Communication and performance in teams
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In chapter 7, we shift our attention from the potential benefits of limiting the communication to the potential benefits of expanding the communication. We hypothesize that communication is important to develop team and situation knowledge in shared mental models and perform teamwork that consists of performance monitoring, evaluation, and determining strategies. The question when and how communication improves performance is under investigation in the two experiments described in this chapter. The opportunity to communicate unrestrictedly was manipulated systematically. In Experiment 4, teams could either communicate unrestrictedly or not, and in Experiment 5 only between or during task execution. The results show that, compared to communicating restrictedly, unrestricted communication had a positive impact on performance in all cases.

7.1 Introduction

In chapter 5 and 6, we concentrated on the question how communication and performance could be improved by fostering team knowledge in the mental models of team members. By providing cross training and team information, we expected that teams would communicate more efficiently and effectively, which should have had a positive effect on performance. Most studies that investigated communication in relation to shared mental models, examined communication in the same manner. Efficient and effective communication as a result of having shared mental models. In chapter 7 to 9, we take another point of view. We are now interested in how team members can use their communication to improve their performance by fostering the knowledge in team members’ mental models. In other words, we investigate communication as an antecedent of shared mental models. Instead of investigating how performance can be improved by limiting the communication (by providing the necessary information on the moments that team members need it), we are now interested in how performance can be improved by expanding the communication in teams.

These perspectives are also reflected in the literature. Researchers claim that performance improves when team members limit their communication by coordinating implicitly (Cannon-Bowers et al., 1998). However, researchers also claim that performance is positively affected when teams communicate extensively to develop a shared understanding of the team, task and situation, plan activities, and cooperatively solve problems (Blickensderfer et al., 1997b; Orasanu, 1993; Rochlin et al., 1987; Seifert & Hutchins, 1992; Stout et al., 1996). The goal of the experiments described in chapter 7 to 9 is to shed light on these claims, and to gain a better understanding of the conditions under which communication in teams affects performance.

In chapter 4 (see section 4.3.1), we described, based on the literature and a cognitive team task analysis, which type of communication is important for performance. We presented a model (see Figure 4.8) in which we illustrated the hypothesized relationships between communication, team and situation knowledge in shared mental models, and performance. Summarizing the model, we hypothesize that communication is important to develop and maintain up-to-date team and situation knowledge in a

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1 This chapter is a revised version of Rasker et al. (2000a)
shared mental model. In turn, this knowledge is used a) to coordinate implicitly and exchange timely the information that team members need to complete their tasks successfully, and b) to perform other teamwork that consists of performance monitoring, evaluation, and determining strategies together. We believe that the timely exchange of necessary information is important for performance. In some conditions, additional communication may be needed to perform teamwork and develop team and situation knowledge in mental models. The question is when and how communication improves performance by fostering the knowledge team members have in their mental models, which is the second research question of this thesis.

The verbal protocol analysis described in chapter 4 (see section 4.3.2) gives insight in the answers of this question. First, when team members communicate, knowledge important for shared mental models is transferred. With respect to team knowledge, the analysis shows that team members informed each other about their tasks and informational needs. Moreover, team members communicated in detail about the time that information must be exchanged. We believe that this type of communication fosters team knowledge. With respect to situation knowledge, team members informed each other about the ongoing developments and the changes in the environment. We believe that this type of communication fosters situation knowledge. Second, the analysis shows that team members communicate to perform teamwork that involves performance monitoring, evaluation, and determining strategies, which also foster team and situation knowledge. Altogether, we expect that these communications have a positive effect on performance.

7.1.1 Research on communication in teams

There are only a few experiments that have investigated communication as an antecedent of shared mental models. In one experiment it was investigated whether team self-correction discussions resulted in an overlap in team members’ expectations (Blickenstaffer et al., 1997c). When team members engage in team self-correction, they communicate to evaluate the past performance and determine how teamwork can be improved for the next time. The results show that teams that were engaged in team self-correction had more overlap in their expectations of team roles, team strategy, and communication manners than teams that did not engage in team self-correction. Although these teams also coordinated more implicitly (measured by the amount of information provided in advance of requests), this resulted not in an improved performance. The results show further that the extent of overlap in expectations was positively correlated to implicit coordination and performance.

In another experiment, the effect of communication on shared mental models and performance was investigated in a similar way (Stout et al., 1999). This time, it was examined how team members use their communication for planning. Planning in this experiment was defined as communication that existed of setting goals, clarifying each team member’s roles and responsibilities, sharing information, and anticipating on how to deal with high workload and unexpected events (e.g., by making agreements about backing each other up). The results show that planning before task execution, allowed teams to use more efficient communication strategies under conditions of high workload during task execution. These teams provided more information in advance of requests and also performed better. Furthermore, these teams had better shared mental models of each other’s informational requirements. However, better shared mental models were not associated to the provision of information in advance of requests. Therefore, better planning directly influenced communication and performance, independent of having shared mental models.

Both experiments have investigated the effect of communication before or between task execution on shared mental models and performance. These experiments show that communication during these
periods had a positive effect on the overlap in team members' expectations or mental models. However, the mediating role of shared mental models and the relationships with the provision of information in advance of requests and, in turn, performance are not clear. Especially the lack of relationship between shared mental models and the provision of information in advance of requests is of concern. It questions the construct validity of shared mental models. What these two experiments also not have captured is how communication to self-correct or to make plans during task execution may improve performance. The interesting point here is that this type of communication, although expected to be beneficial, may conflict with the expected value of coordinating implicitly by communicating as effective and efficient as possible. Finally, these experiments have not investigated communication during versus before (or between) task execution.

That communication during task execution can improve performance can be inferred from the following two studies. In the first study, the communication of cockpit crews during a full-mission simulated flight was observed (Orasanu, 1990, 1993). The author found that effective teams (in terms of fewer flight errors) had more task-oriented communication during the flight. This included the formulation of plans and strategies. The author reasoned that this type of communication is especially beneficial when teams must handle novel or difficult problems. Communication is needed to develop a shared problem model that is necessary to ensure that all members are solving the same problem. Based on this model, team members are able to interpret the communication in the same manner and develop compatible explanations and expectations of the informational needs of the teammates and the strategies needed to deal with novel situations.

In another study, the communication of military teams was observed (McIntyre & Salas, 1995). It appeared that effective teams monitored each other's performance more often than ineffective teams. Performance monitoring consists of communication in which team members give, seek, and receive task-clarifying feedback during a task execution session (see also Cannon-Bowers et al., 1995). Team members monitor the performance of fellow team members, provide constructive feedback regarding errors, and offer advice for improving performance (McIntyre & Salas, 1995). Communication is needed to inform each other about the progress made on the task, the situational changes, and to be able to give feedback. By providing feedback to each other, team members can adjust their task execution immediately when necessary. We believe that performance monitoring is especially important to preserve up-to-date team and situation knowledge of the ongoing developments during task execution. This so-called strategic knowledge is important to ensure that team members keep track of the currently used strategies, team members' progress on the tasks, and the changes in team members informational needs. With respect to the situation, it is important that team members have up-to-date knowledge of the changes in the environment and unexpected problems. Common situation knowledge support team members in evaluating and determining strategies for the same environment or problems faced with.

The final study to be described is a conceptual examination of Stout et al. (1996) that emphasizes the role of communication for the development and maintenance of knowledge specific for a task execution session. According to Stout et al. (1996) team members need three types of knowledge. First, when entering a task execution session, team members need declarative knowledge that comprises knowledge of the mission, task, and members' roles. Second, team members need procedural knowledge about the sequence and timing of activities and information exchange. Third, in changing situations, team members must develop and maintain strategic knowledge that provides them with a common understanding of a) the operational context, b) actions that must be taken when unexpected events occur, and c) the information that should be obtained or exchanged to respond appropriately to the situation. Stout et al. reason that communication is needed to develop this strategic knowledge. This so-called
strategizing involves communication in which team members clarify, confirm and disseminate information, plans, expectations, roles, procedures, strategies, and future states.

7.1.2 Experiment 4 and 5

The above-described research argues for teams to communicate extensively. However, there are no empirical studies that investigated the effect of communication during task execution on performance or studies that contrasted this with the effect of communication before (or between) task execution. In Experiment 4 and 5, we could treat communication as a factor that is manipulated between teams. We used an experimental team task in which the information needed to accomplish the tasks could be exchanged by standardized electronic messages. On top of that, team members could or could not communicate verbally with each other. This way, we were able to create conditions in which team members could communicate either restrictively or unrestrictedly. In the restricted condition, team members cannot communicate to develop team or situation knowledge. Therefore, team members must rely on the knowledge that is developed before task execution. We expect that unrestricted communication improves performance because it fosters the development of team members' knowledge concerning the team and the situation in a shared mental model. This knowledge supports team members in a) predicting each other's informational needs and providing each other with the necessary information within the teammate's task sequence when it is needed, and b) performing additional teamwork that consists of performance monitoring, evaluation, and determining strategies together. We expect that these behaviors have a positive impact on performance.

The experiments described in this chapter address the question whether unrestricted communication improves performance. A comparison is made between teams that have the opportunity to communicate unrestrictedly and teams that communicate restrictively. Figure 7.1 represents the dimensions (denoted by the gray boxes) and the relationship (denoted by the uninterrupted line) that are under investigation in Experiment 4 and 5.

![Figure 7.1](image)

**Figure 7.1:** Hypothesized relationship between unrestricted communication and performance under investigation in Experiment 4 and 5
7.2 Experiment 4

7.2.1 Hypotheses

We expect that the performance improvement will be influenced by unrestricted communication that fosters members’ team knowledge. In turn, this supports team members in predicting each other’s informational needs and providing each other with the information needed to perform the tasks within the task sequence when it is most needed. Therefore, we formulated a hypothesis about the necessary information exchange. In the experimental task used, there is one piece of necessary information that must be exchanged by the standardized electronic messages. Even the team members that could communicate verbally had to provide this information by using the electronic message facility. Although they could also exchange the necessary information verbally, they were not able to put this information into their system and use the information to accomplish their tasks. Hence, by measuring the number and timing of this message, we could determine the team’s ability to exchange the necessary information within the task sequence of the teammate when it is needed. This is regarded as an important indicator for having team knowledge. Furthermore, the timely exchange of this message shows whether team members are able to adjust their strategies in case of novel situations, which is supported by communicating unrestrictedly. To test whether teams that can communicate unrestrictedly are better in the timely exchange of necessary information than teams that cannot communicate unrestrictedly, the following hypothesis is put forward:

1. We expect that the teams that can communicate unrestrictedly exchange more often the necessary information in time than the teams that cannot communicate unrestrictedly.

We also expect that the performance improvement will be influenced by unrestricted communication that fosters the situation knowledge of the team members. Having team and situation knowledge, support team members in performance monitoring, evaluation, and determining strategies together. Especially in novel situations this is expected to be beneficial. To test whether unrestricted communication improves performance, the following hypothesis is put forward:

2. We expect that the teams that can communicate unrestrictedly perform better than the teams that cannot communicate unrestrictedly.

7.2.2 Method

Participants

The data for Experiment 5 were obtained from 44 students of Utrecht University in 22 teams of two participants. The distribution of participants over the different conditions with regard to sex was as follows: three female, three male teams and five mixed teams in the restricted condition; five female and six male teams in the unrestricted condition. Participants that formed the team were not acquainted to each other. The participants were paid Dfl. 60, = and were informed that they had a chance of receiving a bonus of Dfl. 40, = for the best performing team.

Design

Between teams. In order to test the hypotheses, two experimental conditions were designed: the restricted and the unrestricted condition.
Within teams. The presence of novel scenarios was a within team manipulation. Routine and novel scenarios were equally present. Teams were presented with identical scenarios in a fixed order. The first eight scenarios were routine scenarios, followed by eight novel scenarios.

Task

In Experiment 4, Version 2 of the fire-fighting task as described in section 3.3.1 was used.

Manipulation

In the restricted condition, teams could exchange the necessary information by sending and receiving the standardized electronic messages. Team members were placed in separate soundproof rooms and verbal communication was not possible at all. In the unrestricted condition, team members could communicate unrestrictedly in addition to sending and receiving the standardized electronic messages. Unrestricted communication was made possible by giving team members the opportunity to communicate verbally both during and between scenarios. Team members were placed in the same room and verbal communication was made possible face-to-face.

Scenario type was manipulated as follows. In the routine scenarios, the pattern in a series of small fires predicted the large building in danger as learned during the training. For example, team members could predict a fire in a hospital in sector IV when they recognized the pattern of small fires that consisted of “apartment building-house-apartment building” in sector I. In novel scenarios, the large fire was set in another section than team members would expect based on the pattern in a series of small fires they learned in their training. That is, instead of occurring in the diagonally opposite sector, the fire occurred in the sector underneath or above the sector with the pattern. The prediction with regard to the building type (factory or a hospital) remained intact.

Measurements

Communication. The verbal communication was recorded on tape. Two coders analyzed the communication from tape by classifying each statement of the team members into categories. The categories were derived from the model we developed based on the cognitive team task analysis of chapter 4 (see section 4.3.1, Table 4.10). We added one category in which the coders rated the remaining statements that could not be classified because they were not task related or unclear. For each team, each scenario, and the time between the scenarios the communication was rated. Independently from the first coder, the second coder rated the tapes in the same way. The second coder rated the communication of two randomly chosen scenarios for each team (in total 24 scenarios with a total duration of approximately 75 minutes). For these scenarios, an agreement level of the two coders was determined by the percentage of statements that the coders rated in the same category. With respect to the scenarios that both coders rated, the agreement level was 87%. This was considered sufficiently high such that the data obtained from the first coder (the one that scored all scenarios for all teams) were used for further analysis.

The standardized electronic messages were time-stamped and saved in a computer log file for analyses. The messages were used to determine whether there were differences between the conditions with respect to the timely exchange of a crucial piece of information. Note that, regardless of the opportunity to communicate unrestrictedly, team members had to send this message electronically to accomplish the tasks. The measure we were interested was the percentage of scenarios in which the message of the large building in danger was sent and read in time. We believe that this is an important measure for implicit coordination because it measures whether team members have provided the necessary
information on the time in the teammate's task sequence that this information is needed. Moreover, this measure indicates whether team members have team knowledge of what (i.e., the large building in danger) and when (i.e., before Period 8 finishes) information must be exchanged. In the scenarios that were used in Version 2 of the fire-fighting task, it was highly important that this message is sent and read before Period 8 finishes.

**Performance.** In Version 2 of the fire-fighting task, performance was measured by the number of units that were allocated to the large building in danger in Period 10. This measure determined for every team in every scenario, how many units were assigned to the factory or the hospital at the beginning of the fire. Teams could have either sufficient or insufficient units allocated. Sufficient means that for a factory, four units, and a hospital, five units were allocated. With fewer units, a team was not able to achieve the goal and save as many potential casualties as possible.

**Procedure**

An experimenter assigned the participants randomly to the role of dispatcher and observer and told them to read the instruction. They were told not to speak to each other about the experiment and the experimenter was always present in situations where participants were together in the same space. Participants were allowed to ask questions at any point during reading.

The instruction first explained the fire-fighting task in general, followed by instructions specific for each role. This included a systematic instruction on how to manipulate the interface, accompanied by small tasks that had to be carried out by the participants. Subsequently, there was a training session of 16 scenarios. After this first training session, participants were asked to continue to read the instruction. In this instruction, it was explained how participants could predict, based on a pattern in a series of small fires, the location, type, and time of a large fire later in the scenario. These instructions were followed by another training session of 16 scenarios that contained such a pattern in a series of fires.

During the training, the two members of the team played the same scenarios at the same time. The dispatcher played with a computer program that simulated observer behavior (e.g., sending messages and so forth) and the observer played with a computer program that simulated dispatcher behavior. The programs, or "agents" as they were called, displayed ideal observer and dispatcher behavior. That is, the agents were always in time with the right information. The participants were informed of this. Participants were also informed that in the experimental session they would play with their actual teammate. The choice for this technique was made, to ensure an equal level of expertise at the end of the training by controlling the teammate's behavior.

After the training, the experimental session started. Participants were presented with 16 scenarios that existed of 12 periods of 15 seconds each. In total, an experimental session lasted about four hours.

### 7.2.3 Results

**Communication**

The verbal communication that took place in the unrestricted condition was classified into the categories as described in section 4.3.1 (see Table 4.10). The scores can be found in Table 7.1.
Table 7.1: Verbal communication; mean number of statements for each team in the unrestricted condition

<table>
<thead>
<tr>
<th>Communication category</th>
<th>Unrestricted condition</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>% of total</td>
<td></td>
</tr>
<tr>
<td>Information exchange</td>
<td>212</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Performance monitoring</td>
<td>68</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>54</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Determining strategies</td>
<td>20</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Team knowledge</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Situation knowledge</td>
<td>50</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Remaining Communication</td>
<td>23</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>430</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

As can be seen in Table 7.1, team members used the opportunity to communicate unrestrictedly. Most statements could be classified in one of the categories that reflect teamwork. Team members also exchanged information that is needed to accomplish the tasks. Although team members could exchange this information with the standardized electronic messages, it appears that team members found it necessary to exchange this information verbally as well.

With respect to the standardized electronic messages, Hypothesis 1 predicted that the teams in the unrestricted communication exchange more often the necessary information in time than the teams in the restricted condition. In each scenario, teams could be either in time or too late with sending and receiving the message about the large building in danger (i.e., when the message was not sent at all, this was considered as too late). The scores can be found in Table 7.2.

Table 7.2: Standardized electronic messages; communication result of the total number of scenarios in which team members were in time with sending and reading the message about the large building in danger for each condition and scenario type (N = 352)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Scenario type</th>
<th>Message</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In time</td>
<td>Too late</td>
<td></td>
</tr>
<tr>
<td>Restricted</td>
<td>Routine</td>
<td>28</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>11</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>Routine</td>
<td>74</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>51</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>

We fitted three log-linear models to the data. The first model included the general mean and the design (i.e., timeliness, condition * scenario type). The second model included the general mean and the design and the main effect of condition (i.e., timeliness, condition * scenario type, condition * timeliness). For both models, Pearson’s Chi$^2$ was calculated. To test the main effect of condition, the Chi$^2$ of the first model minus the Chi$^2$ of the second model was tested. The degrees of freedom for this test were the ones of the first model minus the ones of the second model. The third model included the general mean and the design and the main effects of condition as well as scenario type (i.e., timeliness, condition * scenario type, condition * timeliness, scenario type * timeliness). To test the interaction effect of condition and scenario type, the Chi$^2$ and the degrees of freedom of this model were tested. To test the differences between conditions on either the routine or novel scenarios, a Chi$^2$ for each separate two-way table was calculated and tested.

The results show that teams that communicated unrestrictedly were more often in time with sending and reading the message about the large building in danger (71%) than teams that communicated restrictedly (22%). $\chi^2(1, N = 352) = 78.26$, $p < .01$. These teams were also more often in time in routine scenarios.
(84%) than teams in the restricted condition (32%), \( \chi^2(1, N = 176) = 49.34, p < .01 \), and in more novel scenarios (58%) than teams in the restricted condition (13%), \( \chi^2(1, N = 176) = 39.84, p < .01 \). The results support Hypothesis 1. Teams of the unrestricted condition were more often in time with sending and reading a crucial piece of information (i.e., the large building in danger) than the teams of restricted condition. There was no interaction between condition and scenario type, \( \chi^2(1, N = 352) < 1 \).

**Performance**

Team members could perform either sufficiently or insufficiently on the performance measure allocation. The scores can be found in Table 7.3.

**Table 7.3:** Performance measure allocation; total number of scenarios in which team members had allocated a sufficient number of units during Period 10 for each condition and scenario type \((N = 352)\)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Scenario type</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sufficient</td>
</tr>
<tr>
<td>Restricted</td>
<td>Routine</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>6</td>
</tr>
<tr>
<td>Unrestricted</td>
<td>Routine</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>28</td>
</tr>
</tbody>
</table>

We fitted three log-linear models to the data. The first model included the general mean and the design (i.e., sufficiency, condition * scenario type). The second model included the general mean and the design and the main effect of condition (i.e., sufficiency, condition * scenario type, condition * sufficiency). For both models, Pearson’s \( \chi^2 \) was calculated. To test the main effect of condition, the \( \chi^2 \) of the first model minus the \( \chi^2 \) of the second model was tested. The degrees of freedom for this test were the ones of the first model minus the ones of the second model. The third model included the general mean and the design and the main effects of condition as well as scenario type (i.e., sufficiency, condition * scenario type, condition * sufficiency, scenario type * sufficiency). To test the interaction effect of condition and scenario type, the \( \chi^2 \) and the degrees of freedom of this model were tested. To test the differences between conditions on either the routine or novel scenarios, a \( \chi^2 \) for each separate two-way table was calculated and tested.

Hypothesis 2, which predicted that teams that can communicate unrestrictedly perform better than teams that cannot communicate unrestrictedly, received support. As can be seen in Figure 7.2, teams that communicated unrestrictedly allocated sufficient units in more scenarios (29%) than teams that communicated restrictedly (7%), \( \chi^2(1, N = 352) = 29.29, p < .01 \). These teams also allocated sufficient units in more routine scenarios (26%) than teams in the restricted condition (7%), \( \chi^2(1, N = 176) = 11.93, p < .01 \), and in more novel scenarios (32%) than teams in the restricted condition (7%), \( \chi^2(1, N = 176) = 17.64, p < .01 \). There was no interaction between condition and scenario type, \( \chi^2(1, N = 352) < 1 \).
7.2.4 Discussion of Experiment 4

Experiment 4 was conducted to investigate the effect of unrestricted communication on performance. The results support our hypothesis that communication without restrictions has a positive effect on performance. We believe that the performance improvement can be ascribed to the development of team members’ knowledge concerning the team and the situation. The communication scores show that team members transferred situation and, to a lesser extent, team knowledge. One of the benefits of having this knowledge is that team members are better in predicting each other’s informational needs and providing each other with the necessary information within the task sequence of the teammate when it is needed. Our hypothesis that team members of the unrestricted condition would exchange more often the necessary information in time is also supported by the results. This indicates that team members that communicated unrestrictedly developed better knowledge of each other’s informational needs.

The verbal protocol analysis described in chapter 4 (see section 4.3.2) shows that team members inform each other in detail what information is needed and when. For example, team members informed each other in which periods information of the large building had to be exchanged. We believe that it is this type of communication that sharpens the knowledge of each other’s informational needs. Based on this knowledge, team members can attune their individual taskwork on that of their teammates such that the necessary information is obtained and exchanged in time. In teams, this is essential for a good performance.

Unrestricted communication gives team members also the opportunity to perform teamwork that cannot be performed when communicating restrictedly. The verbal protocol analysis described in chapter 4 shows that performance monitoring, evaluation, and determining strategies can be distinguished. The communication scores show that teams communicated substantially in the categories that are associated with this teamwork. Team members monitor each other’s performance allowing them to inform each
other about the progress made on the tasks and give feedback immediately when things go wrong. The result is that they are able to prevent each other from making errors. We believe that performance monitoring also fosters the development of team and situation knowledge. Because information is exchanged concerning the ongoing activities, team members develop an understanding of how they are dependent on each other’s information.

Team members that communicate unrestrictedly can also evaluate and determine strategies jointly. Several researchers hypothesized that common knowledge of the team and the situation is important for this type of teamwork (Orasanu, 1990, 1993; Stout et al., 1996). Especially in novel situations it is important that team members keep track of the changes in the situation and, when needed, adjust their strategies. When team members hold common situation knowledge, they are able to provide each other with information, suggestions, alternatives, and expectations that are both explained and expected by the teammates. Given that the teams that communicated unrestrictedly performed also better on the novel situations, it can be concluded that these teams were able to keep up their performance and adjust their strategies successfully. Because the communication scores show that team members evaluated and determined strategies together, we believe that unrestricted communication played an important role herein.

In conclusion, the results of Experiment 4 show that unrestricted communication improves performance. We explained this performance improvement by team members that developed better team and situation knowledge that, in turn, has a positive effect on the timely exchange of necessary information, performance monitoring, evaluation, and determining strategies. The communication measures (electronically as well as verbally) support this explanation.

7.3 Experiment 5

From Experiment 4, we were not able to draw conclusions concerning the relative contributions of communication during task execution or between task execution. In order to investigate this, a second experiment is performed.

7.3.1 Hypotheses

The second experiment is focused on the relative contributions of communication during task execution or in the break between task execution sessions. Based on theoretical grounds, we could not predict which of the two types of communication is more beneficial to improve the performance. Therefore, it is tested whether there is a difference amongst teams depending on the opportunity to communicate unrestrictedly during or between task execution. The conditions of Experiment 5 are also compared with the conditions of Experiment 4. This way, we are able to test directly to what extend unrestricted communication either during or between task execution contributes to performance. To test whether there are differences in the necessary information exchange, the following hypotheses are put forward:

1. We expect that the teams that can communicate unrestrictedly during task execution perform differently with respect to the timely exchange of necessary information than the teams that cannot communicate unrestrictedly between task execution

2. We expect that the teams that can communicate unrestrictedly during task execution exchange more often the necessary information in time than the teams that cannot communicate unrestrictedly
Communication and performance in teams

3. We expect that the teams that can communicate unrestrictedly between task execution exchange more often the necessary information in time than the teams that cannot communicate unrestrictedly.

To test whether there are differences in the performance, the following hypotheses are put forward:

4. We expect that the teams that can communicate unrestrictedly during task execution perform differently than the teams that can communicate unrestrictedly between task execution.
5. We expect that the teams that can communicate unrestrictedly during task execution perform better than teams that cannot communicate unrestrictedly.
6. We expect that the teams that can communicate unrestrictedly between task execution perform better than the teams that cannot communicate unrestrictedly.

7.3.2 Method

For Experiment 5, we used the same methodology as for Experiment 4. Therefore, this section only describes the differences with Experiment 4.

Participants

The data for Experiment 5 were obtained from 44 students of Utrecht University in 22 teams of two participants. The distribution of participants over the different conditions with regard to sex was as follows: six female teams and five male teams in the during scenarios condition; five female teams and six male teams in the between scenarios condition. The participants were paid Dfl. 60, = and were informed that they had a chance of receiving a bonus of Dfl. 40, =.

Design

In order to test the hypotheses, two experimental conditions were designed: the during and the between condition.

Manipulation

In the during condition, team members could communicate verbally without restrictions during the execution of scenarios. In the between condition, team members could communicate verbally without restriction during the break between scenarios. The total time available for unrestricted communication was identical for both conditions (three minutes). In both conditions, teams had also the opportunity to exchange the necessary information by sending and receiving standardized electronic messages. Team members were placed in separate soundproof rooms and verbal communication was made possible via headsets.

7.3.3 Results

Communication

The communication that took place in Experiment 5 was classified into the same categories as in Experiment 4. With respect to the scenarios that both coders scored, the agreement level was 78%. This was considered sufficiently high such that the data obtained from the first coder (the one that scored all scenarios for all teams) were used for further analysis. The scores can be found in Table 7.4.
As can be seen in Table 7.4, team members used the opportunity to communicate unrestrictedly. With respect to percentage of statements of the total amount of communication in each category, we tested post-hoc the differences between the means of the during and the between condition. An analysis of variance, comparing the during and the between condition was used. Because we had no hypothesis, we applied a Bonferroni correction. It appears that the differences for the category situation knowledge and remaining communication did not reach significance. Teams in the during condition communicated mostly in the categories that are associated with the ongoing task performance (i.e., information exchange and performance monitoring). Teams in the between condition communicated mostly in the categories that are associated with past (evaluation) and future (determining strategies) performance. Teams in the between condition, also communicated more team knowledge than the teams in the during condition.

### Table 7.4: Verbal communication; mean number of statements for each team in the during as well as in the between condition

<table>
<thead>
<tr>
<th>Communication category</th>
<th>During condition</th>
<th>Between condition</th>
<th>F(1,20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>% of total</td>
<td>Score</td>
</tr>
<tr>
<td>Information exchange</td>
<td>198</td>
<td>55</td>
<td>32</td>
</tr>
<tr>
<td>Performance monitoring</td>
<td>60</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Evaluation</td>
<td>39</td>
<td>10</td>
<td>109</td>
</tr>
<tr>
<td>Determining strategies</td>
<td>15</td>
<td>4</td>
<td>55</td>
</tr>
<tr>
<td>Team knowledge</td>
<td>7</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td>Situation knowledge</td>
<td>42</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>Remaining Communication</td>
<td>18</td>
<td>5</td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
<td>100</td>
<td>322</td>
</tr>
</tbody>
</table>

*Note. When applying a Bonferroni correction, the differences between the category situation knowledge and remaining communication do not reach significance.*

With respect to the standardized electronic messages, Hypothesis 1 predicted differences between the during and the between condition with respect to the exchange of the necessary messages. In each scenario, teams could be either in time or too late with sending and receiving the message about the large building in danger (i.e., when the message was not sent at all, this was considered as too late). The scores of this measure are shown in Table 7.5.

### Table 7.5: Standardized electronic messages; communication result of the total number of scenarios in which team members were in time with sending and reading the message about the large building in danger for each condition and scenario type (N = 352)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Scenario type</th>
<th>In time</th>
<th>Too late</th>
</tr>
</thead>
<tbody>
<tr>
<td>During</td>
<td>Routine</td>
<td>76</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>68</td>
<td>20</td>
</tr>
<tr>
<td>Between</td>
<td>Routine</td>
<td>79</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>68</td>
<td>20</td>
</tr>
</tbody>
</table>

To test Hypothesis 1 to 3, we fitted the same log linear models on the data and followed the same procedure as for Experiment 4. The results of this analysis show that there are no differences between the teams that communicated unrestrictedly during (82%) and between scenarios (84%), $\chi^2(1, N = 352) < 1$. There were also no differences between the conditions in the routine scenarios (86% for the during and 90% for the between condition), $\chi^2(1, N = 176) < 1$, and the novel scenarios (77% for the during and 77% for the between condition), $\chi^2(1, N = 176) < 1$. There was no interaction between condition and scenario type, $\chi^2(1, N = 352) < 1$. Taken together, these results do not support Hypothesis 1.
Hypothesis 2 predicted that the teams in the during condition are more often in time with the exchange of necessary information than the teams in the restricted condition. With respect to the percentage of scenarios in which the building of the large building in danger was sent and read in time, the results support Hypothesis 2. Teams in the during condition were more often in time (82%) than the teams in the restricted condition (22%), $\chi^2(1, N = 352) = 120.31, p < .01$. These teams were also more often in time in routine scenarios (86%) than the teams in the restricted condition (32%), $\chi^2(1, N = 176) = 54.15, p < .01$, and in more novel scenarios (77%) than teams in the restricted condition (13%), $\chi^2(1, N = 176) = 74.62, p < .01$. There was no interaction between condition and scenario type, $\chi^2(1, N = 352) < 1$.

Hypothesis 3 predicted that the teams in the between condition are more often in time with the exchange of necessary information than the teams in the restricted condition. With respect to the percentage of scenarios in which the building of the large building in danger was sent and read in time, the results support Hypothesis 3. Teams in the between condition were more often in time (84%) than the teams in the restricted condition (22%), $\chi^2(1, N = 352) = 126.54, p < .01$. These teams were also more often in time in routine scenarios (90%) than teams in the restricted condition (32%), $\chi^2(1, N = 176) = 62.00, p < .01$, and in more novel scenarios (77%) than teams in the restricted condition (13%), $\chi^2(1, N = 176) = 74.62, p < .01$. There was no interaction between condition and scenario type, $\chi^2(1, N = 352) < 1$.

Performance

Team members could perform either sufficiently or insufficiently on the performance measure allocation. The scores can be found in Table 7.6. We fitted the same log-linear models on the data and followed the same procedure as in Experiment 4 to test the hypotheses.

### Table 7.6: Performance measure allocation; total number of scenarios in which team members had allocated a sufficient number of units during Period 10 for each condition and scenario type (N = 352)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Scenario type</th>
<th>Allocation</th>
<th>Sufficient</th>
<th>Insufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>During</td>
<td>Routine</td>
<td></td>
<td>28</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td></td>
<td>38</td>
<td>50</td>
</tr>
<tr>
<td>Between</td>
<td>Routine</td>
<td></td>
<td>12</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td></td>
<td>18</td>
<td>70</td>
</tr>
</tbody>
</table>

Hypothesis 4, which predicted that teams perform differently depending on whether they could communicate unrestrictedly during or between scenarios, received support. As can be seen in Figure 7.3, teams that communicated unrestrictedly during scenarios allocated sufficient units in more scenarios (38%) than teams that communicated unrestrictedly between scenarios (17%), $\chi^2(1, N = 352) = 18.02, p < .01$. These teams also allocated sufficient units in more routine scenarios (32%) than teams in the restricted condition (14%), $\chi^2(1, N = 176) = 8.28, p < .01$, and in more novel scenarios (43%) than teams in the restricted condition (20%), $\chi^2(1, N = 176) = 10.48, p < .01$. There was no interaction between condition and scenario type, $\chi^2(1, N = 352) < 1$. 

Hypothesis 5, which predicted that the teams that communicate unrestrictedly during task execution perform better than the teams that communicate restrictedly, received support. Teams that communicated unrestrictedly during scenarios allocated sufficient units in more scenarios (38%) than teams that communicated restrictedly (7%), $\chi^2(1, N = 352) = 47.85, p < .01$. These teams also allocated sufficient units in more routine scenarios (32%) than teams in the restricted condition (7%), $\chi^2(1, N = 176) = 17.64, p < .01$, and in more novel scenarios (43%) than teams in the restricted condition (7%), $\chi^2(1, N = 176) = 31.03, p < .01$. There was no interaction between condition and scenario type, $\chi^2(1, N = 352) < 1$.

Hypothesis 6, which predicted that the teams that communicate unrestrictedly between task execution perform better than the teams that communicate restrictedly, received support. Teams that communicated unrestrictedly between scenarios allocated sufficient units in more scenarios (17%) than teams that communicated restrictedly (7%), $\chi^2(1, N = 352) = 9.17, p < .01$. Surprisingly, these teams did not allocate sufficient units in more routine scenarios (14%) than teams in the restricted condition (7%), $\chi^2(1, N = 176) = 2.23$. In the novel scenarios, however, the teams that communicated unrestrictedly between scenarios performed better (20%) than the teams that communicated restrictedly (7%), $\chi^2(1, N = 176) = 6.95, p < .01$. There was no interaction between condition and scenario type, $\chi^2(1, N = 352) < 1$.

7.3.4 Discussion of Experiment 5

In Experiment 5 we were interested in the question whether there are differences in the performance of teams dependent on the opportunity to communicate unrestrictedly during task execution or in the breaks between task execution. The results show that teams that could communicate during task execution performed better than teams that could communicate between task execution. This supports our hypothesis that teams would perform differently dependent on the opportunity to communicate.
during or between task execution. An explanation for the benefits of unrestricted communication during task execution is that team members developed better team knowledge such that they are better able to provide each other with the necessary information in time. However, the results show no differences in the timely exchange of a crucial piece of information. This indicates that in both conditions, team members had developed team knowledge to the same extent. Regardless of the knowledge that could have been developed, the performance differences cannot be explained by differences in the exchange of necessary information.

We hypothesized that unrestricted communication is also important for teamwork that cannot be performed when team members communicate unrestrictedly. The advantage of communicating unrestrictedly during task execution may be especially important for performance monitoring. When team members can monitor each other’s task performance, they are able to prevent each other from making errors. The communication scores show that the teams of the during condition devoted a considerable part of their total communication to performance monitoring. This communication allowed team members to inform each other about the progress that is made on the tasks and give immediate feedback when things go wrong. Because in the between condition performance monitoring cannot take place immediately, potential errors could not be prevented. This may have caused the performance decrease for the teams that communicated only between task execution.

The conditions of Experiment 4 were also compared to the restricted condition of Experiment 5. This way, we are able to test the effect of unrestricted communication between and during task performance. The results show that unrestricted communication during as well as between task execution improves performance when compared to the restricted communication. The effects of unrestricted communication during task execution replicate the results of Experiment 4. Teams that communicated unrestrictedly exchanged more often the necessary information than the teams that could not communicate unrestrictedly. This indicates that better team knowledge was developed. Furthermore, these teams performed better than the teams in the unrestricted condition.

Our findings show that performance improves when teams communicate unrestrictedly between task execution sessions. The communication scores show that the time between task execution sessions is mostly used to look back and evaluate, and to look ahead and determine strategies. This supports the notion that team self-correction discussions between task performance sessions contribute to team performance (Blickensderfer et al., 1997b).

7.4 Discussion

The purpose of Experiment 4 and 5 was to investigate the effect of unrestricted communication on performance. The results show that teams that communicated unrestrictedly between, during, as well as between and during task execution performed better than teams that communicated restrictedly. Our explanation is that unrestricted communication supported team members in developing team and situation knowledge. Team knowledge supports members in predicting each other’s informational needs and providing each other with the information needed to perform the tasks within the teammate’s task sequence when it is most needed. This line of thinking was supported by the data of the standardized electronic message exchange. Teams that communicated unrestrictedly were more often in time with sending and reading the most important message than the teams that communicated restrictedly. Situation knowledge supports team members in performing teamwork that consists of performance monitoring, evaluation, and determining strategies together. Especially during task execution, team
members benefit from having the opportunity to communicate unrestrictedly because it enables them to monitor each other's performance and prevent each other from making errors. For teams performing in complex and dynamic situations, this is important for a good performance.

The findings of Experiment 4 and 5 suggest that the key to better performance is to expand the communication, not to limit the communication. However, before we can firmly draw such a conclusion, two issues have to be taken into consideration. First, the overall performance was relatively low. Even the teams of the best performing conditions had allocated sufficient units in only one third of the scenarios. It is possible that unrestricted communication had such an impact on performance because team members were not fully trained. Unrestricted communication for performance monitoring, evaluation, and determining strategies was simply needed because team members made many mistakes or had inferior strategies. Hence, when team members are better trained, unrestricted communication is not needed for that matter. Second, it is also possible that the effect of unrestricted communication diminishes after time because team and situation knowledge important for shared mental models is transferred especially in the beginning of a team's lifetime. After working for some time, all the knowledge is transferred and unrestricted communication is, therefore, not needed any more. Both issues are under examination in Experiment 6, described in the next chapter.