Communication and performance in teams
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9 UNRESTRICTED COMMUNICATION AND PERFORMANCE IN ROUTINE VERSUS NOVEL SITUATIONS

The final experiment of this thesis is described in this chapter. In this experiment, we continue to investigate the effect of unrestricted communication on performance. This time, we investigate whether unrestricted communication is needed when teams encounter novel situations. To investigate this question, we separated clearly routine from novel situations. We also equipped team members with a team knowledge schema that consisted of a brief description and graphical representation of each other's tasks, informational needs, and the times when information had to be exchanged. We expected that unrestricted communication would be especially beneficial in novel situations. Because all teams were equipped with the team knowledge schema, unrestricted communication was not needed to develop team knowledge in routine situations. The results support these expectations. Unrestricted communication improved performance in novel situations. In routine situations, however, unrestricted communication had no additional benefits for performance.

9.1 Introduction

The results of Experiment 6 show that, after communicating unrestrictedly in one session, unrestricted communication had a negative impact on performance in a following session. Performance, however, improved for the teams that were forced to communicate restrictedly and coordinate implicitly. An explanation for this result is that too much communication during high workload periods may have distracted team members to perform their individual taskwork accurately. We expected, however, that unrestricted communication would be beneficial because team members were confronted with a constantly changing situation. Unrestricted communication was expected to be needed to maintain up-to-date situation knowledge that supports team members in performing teamwork consisting of performance monitoring, evaluation, and determining strategies. One problem in interpreting the results of Experiment 6 was that the scenarios were mixed, in that they were neither strictly routine nor completely novel. Although we deliberately inserted novel scenarios in between the routine scenarios, the routine scenarios dominated. This may explain why we did not find a positive effect of communication. Thus, in order to examine the effect of unrestricted communication on performance in novel situations, we need to separate the routine from the novel scenarios more clearly. This is the objective of Experiment 7.

In Experiment 7, we also introduced a direct method to ensure that team members have team knowledge. We equipped team members with a team knowledge schema that we created based on the task analysis as described in chapter 3 (see section 3.3). The schema consisted of an A4 paper format with a simplified TOSD (see Figure 3.9 for an example). This represented team members' tasks, the information that had to be exchanged, and the exact periods in which tasks had to be performed and information had to be exchanged. Thus, the schema represented important team knowledge in detail. Team members' tasks and informational needs within the task sequence when this information was

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needed. We expected that, with the help of this schema, unrestricted communication would improve team performance especially when team members encounter novel situations. The reason is that communication is not needed to the same extent to develop team knowledge (as this knowledge could be obtained from the schema). However, in novel situations, communication is needed to maintain up-to-date situation knowledge (and the schema provided no guidance in this respect).

By clearly separating routine from novel situations and equipping team members with a team knowledge schema, we attempt to investigate the effect of unrestricted communication on performance in novel situations. Teams must perform the experimental task in two sessions: one with routine and the other with novel scenarios. The effect of unrestricted communication is investigated by comparing teams that had or had no opportunity to communicate unrestrictedly. The attended reader might notice that the present experimental design is similar to the one of Experiment 4 (see chapter 7). However, there are three important differences. First, in contrast to Experiment 4, teams are equipped with a team knowledge schema in Experiment 7. This way we attempted to ensure that in both conditions team knowledge is equally present, so that the effect of unrestricted communication must be ascribed to the maintenance of up-to-date situation knowledge and determining strategies jointly. Second, we used the same experimental task as in Experiment 6, in which the performance feedback and, therefore the training, was improved as compared to Experiment 4. Third, teams work together for a longer period (i.e., two sessions of 16 scenarios in contrast to one session of 16 scenarios). Altogether, we attempted to design Experiment 7 such that we could investigate the effect of unrestricted communication on performance in novel situations. Turning back to the second research question of this thesis, this should give more insight under which conditions unrestricted communication is beneficial for performance.

9.2 Experiment 7

9.2.1 Hypotheses

Experiment 7 addresses the question whether unrestricted communication improves performance when teams encounter novel situations. A comparison is made between teams that can communicate unrestrictedly and teams that cannot. Figure 9.1 represents the dimensions (denoted by the gray boxes) and the relationship (denoted by the uninterrupted line) under investigation in Experiment 7.

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**Figure 9.1:** Hypothesized relationship between unrestricted communication and performance under investigation in Experiment 7
Chapter 9: Unrestricted communication and performance in routine versus novel situations

We attribute the expected performance improvement in novel situations to unrestricted communication that supports the development of situation knowledge and, in turn, how team members determine strategies. Therefore, we expect that teams in the unrestricted condition will transfer more situation knowledge and determine more strategies in novel than in routine situations. We classified the verbal communication into the same categories as in Experiment 4 to 6. The categories and their definitions can be found in chapter 4 (see section 4.3.1, Table 4.10). We do not expect changes in the communication in the categories: information exchange, performance monitoring, evaluation, and team knowledge. With respect to the category team knowledge, this knowledge remains applicable in routine as well as novel situations. With respect to the other categories, we expect no differences because the novelty of scenarios has no influence upon team members' taskwork, the number of tasks, or potential errors team members might commit in their taskwork. Given that the situation is different in novel situations than in routine situations, and that team members must adjust their strategies to cope with these situations, we do expect that unrestricted communication in the categories situation knowledge and determining strategies is more needed in novel than in routine situations. Therefore, the following hypotheses are put forward:

1. We expect that the teams that can communicate unrestrictedly communicate more concerning situation knowledge in novel situations than in routine situations
2. We expect that the teams that can communicate unrestrictedly communicate more concerning determining strategies in novel situations than in routine situations

One piece of necessary information must always be exchanged by the standardized electronic messages (regardless of the opportunity to communicate unrestrictedly). By measuring the number and timing of this message, we could determine the team’s ability to exchange the necessary information within the teammate’s task sequence when it is needed. The exchange of this message depends largely on the strategies team members have developed. If team members are able to develop accurate situation knowledge of the novel situation and to determine the right strategy, then team members are able to send this message in time. The team knowledge schema, provided to the teams in both conditions, describe explicitly when this message must be send. Thus, in routine as well in novel situations, this schema describes explicitly what information must be exchanged when (i.e., team knowledge). In novel situations, however, other strategies than the ones learned during training are needed to obtain this information (before being exchanged among members). In other words, sending this message in time in novel situations depends on team members’ strategies. The better the strategies, the more team members are able to send this message in time. 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:

3. We expect that the teams that can communicate unrestrictedly exchange more often the necessary information in time than the teams that cannot communicate unrestrictedly; this communication improvement will be more pronounced in novel scenarios

Because we expect that performance improves because of unrestricted communication, the following hypothesis is put forward:

4. We expect that the teams in the unrestricted condition perform better than the teams in the restricted condition; this performance improvement will be more pronounced in novel scenarios
9.2.2 Method

Participants

The data for Experiment 7 were obtained from 80 students of Utrecht University in 40 teams of two participants. Men and women were equally represented (40 male and 40 female). Each team consisted of two male or two female participants. In each of the two conditions, 10 male and 10 female teams performed the task. Participants that formed the team were not acquainted to each other. The participants were paid Dfl. 60, = for their contribution.

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 situations was a within teams manipulation. In both conditions, 10 teams started with a session of 16 routine scenarios and ended with a session of 16 novel scenarios, while 10 teams started with a session of 16 novel scenarios and ended with a session of 16 routine scenarios. The reason for using this balanced design is that when teams start with routine scenarios, a possible effect during novel scenarios could be diminished as a result of learning.

Task

In Experiment 7, Version 3 of the fire-fighting task as described in section 3.3.2 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 separate soundproof rooms and verbal communication was made possible via headsets.

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 on fire in another section and building than team members would expect based on the pattern in a series of small fires they learned in their training. If, for instance, a hospital was expected in the diagonally opposite section, a factory would be in danger above or beneath the section in which there were three sequential fires.

Measures

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. For each session, the second coder rated the communication of two randomly chosen scenarios for each team (in total 80 scenarios with a total duration of approximately 240 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 79%. 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. We measured the percentage of scenarios in which the message of the large building in danger was sent and read in time. Regardless of the opportunity to communicate unrestrictedly, team members had to send this message electronically to accomplish the tasks. Therefore, we could use this measure to determine whether there are differences between the conditions with respect to the provision of necessary information on the time in the teammate’s task sequence that this information is needed. Besides that this is an important measure of implicit coordination, which indicates whether team members have team knowledge, this measures also whether teams have developed the appropriate strategies.

**Performance.** Performance was measured by the percentage of casualties saved out of the total number of potential casualties that could be saved in a scenario.

**Procedure**

An experimenter assigned the participants randomly to the role of dispatcher and observer and told them to read the instruction. Participants were placed in separate soundproof rooms and communication between the participants was made possible by sending and receiving the standardized electronic messages. 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 five 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 five scenarios that contained such a pattern in a series of fires. In this session, participants had the team knowledge schema at their disposal.

After the training, two experimental sessions of 16 scenarios each started. In each session, participants were presented with 16 scenarios that existed of 11 periods of 15 seconds each. In total, an experimental session lasted about four hours.

**9.2.3 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 9.1. With respect to the
amount of communication in each category, an analysis of variance was used to test the differences between the routine and novel session in the unrestricted condition.

Table 9.1: Verbal communication; mean number of statements for each team for the routine and the novel session in the unrestricted condition

<table>
<thead>
<tr>
<th>Communication</th>
<th>Routine Session</th>
<th>Novel Session</th>
<th>F(1,38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Exchange</td>
<td>212</td>
<td>185</td>
<td>= 1.09</td>
</tr>
<tr>
<td>Performance monitoring</td>
<td>92</td>
<td>80</td>
<td>= 1.19</td>
</tr>
<tr>
<td>Evaluation</td>
<td>40</td>
<td>37</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Determining strategies</td>
<td>16</td>
<td>28</td>
<td>= 4.79**</td>
</tr>
<tr>
<td>Team Knowledge</td>
<td>26</td>
<td>26</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Situation knowledge</td>
<td>26</td>
<td>39</td>
<td>= 5.25**</td>
</tr>
<tr>
<td>Remaining</td>
<td>18</td>
<td>19</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Total</td>
<td>430</td>
<td>413</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

Note. **p < .05

Hypothesis 1 and 2 predicted that team members in the unrestricted condition would communicate more concerning situation knowledge and determining strategies in the novel than in the routine session. As can be seen in Table 9.1 both hypotheses are supported.

With respect to the standardized electronic messages, Hypothesis 3 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 9.2.

Table 9.2: 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 = 1280)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Scenario type</th>
<th>In time</th>
<th>Too late</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>Routine</td>
<td>282</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>117</td>
<td>203</td>
</tr>
<tr>
<td>Unrestricted</td>
<td>Routine</td>
<td>294</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Novel</td>
<td>168</td>
<td>152</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 Chi² was calculated. To test the main effect of condition, the Chi² of the first model minus the Chi² 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, scenariotype * timeliness). To test the interaction effect of condition and scenario type, the Chi² and the degrees of freedom of this model were tested. To test the differences between conditions on either the routine or novel scenarios, a Chi² for each separate two-way table was calculated and tested.

The results support Hypothesis 3. Teams that communicated unrestrictedly were more often in time with sending and reading the message about the large building in danger (72%) than the teams that communicated restrictedly (62%), χ²(1, N = 1280) = 15.12, p < .01. In the routine scenarios there was
no difference between the unrestricted (92%) and the restricted condition (88%), \( \chi^2(1, N = 640) = 2.50 \). In the novel scenarios, however, teams of the unrestricted condition were more often in time (53%) than teams in the restricted condition (37%), \( \chi^2(1, N = 640) = 16.45, p < .01 \). There was no interaction between condition and scenario type, \( \chi^2(1, N = 1280) < 1 \).

**Performance**

In order to test Hypothesis 4, an analysis of variance using repeated measures for each scenario was performed. The repeated measure design consisted of two sessions with 16 scenarios each. For the routine and the novel sessions, a separate analysis was performed using repeated measures for each scenario. Because there were differences in the performance of teams on the training scenarios (the training was identical for all teams), the mean of the performance during the training (the five scenarios containing a pattern) was taken into account as covariate. The results are shown in Figure 9.2.

\[
\begin{array}{c|c|c|c}
\text{Session} & \text{Total} & \text{Routine} & \text{Novel} \\
\hline
\text{Restricted} & 61 & 45 & 56 \\
\text{Unrestricted} & 77 & 68 & 80 \\
\end{array}
\]

**Figure 9.2:** Mean percentage of potential casualties saved in the restricted and the unrestricted condition for both sessions and the routine and novel session separately

Hypothesis 4 predicted that teams in the unrestricted condition perform better than teams in the partial restricted condition. The results support this hypothesis, \( F(1,37) = 4.75, p < .05 \). When both sessions are taken into account, teams in the unrestricted condition performed better (68%) than the teams in the restricted condition (61%). As expected, the performance improvement was most pronounced in the novel session. There was no difference between the conditions in the routine session, \( F(1,37) < 1 \), whereas in the novel session the teams in the unrestricted restricted condition performed better (56%) than the teams in the restricted condition (45%), \( F(1,37) = 6.08, p < .05 \). There was no significant interaction between condition and session, \( F(1,37) < 1 \).
9.3 Discussion

Experiment 7 was performed to investigate whether unrestricted communication improves performance when teams encounter novel situations. Therefore, we compared teams that could communicate unrestrictedly with teams that could not. In both conditions, teams were presented with routine as well as novel situations and we equipped teams with a team knowledge schema. The team knowledge schema was provided to ensure that in both conditions team knowledge was equally present. For that reason, we expected that unrestricted communication was not needed to develop team knowledge. We expected also that, in routine situations, unrestricted communication was not needed to maintain up-to-date situation knowledge and determine strategies together. In routine situations, team members could apply their strategies as learned in the training. In novel situations, however, we expected that unrestricted communication would improve performance because it helps to maintain up-to-date shared situation knowledge that, in turn, supports team members in performance monitoring, evaluation, and determining strategies jointly.

The results supported the hypothesis that teams that communicated unrestrictedly perform better than teams that did not communicate unrestrictedly. As expected this performance increase became apparent in novel situations, whereas in routine situations unrestricted communication had no additional value. The communication scores additionally show that teams in the unrestricted condition transferred more situation knowledge in novel situations than in routine situations. This indicates that team members maintain up-to-date knowledge concerning the situation. Based on this knowledge team members could determine strategies together by making suggestions, providing alternative explanations, employing their expertise, generating and testing hypothesis, and offering information relevant for that situation. The communication scores also show that teams did this more often in novel than in routine situations. Finally, with respect to the standardized electronic message exchange, the results show that the teams in the unrestricted condition were more often in time with sending the crucial message than the teams in the unrestricted condition. This indicates that the teams that communicated unrestrictedly indeed developed better strategies than the teams that did not communicate unrestrictedly.

In Experiment 6, a negative effect of unrestricted communication was found, whereas in Experiment 7, unrestricted communication had no negative effect on performance. As mentioned in the discussion of Experiment 6, these apparently discrepant results can be reconciled by noting that the scenarios in Experiment 6 consisted of a mix of routine and novel situations. In that case, there was too much of a good thing. Team members communicated too much about the changing situation, particularly during the most hectic periods in their task performance. In Experiment 7, the routine scenarios evolved as expected from the training sessions, and there was no need to communicate unrestrictedly. Therefore, there was no interference with task performance, and teams performed no better and no worse than those teams that were unable to communicate unrestrictedly.

In constantly changing situations, such as on aircraft carriers (Rochlin et al., 1987), constant overt communication may be required to keep team members up-to-date. This corroborates our results on the value of unrestricted communication in novel situations in Experiment 7. Nevertheless, when teams are confronted with a mixture of routine and novel situations such as in Experiment 6, communication may have a negative impact on team performance. This situational uncertainty causes teams to engage in constant overt deliberation, which may actually degrade performance during high workload periods. One important teamwork skill is therefore, knowing when to communicate.