use the media as intended, which may have affected the amount of cognitive resources that team members allocated for the sharing of information. Team members were not used to using a shared digital workspace, and this may be the reason that team members shared information both by email and in the shared workspace. This may have diminished the expected positive effects of interaction through media synchronicity.

The results of the study contribute to the theory on media synchronicity (Dennis et al., 2008) by demonstrating that higher levels of media synchronicity on a complex, interdependent task may not affect team coordination processes and team performance when teams use multiple media. The present research suggests that teams may experience difficulties to the different media as was intended (sharing information in the shared digital workspace, and discussing shared information via email messages). Since there is little research on the use of multiple media in virtual teams, the findings suggest that the use of media configurations that have overlap in their capabilities may not enhance coordination in virtual teams.

Distribution of information. The results of distribution of information were not in line with expectations. Teams that had shared information did not differ from teams that had unique information on any of the team coordination or performance measures. Three possible reasons were proposed to address these unexpected findings. First, when team members completed their tasks correctly, the added value of information on other AORs may have been limited. In this situation, checking information on the AORs of other team members did not help teams to coordinate better or to construct a better planning. Second, team members did not make effective use of the information on AORs of other team members, because they were fully occupied with their own task. Team members had to perform several tasks during the experiment, such as obtaining information from the task materials, sharing information with team members, and construing a planning. It was proposed that all these activities left limited possibilities for other activities such as helping other team members or checking the accuracy of information of other team members. The third explanation for the obtained results may be the type of task used. The majority of research on distribution of information used so-called hidden profile tasks (for a discussion, see Wittenbaum, Hollingshead, & Botero, 2004). Hidden profile tasks are designed in a way that information that advocates the best alternative is largely not shared, so that team members have to share unique information in order to reach the optimal outcome. Our hypotheses were based on this kind of research. However, the present planning task did not feature a hidden profile. Teams received no information that advocated a specific solution, and teams had to process all information to arrive at the best route. Since all information contributed to team performance, the differences between the unique and shared conditions were less dramatic as compared to hidden profile tasks. Although this design was chosen to reflect the use of electronic communication media in virtual teams, the results did not yield evidence that distribution of information helped teams to perform a complex, interdependent planning task.

In sum, the findings suggested that use of electronic communication media for distributing information across all members of the team did not affect coordination processes in this study. The findings contribute to theories on information processing in virtual teams (for an overview, see Curşeu et al., 2008) that the expectation that virtual teams are able to overcome biases in information processing (e.g., not using all relevant information) may not be warranted.

Practical implications

Virtual teams are found in many organizations, performing a wide variety of tasks. Virtual teams typically consist of team members with different expertise and capabilities, which increases the amount of knowledge and capabilities that teams can use when performing tasks. The findings of the present research can be used by organizations to improve the effectiveness of virtual teams, by exploiting the benefits and minimizing the drawbacks of virtual teams. Practical implications are discussed separately for two different aspects of team performance: leadership style and the use of information and communication technology in teams that are high in virtuality. Further, practical implications for networked military operations will be formulated.

Leadership style. The findings indicate that participation of team members in decision making is important for virtual teams to establish coordinated action. Literature on virtual team leadership (Bell & Kozlowski, 2002; Hambley et al., 2007; Zaccaro et al., 2004) indicates that virtual teams find it hard to coordinate team member actions into coherent actions. Participation of team members may help to coordinate their actions more effectively. In virtual teams, team members may complete their tasks individually, until it becomes important that their actions have to be integrated. To establish this, team leaders should encourage team members to participate in finding the optimal way to coordinate their actions, and seek to delegate (sub)tasks to team members. Virtual teams profit from participative, delegating leadership styles when working in complex and dynamic environments, where they have to adapt to unpredictable change. This requires teams to reconsider existing routines and to develop new ways to reach their goals. Team coordination heavily relies on the input and feedback of team members, and therefore participation of team members in the decision process is important (Burke et al., 2006; LePine, 2005). Changes in the individual tasks of team members may affect the activities of other team members, and therefore the team has to reconsider how to accomplish its goals. Team member participation is important in this process because team members have to discuss alternatives and establish consensus on how to adapt to the new situation. When team leaders share authorities with team members, this enables team members to take over some of the leadership functions. This helps teams to share workload and make effective use of available resources.

An important limitation of virtual team leadership is that the different backgrounds and individual perspectives of team members make it hard to develop similar perceptions of the situation. The findings of Experiments 2 and 3 indicated that virtual teams experience difficulties to establish and maintain similar team situation models, which are considered to have a positive effect on team coordination and performance (Rico et al., 2008). Although the present findings did not indicate that team leaders can facilitate team situation model similarity, we propose that team leaders may help team members to develop a similar understanding of the situation by involving team members in decision making processes and by delegating (sub)tasks to team members. This can take the form of providing team members with situational information and discussing his or her opinion on the situation at hand, or delegating situational assessment to team members. Further research should make clear to what extent virtual team leaders can foster the establishment of similar team situation models in virtual teams, and if they can be trained to do this.

Information and communication technology. We propose that team leaders have to make a selection of the different types of media that can be used for communication in virtual teams. Experiment 3 was based on the assumption that virtual teams may communicate via different types of media, and that different media are used for sharing information and discussing information that has been shared in the light of the team goals. The findings indicated that members of virtual teams do not switch between different media for different types of communication (e.g., emails for sharing information and chat for discussing the best alternative), but use different types more or less simultaneously. We propose that this redundant use of communication media can potentially diminish the benefits that are associated with using electronic communication media in teams, and that it may be wise to minimize the overlap of media capabilities when teams use multiple media simultaneously

Implications for networked military operations. The research that was presented in this thesis was aimed at gaining more insight in coordination processes in virtual teams and investigating what factors foster effective coordination in virtual teams. At the same time, the findings may also be applied to networked military operations.

First, the findings on joint experience show that prior command and control experience did not affect the ability of teams to adapt to new, decentralized command structures. These findings suggest that it is beneficial to invite all teams in the network that have relevant capabilities for an operation, regardless of their level of joint experience.

Second, many military teams can share information and communicate via multiple media in networked military operations (i.e., datalinks, local digital radio, mobile devices). The findings of Experiment 3 imply that it may difficult to switch between media for sharing information and discussing information. This may lead to redundant sharing of information, and military teams may not make optimal use of the possibilities that electronic communication media offer for information sharing and communication in complex and dynamic environments. Teams that participate in networked military operations may therefore profit from training and guidelines that are focused on the effective use of multiple media in these environments.

Third, the findings of Experiments 2 and 3 suggest that the establishment of similar team situation models may be difficult when team members rely exclusively on electronic communication media. As verbal communication has been shown to positively influence the establishment of similar team situation models in teams (Rasker, 2002; Rasker et al., 2000), it may be important that virtual teams can communicate unrestrictedly. In terms of the Media Richness Theory (Daft & Lengel, 1987), the use of rich media may be important for this.

Strengths and limitations

The present research was intended to study coordination in virtual teams. The research examined factors that are assumed to influence the effectiveness of virtual teams. Research was conducted to determine in what way team members of virtual teams coordinate their decision s and actions with those of other team members during team performance.

The strength of the present research is that coordination processes were studied in different environments. Experiment 1 was an explorative experiment that was conducted in a simulated, but realistic setting. This enabled us to study coordination processes in existing teams in a realistic setting. Further, establishing some level of control made it possible to examine the effects of two factors as well. Coordination processes were studied in controlled settings in Experiments 2 and 3. Since the relations between factors, team processes, and outcomes are complex in team research, controlled experiments are an effective research methodology for disentangling the multiple factors that influence team processes. Combining these two types of experiments allowed us to gain more insight in coordination processes in virtual teams in comparison to research that studies coordination processes in a single setting.

Another strength of the present research was the mix of data sources. A mix of log file and self-report data was used in all experiments. It was discussed above that low correlations were observed between different sources of data, indicating that the perceptions of coordination processes differ from team members' behaviour. Developing reliable and valid measures remains to be an important issue in team research (see also Cooke, Salas, Cannon-Bowers, and Stout, 2000). The development of measures in team research is an ongoing process and it appears that an effective way to gain a better understanding of team processes is to assess team processes via multiple measures.

Further, the present research featured a set of factors that were related to the team, the organization, and the context in which the teams worked. Contextual factors were technological factors. Investigating the effects of a variety of factors gave us the advantage of gaining a deeper understanding of coordination processes in virtual teams, rather than focussing on a single aspect.

Limitations of the present research result from methodological issues. The goal of Experiment 1 was to gain more insight in coordination processes in virtual teams by studying existing military teams in a realistic environment. The study had a explorative research approach (e.g., realistic environment, existing teams, diverse measures) while some level of control over the environment was established by using scenarios , by varying the command structure, and by inviting teams with different levels of joint experience. However, this study faced us with several methodological issues. First, the exploration of a new command structure inherently means that observers were not blind to conditions. Second, learning effects may have occurred regarding the roles and responsibilities, and regarding the task itself. Third, it is possible that learning effects have confounded with the manipulation of level of authority. We propose that all possible measures have been taken to reduce the possibility that these issues have influenced the results of Experiment 1. These measures were discussed in detail in Chapter 2. However, no empirical support can be presented that these measures were sufficient for dealing with these methodological issues.

Another limitation resulted from the manipulation of joint experience. This factor was manipulated by inviting existing air defence command teams that differed in their experience with working in joint operations. However, there were considerable differences between teams that had similar levels of joint experience regarding the extent to which team leaders shared the extra authorities with team members, and communication between the team and the higher level. The differences between teams with similar levels of experience made it difficult to determine the effects of joint experience on team coordination in networked operations and the importance of joint information for making effective use of extra authority in decentralized command structures. The present research also contained several limitations that resulted from the problems with the development of the self-synchronization questionnaire. The adjustments that were made to the self-synchronization questionnaire on the basis of the results of Experiment 2 did not improve the quality of the questionnaire in Experiment 3. The self-synchronization questionnaire had relatively low correlations with other team process measures and lower scores for within-group agreement. This indicates that team members differed on their perceptions of self-synchronization.

Finally, the research considered two types of teams. Teams that participated in Experiment 1 were professional teams, and had a history of working together. These teams would also be working together in the future. Alternatively, teams that participated in Experiment 2 and Experiment 3 were so-called short-term terms. These teams were formed shortly before the experiment, and abandoned when the experiment was finished. In other words, these teams have no history and would not be working together in the future. Short-term teams may show less effort to adapt to other team members and to the media (e.g., Cornelius & Boos, 2003; Walther, 1992). This means that teams that participated in Experiment 2 and Experiment 3 may have had reduced motivation to use the media as was intended.

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Summary

Background

Similar to other organizations, military organizations use information and communication technology to coordinate their actions in many situations. Military operations have a strong focus on establishing coordinated action, ‘synchronization’, in particular in complex and dynamic operational situations when actions have to be adapted to emerging conditions. Military operations are ‘tight’ by nature, as the activities of a unit directly affect the activities of another unit. Therefore, effective coordination of actions by several units is important.

Networking the contributions of dispersed teams, by timely coupling their capabilities, competencies and resources, results in more flexible and adaptive, ‘agile’, command and control processes. Military operations where information and communication technology is used for the synchronization of the actions of teams or units are labelled *networked military operations*. Theoretical foundation is sought in complexity science, and theorists on networked military operations particularly refer to the concepts of emergence and self-synchronization in order to explain the kind of dynamic they aim to capture. Emergence refers to bottom-up processes in which behaviours of individuals are amplified by interactions with others, and lead to collective action. Self-synchronization is used in theory on networked military operations to describe the alignment of actions of teams that are networked through information technology, without direct control from the higher level.

Teams that participate in networked military operations are faced with increased demands regarding team coordination, including information processing, developing dynamic understanding of the environment, anticipating on the actions of other team members, other teams and future task states, and adjusting own behaviour accordingly. Therefore, gaining more insight in team coordination processes at the team level in teams that are networked through technology is crucial for developing effective, networked military organizations.

Present research

Teams are called ‘virtual teams’ if the team members’ interactions are to a large degree mediated by information and communication technology, such as email, chat, and digital workspaces. The technology is used for distributing information and for facilitating interactions between team members. Virtual teams can perform their task while being dispersed geographically, in time, or across different organizations.

Despite the benefits that information and communication technology offers to organizations in terms of flexibility and adaptability, research indicated that virtual teams also may have their drawbacks. Research on virtual teams has demonstrated that information and communication technology can have negative effects on team processes and performance. Team processes that were negatively affected are: the establishment of effective communication, interpersonal relations, shared vision, and mutual knowledge. These drawbacks have been attributed to the decrease of social cues in computer-mediated communication, difficulties that virtual teams experience in the development of trust, and the reduced informal and non-task communication. Members of virtual teams reported lower levels of communication between the members, lower levels of satisfaction with group processes and higher levels of frustration. Effects of information and communication technology on team performance levels were mixed: both negative and positive effects were found, while other studies reported no differences. In attempting to gain more insight in coordination in virtual teams, the present research was intended to analyse how virtual teams coordinate their actions and further to determine which factors foster effective coordination in virtual teams:

> *Research question 1:* How do team members in virtual teams coordinate their actions with those of other team members during team performance?
>
> *Research question 2:* What factors foster the effective coordination of team member contributions in virtual
> teams?

Team coordination

When teams perform complex, interdependent tasks, team members often have different roles, responsibilities, expertises, and resources. Team coordination refers to the effective management of mutual dependencies between the actions of the team members. Team coordination refers to the process of orchestrating the sequence and timing of interdependent actions in teams that perform complex, interdependent tasks. Team coordination processes are either explicit or implicit. Coordination processes are explicit when team members use them purposely for coordination. Explicit coordination is effective regarding tasks that have many routine aspects and when there are no changes in the task or in the environment that interfere with the routines of teams. For tasks and environments that are characterized by higher levels of change, explicit coordination mechanisms are less optimal because these coordination mechanisms can be time-consuming and often do not offer the flexibility that is required for dealing with change in the task or in the environment. Teams will rely on implicit coordination in these situations.

Implicit coordination may be described as the synchronization of member actions based on unspoken assumptions about what others in the group are likely to do. When team members interact with each other and become experienced in a task, team members develop shared knowledge of the team and the task. This shared knowledge enables members of a team to anticipate to the needs and actions of others and adjust their behaviour accordingly without having to communicate directly with each other or plan the activity of coordinating.

The research considers five aspects of team coordination. Team processes that are related to implicit coordination are team information processing, transactive memory systems, team situation models, and self-synchronization. Explicit coordination is studied by means of communication. Three experiments were conducted in order to answer the research questions.

It was investigated in Experiment 1 in what ways level of authority and joint experience affected team coordination in existing air defence command teams. These factors were studied to address the effects of decentralization of decision-making authority and the effects of experience to work with team from other services on team coordination. A explorative experiment was conducted in which air defence command teams engaged in a simulated, but realistic joint air defence task. Level of authority was manipulated by adjusting the command structure on the second session. Air defence teams were given more decision-making authority by delegating the authority to handle incidents without direct control from the higher level, and moreover teams were given the freedom to collaborate directly with other networked units. Joint experience was studied by selecting teams with different levels of joint experience.

Experiment 2 examined in what way leadership style affected team coordination and performance. Participative leadership styles refer to leadership styles in terms of team member participation. Team leaders can adopt leadership styles that do not include participation of team members (directive leadership styles), or team leaders can involve team members in decision making and/or share their responsibilities with team members (participative, delegative leadership styles). It was hypothesized that participation of team members is important for virtual teams because team members may come from different organizations, may enter and leave the team depending on their specific role or contribution, and the limitations of team leaders to execute leadership functions in virtual teams. Experiment 2 was designed to test these expectations. Three-person teams engaged in a complex planning task. Team leaders were assigned randomly, and received either a directive or a participative leadership training prior to task execution.

Experiment 3 was focused on two characteristics of information and communication technology. First, media synchronicity was described as the extent to which media enable synchronous interactions between members of virtual teams. Media synchronicity was considered to be important for virtual teams that perform complex, interdependent tasks because team members can work together at the same time with a shared pattern of coordinated behaviour. It was expected that media synchronicity would positively affect team coordination in virtual teams. Media synchronicity was manipulated in Experiment 3 by adjusting the configuration of the electronic communication media that were available to teams. Teams that used a synchronous media configuration could use both email and the shared electronic workspace, whereas teams that used a media configuration that was low in synchronicity could only use email.

The second factor that was addressed in Experiment 3 was distribution of information.
Distribution of information was described as the variability of how many group members have access to a piece of information. An important benefit of organizing work in virtual teams is that electronic communication media make it easy to share information within the team. Sharing information via shared digital workspace or storing documents on a network drive or the internet requires little effort of team members, and rapidly expands the pool of information that is available to the team. Therefore, having more task-relevant information available means that more information can be processed and therefore can be utilized in the creation of responses. Higher levels of information distribution were expected to positively affect team coordination. Distribution of information was manipulated by giving team members unique information versus shared information. The expectations of media synchronicity and distribution of information were studied in Experiment 3, where three-person teams performed a complex planning task.

Results and conclusions

Level of authority. The results of Experiment 1 showed that level of authority in a joint air defence command structure did affect team coordination and team performance. Regarding explicit coordination, level of authority affected communication between the air defence command teams and other teams. The air defence command teams communicated less with the higher level and more with other units that had capabilities that were relevant to the task. Level of authority did not affect communication within the team. With regard to implicit modes of coordination, results indicated that decentralization did affect self-synchronization. Results further demonstrated that level of authority improved team performance by better handling critical incidents and reaching higher levels of overall team performance.

The outcomes of the group discussions indicated that the effects of level of authority hinge on the way that team leaders adapt to the increased level of authority. Team leaders need to reconsider the roles and responsibilities of all members of the team in order to make effective use of the extra authority. Facilitating and stimulating team leaders in this process will be an important issue for leveraging the opportunities of networked military operations. The findings implies team leadership in virtual teams faces team leaders with extra demands, and team leaders have to be trained to meet these demands.

Joint experience. Experiment 1 also considered the effects of experience with working with teams from other services, or: joint experience, on team coordination. Results on joint experience indicated that this factor affected communication between teams and the higher level. In contrast to our expectations, team members communicated more with the higher levels, whereas no differences were found for communication between members of the team. Results also showed that joint experience positively affected self-synchronization. Further, joint experience positively affected team performance in terms of handling of critical events and overall team performance. Importantly, the differences on communication between teams, self-synchronization, and overall team performance disappeared in the condition in which teams were given higher levels of authority, indicating that joint experience helped teams to perform better on the first session, but higher levels of joint experience did not help teams to make effective use of the extra authority that was given to them on the second session. In other words, no support was found that joint experience helped air defence command teams to make effective use of the extra authority that were given to them.

Leadership style. Experiment 2 was focused on the effects of leadership style on coordination in virtual teams. Participative leadership styles fostered team information processing and self-synchronization, but it did not help teams to perform better. The findings that leadership style did not affect team performance converged with the decrease in the similarity between team situation models that was observed throughout task performance. This reduction indicated that members of virtual teams had increasingly different understandings of the situation during task performance. Further, the absence of differences between teams with participative and directive leaders regarding team situation model similarity suggests that virtual team leaders may have had limited possibilities to enhance the similarity of team situation models between members of the team.

The results of Experiment 2 indicated that team leaders affect some team coordination processes, but not others. The findings of the Experiment 2 indicate that participation of team members will help teams to process task-relevant information and synchronize their actions, but that technological mediation makes it difficult for team leaders to develop and maintain similar team situation models, which may lead to difficulties to operate effectively in complex and dynamic environments. Future research is needed to address what leadership styles are appropriate for virtual teams, and in which way team leaders can influence team processes that include situational information.

Media synchronicity. Results of Experiment 3 demonstrated that media synchronicity did not positively affect team coordination and performance. No effects were found for team coordination processes and performance. Additional analyses revealed that some aspects of team coordination were affected. However, contrary to expectations, media synchronicity *negatively* affected perceptions of team member credibility, team situation model similarity at the end of the task, and initiative taking. These effects were attributed to an unexpected effect of media synchronicity. Team members could observe the actions of other team members in the shared workspace, and this may have negatively affected team member credibility for instance if team members noticed that other team members performed their task slowly or badly. This may also have negatively affected the perception of initiative taking in the team. Another possible explanation for the lack of results may be that teams were not used to interact via multiple media, and that this affected coordination processes. Other researchers have argued that the motivation to learn how to use media may be lower for teams that are only formed for research purposes, than for teams that continue to work together after the research.

The results on explicit coordination yielded an interesting finding. In contrast with expectations, teams that used a media configuration that was high in synchronicity did not differ from teams that used a media configuration that was low in synchronicity for the amount of explicit coordination. Instead, higher levels of media synchronicity led to an *increase* in the effort teams devoted to communication. It was concluded that team members may find it difficult to switch between media for sharing information (shared digital workspace) and discussing shared information (email).

The results of the study contribute to theories on virtual teams by demonstrating that using multiple media for sharing and discussing shared information may not lead to better coordination processes or performance. The present research suggests that because of the potential redundant use of electronic communication media, media configurations should not contain media that have overlap in their capabilities to share information and discussing shared information.

Distribution of information. The results of Experiment 3 demonstrated that distribution of information did not affect coordination processes. Teams that had shared information did not differ from teams that had unique information on coordination or performance measures. Thus, giving all team members access to all information did not help teams to coordinate their efforts better and did not lead to better performance. These unexpected outcomes were attributed to a factor that is related to the task. Higher levels of distribution of information may not have affected team coordination processes because team members had to perform several activities for their individual tasks, which led to a reduced focus on anticipating on the actions of other team members and adjusting own behaviour accordingly. Although this design of the task was intended to reflect the use of information and communication technology in virtual teams, the results did not yield evidence that distribution of information helped teams to perform a complex, interdependent task.

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Samenvatting (summary in Dutch)

Achtergrond van het onderzoek

Stel je eens een infanterie peloton voor dat een dorp doorzoekt op de aanwezigheid van wapens of materialen die gebruikt kunnen worden voor het maken van geïmproviseerde bommen. Wanneer het peloton het dorp binnen gaat, zal niet meteen duidelijk zijn of er gewelddadige intenties zijn bij leden van de bevolking. De groepen die deel uitmaken van het peloton zullen spreken met leden van de plaatselijke politie, terwijl andere groepen huizen en andere gebouwen doorzoeken of de veiligheid in de gaten houden. De groepen kunnen hun activiteiten coördineren door gebruik te maken van radio en digitale apparatuur. Deze technologie stelt groepen in staat om met elkaar te communiceren en informatie met elkaar te delen. Dit maakt het mogelijk dat het peloton effectief gebruik maakt van informatie van de politie of in kan spelen op gebeurtenissen tijdens de doorzoeking. Op deze wijze kunnen groepen overleggen hoe ze iets zullen aanpakken of, indien nodig, vragen om assistentie.

In militaire operaties is het belangrijk dat leden van militaire eenheden hun activiteiten op elkaar afstemmen, ofwel coördineren. Goede coördinatie is belangrijk omdat militaire eenheden werken in omgevingen die complex (oorzaken en gevolgen zijn moeilijk van elkaar te onderscheiden) en dynamisch (aan veranderingen onderhevig) zijn. Deze eigenschappen zorgen ervoor dat complexe en dynamische omgevingen een zekere mate van onvoorspelbaarheid hebben. Om deze reden is de situatie ter plaatse bepalend voor de wijze waarop eenheden hun doelen bereiken. Dit betekent dat de doelen van een operatie vooraf vastgelegd zijn, maar dat *de wijze waarop* de doelen bereikt moeten worden niet op voorhand bepaald kan worden. Een andere eigenschap van militaire operaties is dat zij ‘strak’ georganiseerd zijn. Dit wil zeggen dat activiteiten van een eenheid direct van invloed zijn op de activiteiten van andere eenheden. In het eerder genoemde voorbeeld betekent dit dat de activiteiten van de groep die overlegt met de plaatselijke politie van invloed zijn op de activiteiten van de groep die het dorp doorzoeken (op de plaatsen die aangegeven worden door de eerste groep), en vice versa (bijvoorbeeld informatie over gevonden wapens wordt doorgegeven aan de groep die in overleg is met de politie).

Ontwikkelingen in informatie- en communicatietechnologie maken het voor leden van militaire eenheden steeds beter mogelijk om hun activiteiten aan elkaar te koppelen, door de capaciteiten, competenties en hulpbronnen van eenheden samen te brengen in een netwerk. Netwerken bieden de flexibiliteit en het aanpassingsvermogen die nodig zijn voor de aansturing van militaire operaties in complexe en dynamische omstandigheden. Militaire operaties waarin gebruik wordt gemaakt van informatie- en communicatietechnologie voor de coördinatie van activiteiten worden *genetwerkte militaire operaties* genoemd. In theorieën over genetwerkte militaire operaties wordt veel belang gehecht aan zelfsynchronisatie als wijze waarop leden van eenheden hun activiteiten met elkaar coördineren. Zelfsynchronisatie verwijst naar coördinatie van activiteiten door leden van eenheden via informatietechnologie zonder controle van hogere organisatieniveaus. Door de coördinatie van activiteiten uit te laten voeren door eenheden zelf, kunnen zij inspelen op veranderingen in de omgeving. Op dit punt wijken genetwerkte militaire operaties af van ‘traditionele’ militaire operaties, waarbij de coördinatie van de acties voor een belangrijk deel gebeurt vanuit een centrale commandopost.

De verschuiving van de verantwoordelijkheid voor coördinatie naar eenheden, zorgt ervoor dat eenheden zelf moeten zorgen voor informatieverwerking, het ontwikkelen van een gevoel voor de omstandigheden waarin zij opereren, anticiperen op de activiteiten van andere leden van de eenheid, andere eenheden en nadenken over mogelijke ontwikkelingen in de situatie in de nabije toekomst. Bovendien moeten eenheden hun eigen activiteiten aanpassen op deze mogelijke ontwikkelingen. Het is belangrijk om meer inzicht te krijgen in de coördinatieprocessen van eenheden die deelnemen aan genetwerkte militaire operaties omdat deze kennis kan worden gebruikt om de effectiviteit van genetwerkte militaire operaties te vergroten.

In termen van sociaalwetenschappelijk onderzoek zijn militaire eenheden teams, omdat leden van een eenheid een gemeenschappelijk doel hebben, van elkaar afhankelijk zijn om het doel te bereiken en samenwerken om dit doel te bereiken. Wanneer teamleden voornamelijk via informatie- en communicatiemedia met elkaar samenwerken wordt gesproken van *virtuele teams*. Voorbeelden van informatie- en communicatiemedia die gebruikt worden in virtuele teams zijn email, chat, datalinks en digitale werkplekken. Teamleden van virtuele teams kunnen hierdoor samenwerken terwijl zij gescheiden zijn van elkaar in termen van afstand en tijd, of werken voor verschillende organisaties. Het onderzoek is gericht op virtuele teams. Daarom zijn de uitkomsten van het onderzoek alleen van toepassing op teams waar teamleden uitsluitend communiceren via informatie- en communicatietechnologie.

Dit onderzoek gaat specifiek in op coördinatieprocessen in virtuele teams. Het onderzoek moet uitwijzen hoe teamleden van virtuele teams hun activiteiten op elkaar afstemmen en welke factoren van invloed zijn op effectieve coördinatie in virtuele teams. De onderzoeksvragen zijn:

> *Onderzoeksvraag 1:* Hoe stemmen leden van virtuele teams hun acties af met de acties van andere teamleden tijdens het uitvoeren van een taak?
>
> *Onderzoeksvraag 2:* Welke factoren helpen om de bijdragen van teamleden effectief te integreren in virtuele teams?

Het onderzoek

Hieronder worden de coördinatieprocessen en de factoren beschreven die bestudeerd zijn in het onderzoek, alsmede de wijze waarop het onderzoek is uitgevoerd.

C*oördinatieprocessen*. Coördinatieprocessen zijn *expliciet* wanneer teamleden bewust bezig zijn met coördinatie, zoals bij een werkoverleg. Expliciete coördinatie is vooral effectief in situaties waarin veel routines zijn, zoals bij de planning van diensten in een fabriek. Communicatie is een andere vorm van expliciete coördinatie, bijvoorbeeld wanneer teamleden elkaar feedback geven. Coördinatieprocessen zijn *impliciet* wanneer teamleden anticiperen op het (veronderstelde) gedrag van andere teamleden en hun gedrag hierop aanpassen. Impliciete coördinatie is vooral belangrijk in omstandigheden waar onverwachte veranderingen kunnen optreden, bijvoorbeeld bij militaire teams die een dorp doorzoeken. Hier moeten teams snel kunnen inspelen op veranderingen en is er weinig tijd voor overleg. Enkele veelvoorkomende impliciete coördinatieprocessen zijn het uitvoeren van (sub)taken van andere teamleden wanneer andere teamleden druk zijn en het geven van relevante informatie aan andere teamleden zonder dat daarom gevraagd werd. Veel teams gebruiken een mix van expliciete en impliciete coördinatieprocessen.

In dit onderzoek werden beide soorten coördinatieprocessen bestudeerd. Expliciete coördinatie werd bestudeerd aan de hand van de hoeveelheid communicatie tussen teamleden. Impliciete coördinatie werd bestudeerd aan de hand van informatieverwerking, transactief geheugen systeem (TGS), gelijkheid van percepties van de situatie en zelfsynchronisatie. Informatieverwerking beschrijft de mate waarin teams effectief gebruik maken van de aanwezige informatie voor het uitvoeren van de taak. TGS refereert aan de kennis van teamleden over de verdeling van kennis en vaardigheden binnen teams. Het onderliggende principe van TGS is dat niet alle teamleden alles hoeven te weten, zolang maar duidelijk is welk teamlid wat weet. TGS stelt teams in staat om effectief gebruik te maken van informatie, omdat teamleden kennis hebben van elkaars expertise en vaardigheden. Perceptie van de situatie refereert aan de mate waarin teamleden een gemeenschappelijk beeld hebben van wat er aan de hand is. Wanneer teamleden verschillende percepties hebben van de situatie (bijvoorbeeld omdat ze op andere locaties zijn), kunnen teamleden verschillende ideeën hebben over de situatie en de wijze waarop het team haar doelen kan bereiken. Gelijkheid van percepties van de situatie is belangrijk in complexe en dynamische situaties om snel tot overeenstemming te komen over wat er moet gebeuren. In deze omgevingen is er vaak weinig tijd om te overleggen en is een snelle reactie van een team vereist. Zelfsynchronisatie refereert aan coördinatie van beslissingen en activiteiten van teamleden zonder dat teamleden openlijk met elkaar communiceren. Zelfsynchronisatie slaat op de mate waarin teamleden elkaar aanvoelen. Goede zelfsynchronisatie is bijvoorbeeld te zien in teams waarin teamleden passende initiatieven nemen en snel in staat zijn om te reageren op onverwachte gebeurtenissen.

Factoren. Hieronder worden de factoren beschreven die verondersteld werden van invloed te zijn op coördinatieprocessen in virtuele teams. Factoren kunnen te maken hebben met de taak die het team uitvoert, met het team en de context waarin het team haar taken uitvoert. Op basis van de achtergrond van het onderzoek is gekozen om factoren te bestuderen die uit alle categorieën afkomstig zijn, in plaats van factoren die uit dezelfde categorie komen. Deze aanpak maakt het mogelijk om factoren te bestuderen die samenhangen met de taak die het team uitvoert, het team en met technologie.

In dit onderzoek zijn vijf factoren onderzocht. De eerste factor was niveau van autoriteit. Deze factor is gerelateerd aan de taak. Hierboven werd beschreven dat genetwerkte teams zelf zorg dragen voor goede coördinatie met andere teamleden. Verwacht werd dat hogere niveaus van autoriteit virtuele teams zou helpen om beter te coördineren, omdat teams met hogere niveaus van autoriteit minder hoeven af te stemmen met hogere organisatieniveaus, bijvoorbeeld het verkrijgen van toestemming. Verwacht werd dat hogere niveaus van autoriteit teams in staat stellen om zich meer te richten op de taak die zij uitvoeren. Deze verwachting werd getoetst door teams met verschillende niveaus van autoriteit gelijkwaardige taken uit te laten voeren.

De tweede factor was ervaring met samenwerken met leden van andere genetwerkte teams. Deze factor is gerelateerd aan het team. Verwacht werd dat teams die veel ervaring hadden met samenwerken met andere genetwerkte teams beter in staat waren om hun acties effectief te coördineren met andere teamleden en andere genetwerkte teams. In het onderzoek is deze factor vormgegeven door te kijken naar de ervaring van teams in ‘joint’ operaties, ofwel het samenwerken met teams van andere krijgsmachtdelen. De verwachting werd getoetst door teams met verschillende niveaus van ervaring uit te nodigen voor het onderzoek.

De derde factor was leiderschapsstijl. Deze factor is gerelateerd aan het team. Participatieve en directieve leiderschapstijlen verwijzen naar leiderschapsstijlen waar teamleden door teamleiders betrokken worden in besluitvorming (participatieve leiderschapsstijlen) danwel leiderschapsstijlen waar teamleiders beslissingen nemen zonder inbreng van teamleden (directieve leiderschapsstijlen). Verwacht werd dat virtuele teams gebaat zijn bij participatieve leiderschapsstijlen, omdat teamleden vaak geselecteerd zijn vanwege hun specifieke expertise of vaardigheden. Andere redenen waarom participatie van teamleden belangrijk is in virtuele teams, zijn de beperkte mogelijkheden van teamleiders om controle uit te oefenen op teamleden, omdat teamleden verspreid zijn over verschillende locaties en mogelijk van verschillende organisaties komen. Om deze redenen werd verondersteld dat teams met teamleiders die een participatieve leiderschapsstijl hadden, beter in staat waren om hun activiteiten te coördineren dan teams met teamleiders die een directieve leiderschapsstijl hadden. Deze verwachting werd getoetst door teamleiders voorafgaand aan het onderzoek een leiderschapsinstructie te geven voor een participatieve danwel een directieve leiderschapstijl.

De vierde factor was media synchroniciteit, ofwel de mate waarin teamleden met elkaar kunnen communiceren zonder vertraging. Deze factor is gerelateerd aan de context waarin teams hun taken uitvoeren. Chatten en het delen van informatie in een gedeelde digitale werkplek zijn voorbeelden van media met een hoge mate van synchroniciteit. Emails en berichten op een internetforum zijn voorbeelden van media die een lage mate van synchroniciteit hebben. Verwacht werd dat media die een hoge mate van synchroniciteit hebben, teams beter in staat zou stellen om effectief te coördineren, omdat het delen van informatie en communicatie sneller gaat dan via media met een lage mate van synchroniciteit.

De vijfde factor was de verdeling van informatie. Het doorsturen van emails of databestanden maakt het mogelijk dat teamleden van virtuele teams beschikken over dezelfde informatie. Dit wordt gezien als een groot voordeel, omdat verondersteld wordt dat het bestuderen van dezelfde informatie ervoor zorgt dat teamleden op dezelfde manier naar de situatie kijken. Teamleden lezen, zoals een bekende uitdrukking zegt, 'van hetzelfde blad papier'. Bovendien hebben teamleden alle informatie beschikbaar die relevant is voor hun individuele taakuitvoering. Deze verwachting werd getoetst door de verdeling van informatie te variëren.

Dataverzameling. Voor het beantwoorden van de onderzoeksvragen zijn drie experimenten uitgevoerd. In Experiment 1 zijn de effecten onderzocht van niveau van autoriteit en ervaring van teamleden met het samenwerken met andere teams op teamcoördinatie en team prestatie. Het onderzoek was een verkennend experiment waarin vier bestaande 'air defence command teams' van de Koninklijke Luchtmacht en van de Zweedse Luchtmacht deelnamen. Deze teams voerden luchtverdedigingstaken uit in een daartoe uitgerust laboratorium van TNO in Den Haag (TNO ACE; Advanced Concept Development & Experimentation Environment).

Experiment 2 was een laboratoriumonderzoek waarbij teams een planningstaak uitvoerden in een laboratorium van TNO in Soesterberg. Deelnemers aan dit onderzoek hadden zich opgegeven via TNO. In dit experiment zijn de effecten onderzocht van leiderschapsstijl op coördinatieprocessen en teamprestatie. Teamleiders werden willekeurig aangewezen en kregen voorafgaand aan het onderzoek een korte instructie voor de wijze waarop zij het team moesten leiden.

Experiment 3 was een laboratoriumonderzoek waarbij teams een planningtaak uitvoerden in een daartoe ingerichte ruimte van de KMA in Breda. Deelnemers aan dit onderzoek waren cadetten van de KMA. In dit experiment stonden twee eigenschappen van informatie- en communicatietechnologie centraal, mediasynchroniciteit en verdeling van informatie. De verwachtingen op het gebied van mediasynchroniciteit zijn getoetst door een deel van de teams via email met elkaar te laten samenwerken, terwijl een ander deel van de teams kon samenwerken via email en via een gedeelde digitale werkplek. De verwachtingen op het gebied van de verdeling van informatie zijn getoetst door bij een deel van de teams deelnemers alleen informatie te geven over hun individuele taak, terwijl bij een ander deel van de teams deelnemers informatie kregen over alle taken.

Resultaten en conclusies

Resultaten. De resultaten van Experiment 1 laten zien dat niveau van autoriteit en ervaring met samenwerken met leden van andere genetwerkte teams positieve effecten hadden op coördinatieprocessen en teamprestaties.

Niveau van autoriteit beïnvloedde zowel expliciete als impliciet coördinatieprocessen. Teams communiceerden minder met hogere organisatieniveaus en meer met andere teams in het netwerk. Daarnaast gaven teamleden aan dat zij beter in staat waren om activiteiten te coördineren met andere teamleden. Met betrekking tot teamprestatie gaven observatoren aan dat teams met hogere niveaus van autoriteit beter inspeelden op onverwachte ontwikkelingen in de taak en beter presteerden. Hiermee zijn de verwachte positieve effecten van niveau van autoriteit uitgekomen.

De resultaten met betrekking tot ervaring met samenwerken met leden van andere genetwerkte teams waren minder overtuigend. Ervaring was niet van invloed op expliciete coördinatie. Positieve effecten van ervaring op impliciete coördinatieprocessen werden gevonden voor zelfsynchronisatie, maar alleen wanneer teams een lager niveau van autoriteit hadden. De effecten verdwenen wanneer teams een hoger niveau van autoriteit hadden. Ervaring was ook van invloed op teamprestaties. Observatoren gaven aan dat teams met meer ervaring beter presteerden. Ook hier verdween het effect wanneer teams een hoger niveau van autoriteit hadden. Deze resultaten geven aan dat ervaring met samenwerken met leden van andere genetwerkte teams weliswaar een voordeel is wanneer teams moeten samenwerken met andere genetwerkte teams, maar dat ervaring teams niet helpt om te leren hoe zij effectief gebruik kunnen maken van hogere niveaus van autoriteit.

De uitkomsten van de groepsdiscussies die na afloop van de sessies met teamleden en observatoren werden gehouden, gaven aan dat de leiderschapsstijl van de teamleider belangrijk was om effectief gebruik te maken van hogere niveaus van autoriteit. Wanneer teamleiders niet een aantal van hun taken en verantwoordelijkheden delegeerden naar andere teamleden, konden teams niet effectief gebruik maken van de hogere niveaus van autoriteit, bijvoorbeeld omdat teamleden moesten wachten op toestemming om een actie uit te voeren. Zowel ervaren als minder ervaren teams lieten zien dat zij effectief gebruik konden maken van hogere niveaus van autoriteit. Deze uitkomst wijst erop dat leiderschapsstijl van de teamleider een belangrijke rol speelt in coördinatieprocessen in virtuele teams.

De resultaten van Experiment 2 lieten zien dat participatieve leiderschapsstijlen overwegend positieve effecten hadden op coördinatieprocessen in virtuele teams, maar deze effecten leidden niet tot betere teamprestaties. Teamleden gaven aan dat participatieve leiderschapsstijlen hen in staat stelden om informatie te verwerken en activiteiten met elkaar te synchroniseren. Leiderschapsstijlen waren echter niet van invloed op de gelijkheid van de perceptie van de situatie. Een mogelijke verklaring voor de verschillende effecten van leiderschapsstijl op coördinatieprocessen is dat het creëren van een gemeenschappelijk beeld van de situatie op basis van situationele (en dus steeds veranderende) informatie moeilijker is, dan het verwerken van informatie en synchroniseren van activiteiten met andere teamleden. Informatieverwerking en zelfsynchronisatie zijn processen waarbij teamleden gebruik maken van stabiele informatie, zoals informatie over de taakverdeling en informatie over de verdeling van expertise en hulpbronnen. Om deze reden zouden coördinatieprocessen waarin informatie over de situatie belangrijk is moeilijker zijn voor virtuele teams dan coördinatieprocessen waarin situationele informatie niet belangrijk is. Deze mogelijke relatie tussen gelijkheid van percepties van de situatie en de mate waarin teams afhankelijk zijn van technologie, zal in nieuw onderzoek getoetst moeten worden.

De resultaten van Experiment 3 waren niet in overeenstemming met de verwachtingen. De verwachte effecten van media synchroniciteit en verdeling van informatie op coördinatieprocessen werden niet gevonden. Additionele analyses wezen uit dat media synchroniciteit *negatieve* effecten had op enkele aspecten van coördinatieprocessen: percepties van de geloofwaardigheid van andere teamleden, gelijkheid van percepties van de situatie op het einde van de taak en het nemen van initiatieven. Er werden geen effecten gevonden van verdeling van informatie op teamprestatie.

Een mogelijke verklaring voor deze resultaten heeft te maken met huidige theorieën over virtuele teams. Theorieën over virtuele teams zijn gericht op de media die teamleden gebruiken om met elkaar te communiceren en informatie met elkaar te delen. Deze theorieën gaan uit van de eigenschappen van verschillende media. Echter, in dit onderzoek had een deel van de teams de beschikking over meerdere media tegelijk, namelijk email en een gedeelde digitale werkplek. De resultaten geven aan dat teamleden niet altijd in staat waren om te wisselen tussen deze media (informatie delen in de digitale werplek, overleggen via email berichten). Teamleden gebruikten vaak beide media naast elkaar, bijvoorbeeld door informatie in de digitale werkplek te zetten en daarna een email te maken waarin dezelfde informatie stond. In theorie over virtuele teams is vooralsnog geen aandacht voor het gebruik van meerdere media tijdens het uitvoeren van een taak. Door de opkomst van informatie- en communicatietechnologie bieden werkplekken verschillende mogelijkheden om met anderen samen te werken. Nieuw onderzoek in deze richting is nodig om meer te weten te komen over het wisselen tussen verschillende media die overlap hebben in hun capaciteiten om informatie te delen en te communiceren.

Conclusies. Tezamen laten de resultaten van het onderzoek zien dat virtuele teams een mix gebruiken van expliciete en impliciete coördinatieprocessen. Teamleden die uitsluitend met elkaar samenwerken via informatie- en communicatietechnologie integreren hun activiteiten niet alleen aan de hand van getypte email berichten, maar zij leren tijdens het uitvoeren van een taak ook om elkaar aan te voelen en hun activiteiten te coördineren, zonder dat daar overleg bij nodig is. De resultaten wijzen erop dat impliciete coördinatieprocessen waarin stabiele informatie belangrijk is (bijvoorbeeld weten voor welk teamlid een stukje informatie belangrijk is), beter tot stand komen tijdens taakuitvoering dan impliciete coördinatieprocessen waarin situationele informatie belangrijk is (bijvoorbeeld inschatten wat de implicaties zijn voor het team van een onverwachte ontwikkeling in de taak). Virtuele teams voeren hun taken vaak uit in omgevingen waarin situationele informatie belangrijk is. Daarom is aanvullend onderzoek op dit onderwerp gewenst.

De resultaten van het onderzoek laten zien dat coördinatieprocessen in virtuele teams beïnvloed kunnen worden door factoren die te maken hebben met de taak (niveau van autoriteit) en het team (leiderschapsstijl). Tezamen wijzen deze resultaten erop dat teamleiders van virtuele teams goed voorbereid moeten worden op hun taken, omdat participatie van teamleden een voorwaarde is om te kunnen profiteren van hogere niveaus van autoriteit. Participatieve leiderschapsstijlen en het delegeren van taken naar teamleden zijn belangrijk hiervoor. Er is in het onderzoek geen bewijs gevonden voor de rol van contextuele factoren (technologie). Hiervoor is een theoretische verklaring geformuleerd. Met name het samenspel van verschillende media werd niet verwacht. Teamleden blijken moeilijk te kunnen wisselen tussen media voor verschillende subtaken wanneer media overlappende capaciteiten hebben voor communiceren en het delen van informatie. Nieuwe theorievorming en verder onderzoek op dit onderwerp zijn gewenst om coördinatieprocessen in virtuele teams goed te kunnen doorgronden.

Het onderzoek heeft implicaties voor theorie over genetwerkte militaire operaties. Teamleiders van genetwerkte teams spelen een hoofdrol wanneer het gaat om het verschuiven van verantwoordelijkheden naar teams zelf. Echter, participatie van teamleden in besluitvorming en het delegeren van verantwoordelijkheden naar teamleden is niet in alle situaties vanzelfsprekend, zoals bijvoorbeeld tijdens (gewelds-)incidenten. Om deze reden is het voorbereiden van teamleiders op de eisen van het opereren in genetwerkte militaire operaties van het grootste belang, en is het uitrusten van militaire teams met informatie- en communicatietechnologie vooral een uitgangspositie. Het aansturen en uitvoeren van genetwerkte militaire operaties blijven boven alles activiteiten van mensen, gesteund door technologie.

Dankwoord (acknowledgements)

Sommige boeken zijn het waard om steeds opnieuw te lezen. Voor mij is "Zen en de kunst van het motoronderhoud, een onderzoek naar waarden"[1] een boek dat me iedere keer weer aan het denken zet en inspireert. In dit boek wordt verslag gedaan van een reis per motor van Minneapolis naar San Francisco (en, inderdaad, het onderhoud aan die motor tijdens de reis), maar vooral beschrijft het boek een poging van de hoofdpersoon om twee verschillende manieren om de wereld te beschouwen met elkaar te verenigen. De hoofdpersoon probeert uit alle macht om de romantische benadering van de werkelijkheid te verenigen met de intellectuele benadering. Deze scheiding is volgens de hoofdpersoon strijdig met het grondbeginsel van de wetenschap, want: "*De wetenschappelijke methode heeft tot doel een enkele waarheid te schiften uit een veelheid van hypothetische waarheden. Meer dan wat ook, is dat het voornaamste streven van de wetenschap*". Op zoek naar een wetenschappelijke methode die leidt tot 'enkele waarheden', doet de hoofdpersoon wanhopige pogingen om de scheiding tussen de romantische benadering en de intellectuele benadering op te heffen. De onverenigbaarheid van de benaderingen van de werkelijkheid drijft de hoofdpersoon uiteindelijk tot waanzin, met grote gevolgen voor zijn wetenschappelijke loopbaan en zijn persoonlijke leven.

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[1] Nederlandse vertaling van: Zen and the Art of Motorcycle Maintenance: An inquiry into values, Robert M. Pirsig (1974).

de kern door te dringen. In plaats van de aanpak "twee stappen vooruit, één terug", heb ik geleerd hoe belangrijk het is om deze stappen in de omgekeerde volgorde te nemen. Ik bewaar goede herinneringen aan ons verblijf in New York, waar we samen met andere onderzoekers van TNO wetenschap afwisselden met bezoeken aan de BB King Blues Club en een ronddraaiende cocktailbar.

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Bart van Bezooijen
Maart 2011, Bergen op Zoom

Curriculum Vitae

Bart van Bezooijen was born in Leiderdorp on August 18, 1979. He attended secondary school in Leiden, and went to Tilburg to study Economic Psychology at the Tilburg University. After discovering the joyful lifestyle of the southern part of The Netherlands and the inspiring education of Tilburg University, he earned his master's degree in Economic Psychology in 2004, with a minor in Social Psychology. He started as a data-analyst and junior project leader at a small market research agency in Zeist, but returned to the Tilburg University as a PhD-student in 2005.

From 2005 until 2010 he conducted the research reported in this dissertation, under supervision of Prof. dr. Ad Vogelaar (Netherlands Defence Academy), Dr. Peter Essens (TNO Human Factors), and Prof. dr. Tony Gaillard (Tilburg University). As from February 2011, he is working as a post-doctoral researcher at the Eindhoven University of Technology, at the Department of Industrial Engineering & Innovation Sciences[1]. The research is a collaborative effort of the Eindhoven University of Technology, the Netherlands Defence Academy, and TNO Human Factors.

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