SUMMARY

Background

Communication among team members is an important contributor of performance in teams. Especially when teams work in conditions characterized by high time pressure and rapidly changing situations. Teams working in military command and control, aircraft cockpits, crisis management often work in such conditions. In such teams, communication can be problematic. Communication is needed because team members depend on each other's information. In addition, communication is needed because it helps team members to evaluate and improve task performance, jointly determine strategies, and keep each other up-to-date with the changes in the situation. Nevertheless, potential problems are that there is too little time to communicate and that it disrupts the individual task performance of team members.

Communication can be especially problematic in conditions of high time pressure. In those conditions, there is no time to discuss extensively about "who is responsible for what task" or "who needs what information and when." Moreover, team members can be too late with exchanging the necessary information. In effective teams, members adapt to such conditions by providing each other the necessary information in advance of requests. Hence, team members anticipate on each other's informational needs. There are no extensive discussions to coordinate and there are no unneeded requests for information. This is called implicit coordination. The blind pass in basketball, where a player passes the ball over his or her shoulder to another player without looking and talking, is an example of implicit coordination.

In sum, communication has its benefits and costs and effective teams are able to adapt their communication when necessary. Teams should restrict their communication as much as possible, and communicate only if it is necessary or contributes to performance. The question is how teams can achieve this. Thus, how can teams limit their communication and when is communication needed?

Recent literature has advanced the construct of shared mental models among team members as an underlying mechanism of team processes and performance in teams. Shared mental models are organized knowledge structures that allow team members to describe, explain, and predict the teamwork demands. It comprises team knowledge such as knowledge about the tasks, responsibilities, and informational needs of the team members and situation knowledge such as knowledge of the ongoing developments in the external situation. The explanations and expectations generated by the shared mental models allow team members to anticipate on each other's task-related needs by providing each other information, resources, or other support in time.

With respect to communication, shared mental models allow team members to explain and predict the informational needs of teammates. Therefore, communication can take place efficiently and effectively. Efficiently, because explicit and extensive communication to ask for information or to make arrangements concerning "who does what when" and "who provides which information when" are not needed. Effectively, because team members are able to provide each other with a) the information needed to complete the tasks successfully, b) without explicit communication, and c) on the time in the task sequence of a teammate when this information is needed. In other words, shared mental models allow team members to coordinate implicitly. The result is the smooth team functioning of team members who are in sync with each other, and who know exactly when to talk and what to say.

Although shared mental models may result in efficient and effective communication, communication is also important for the development and maintenance of shared mental models. Communication during
task execution refines team members’ shared mental models with contextual cues. For example, team members can inform each other precisely which information they need. For maintenance purposes, communication is needed to keep the shared mental models up-to-date with the changes that occur during task execution. Especially in dynamic or novel situations, communication is needed to preserve an up-to-date shared mental model of the situation and to adjust strategies or develop new ones to deal with the situation. Shared mental models in changing and novel situations enable team members to make suggestions, provide alternative explanations, employ their expertise, generate and test hypotheses, and offer information useful to determine strategies in that particular situation. In contrast to implicit coordination, which implies that mature teams are silent teams, this emphasizes the need for explicit communication to arrive at a joint interpretation of the situation and the generation of strategies to deal with that situation.

Present research

The shared mental model construct explains how communication can be limited. Team members that rely on their mental models provide each other the necessary information in time, that is, in advance of requests. It also explains why and when communication is needed: to develop shared mental models and to keep them up-to-date. These notions inspired us to perform the research described in this thesis. The main objective was to investigate empirically the relationship among communication and performance in teams. This was investigated from two different perspectives.

From the first perspective, we were interested in how communication can be limited by communicating as efficiently and effectively as possible. We expected that communication and performance in teams could be improved when the knowledge in team member’s mental models is fostered. The research question for this first perspective was: how can communication and performance be improved by fostering the knowledge team members have in their mental models?

To answer this question we conducted three experiments. In Experiment 1 and 2 (see chapter 5), we provided teams with a cross training method in which members were trained in each other’s tasks. In Experiment 3 (see chapter 6), we provided team members with information that contained an explicit description of each other’s tasks and which information should be exchanged when. For both methods we expected that team members would develop team knowledge of each other’s tasks, responsibilities, and informational needs. Based on this knowledge, team members can anticipate each other’s informational needs by exchanging the necessary information in time.

To investigate these methods, we used an experimental team task for two members (see chapter 3). This task was especially designed to investigate team processes of teams that work in time-pressured and rapidly changing situations. A cognitive team tasks analysis showed that the task is suitable to investigate team processes in relation to shared mental models (see chapter 4). This task is (in different, enhanced versions) also used for the experiments that were conducted from the second perspective.

From the second perspective, we were interested in how team members can use their communication to improve their performance. In contrast to the first perspective, in which we investigated how communication could be limited, we were now interested in how performance can be improved by expanding the communication. We expected that the performance of teams can be improved because communication fosters the development and maintenance of the knowledge in team members’ mental models. The research question for this second perspective was: how and when does communication improve performance by fostering the knowledge team members have in their mental models?
To answer this question we used an opportunity of the experimental team task to manipulate the communication. The task was designed such that the necessary information could be exchanged by sending standardized electronic messages. By giving teams, on top of the electronic message exchange, the opportunity to communicate verbally or not, we could design conditions in which teams could communicate restrictedly or unrestrictedly. In the unrestricted communication conditions, team members could transfer team and situation knowledge and perform teamwork that consists of performance monitoring, evaluation, and determining strategies. Therefore, we expected that unrestricted communication would improve performance.

Experiment 4 and 5 were the first experiments in which we investigated the effect of unrestricted communication on performance (see chapter 7). Although unrestricted communication can have a positive effect on team performance, it can be argued that the effect of unrestricted communication diminishes with time. All team and situation knowledge is then transferred and teams are possibly better trained. Communication to transfer knowledge, evaluate, and determine strategies is then not needed any more. Therefore, we investigated in Experiment 6 the effect of unrestricted communication in two subsequent sessions (see chapter 8). Finally, in Experiment 7, we investigated the effect of unrestricted communication in novel versus routine situations (see chapter 9).

Results and conclusions

With respect to the first research question: training in each other’s tasks did not improve communication or performance in Experiment 1 and 2. Training in each other’s tasks is not an effective method to provide team members with the knowledge needed to develop an understanding of what information must be exchanged at what moments. Given the sparse support for the assumed effect of training in each other’s tasks, from our experiments as well as from the experiments of other researchers, we conclude that the effectiveness of this type of cross training method is questionable.

Better results were obtained with training methods, such as the provision of team information, that are directly aimed at the development of team knowledge. In Experiment 3, this improved communication and resulted in better team knowledge. Moreover, the scores on the questionnaire that measured this knowledge were positively correlated with several communication measurements. This indicates that the better the team knowledge, the better the communication. Surprisingly, the improved communication did not result in improved performance. We explain this by the individual task performance of team members. Although team members improved their teamwork and communicated more efficiently and effectively, they failed to perform well on their taskwork. Therefore, we expect that the effectiveness of the provision of team information will be further improved when team members are fully skilled in their taskwork.

In conclusion, more work is needed to find the best method for improving communication and performance in teams. For now, we demonstrated that the provision of team information is an effective method to improve communication and possibly performance given adequate taskwork.

With respect to the second research question, the results of Experiment 4 to 7 show that unrestricted communication improves performance, however, not in all conditions. In Experiment 4 and 5, unrestricted communication did improve performance. The communication was analyzed by means of verbal protocols and rated using a classification schema developed on the basis of the literature (see chapter 4). The analysis shows that teams transferred team and situation knowledge. Moreover teams communicated to perform additional teamwork that consisted of performance monitoring, evaluation, and determining strategies. This supports our explanation that team performance improved because
communication supports the development and maintenance of up-to-date team knowledge and facilitates teamwork.

The results of Experiment 6 further support this explanation. Teams that communicated unrestrictedly had higher scores on the knowledge questionnaire than teams that communicated restrictedly. This indicates that unrestricted communication fosters team and situation knowledge. Experiment 6 further shows that, after communicating unrestrictedly in one session, teams performed better in a subsequent session when they communicated restrictedly. Based on the knowledge developed through unrestricted communication in Session 1, team members could, despite the restricted communication, improve their performance in Session 2. The team and situation knowledge developed in Session 2, supported teams in exchanging the necessary information with a limited number of messages.

Nevertheless, things went wrong for the teams that continued to communicate unrestrictedly in Session 2. Compared to the teams that communicated restrictedly, their performance decreased in Session 2. We had expected that communication was needed to preserve up-to-date situation knowledge (the situation changed continuously). An explanation for this performance decrease is that too much communication in periods with high workload distracted team members from executing their individual tasks. A post-hoc analysis of the verbal communication showed that team members indeed did not adapt to high workload periods. They communicated as much in high workload periods as in low workload periods.

Experiment 6 shows that the effect of unrestricted communication diminishes after time. Unrestricted communication might be needed only to preserve up-to-date situation knowledge. This was investigated in Experiment 7. To ensure that team knowledge was present, we equipped team members with a team knowledge schema. The results show that unrestricted communication improved performance during the novel scenarios but not during the routine scenarios. Thus, when teams have developed sufficient team knowledge, unrestricted communication is only needed in novel situations and not in routine situations.

Based on Experiment 4 to 7, we conclude that communication is especially important in the beginning of a team’s lifetime. Communication is beneficial to develop team and situation knowledge. Once this knowledge is developed, teams should limit their communication as much as possible. In that case, performance can be maintained when team members exchange the necessary information without explicit coordination.

Nevertheless, communication can be beneficial because it facilitates additional teamwork such as jointly determining strategies. For teams that perform in routine situations and are fully trained, communication is less important than for teams that are not fully trained or encounter novel situations. Hence, the answer to the question whether teams should communicate or not, cannot be easily answered with a simple yes or no. In general, we conclude that teams should limit their communication with respect to the fixed elements in team functioning. More precisely, teams should a) not transfer team and situation knowledge in routine situations, b) not coordinate explicitly and communicate about "who does what" and "who needs what information and when," and c) not continuously request each other for information. Limiting this type of communication should leave team members free to perform their own tasks as well as they can. At the same time, this would leave as much spare communication capacity available for that type of communication that is important for performance. That is, for performance monitoring, evaluation, and determining strategies together and, only in changing or novel situations, to transfer situation knowledge.

The research in this thesis found support for several hypotheses with regard to the mental model construct (see chapter 10). The shared mental model construct is a powerful construct to explain team
processes and performance in teams that work in time-pressured and rapidly changing situations. From the mid nineties (at the time the research described in this thesis started) the construct has gained substantial attention. When looking across the total body of research, however, there is still confusion about how shared mental models exactly operate and can be measured and manipulated. The various studies do not show a consistent picture and even yield conflicting results. The problem is that researchers employ such different interpretations, definitions, and measurements of the shared mental model construct that it is difficult to give unequivocal explanations and to make predictions. The danger is that the shared mental model construct becomes meaningless. The research so far yields no indisputable evidence for the existence and working of shared mental models.

Future research must clarify what shared mental models are, how they work, and how they can be measured. Important topics to consider are the extent of sharedness, the hypothesized organization of knowledge in mental models, and how they exactly influence team processes.

Finally, the research described in this thesis has taught us much about team behavior in general, and, more specifically, communication in teams. This helped us to formulate several practical implications with respect to team design, training, and support.