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Effects of time pressure and communication environment on team processes and outcomes in dyadic planning

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Abstract

An experiment compared dyadic performance in a radio communication and a more sophisticated communication environment to face-to-face (FtF) meetings. Thirty-six dyads, working under low or high time-pressure conditions, needed to combine information and to produce a written plan. Teams working in the sophisticated communication environment collaborated from separate locations over a networked computer system allowing them to share a note-taking program, work in parallel, and exchange in real-time audio as well as video. Results revealed detrimental effects of time pressure on both team processes and outcomes, and supported our hypothesis that distributed teams can perform as well as FtF teams. No differences were found between FtF teams and teams working in the sophisticated communication environment on process and outcome measures, except for the quantity of performance: The sophisticated communication environment enabled distributed teams to work on the task more rapidly than their FtF counterparts. Radio teams produced plans of lower quality and were less satisfied with the quality of their planning process than FtF teams.

Keywords: Dyadic planning; Time pressure; Distributed teamwork; Virtual teams; Electronic communication; Computer-supported cooperative work

1. Introduction

The integration of computers and communication technologies has increased the possibilities for distributed teamwork both within and across organizations. The combination of telecommunications, information technologies and increases in bandwidth allows for the digital transmission of text, audio, and (streaming) images, thus facilitating collaborative work such as communication, coordination, decision making, and the sharing of information across time and space. In fact, these specialized capabilities and tools, often labeled as groupware (Ellis et al., 1991; Hinssen, 1998), assist teams in communicating and in coordinating their activities, and make collaboration between distributed team members more convenient and less time consuming than traveling to meet face-to-face (Hollingshead and McGrath, 1995). But groupware has other indisputable benefits. For example, groupware allows teams to include more than one colleague in discussions and planning at the same time while encouraging input, even from relatively low-status individuals (Kiesler and Cummings, 2002), and, with the use of text-based groupware such as Internet chat, these facilities allow teams to maintain a record of their communication (Thompson and Coovert, 2006).

These potential benefits of groupware notwithstanding, the increased reliance on distributed teamwork raises questions about the possible negative effects of geographical dispersion on communication processes and team performance, such as (a) difficulties in communicating information (Driskell et al., 2003; Lea and Spears, 1991; Priest et al., 2006; Siegel et al., 1986; Straus, 1997), (b) a lack of awareness of other team members' accomplishments (Carroll et al., 2006; Van der Kleij, 2007), or (c) a failure to develop effective interpersonal relationships (Thompson and Coovert, 2006). These putatively detrimental aspects of

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geographical dispersion are often invoked to justify reluctance "to go virtual", even though for some tasks, and under some conditions, groupware may allow virtual teams to perform as good as, or perhaps even better than face-to-face teams. In other words, we need to know how teams perform under specific communication conditions, and the primary goal of the current research was to contribute to this insight. We focus on dyadic planning, and compare both a rudimentary and a sophisticated distributed communication environment to collocated face-to-face meetings. Moreover, we will examine whether these different communication environments affect team processes and performance differently in a setting that is characterized by high time pressure, a typically defining characteristic of command and control teams (Hackman, 1990; Priest et al., 2006).

1.1. Distributed teamwork

The importance of the communication environment for effective team functioning has been the topic of a great number of studies. Much of this work is inspired by, or otherwise influenced by media richness theory (Daft and Lengel, 1984, 1986). Media richness theory (MRT) (Daft and Lengel, 1984, 1986) starts from the premise that communication media differ in terms of the richness of the information that can be transmitted (Martins et al., 2004). Richness refers to the degree to which the information flowing through communication media contains emotional, attitudinal, normative, and other meanings, beyond the literal cognitive denotations of the symbols used to express it. MRT suggests that rich media convey more such cues than lean media. According to MRT, face-to-face communication is the richest communication medium because it allows for the simultaneous observations of multiple cues, including body language, facial expression, tone of voice, and so forth. In addition, face-to-face conversations provide immediate feedback. With feedback, understanding can be checked and interpretations corrected. Audio conversations — through telephone, for example — are less rich than face-to-face interactions. Feedback is fast, but visual cues are absent. Group members have to rely on language content and audio cues to reach understanding.

Daft and Lengel (1984, 1986) argue that task performance improves when task needs, which differ in terms of the degree to which effective performance on them requires the transmission of information that is more or less rich in its contents, are matched to the communication medium's richness. Interpersonal factors, such as cohesiveness, trust, satisfaction and conflict resolution, might also be enhanced in situations of good fit between task and communication medium (Zigurs and Buckland, 1998).

MRT assumes that for routine tasks that are well understood and in which emotional connotations about message and source are not required (e.g., brainstorming) media of lower richness, such as Internet chat or e-mail, would provide sufficient information. Emotional connotations about message and source are not required for routine tasks and are often considered a hindrance. Face-to-face settings, or media capable of transmitting rich information, such as video communication technologies, are better suited to support equivocal tasks (e.g., negotiations or [strategic] decision making) for which there are multiple interpretations for available information and that require the resolution of conflict. The more the task requires rich information exchange, the richer the medium required. Performing a complex task through a simple medium is ineffective. Performing a simple task through a rich medium is inefficient.

Although MRT has strong face validity, it has also met with some criticism (for example, see Van der Kleij, 2007). One important source of criticism emanates from theories that consider how groups adapt over time to their changing environment (Arrow et al., 2004; McGrath, 1991; McGrath et al., 1993; Poole and DeSanctis, 1990). These theories see adaptation as a reaction to a mismatch between the task, and the set of tools and resources for carrying out that task. Moreover, these theories assume that a perfect fit between task and the communication medium is not a prerequisite to performing well on a collaborative task. However, this does not mean that both theories are incompatible. Adaptation theories agree with the notion proposed by MRT that there should be some kind of fit between the task and the communication medium. If there is a complete misfit, then the medium is not easily used and adaptation is not viable. Otherwise, groups are able to compensate for the misfit.

A second source of criticism stems from empirical studies. MRT assumes that a rich medium is a necessary condition for rich communication. However, empirical tests of MRT have not been terribly convincing, particularly for modern communication media. It seems that MRT is outdated because it does not recognize the qualities of modern communication technologies. Moreover, there are only few examples of complex equivocal tasks for which the superiority of face-to-face over computer-mediated communication has been clearly proven. In fact, research data often do not support MRT (cf. Kiesler et al., 1984; Kiesler and Sproull, 1992; Olson et al., 1997; Sproull and Kiesler, 1986).

To address these issues, Dennis and Valacich (1999) propose a modernization of MRT: media synchronicity theory. Their theory is commendable in that it incorporates the qualities of modern communication technologies that are not present in traditional technologies, such as the telephone. For example, some modern communication media can be structured in such manner allowing for simultaneous conversations. In comparison, in a face-to-face meeting, only one person can talk at a time. Moreover, talking time is usually not distributed evenly across participants and loud talkers or people who have less knowledge than they have prestige often dominate these meetings. Thus, convincing others to adopt a good idea can be difficult if the person with this idea has low status. Such groups could benefit from the reduced availability of social context cues in electronic meetings. There is even groupware on the market nowadays that allows for the simultaneous inputs of all participants. For example, with help of the shared session feature of the Microsoft Office OneNote 2003 note-taking program and a local area network, it is possible to create a session in which distributed team members are able to share a document, and see the comments and additions of their counterpart in real time. Taken together, these media characteristics can affect communication effectiveness. No medium could therefore be labeled as the richest in Daft and Lengel's terms, and ranking media in absolute terms is not practical.

In complex tasks that both require coordination and communication among group members, virtual teams can thus be as effective as collocated face-to-face teams provided that the communication environment allows the transmittance and processing of task-relevant information as well as social cues that enable team members to work well together. There is some evidence that supports this assertion (Baltes et al., 2002; Olson et al., 1997). Baltes et al. (2002) found that compared with face-to-face groups, computer-mediated communication decreased group decision-making effectiveness, increased time required to reach a decision, and decreased group member satisfaction. However, when various moderators were considered, it was found that virtual teams could be just as effective as face-to-face decision-making teams. For instance, when virtual teams were given unlimited discussion time, no decrease in effectiveness was found.

The present study tested the general idea that face-to-face communication is not required for teams to perform well. In contrast to previous work comparing face-to-face communication to either video-conferencing or to computer-mediated communication, we focused on a high fidelity collaborative environment, in which distributed teams collaborate over a networked computer system allowing them to share a note-taking program, work in parallel, and exchange in real-time high-quality audio as well as video. This sophisticated communication environment, which we have named SHAPE, an acronym for SHAred Planning Environment, combines the advantages of communication media that are capable of transmitting rich information with the growing opportunities of groupware (Van der Kleij and Schraagen, 2006; see also Siegel et al., 1986; Olson et al., 1997). For instance, SHAPE-dyads are enabled to work simultaneous and revise each other's input in real time, thereby decreasing many of the challenges of distributed teamwork.

We were especially interested in how SHAPE would compare to a collocated face-to-face setting — which is usually considered the gold standard of work environments — on process and performance measures. We also compared this communication environment to a single duplex audio-only communication environment, in which distributed dyads had to communicate through push-to-talk radios, to assess the added effect of extra communication capabilities.

Based on the aforementioned literature review and discussion on the effects of technological mediation of communication, we are able to make several predictions regarding to the outcomes of this experiment. First, it is known that technological mediation can make it more difficult to communicate information (Driskell et al., 2003; Thompson and Coovert, 2006). Many of the challenges faced by virtual teams stem from inefficient and ineffective communication. Telephone or radio conversations for example, are less rich than face-to-face. Visual cues are absent and group members must rely on language content and audio cues to reach an understanding. Therefore, our first hypothesis is:

Hypothesis 1. We expect that face-to-face dyads will outperform distributed push-to-talk radio dyads.

In addition, we think that a distributed communication environment, which allows for the transmittance and processing of task-relevant information as well as social cues, will help virtual teams to perform in an optimal manner. In other words, our second hypothesis is:

Hypothesis 2. We expect that SHAPE, which is capable of transmitting rich information and permits distributed team members to enter information at the same time, will enable dyads to produce work that is indistinguishable in quantity and quality from face-to-face dyads.

1.2. The role of time pressure

Our literature review revealed that when distributed teams are given unlimited discussion time, these teams could be just as effective as collocated face-to-face teams (e.g., Baltes et al., 2002). However, such situations are not very common. More common are situations in which teams are expected to achieve high levels of performance under extreme time pressure (Waller et al., 2001). In general, time pressure has a number of different consequences. At the individual level, time pressure leads to (a) faster performance rates, (b) lower performance quality, and (c) more heuristic information processing: people stop considering multiple alternatives, engage in shallow rather than thorough and systematic processing of information, and refrain from critical probing of a given seemingly adequate solution or judgment (e.g., De Dreu, 2003; De Grada et al., 1999; Durham et al., 2000; Karau and Kelly, 1992; Kelly et al., 1997; Kelly and Karau, 1999; Kelly and Loving, 2004; Kruglanski and Freund, 1983). In terms of the attentional focus model (Karau and Kelly, 1992; Kelly and Loving, 2004) increasing levels of time pressure narrows team members' focus on a limited range of task-salient cues in both team interaction patterns and team task performance. Under high time-pressure group members see task completion as their main interaction objective, and the group attempts to reach consensus and complete the task as quickly as possible, but at the sacrifice of quality. Groups under mild or no time pressure can, in contrast, consider a wider set of task features, devote their resources to performing as well on the task as possible, and tend to employ more effortful systematic information processing that gives serious considerations to all possible alternative solutions for a task.

Only few studies examined how time pressure moderated the effects of communication media on group processes and outcomes (Caballer et al., 2005; Salanova et al., 2003). Salanova et al. (2003) studied the moderating role of perceived collective efficacy between group communication systems (i.e., chat vs. face-to-face) and time pressure on collective well-being (i.e., anxiety and engagement) and task performance. Groups working under time pressure performed their task less well compared with groups working without time pressure. At the same time it was found that high levels of perceived collective efficacy buffered the negative effects of time pressure on collective well-being and task performance. Groups high on collective efficacy suffered less from time pressure than groups low on collective efficacy.

Caballer et al. (2005) investigated the combined effects of communication media and time pressure on the affective responses of team members (i.e., satisfaction and commitment to the solution achieved) while performing intellective tasks. It appears that in face-to-face groups increasing levels of time pressure undermined positive affect and satisfaction, whereas groups mediated by video-teleconferencing improved their affective responses when working under time pressure. All in all, and consistent with media synchronicity theory, social information processing perspectives, and the attentional focus model, it seems that when no time constraints are present, face-to-face groups benefit from the excessive richness of their communication medium to fulfill social functions other than those that are instrumental to focusing on the task. However, under conditions of time pressure, face-to-face communication may provide too much information flow, inducing the group to operate in a sub-optimal manner and undermining positive affect and satisfaction. Thus, our third and fourth hypotheses are:

Hypothesis 3. We expect time pressure to undermine team processes and outcomes.

Hypothesis 4. We expect a significant interaction between communication environment and time pressure. Under low time pressure, we expect that face-to-face and SHAPE-teams do not differ and outperform push-to-talk radio teams, whereas under high time pressure, the excessive richness of their communication channel induces the face-to-face teams to operate in a sub-optimal manner, leading to a relatively strong decline in effectiveness as compared with SHAPE-teams and push-to-talk radio teams.

2. Method

2.1. Participants and experimental design

Seventy-two participants, primarily students from the University of Utrecht in the Netherlands, took part in present study. Their age ranged from 18 to 37 years ($M = 22.15$, $SD = 3.01$). Each participant was assigned to one of 36 mixed-gender two-person teams (dyads), leaving us with 12 dyads per experimental group. Participants were paid €40 — for participation, and were promised another €60 for the best-performing dyad in each experimental condition.

The design was a 3×2 factorial, with communication condition (face-to-face, SHAPE, push-to-talk radio) as between-groups factor, and time pressure (low, high) as within-groups factor. The sequence of the levels of time pressure was counterbalanced for all dyads, but since order had no effects whatsoever it is not discussed further. Dyads were randomly assigned to experimental conditions.

2.2. Task and manipulation of communication media

Planning is important to good teamwork. Planning requires teams to combine information from various informational resources, and come to consensus in selecting the best possible options. Prior research shows that planning prior to the execution of a task or mission, during task performance, or both contributes to effective coordination and enhances successful performance in groups (Stout et al., 1999; Janicik and Bartel, 2003). For this reason, and to understand better what opportunities exist for supporting teams in which planning constitutes an important part of the job, such as command and control teams, it was decided to focus this research on a collaborative planning task.

The task required our dyads to write out a plan of action describing how to attain certain objectives central to task completion (cf. Hayes-Roth and Hayes-Roth, 1979; Janicik and Bartel, 2003; Karau and Kelly, 1992; Kelly and McGrath, 1985). According to McGrath's typology of tasks, our task can best be designated as a generating task; requiring the generation of plans or ideas (McGrath, 1984). The task was developed on the basis of the following criteria: (1) There had to be a strong similarity with planning practice; (2) The task had to be in accordance with definitions of planning; (3) Our student subjects had to be familiar with the topic; (4) The task needed to be a team task in which each subject had unique knowledge that had to be exchanged to reach an optimal solution; (5) Multiple and novel solutions had to be possible. More specifically, our dyads had to plan a day-trip to the Belgian Ardennes — a popular holiday destination — for a group of foreign tourists. The task was to combine information from various informational resources, and to reach consensus in selecting the best possible options (i.e., solutions that satisfied all task restrictions).

A second planning task was developed as a training task for our subjects. Our teams had to set up a campaign for the government to help minimize traffic jams. Dyads had to write down their campaign within 15 min, which was more than enough time to complete the task. In this manner our subjects were able to get acquainted with their fellow team member, and to familiarize themselves with deadlines and

Fig. 1. Face-to-face communication environment.

Fig. 2. Push-to-talk radio communication environment.

the communication equipment in their communication group. After completion of the task the dyads were debriefed and received feedback on their performance.

2.2.1. Equipment and task materials

Three communication environments were designed, one for each communication condition: face-to-face, SHAPE, and push-to-talk radio. In the face-to-face communication condition, team members were collocated and seated next to each other at a table behind a 19-inch Iiyama computer screen (1024×768 pixels) and a computer equipped with Microsoft Office OneNote 2003 note-taking program. Members were allowed to choose who was responsible for completing the written itinerary. Each team member was given a binder with eight unique pieces of information, all about available activities, accommodations, and eating places in the Ardennes. In this manner team members were made interdependent for fulfilling all task restrictions and completing the task in an optimal manner. Each binder also contained general information, including prices for lunches and diners, the formula for calculation of the traveling times across cities on the map, and so forth. In total, there were four binders, which each contained eight comparable pieces of unique information: two binders for each successive level of the time-pressure manipulation. A Latin square design was applied to ensure that the binders were equally divided across time-pressure conditions and order of appearance. Furthermore, dyads had at their disposal a note-block and pencil, a map of the Ardennes, a calculator, and a digital egg-timer showing the remaining time. A picture of the face-to-face condition is shown in Fig. 1.

In the push-to-talk radio communication condition, participants were located in different rooms and communicated through push-to-talk radios,[1] similar to a dispatcher's radio like the police, fielded first responders or taxi companies use. Push-to-talk radios were added as a level of the communication condition, because we were especially interested in supporting collaborative planning in geographically dispersed command and control teams. Currently, coordination in these teams is carried out using walkie-talkies or radios. Again, one participant was made responsible for completing the written itinerary. This person was equipped with a computer and the Microsoft Office OneNote 2003 note-taking program. A picture of the radio condition is depicted in Fig. 2.

In the SHAPE communication condition, participants were seated in separate rooms and both of them were equipped with a computer and the Microsoft Office OneNote 2003 note-taking program. With help of the Shared Session feature of OneNote and a local area network a peer-to-peer network session was created in which both participants were able to share the written plan, and see the comments and additions of their counterpart in real time. SHAPE-dyads communicated through a full-duplex good-quality video-teleconferencing system that consisted of a Panasonic color monitor WV-CM 1470, JVC TK C1381 digital video camera, microphone and loudspeaker. There was no processing required for coding and decoding of the audio and video signals. Therefore, no unwanted round-trip delays and delays between audio and video were present during communication. SHAPE is depicted in Fig. 3.

2.2.2. Manipulation of time pressure

We varied time pressure by manipulating the amount of time participants were given to produce a written plan. Several pre-test teams for each of our experimental conditions were run and on the bases of these trials it was determined that 80 min would allow dyads in all three experimental conditions more than sufficient time for performing the task, but would still induce some sense of urgency. In the high time-pressure conditions, we only provided a 20 min time period (none of our pre-test dyads completed the task in less than 20 min).

[1]A normal cell phone call uses two separate frequencies, one to send and one to receive, for each call while a push-to-talk (PTT) radio uses only a single frequency. PTT requires the person speaking to press his button while talking and then release it when he is done. The listener then presses his button to respond. This way the system knows which direction the signal should be travelling in.

Fig. 3. The SHAred Planning Environment (SHAPE).

2.3. Procedure

At the start of the experiment participants received a general instruction, stating the purpose of the experiment. Participants in all three communication conditions were given the same written and oral instructions, except for instructions pertaining to the time limit. Participants were told that the experiment studied the interaction in teams and that they had to work together on a planning task. They were also informed that their written plan would be judged and rated on its quality. Then, participants were given informed consent forms and a short pre-experimental questionnaire pertaining to demographic characteristics and initial experience with teamwork, teleconferencing, and computers. Because exploratory analyses revealed no significant differences between communication conditions on any of these pre-test questionnaire items, we conclude that randomization was successful and do not discuss these variables further.

Next, participants were given task-specific instructions relating to the traffic jams training task and were given 5 min to read the instruction. Then, participants were given instructions on the usage of the communication equipment and the Microsoft Office OneNote 2003 note-taking program. They were also given some time to practice with the equipment and task materials. During task performance and after task completion, participants received feedback and help concerning the usage of the equipment.

After a short break, participants received instructions and binders with information concerning the Belgian Ardennes planning task. They were given 10 min to study the instructions and the content of their binder. Participants in the face-to-face condition received the additional instruction that they were not allowed to give their binder to their fellow team member. Dyads that started in the high time-pressure condition were given the extra instruction that there was limited time for task completion but that previous testing had shown that it was possible for them to complete the task in time. After completion of the planning task, the experimenter saved the dyad's written solution on the computer and handed out questionnaires on planning process quality and time pressure. The members were not allowed to speak to each other during this break.

The task was given twice, once for each level of the time-pressure manipulation. For the second task version of our planning task the same procedure was followed as described above. However, participants were given new binders containing comparable pieces of unique information, new time-pressure instructions, and a different amount of time to complete the task. Finally, participants were debriefed and interviewed, thanked for their co-operation, and excused.

2.4. Dependent variables

2.4.1. Group performance

Two objective measures of the dyads' planning processes and outcomes were assessed and one subjective measure: length, the quality of the planning solution, and outcome satisfaction, respectively.

2.4.1.1. Length. Length was assessed as the number of words in the written team products (see also Karau and Kelly, 1992). To standardize this measure across the two time-pressure conditions, the total number of words that each written itinerary contained was divided by the time given to complete the task in minutes (20 or 80 min).

2.4.1.2. Quality of the planning solution. To assess the quality of the planning solution, written itineraries of each dyad were rated on nine interrelated dimensions by two judges simultaneously. Initial discrepancies between judges were discussed until consensus was reached. The dimensions were in fact essential task restrictions that were communicated to the participants both orally and on paper in the instructions at the start of the experiment. For instance, dyads had to include both one cultural and one active endeavor in their planning, and the plan had to include both a lunch and a dinner. For fulfilling each task restriction, 10 points were awarded to the dyad to a maximum score of 90 points. To exclude effects of possible response bias in judges, plans were numbered, presented in random order, and all information pertaining to experimental conditions was removed.

2.4.1.3. Outcome satisfaction. For team performance, not only the outcome itself is important, but also the affective reactions team members have. According to Thompson and Coovert (2003), outcome satisfaction encompasses approval of the final team decision. The questionnaire we developed to capture outcome satisfaction was adapted from Green and Taber (1980) and includes the following five items: "How satisfied or dissatisfied are you with the quality of your team's outcome?", "To what extent do you feel committed to the team's outcome?", "To what extent are you confident that the team's outcome is correct?", "To what extent do you feel personally responsible for the correctness of the team's outcome?", "To what extent does the final outcome reflect your inputs?" (5 items, Cronbach's $\alpha = .81$). All items were measured on 7-point Likert scales in which a score of 1 corresponds to the most negative option and a score of 7 corresponds to the most positive option.

2.4.2. Group processes

Several questionnaires were administered in order to explore the effects of technological mediation and time pressure on participants' perceptions of information exchange, process satisfaction, and the quality of the planning process. Participants had to fill in each questionnaire twice, after each successive time-pressure condition. Again, all questionnaire items were measured on 7-point Likert scales in which a score of 1 corresponds to the most negative option and a score of 7 corresponds to the most positive option.

2.4.2.1. Information exchange. The sharing of members' expertise and knowledge is one of the main goals of planning in groups (Stasser and Titus, 1985). It was found that the effectiveness of groups fluctuate as a function of what information is shared and the degree that information is shared (Stasser et al., 1989). Information exchange was assessed with a questionnaire to assess the perceptions of our participants concerning the completeness, speed, and amount of information given and received in discussions while performing the task. The questionnaire included the following four items: "Our written itinerary was based on all available information", "There was enough opportunity to exchange information", "During task execution, I exchanged a lot of information with my team member" and "The information we exchanged, was without any delay" (4 items, Cronbach's $\alpha = .70$).

2.4.2.2. Process satisfaction. Process satisfaction — the contentment with the interactions that occur while team members are devising decisions (Thompson and Coovert, 2003) — was assessed with an adapted version of the questionnaires used by Green and Taber (1980) and Dennis (1996). It contained the following two items: "I am satisfied about the course of discussions in our team" and "I am satisfied about the quality of the interactions in our team" (2 items, Cronbach's $\alpha = .90$).

2.4.2.3. Quality of the planning process. In the literature several dimensions are identified as important to good planning (Smith et al., 1990; Stout, 1995). The idea is that teams that score high on these planning dimensions would have a higher quality planning process than teams with lower scores, and higher quality planning solutions. For example, according to Smith et al. (1990) high-quality planning can be characterized by: (1) a future orientation; (2) extensive interaction between organizational members; (3) a systematic and comprehensive analysis of the organization's strengths, weakness, opportunities and threats; (4) a clear definition of the roles and functions of all members; and (5) the development and communication of action plans and the allocation of resources to action plans.

The following seven items, adapted from Smith et al. (1990) and Stout et al. (1999), were used in a questionnaire to assess the planning process quality: "Our team developed goals and there was awareness of consequences of errors", "Our team exchanged preferences and expectations", "Our team clarified roles and information to be traded", "Our team clarified sequencing and timing of information to be traded", "Our team knew how to deal with unexpected occurrences", "Our team knew how to deal with high workload and time pressure", and "Our team was highly capable of correcting its actions" (7 items, Cronbach's $\alpha = .80$).

3. Results

3.1. Data analysis and descriptive statistics

A 2×3 General Linear Model (GLM) Repeated Measures design was used to analyze the data, with time

Table 1
Summary of cell means and standard deviations as function of communication condition and time pressure condition ($n = 36$).

Dependent variable	Communication condition	Time pressure condition		Row
		Low (80 min)	High (20 min)	
Length[a]	Face-to-face	4.56 (1.00)	5.99 (2.34)	5.28 (1.91)
	SHAPE	7.40 (3.79)	10.95 (4.85)	9.17 (4.63)
	Push-to-talk radio	4.75 (1.32)	6.58 (3.50)	5.66 (2.75)
	Column	5.57 (2.66)	7.84 (4.24)	6.70 (3.70)
Quality of the planning solution[b]	Face-to-face	71.67 (9.37)	41.25 (14.79)	56.46 (19.70)
	SHAPE	68.75 (10.47)	48.75 (15.24)	58.75 (16.37)
	Push-to-talk radio	58.33 (8.88)	41.67 (12.31)	50.00 (13.51)
	Column	66.25 (10.98)	43.89 (14.20)	55.07 (16.90)
Outcome satisfaction[c]	Face-to-face	5.95 (.32)	5.13 (.86)	5.54 (.76)
	SHAPE	5.67 (.74)	4.91 (.66)	5.29 (.68)
	Push-to-talk radio	5.73 (.46)	4.99 (.89)	5.36 (.79)
	Column	5.78 (.53)	5.01 (.79)	5.40 (.77)
Information exchange[c]	Face-to-face	5.90 (.59)	4.56 (.85)	5.23 (.99)
	SHAPE	6.07 (.59)	4.70 (.59)	5.39 (.91)
	Push-to-talk radio	5.70 (.58)	4.18 (.66)	4.94 (.99)
	Column	5.89 (.59)	4.48 (.72)	5.18 (.96)
Process satisfaction[c]	Face-to-face	5.92 (.43)	5.56 (.65)	5.74 (.57)
	SHAPE	5.98 (.41)	5.60 (.52)	5.79 (.50)
	Push-to-talk radio	5.79 (.47)	5.21 (.82)	5.50 (.72)
	Column	5.90 (.43)	5.46 (.68)	5.68 (.61)
Planning process quality[c]	Face-to-face	5.55 (.38)	5.34 (.45)	5.44 (.42)
	SHAPE	5.37 (.58)	5.14 (.56)	5.26 (.57)
	Push-to-talk radio	5.18 (.28)	4.87 (.53)	5.03 (.44)
	Column	5.37 (.45)	5.12 (.54)	5.24 (.51)

Note: Values enclosed in parentheses represent standard deviations (SD).
[a]The values on this scale represent the mean number of words per minute in the written plan.
[b]The values represent mean scores on the planning task for each team. The maximum score is 90.
[c]The values represent mean scores on 7-point Likert scales, in which a score of 1 corresponds to the most negative option and a score of 7 corresponds to the most positive option.

pressure as within-groups variable and communication condition as between-groups factor. Analyses were performed at the group level to account for statistical interdependence (Kenny et al., 1998). Table 1 summarizes the means and standard deviations for the dependent variables across conditions. Table 2 gives the zero-order correlations for all the dependent variables. As can be seen in Table 2, there appears to be a cluster of strongly correlated process measures (information exchange, process satisfaction and planning process quality). Second, the quality of the planning solution was significantly correlated to length, the perceived quality of the planning process, and information exchange, but not to both measures of perceived satisfaction.

3.2. Time-pressure manipulation check

The perceived time pressure was assessed on a post-task questionnaire with four items adapted from Karau and Kelly (1992), Durham et al. (2000), and Zaccaro et al. (1995), and translated into Dutch (Cronbach's $\alpha = .88$). The questionnaire items were measured on 7-point Likert scales in which a score of 1 corresponds to the most negative option and a score of 7 corresponds to the most positive option. A significant main effect for time pressure was found, $F(1,30) = 190.91$, $p < .01$, $\eta_p^2 = .86$. Dyads in the high time-pressure condition ($M = 5.55$, $SD = .83$) reported significantly more time pressure than did dyads in the low time-pressure condition ($M = 2.81$, $SD = 1.36$).

3.3. Group performance

3.3.1. Length

A significant main effect of time pressure was found for the number of words per minute in the written plan, $F(1,30) = 17.15$, $p < .01$, $\eta_p^2 = .36$. Dyads in the high time-pressure condition ($M = 7.84$, $SD = 4.24$) contributed

Table 2
Means, standard deviations and Pearson's bivariate correlations between the dependent variables (2-tailed, $n = 36$).

Dependent variable	*M*	*SD*	1	2	3	4	5	6
1. Length	6.70	3.10	–					
2. Quality of the planning solution	55.07	9.48	.57**	–				
3. Outcome satisfaction	5.40	.51	.21	.30	–			
4. Information exchange	5.18	.60	.20	.39*	.43**	–		
5. Process satisfaction	5.68	.47	.34*	.24	.63**	.48**	–	
6. Planning process quality	5.24	.40	.11	.48**	.52**	.37*	.58**	–

Note: SD = standard deviation, M = mean.
*$p<.05$, two-tailed.
**$p<.01$, two-tailed.

more words to their written itineraries per minute of the interaction than dyads working in the low time-pressure condition ($M = 5.57$, SD = 2.66). Moreover, the analysis revealed a significant main effect of communication condition on length, $F(2,30) = 8.19$, $p<.01$, $\eta_p^2 = .35$. Tukey's post-hoc pairwise comparisons revealed that significant differences were present between dyads in the face-to-face ($M = 5.28$, SD = 1.91) and the SHAPE condition ($M = 9.17$, SD = 4.63), $p<.01$, and between dyads in the push-to-talk radio ($M = 5.66$, SD = 2.75) and SHAPE condition ($p<.01$). These results indicate that SHAPE is the most optimal communication environment for efficient use of time while working on a collaborative planning task, compared with both the face-to-face and the push-to-talk radio communication conditions. No interaction of time pressure and communication condition on length was found, $F(2,30) = 1.86$, $p = .17$, $\eta_p^2 = .11$.

3.3.2. Quality of the planning solution

As expected, a significant main effect of time pressure was found, $F(1,30) = 77.35$, $p = .00$, $\eta_p^2 = .72$, showing better quality solutions in the low time pressure ($M = 66.25$, SD = 10.98) than high time-pressure condition ($M = 43.89$, SD = 14.20). In addition, a significant main effect of communication condition was found, $F(2,30) = 3.39$, $p<.05$, $\eta_p^2 = .18$. Post-hoc analysis revealed that SHAPE-dyads ($M = 58.75$, SD = 16.37) outperformed push-to-talk radio dyads ($M = 50.00$, SD = 13.51; $p<.05$), and that the face-to-face communication condition ($M = 56.46$, SD = 19.70) took an intermediate position that did not differ from both the SHAPE and push-to-talk radio communication condition. No interaction effect was found between time pressure and communication condition, $F(2,30) = 2.12$, $p = .14$, $\eta_p^2 = .12$.

3.3.3. Outcome satisfaction

A significant main effect for time pressure showed that dyads in the low time-pressure condition ($M = 5.78$, SD = .53) were more satisfied with their performance than dyads in the high time-pressure condition ($M = 5.01$, SD = .79), $F(1,30) = 41.60$, $p<.01$, $\eta_p^2 = .58$. No other effects were found.

3.4. Group processes

3.4.1. Information exchange

Results revealed a significant main effect for time pressure, demonstrating that dyads in the low time-pressure condition perceived the exchange of information as more effective and efficient ($M = 5.89$, SD = .59) than did dyads in the high time-pressure condition ($M = 4.48$, SD = .72), $F(1,30) = 204.73$, $p<.01$, $\eta_p^2 = .87$. No significant main effect for communication condition was found on information exchange in dyads, $F(2,30) = 1.88$, $p = .17$, $\eta_p^2 = .11$. The interaction effect was not significant either, $F(2,30)<1$, ns., $\eta_p^2 = .02$.

3.4.2. Process satisfaction

A significant main effect for time pressure showed that dyads in the low time-pressure condition ($M = 5.90$, SD = .43) were comparatively more satisfied about their group processes than dyads in the high time-pressure condition ($M = 5.46$, SD = .68), $F(1,30) = 16.17$, $p<.01$, $\eta_p^2 = .35$. No other effects were significant.

3.4.3. Planning process quality

A significant main effect for time pressure showed that dyads in the low time-pressure condition ($M = 5.37$, SD = .45) reported a planning process of higher quality than dyads in the high time-pressure condition ($M = 5.12$, SD = .54), $F(1,30) = 10.05$, $p<.01$, $\eta_p^2 = .25$. Further, there was a significant main effect for communication condition on planning process quality, $F(2,30) = 4.42$, $p<.05$, $\eta_p^2 = .23$. Post-hoc analysis with Tukey's pairwise comparisons showed that face-to-face dyads were significantly more satisfied with the quality of their planning process ($M = 5.44$, SD = .42) than dyads in the push-to-talk radio communication condition ($M = 5.03$, SD = .44, $p<.01$). No significant difference was found for planning process quality between face-to-face and SHAPE-dyads ($M = 5.26$, SD = .57, $p = .22$), or between SHAPE and push-to-talk radio dyads ($p = .10$). The interaction between time pressure and communication condition was not significant, $F(2,30) = .25$, $p = .78$, $\eta_p^2 = .02$.

4. Discussion

The primary goal of this experiment was to explore the effects of geographical dispersion on collaborative planning and to investigate the role of time stress as a moderator. We also sought to examine whether virtual teams can be as effective as collocated face-to-face teams. To accomplish these goals, we compared dyadic performance on a collaborative planning task in both a rudimentary and a sophisticated distributed communication environment to collocated face-to-face meetings. The present research showed that the limitations of geographical dispersion can be overcome. By providing the proper groupware, virtual teams were able to produce work that was indistinguishable in quantity and quality from comparable face-to-face teams. In the following, we will discuss our findings organized around the effects on teamwork of communication environment and time pressure. We close with a discussion of the limitations of this study and suggestions for the design of distributed communication environments.

4.1. Effects of communication environment on teamwork

We expected that SHAPE would enable virtual teams to interact and perform in a manner that is comparable to face-to-face teams. Indeed, our data provided strong support for this position and corroborate earlier findings that distributed collaboration can be done without loss of quality (e.g., Olson et al., 1997). No differences between collocated and SHAPE-dyads were found, except for the quantity of performance: SHAPE-dyads were able to contribute more words to their written solution per minute of the interaction than dyads working in the other communication conditions. This finding provides support for media synchronicity theory. Because both participants were able to share the written plan, submit ideas at the same time, and see the comments and additions of their counterpart in real time they could work on the task more rapidly than dyads in the other two conditions.

As was expected, SHAPE-dyads outperformed push-to-talk radio dyads: SHAPE-dyads produced lengthier plans of higher quality than radio dyads. However, no differences were found between both conditions in the perceived exchange of information, satisfaction, and the quality of the planning process. This was unexpected, especially with regard to satisfaction, because previous research has repeatedly demonstrated that distribution, due to the relative restriction in the transmission of social and contextual cues, lowers satisfaction with both the process and the outcomes (Baltes et al., 2002; Straus, 1997). We discuss this finding from a cost–benefit perspective.

The cost–benefit perspective suggests that task performance should be related to the amount of effort expenditure on the task. The cost–benefit rationale would hold that in the absence of differences between costs and benefits, no differences in the perceived effort expenditure would emerge between communication conditions (cf. Thompson and Coovert, 2003). Our design allowing dyads in both conditions an equal amount of time for planning supports this notion. Moreover, we gave our teams no direct performance feedback upon completion of their plan. In addition, there was no single best plan to which dyads could compare their planning solutions. This means that there were no reasons to expect any differences between conditions in the perceptions of costs (e.g., the amount of information exchange) and benefits (e.g., the quality of the planning solutions). The cost–benefit rationale states that in the absence of such differences between cost and benefit ratios, no differences in participants' perceptions of the quality of their interaction and outcomes were to be expected between communication conditions.

Our observations during the experiment provided some additional insights. We observed that some of the radio dyads adopted coping strategies to compensate for experienced shortcomings in the communication environment. The members of these dyads divided the work between them at the beginning of the session and worked individually until a pre-agreed time (e.g., every 5 min), at which moment the work efforts were integrated into a single written plan of action. Thus, both the need for information exchange and communication were lowered, thereby reducing their effort expenditure. This could have enabled these dyads to compensate to some extent for increases in the costs of collaboration due to experienced communication limitations.

4.2. The role of time pressure

The data supported our hypothesis that time pressure harms the planning process of teams and, subsequently, how well the team performs. Our findings are generally supportive of models of time stress and performance such as Karau and Kelly's (1992) attentional focus model and confirm the detrimental effects of time pressure as a situational constraint on team processes and outcomes (Kelly et al., 1997). The quality of the dyads' written itinerary was substantially higher for dyads that had low time pressure imposed upon them as compared with dyads that had to work in high time-pressured conditions. It appears that dyads that have to work under high time pressure engage in lower quality teamwork and produce team products of lower quality as well. Indeed, additional examination of the data revealed a strong correlation between the quality of the planning process and the quality of the planning solution.

Furthermore, we found that dyads in high time-pressure conditions worked at a faster rate, writing down more words per minute of the interaction, than dyads in low time-pressure conditions. At the same time, teams working under high time pressure were less satisfied with the quality of their planning process, less content about their interaction with their fellow team member, and were less satisfied with the results of their planning process than dyads that had low time pressure imposed upon them when collaborating. Moreover, it was found that dyads in the high time-pressure condition exchange information in a less optimal manner than did dyads in the low time-pressure condition. Taken together, these results concur with earlier studies on time stress at the individual level, where it was found that individuals working under time pressure work at a faster rate, but often at the cost of lower performance quality (e.g., Kelly and McGrath, 1985; Smith et al., 1982). It is likely that the increase in contribution rate in the high time-pressure condition is the consequence of coping strategies to deal with the disadvantageous aspects of time pressure (see also De Dreu, 2003).

To our surprise, we found no interaction effects between time pressure and communication environment. There were no effects found of communication condition on the relationship between time pressure and team performance. These results differ from the work of Caballer et al. (2005), who found interaction effects between time pressure and the communication environment on a simple task in which four-member groups had to solve a logic problem with a correct solution. For instance, Caballer et al. found that the most deleterious effects of time pressure were produced in groups working together face-to-face, compared with groups mediated by video teleconference. According to their line of reasoning, mediated communication mitigated the unequal allocation of discussion time and centralization under time pressure. However, we were unable to replicate these findings in a setting in which dyads had to make a rather complex plan for which there was no single correct solution.

4.3. Limitations and implications for practice

Our study has some limitations that should be taken into account before generalizing our results to other settings and populations. First, our SHAPE environment differed on more than one aspect from our radio and face-to-face communication environments. SHAPE-dyads communicated through a video-teleconferencing system, and were equipped with a shared-workspace application that enabled them to share the written plan, and see the comments and additions of their counterpart in real time. This means that for some of the observed effects it is difficult to address whether the observed effects need to be subscribed to the difference in communication environment, to the addition of the shared-workspace application, or to both. This makes it difficult to draw specific conclusions about why SHAPE appears to be useful. However, according to media synchronicity theory, the best medium is that which provides the set of capabilities or characteristics that are most important for a given situation: the individuals, the task, and social context in which the team members interact. Thus, choosing one single medium for any task may prove less effective than choosing a set of media, or switching between media depending on the current communication process. This was clearly demonstrated in this study.

Second, our tested teams consisted of no more than two participants. The use of dyads is not ideal. For larger groups (i.e., three or more members) it is known that the regulation of conversational behavior and the need for coordination becomes more important (cf. Doherty-Sneddon et al., 1997; Hancock and Dunham, 2001; Sellen, 1995; Van der Kleij et al., 2004). The SHAPE condition allows for the simultaneous contribution of various members. This should be a greater advantage with larger groups consisting of at least three persons where participation differences and production blocking are more pronounced (see also DeSanctis and Gallupe, 1987; Jarvenpaa et al., 1988; Jessup and Valacich, 1993). Thus, it may well be that the trends that emerged in this study are amplified for teams that consist of more than two participants. The fact that we still were able to demonstrate differences between communication conditions shows that our findings are fundamental to virtual teams, whether small or large. Future research should explore this issue into more detail.

To conclude, our findings have some interesting practical implications as well. This research can be used to help teams, their leaders, and the organizations that implement virtual teams to make informed decisions on when and whether to engage in distributed collaboration. Likewise, this research contributes to the future development of innovative and workable concepts for the organization of distributed teamwork. It also helps designers to construct state-of-the-art groupware to support virtual teams. For example, SHAPE-dyads, which were equipped with a shared note-taking program, were enabled to work in parallel. Consequently, there was less need to explicitly communicate changes in the current state of the task, as compared with the push-to-talk radio dyads, leading to more efficient and better task performance (see also Whittaker, 2003). That is, although several studies show that distributed work leads to decreases in group effectiveness, increases in time required to complete tasks, and decreases in member satisfaction compared with face-to-face meetings, in this research we have shown that virtual teams can be just as effective as collocated teams.

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