Overview maintenance in man-machine environments: applications in ship navigation
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4. TASK FACTORS PROVOKING OVERVIEW LOSS ON A SHIP’S BRIDGE

As the experiments in the previous chapter provided evidence that engaging information increases the risk of attention narrowing and overview loss in a generalised and simple man-machine environment, the subsequent step was to examine whether similar evidence could be found in an applied man-machine setting. Since the focus of this dissertation is the setting of the ship’s bridge, the present chapter examines information characteristics that provoke overview loss during keeping watch on a ship’s bridge.

The series of experiments in this chapter (Experiments III to V) were all conducted on a high-fidelity bridge simulator and examined the effect of a number of engaging information characteristics on the range of attention and the risk of overview loss.

4.1. EXPERIMENT III: DISTRACTING INCIDENTS ON A SHIP’S BRIDGE

In a realistic environment, rare events or incidents are most likely to distract the operator and disturb task performance. The operator has to assess the situation and plan how to manage the event. Too much preoccupation with such an event decreases his attention range, which may increase the risk of overview loss since the operator may fail to attend other information sources in time.

The risk of failing to attend other relevant information sources in time may particularly increase when distracting information or events are engaging due to their difficulty. Evidence for this issue in a generalised man-machine setting was found in the experiments of the previous chapter. In combination with continuous (background) tasks, such as navigation, situations can become very complex and difficult to manage. In order to examine whether engaging situations increased the risk of overview loss at a ship’s bridge also, this experiment examined whether managing complex situations increased the risk of overview loss in the realistic setting of a simulated ship’s bridge.

4.1.1. The experiment

The experiment was performed by means of a specially developed test (SIM I) on a high-fidelity bridge simulator. SIM I consisted of a continuous primary navigation task, which was incidentally accompanied by incidents that had to be managed. Since the ship sailed in a curved fairway, which increases the risk of grounding, good navigation required frequent monitoring of the ship position and steering. As would be the case in real-life, the incidents that occurred differed on a large number of characteristics. What they had in common was the potential to distract the attention of the operator from his primary navigation task and thus increase the risk of attention narrowing and overview loss. The expectation was that operators would more frequently fail to check the position of the ship in time when they had to manage distracting incidents in comparison to situations without such incidents. On a detailed performance level, failure to check the position of the ship in time was expected to result in a lower steering frequency, which would be accompanied by bigger rudder deflections due to more crude correction behaviour when the steering task was performed. On a broad and more far-reaching performance level, failure to attend the position of the ship in time was expected to result in sailing outside the safe water limits, which were marked by the buoyage of the fairway.
One of the main characteristics in which the incidents differed was *situation complexity*. Due to the engaging character of the more difficult and complex situations, the expectation was that they would increase preoccupation with the incident and increase the risk of overview loss. Since preoccupation with more complex incidents was expected to distract the attention of the operator from his primary navigation task, a serious consequence of overview loss would be sailing outside the indicated fairway. However, since behaviour in realistic situations may be more diverse than in a generalised and computerised setting, the complexity of the incidents could also cause several other kinds of errors that reflected quality of performance.

To check for differences in performance strategies and shifts of task performance priority, this experiment also examined the difference in incident managing between operators that performed the primary navigation task well and operators who did not navigate well.

**4.1.2. Method**

**4.1.2.1. Participants**

Thirty-two experienced watch officers of the Royal Netherlands Navy (27 males, 5 females) participated in the experiment. They were between 23 and 33 years of age. They also participated in experiment I. Eighteen participants were watch officer on board frigates, minehunters or provision vessels. The other 14 participants had a higher function such as operations officer or air defence officer. Of these participants, 12 were trainees. All operators participated voluntarily.

**4.1.2.2. Test: SIM I**

SIM I was a bridge simulator test, located in the Humber (UK). Participants ‘sailed’ on their own with a huge naval provision vessel (the ‘HNLM Amsterdam’) in the Hawk and Sunk Channel, in the direction of the harbour of Hull (Appendix IVa). No helmsman was available and the participants had to navigate the vessel between the buoyage of a curved fairway to prevent grounding.

To enforce continuous steering, participants steered in the manual ‘non follow-up’ mode. In this mode, a port and starboard push button are available for steering. Pushing one of these buttons causes the ship to turn in the desired direction. As long as the rudder is not returned to its neutral middle position, the ship increases its rate of turn. As a result, this steering mode requires frequent alertness regarding the position and heading of the ship.

Because a pilot was waiting at the Immingham oil station, the ship had to arrive on time and thus required maintaining a speed of 15 knots. Participants navigated visually on the buoys.

During SIM I, eight incidents occurred that were divided into four categories of situation complexity (see Appendix IVb for details). The ‘very low complexity’ category contained incidents that were related visually and performancewise to the main navigation task (managing near-by traffic). Both tasks were easy to perform and incidents were unambiguous. The ‘low complexity’ category contained incidents that required other actions besides navigation, but with both tasks easy to perform. The ‘moderate complexity’ condition contained incidents that required several different actions, but the navigation task was easy to perform. The final ‘high complexity’ category contained the most difficult and complex situations in which the navigation task was difficult to perform and the incident was difficult to assess.
4.1.2.3. Apparatus

SIM I was administrated on the primary bridge simulator of the Royal Netherlands Naval College (Appendix III). This high-fidelity fixed-base naval bridge simulator has an outside view of 280°, projected on a round screen outside the bridge. For SIM I, the bridge contained all navigation equipment except for radar. The simulated starting time was 5.00 PM. Visibility was good and the illumination did not change over time.

4.1.2.4. Design

Since SIM I was a realistic test, variation in the order of the incidents was impossible without altering their content. Some of the incidents were even bound to a particular location. Therefore, the order of incidents in SIM I was equal for all participants.

4.1.2.5. Procedure

Before SIM I was started, the participant read the instructions of the test and oriented himself using a chart of the area in which he was going to sail (Appendix IVa). The test leader answered any remaining questions and emphasised that the main task was to remain between the buoys and ensure the safety of the ship. The test leader made clear that the participant was supposed to behave as a watch officer would on board a ship. After a few minutes of preparation, the test started. SIM I lasted for 45 minutes. Afterwards, the test leader discussed test observations per incident with the participant, in order to get a better idea of the participant’s experiences.

4.1.2.6. Dependent measures

The most important measures for (primary) navigation task performance were the steering frequency and rudder deflection, and the number of times participants steered outside the buoyage (buoyage crossing). To determine the rudder deflection, the rudder angle was divided into four ranges: 0 = no deflection, 1 = deflection between 1 and 10°, 2 = deflection between 10 and 20°, 3 = deflection beyond 20°. Measures for (secondary) incident managing were the mean number of incident-related errors per incident category.

Failure to perform the navigation task in time due to preoccupation with an incident was measured by the steering frequency and the rudder deflection in periods with versus without an incident. Per incident or period without an incident, the most extreme deflection was taken. Since crossing the buoyage, as a serious result of overview loss, could not be determined for periods with and without an incident due to a delay of the effect to become apparent, the rate of buoyage crossing was only compared among different incident categories. Per incident category, the risk of overview loss was computed by counting the number of buoyage crossings per incident category and correcting this rate for the total number of participants \((n = 32)\) and the number of incidents per category \((n = 2)\). In order to take a view of the overall task performance during the different incident categories as a second measure for overview maintenance, the number of incident-related errors were added to the number of buoyage crossings per incident category and formed the overall performance errors.
4. Overview loss on a ship’s bridge

4.1.3. Results

4.1.3.1. Primary task performance: steering and navigating the ship between the buoyage

The mean steering frequency was 12.9 steering actions per minute (SD = 7.0) with a mean of most extreme rudder deflections of 14.3° (SD = 4.3).

Nineteen of the 32 participants managed to remain within the fairway. Of the other participants (41%), nine steered outside the buoyage once, two twice, and another two steered three times outside the buoyage.

4.1.3.2. Secondary task performance: managing incidents

Incident-related errors consisted of small mistakes in communication or execution of procedures, or close passage of objects such as other ships. All participants made errors during at least one of the incidents in SIM I (Table 8). A repeated-measures ANOVA of the errors per incident category showed that participants made more errors in more complex or ambiguous incidents ($F_{(1, 31)} = 29.136, p > .001$).

<table>
<thead>
<tr>
<th>SIM I</th>
<th>Measures</th>
<th>Situation complexity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Participants with error</td>
<td>15 (47%)</td>
<td>24 (75%)</td>
</tr>
<tr>
<td></td>
<td>Number of errors</td>
<td>15</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Mean per incident</td>
<td>.23 (.28)</td>
<td>.48 (.43)</td>
</tr>
</tbody>
</table>

4.1.3.3. Steering performance

Due to the turning delay of the ship, the behaviour of the participants could only roughly be divided into periods with and without incidents. Steering frequency and rudder deflection during periods with and without incidents were analysed with repeated-measures ANOVA.

**Figure 4a:** Steering frequency ($n = 32$) and SD during periods with and without incidents.

**Figure 4b:** Maximal rudder deflections ($n = 32$) and SD during periods with and without incidents.
In contrast to what was expected, steering frequency during incident managing was higher than during periods when participants had only the navigation task to perform \((F_{1,31} = 14.982, p < .01; \text{Figure 4a})\). Rudder deflection also showed the reverse effect of what was expected and was larger during periods in which participants only had to perform the navigation task than in periods in which an incident occurred \((F_{1,31} = 28.234, p < .001; \text{Figure 4b})\). The relationship between large rudder deflections and infrequent steering was as expected.

### 4.1.3.4. Overview loss

The effect of incident difficulty on the incidence of buoyage crossing was analysed by repeated-measures ANOVA with repeated contrasts. The three incident categories with low complexity showed no increase in the incidence of buoyage crossing (difference between all subsequent incident categories: \(F_{1,31} < 1\)). However, when the situation was most complex, participants crossed the buoyage more frequently than in other conditions \((F_{1,31} = 10.622, p < .01; \text{Figure 5a})\).

**Figure 5a:** Buoyage crossing rate and SD per incident complexity category, corrected for the number of operators \((n = 32)\) and the number of incidents per category \((n = 2)\).

**Figure 5b:** Rate of total overall performance errors and SD per incident complexity category, corrected for the number of operators \((n = 32)\) and the number of incidents per category \((n = 2)\).

In order to examine the total performance of the participants, the incident-related errors were added to the buoyage crossing as a failure of navigation task performance. This resulted in the total overall error rate during the different situation complexity categories (Figure 5b). A repeated-measures ANOVA of the overall error rate during the four different incident categories showed that the more complex or ambiguous the situation, the more overall errors were made \((F_{1,31} = 44.501, p < .001)\).

### 4.1.3.5. Performance priority

To check for differences in task performance priority and shifts in task performance, the total number of incident-related errors was compared between participants who managed to maintain within the fairway \((n = 19)\) and participants who failed to do so \((n = 13)\). ANOVA showed that the number of incident-related errors did not differ between participants who sailed outside the buoyage and participants who navigated well \((F_{1,31} < 1; \text{Table 9})\).
4. Overview loss on a ship's bridge

Table 9: Incident-related errors of participants who managed to navigate between the buoyage (n = 19) and participants who sailed outside the buoyage (n = 13).

<table>
<thead>
<tr>
<th>SIM 1</th>
<th>Incident-related errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Navigation performance</td>
<td></td>
</tr>
<tr>
<td>Poor performers</td>
<td>.55</td>
</tr>
<tr>
<td>Well performers</td>
<td>.51</td>
</tr>
<tr>
<td>Total</td>
<td>.52</td>
</tr>
</tbody>
</table>

4.1.4. Discussion

Due to the complexity of high-fidelity simulation experiments, behaviour in the present experiment was more ambiguous and therefore harder to interpret than behaviour in the more simple and clear-cut computerised tests.

Although less frequent steering and larger rudder deflections seemed a logical consequence of occupation with incident managing, steering behaviour did not show this relationship. The rudder deviation was indeed larger when the operators steered less frequently, but these rudder actions appeared in the opposite situations as was expected. That is: operators steered less frequently and with larger rudder deviations in periods without incidents. A possible explanation for lower steering frequencies during navigation-only situations may be that, after the occurrence of an incident, participants used the calm situation to reorient themselves and check information, resulting in fewer navigation activities. This behaviour was indeed frequently observed. Furthermore, the interpretation of the steering behaviour did not take into account experience and navigation ability. Thus, steering behaviour did not appear to be a good measure for overview loss during incidents. Therefore, only buoyage crossing and the total number of errors were taken as measures for overview loss.

Forty-one percent of the participants did not pay enough attention to the primary navigation task and steered outside the buoyage at least once. The risk of buoyage crossing due to overview loss increased during very complex situations. This supports the hypothesis that complex situations cause more attention narrowing since they are so engaging that operators become easily preoccupied with one information source or task and fail to attend other information sources in time. However, the incidence of failure to attend the primary task in time increased only when both the navigation task and the incident to manage were difficult, so creating a complex situation that required very active performance management of the operator. It may have been the case that in the less complex situations, failure to perform the primary task in time did not very frequently result in buoyage crossing due to the lack of a sufficient amount of precursors in the navigation situation (see also Wagenaar, Hudson & Reason, 1990). That is, the navigation situation may not have offered sufficient ‘opportunities’ in less complex conditions for failure of primary task performance to have severe consequences such as buoyage crossing. Another possibility is that incidents during less complex situations did not engage the operators so much that they failed to perform the primary task in time. Since the navigation situation differed between situations due to natural variations in the simulated sailing environment, the first option seems most likely.

Since buoyage crossing reflected serious consequences of overview loss due to preoccupation with managing an incident, additional incident-related errors gave more
detailed information of total operator performance and situation management. Incident-related errors were not so serious and occurred more frequently than buoyage crossing. Overall performance, as a second measure of overview maintenance, showed the expected deterioration with increasing situation complexity, also during less complex situations.

Operators who managed to perform the primary navigation task in time, did manage incidents as well as operators who failed to perform the navigation task in time. This indicates that well performing operators had overview of the situation and did not focus on the navigation task at the expense of incident managing. This finding might also be an indication that some individuals are better at maintenance of overview than others when they are exposed to complex situations.

In conclusion, it may be stated that situation complexity increases the risk of overview loss, but this will only have dangerous consequences if other precursors are available as well.

4.2. EXPERIMENT IV: SITUATION FAMILIARITY AND ATTENTION RANGE

Not only complex situations may provoke overview loss, also situations that are unfamiliar and do not consist of engaging incidents may narrow the range of attention. Unfamiliar situations require attention of the operator in order to interpret the situation and determine what actions are eventually required. Operators may not be able to rely on previously learned rules, or automatic performance structures (i.e. the rule-based level of performance, cf. Rasmussen, 1983). Since such unfamiliar situations may engage the operator and distract his attention from other relevant information sources, unfamiliar situations may be a potential hazard to maintenance of overview.

The present experiment examined whether subtle changes in situation familiarity affected the range of attention in the realistic setting of a ship’s bridge simulator.

4.2.1. The experiment

For the present experiment, a specially developed test (SIM II) on a high-fidelity bridge simulator was used. Operators had the task to sail safely along an indicated route of three tracks. To measure the state of overview in a way that was less dependent on a-priori determined behavioural measures and clear-defined tasks, this experiment used a knowledgeelicitation method based on the Situation Awareness Global Assessment Technique (SAGAT) of Endsley (1988, 1995b). Using this method, task performance was interrupted during which the operator had to answer a list of questions about aspects of the environment relevant for task performance. An operator was supposed to have a wider range of attention if he had rough knowledge of many information sources in contrast to detailed knowledge of only a few information sources.

Situation familiarity was manipulated. The expectation was that less familiar situations would increase the risk of attention narrowing in comparison to familiar situations since in the former, operators would be more engaged with collecting relevant information about the situation. To examine the general extension of the attention range, two additional hypotheses were tested. First, the expectation was that operators would be more aware of information that

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6 This experiment was performed with the help of naval academy student Wim Talma.
7 A ‘track’ is nautical jargon for the path the ship has to sail.
might be currently important than of information relating to the recent past or near future since operators would particularly be engaged with information concerning the actual situation. Secondly, the expectation was that operators would be especially aware of information in their vicinity (e.g. self-performed actions and knowledge of the state of the own ship), and less aware of more distant information since performed actions and information in the vicinity would be more relevant from the view of the operator.

4.2.2. Method

4.2.2.1. Participants

Thirty-two experienced watch officers of the Royal Netherlands Navy participated in this experiment (27 males, 5 females). They were between 23 and 34 years of age. They had not participated in the previous experiment, but thirty of them also participated in experiment I. Twenty participants were watch officer on a frigate or mine-hunting vessel, 2 were navigation officer, and the other 10 trained for air defence officer or operations officer.

4.2.2.2. Test: SIM II

In SIM II, participants sailed on their own along a route of three tracks. The route took them along the Belgian-French coast in the direction of the harbour of Dunkirk (Appendix Va). The frigate sailed on automatic pilot mode and the task of participants was to change course when they approached the subsequent track. Although it was totally dark outside, participants navigated visually using lighted buoys. Participants were instructed that there was no need to contact other ships or inform the captain.

On two fixed moments during each track, the test leader entered the simulator with a list of 10 questions about objects, events, actions, and planning aspects in relation to the environment of the participant (Appendix Vb). The participant answered as many questions on the list as possible within one minute, and had to write each answer (or part of an answer) in the answer box behind the question on the list.

The first questionnaire about each track was administered at the beginning of the track, when the participant sailed a steady course. These lists were called the ‘new orientation’ (NO) lists. The second question list about each track, called the ‘familiar orientation’ (FO) list, was administered after approximately 10 minutes sailing on the track.

4.2.2.3. Apparatus

For SIM II the same simulator with similar equipment was used as in the previous experiment. Although the simulated starting time was 2.00 AM (total darkness outside), radar was not allowed because participants could orient themselves by means of lighted buoys.

4.2.2.4. Design

Since the questions on the lists were linked to sailing location, their administration was not counterbalanced over time. The order of the questions within each list was mixed over participants in order to prevent some questions being answered more frequently than others due to their placement on the list.
4.2.2.5. Procedure

After the participant had read the instructions, 5 minutes were available for studying the chart of the sailing area (Appendix Va). Participants could ask remaining questions and then entered the simulator to adapt to the dark and orientate. Before the test started, the test leader repeated the instructions and emphasised that only one minute was available for answering as many questions as possible when the test leader presented the questionnaire. Participants were instructed to estimate the answer if they were unsure. Furthermore, participants had to behave as they normally would on a real bridge, except for contacting other vessels and port authorities, or informing the captain.

During the test, the test leader presented an NO question-list after changing orientation. After approximately 10 minutes of sailing on a track, the test leader presented an FO question-list. Participants had to interrupt their current activity and write down the answers to as many questions on the list as possible. The test leader removed the list when one minute had passed. In the meantime, a nautical expert noted the correct answers to the questions. After answering the last FO list (FO3), SIM II was finished. Participants did not receive feedback about the result of each questionnaire.

4.2.2.6. Dependent measures

The main data from SIM II were the answers on the 6 question-lists (NO1 up to FO3), which were scored on their accuracy by comparing them with the expert answers. The more accurate the answer, the higher the score, with a maximum of 1 point per question. Within certain limits, the score decreased gradually with increasing inaccuracy (Appendix Vb). Answers that were outside the permitted area of inaccuracy were scored with 0.

Since the overall range of attention was the main interest of the experiment, the total score of each question-list was multiplied by the percentage of answers that were given a score greater than 0 points. This correction meant that participants who knew a lot, but only approximately (and thus had a wider attention range), were rewarded more than those who knew a few things precisely (and thus had a narrow attention range).

Each question related to a particular time range (past, present or future) and closeness to the participant (self-performed action, state of own ship, interacting objects, and non-interacting objects in the environment).

4.2.3. Results

4.2.3.1. Attention range

The answer ratings on the questions in SIM II discriminated sufficiently between participants, with the exception of one question in the second FO-list. All participants scored 0 on this question, so it was omitted from the analyses.

The scores, number of answered questions and the number of answers with a score higher than 0 during NO and FO situations were analysed by repeated-measures ANOVA. During NO situations, participants had lower questionnaire scores than during FO situations ($F_{(1, 31)} = 37.022, p < .001; \text{Table 10}$). During NO situations, participants could answer fewer questions and did not have correct or partly correct knowledge of as many issues as compared to FO situations (respective analyses: $F_{(1, 31)} = 47.495, p < .001; F_{(1, 31)} = 29.418, p < .001; \text{Table 10}$).
4. Overview loss on a ship’s bridge

**Table 10**: Attention range scores in SIM II (n = 32) during new orientation (NO) and familiar orientation (FO) situations. The marked cells in list FO2 indicate that the results are based on only 9 of the 10 questions in the list (see text).

<table>
<thead>
<tr>
<th>SIM II Question list</th>
<th>Mean attention range score</th>
<th>SD</th>
<th>Number of questions answered</th>
<th>Percentage of scores &gt; 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO1</td>
<td>.232</td>
<td>.109</td>
<td>7.14</td>
<td>56%</td>
</tr>
<tr>
<td>NO2</td>
<td>.322</td>
<td>.128</td>
<td>8.06</td>
<td>64%</td>
</tr>
<tr>
<td>NO3</td>
<td>.179</td>
<td>.091</td>
<td>7.47</td>
<td>48%</td>
</tr>
<tr>
<td>NO total</td>
<td>.244</td>
<td>.085</td>
<td>7.56</td>
<td>56%</td>
</tr>
<tr>
<td>FO1</td>
<td>.251</td>
<td>.137</td>
<td>8.09</td>
<td>54%</td>
</tr>
<tr>
<td>FO2</td>
<td>.386‘</td>
<td>.184‘</td>
<td>8.72</td>
<td>68%*</td>
</tr>
<tr>
<td>FO3</td>
<td>.401</td>
<td>.194</td>
<td>8.25</td>
<td>70%</td>
</tr>
<tr>
<td>FO total</td>
<td>.346</td>
<td>.128</td>
<td>8.35</td>
<td>64%</td>
</tr>
</tbody>
</table>

4.2.3.2. The range of attention in relation to time and space

The scores of questions referring to the recent past, the present, or the near future were analysed by repeated-measures ANOVA with repeated contrasts. No difference was found between the scores for knowledge of topics related to the near-past or the present ($F_{(1,31)} < 1$). The scores for knowledge of topics related to the near-future was lower than the scores for topics related to the present ($F_{(1,31)} = 17.122, p < .001; Table 11$).

**Table 11**: Attention range scores within the categories of two different question divisions (note: each division contains all 59 questions).

<table>
<thead>
<tr>
<th>SIM II Division</th>
<th>Topic</th>
<th>Attention range score</th>
<th>SD</th>
<th>Number of questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Recent past</td>
<td>.311</td>
<td>.169</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Present</td>
<td>.307</td>
<td>.094</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Near-future</td>
<td>.259</td>
<td>.115</td>
<td>17</td>
</tr>
<tr>
<td>Environment</td>
<td>Own actions</td>
<td>.508</td>
<td>.118</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>State of the own ship</td>
<td>.344</td>
<td>.118</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Interacting objects</td>
<td>.275</td>
<td>.119</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Non-interacting objects</td>
<td>.214</td>
<td>.099</td>
<td>25</td>
</tr>
</tbody>
</table>

The questionnaire scores in relation to four levels of environment at different distances of the participant were analysed by repeated-measures ANOVA. As was expected, participants had higher scores for information in their near environment than for more distant information ($F_{(1,31)} = 280.312, p < .001; Table 11$).

4.2.4. Discussion

The narrowing attention range of watch officers during reorientation after changing course shows that relatively unfamiliar situations or orientations engage the operator to re-establish his knowledge of what is going on. The reduced attention range during new orientations may
also be interpreted as poor anticipation of the future and postponement of information collection until the operator encounters a situation in which he notices that he does not have knowledge of all relevant information. The finding that operators indeed had less knowledge of future-related information in comparison to information related to the recent past or the present, supports this conclusion. Apparently, operators were too much engaged with current activities and actual information and did not use their time (or had no time available) to look ahead.

In relation to their environment, operators had less knowledge of more distant information. It is likely that, particularly for those information sources that are less frequently in the focus of attention, information changes are unnoticed and thus form a potential danger.

A suggestion for training may be to make watch officers more aware of the importance of shifting their information collection to the future and also to more distant information. In this context, over-learning of skills may help to reduce the mental load of task performance, giving the operator more time to enlarge his attention range.

4.3. EXPERIMENT V: MANAGING UNEXPECTED EVENTS ON A SHIP’S BRIDGE

If operators fail to attend information that is more distant or that will become relevant in the near future, events may appear unexpectedly and take the operator by surprise. The confrontation with unexpected information may cause preoccupation with managing the incident before it is too late and so increases the risk of overview loss due to failure to attend other relevant information sources in time.

The present experiment examined systematically the distraction effect of events that differed in the level of unexpectedness. As the previous experiments, also this experiment used a realistic ship’s bridge simulator to simulate natural complexity of man-machine operation in real-life.

4.3.1. The experiment

In the present experiment, again a specially developed bridge-simulator test was used (SIM III), which consisted of four subtests. In each subtest, the operator had to sail an indicated track and manage incidents. All subtests were situated in the same location and had a similar background in order to increase the comparability among subtest. An additional effect was that operators would become increasingly familiar with the navigation environment. As operators would become familiar with the environment, they would more easily assess (part of) the situation, making the information collection process less engaging and time consuming. Supported by evidence of the previous experiment that familiarity with a particular situation reduced the risk of attention narrowing and overview loss, the expectation was that operators would experience overview loss less frequently when they became familiar with the environment.

To examine the effects of unexpected and unfamiliar information on overview loss in a systematic way, the events that occurred in the subtests differed in expectedness and general familiarity among subtests. Some subtests contained events that could be anticipated a long time before they became relevant or were in general familiar to the operators; others contained events that were hard to anticipate or ambiguous and provoked preoccupation with event managing. The expectation was that managing unexpected and complex events increased the risk of losing overview.
To check for differences in task performance priority or task performance shifts, the errors related to incident managing were compared between operators who managed to perform the primary navigation task in time and participants who failed to do so.

4.3.2. Method

4.3.2.1. Participants

Thirty-two experienced watch officers of the Royal Netherlands Navy participated in the experiment (30 males, 2 females). They were between 22 and 45 years of age. Twenty-two participants were watch officer on board frigates or minehunters; eight participants were operations officer or air defence officer on board frigates, one participant was captain of a ship, and one participant was a colonel who was recently placed on a shore-function.

4.3.2.2. Test: SIM III

SIM III consisted of four subtests that all had the following background situation in common: participants sailed along an indicated track on the Westerschelde in the Channel of Terneuzen (The Netherlands), heading to Antwerp. The track was drawn in the chart of the sailing area (Appendix VIa). Besides keeping watch, the participant steered the ship using the steer wheel and had no automatic pilot available. A South Western current of 3 knots pushed the ship to the starboard side of the channel and required the participant to correct his heading sufficiently to port. A moderate North Eastern wind enlarged the current-effect. A basic speed of 16 knots was required.

The four runs differed in the occurrence of distracting events, which were as follows (Appendix VIb):

1. Control/current: basic run with current and wind, without events. Some non-important ships on a parallel lane were used as visual noise.
2. Traffic: run with three distracting traffic incidents. Background factors were as in the ‘control/current’ subtest.
3. Verbal/ambiguous: run with three verbal and/or ambiguous incidents. Background factors were as in the ‘control/current’ subtest with VHF noise added.
4. Combined: combined run with current and wind. Distractions consisted of three verbal and/or ambiguous incidents, and three traffic incidents. Background factors were as in the ‘verbal/ambiguous’ subtest.

Participants were instructed not to initiate any contact with other parties inside or outside the ship, but reaction on a call was allowed. In case of dangerous traffic situations, the instruction was to avoid an accident by reducing or increasing speed. Speed adaptations were allowed to a minimum of 6 and a maximum of 20 knots, and were only allowed for as long the hazard was present. Participants thought aloud and reported their observations, hazard assessments, and comments on token actions to the test leader.

4.3.2.3. Apparatus

SIM III was administrated in the same bridge simulator as the previous two experiments. All equipment was available, except for radar. The simulated starting time of each subtest was 3.00 PM.
4.3.2.4. Procedure

The procedure of all SIM III sessions was as follows: first, participants read the general test instructions outside the simulator. Before the start of each subtest, participants had 2 minutes for orientation using a chart and the outside view. After each subtest, the incidents and observations were discussed with the participant and a nautical expert in order to get information about the experiences of the participant.

4.3.2.5. Design

The subtests were administered in a semi-counterbalanced order: the most easy ‘control/current’ subtest and the most complex ‘combined’ subtest never followed each other, as was the case with the moderately complex ‘traffic’ and ‘verbal/ambiguous’ subtests.

Participants participated in two of the four subtest at a time. The other couple of subtests was administered at least one day and sometimes a number of weeks later.

4.3.2.6. Dependent measures

Measures for (primary) navigation performance were the number of times participants sailed outside the buoyage (buoyage crossing) and the total area of deviation when participants sailed outside the buoyage. The deviation area was formed by the buoyage and the route participants sailed outside the buoyage. The number of incident-related errors was scored as a measure of quality of incident management.

Sailing outside the buoyage was interpreted as a result of overview loss due to engagement with an incident, and lack of understanding of the navigation situation. More detailed information about the duration of overview loss was available from the deviation area, since the longer a participant would not know what was going on (i.e. where he was sailing), the larger the area would become that was formed by the buoyage and the route sailed outside the buoyage. Combination of buoyage crossing rates and incident-related errors during the different subtests of SIM III was an overall performance score and a second overview-related measure.

4.3.3. Results

4.3.3.1. Primary task performance: navigating the ship between the buoyage

Over all subtests, 13 participants (41%) managed to navigate the ship between the buoyage that marked the fairway. Twelve participants (38%) sailed once outside the buoyage, 3 participants (9%) sailed two times, one participant (3%) three times, and three participants even four times outside the buoyage during one or more of the subtests of SIM III.

Over all subtests and all participants, the mean route deviation was .058 square nautical miles (SD = .097).

4.3.3.2. Secondary task performance: managing incidents

Since the number of incidents differed between the subtests (6 incidents in the ‘combined’ subtest, and 3 in the other two subtest with incidents), only the mean number of incident-related errors per subtest could be analysed (Table 12). A repeated-measures ANOVA showed that in the subtests with traffic incidents (the ‘traffic’ and the ‘combined’ subtest), more errors
were made than in the ‘verbal/ambiguous’ subtest ($F_{(1, 31)} = 42.325$, $p < .001$; $F_{(1, 31)} = 132.941$, $p < .001$).

Table 12: Mean number of errors and SD ($n = 32$) in the three subtest with incidents.

<table>
<thead>
<tr>
<th>SIM III Measures</th>
<th>‘Traffic’ Errors</th>
<th>‘Verbal/ambiguous’ Errors</th>
<th>‘Combined’ Errors</th>
<th>Total Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants with error</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td>29 (91%) .64 (.32)</td>
<td>18 (56%) .20 (.21)</td>
<td>32 (100%) .60 (.19)</td>
<td>32 (100%) .48 (.24)</td>
</tr>
</tbody>
</table>

4.3.3.3. Overview loss

The number of buoyage crossings and the deviation area were analysed by regression analysis, with subtest type and subtest order as independent factors. The more complex and unexpected events, the more participants steered outside the buoyage ($F_{(1, 126)} = 4.768$, $p < .05$; Figure 6a). Incident complexity and unexpectedness contributed to 3.6% of the variance in buoyage crossing. Familiarity with the environment decreased the occurrence of buoyage crossing ($F_{(1, 125)} = 4.916$, $p < .05$), and contributed, together with unexpectedness of incidents to 7.3% of the buoyage crossing variance.

![Figure 6a: Mean number of buoyage crossings and SD ($n = 32$) during the four subtests of SIM III.](image)

![Figure 6b: Mean deviation area (in square nautical miles) and SD ($n = 23$) of the route sailed outside the buoyage in the four SIM III subtests.](image)

Since the deviation area of nine participants was not available for all subtests, analysis of the deviation area was performed on the data of 23 complete cases. Only familiarity with the environment caused smaller deviation area’s ($F_{(1, 116)} = 6.298$, $p < .05$; Figure 6b), and contributed to 5.1% of the variance in track deviation.

Combining the number of buoyage crossings with the number of errors per subtest (errors were only available of the three subtests with incidents), a total performance score was computed (Figure 6c). Participants performed worse in the ‘traffic’ subtest compared to the ‘control/current’ subtest ($F_{(1, 31)} = 46.156$, $p < .001$), and compared to the ‘verbal/ambiguous’ subtest ($F_{(1, 31)} = 12.189$, $p < .01$). In the ‘verbal/ambiguous’ subtest, participants performed
worse than in the ‘control/current’ subtest \(F_{(1,31)} = 22.724, p < .001\), but in the ‘combined’ subtest, participants did not perform worse than in the ‘traffic’ subtest \(F_{(1,31)} = 1.459, p > .10\).

![Diagram](image)

**Figure 6c:** Total error score \((n = 32)\) over the four subtests.

### 4.3.3.4. Performance priority

To check whether participants who succeeded in sailing between the buoyage could manage navigation as well as incidents, the differences in incident-related errors were compared between participants who sailed between the buoyage and participants who failed to do so. Since SIM III consisted of different subtests, the difference in incident-related errors between well and poorly performing participants was not only compared on an overall level, but also per subtest.

ANOVA showed that, overall as well as separately within each subtest, participants who navigated correctly between the buoyage did not make more incident-related errors than participants who sailed at least once outside the buoyage \((F_{(1,31)} < 1\) for all analyses; Table 13).

| Table 13: Incident-related errors of participants who managed to navigate between the buoyage and participants who sailed outside the buoyage. The SD is between brackets. |
|---|---|---|---|---|
| **SIM III** | **Navigation performance** | **Subtests** | **Total** |
| | | ‘Traffic’ | ‘Verbal/ambiguous’ | ‘Combined’ |
| **Poor performers** | .67 (.37) | .19 (.18) | .62 (.16) | .50 (.15) |
| | \(n = 7\) | \(n = 9\) | \(n = 11\) | \(n = 19\) |
| **Well performers** | .63 (.31) | .20 (.22) | .59 (.20) | .45 (.15) |
| | \(n = 25\) | \(n = 20\) | \(n = 21\) | \(n = 13\) |
| **Total** | .64 (.32) | .20 (.21) | .60 (.19) | .48 (.24) |

### 4.3.4. Discussion

Watch officers had a higher risk of sailing outside the buoyage when they had to manage complex or unexpected events. Familiarity with the environmental characteristics reduced the risk of serious navigational failures such as buoyage crossing, because operators had more prior knowledge about information in their environment. Since buoyage crossing was interpreted as being a result of overview loss due to preoccupation with other information, these findings are again evidence that occupation with engaging information increases the risk.
4. Overview loss on a ship’s bridge

of overview loss. In the present experiment, engaging situations were complex or unexpected, which resulted in failure to attend relevant information sources in time and prevent dangerous situations to develop.

Since operators who managed to perform the navigation task correctly and in time did not make more incident-related errors, these operators had overview and did not perform the primary navigation task at the expense of incident managing. Forty-one percent of the operators even succeeded in correct navigation in all situations. This finding may show that some individuals are better at maintaining overview than others during situations that have the potential to disturb the operator from maintaining overview. The next chapter examines this issue.

The finding that operators even sailed outside the buoyage when no incidents occurred, may be an effect that is related to prior bridge-simulator experiences: during previous bridge-simulator sessions, which were particularly used for training purposes, participating operators expected incidents to occur. When nothing occurred, they often became suspicious, and a number of operators were engaged with finding a possible ‘hidden’ incident. This behaviour may have increased the risk of failure to attend their navigation situation in time and to check their position.

It is not surprising that watch officers sailed a greater distance outside the buoyage when they were less familiar with the environment. Being unfamiliar with the environment, it was more difficult to recognize the right sailing track if an operator had lost overview and had crossed the buoyage. The relatively large deviation area in the subtests without incidents may be the result of absence of cues to assess the situation and return to the right fairway. It may also be the result of the earlier mentioned engagement with seeking information that might indicate some ‘hidden’ incident.

Concerning the total amount of performance-related errors that were made during the different subtests, it appears that most errors were made during situations including traffic incidents. Since the situation with traffic incidents only was judged less complex and ambiguous than the situation with verbal and ambiguous incidents, less overview loss was expected during traffic incidents. This appeared to be the case for failure to attend the navigation situation in time, but the (overall) amount of errors indicated that operators often managed traffic incidents not very well. Since traffic incidents were visually related to the navigation environment, a possible explanation is that, during managing traffic incidents, operators were better able to attend the navigation situation more or less simultaneously with the traffic situation, and were better able to perform the navigation task in time. Incident management may have suffered due to more attention for the navigation task. Another explanation may be that there were more opportunities during traffic incidents to make errors. Since the situations were complex and not as easy to interpret as behaviour in the computerised tests, more research is required to investigate these issues further.

In conclusion, these findings show that good (journey) preparation may prevent the occurrence of serious accidents due to overview loss. Well-prepared operators can rely on more (detailed) knowledge when they encounter unexpected events, which has the result that they need less time to collect all relevant information.
4.4. CONCLUSIONS ABOUT OVERVIEW LOSS ON A SHIP'S BRIDGE

The experiments in the present chapter provided evidence that engaging information increases the risk of attention narrowing and overview loss in a realistic man-machine environment, such as a ship’s bridge. Watch officers showed to cross the buoyage more frequently or have less knowledge of information in their environment during managing engaging incidents and unfamiliar situations. The experiments of this chapter added situation complexity, situation unfamiliarity, and situation unexpectedness to the engaging information characteristics that were found in the experiments of the previous chapter to increase the risk of overview loss.

As was outlined in a study of Wagenaar, Hudson, and Reason (1990), performance failures only have serious consequences if sufficient precursors are available. This means that unsafe behaviour, for instance caused by overview loss, may only result in an accident if the situation offers opportunities, and no buffers are available to prevent the accident from occurring. Therefore, it is important to know what kind of situations are a hazard for operator performance and overview loss in particular, and what kind of applications may prevent failures and overview loss to have serious consequences.

To be able to maintain overview while managing complex, difficult, or new situations, it may be important that operators can rely on well-trained skills and well preparation of what they might expect to encounter. Such skills and preparations may decrease the tendency to focus too much on details and become preoccupied with information. This may benefit anticipation of future events and correct management of complex and unexpected situations. A study of Damos (1978) supports this view. She found that student pilots showed an increase in residual attention with training, which related positively to flight performance.

In dynamic man-machine environments, such as in transportation, information characteristics are hard to alter. Since increasing the number of personnel or automating operator support may not always help the operator to obtain and maintain overview, excellent training and sufficient real-life experience seem to be necessary factors for safe operator performance in a dynamic multiple-task environment.