Sticking to plans: capacity limitation or decision-making bias?

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3. Cognitive lockup: Capacity limitation or decision-making bias?

Previous research has indicated that operators have a tendency to continue with an ongoing task and ignore additional tasks (cognitive lockup). In this chapter we report two experiments in which we examined whether this phenomenon is caused by capacity limitations or by a decision making bias. Participants are required to monitor a simulated fire control task and to deal with fires that occurred either sequentially or simultaneously. Results show that the tendency to continue with an ongoing task is not affected by the workload of the diagnosis process but rather by the perception of the costs making of a reassessment. We conclude that cognitive lockup is due to a deliberate decision rather than capacity limitations. We provide some suggestions for future system support.

Introduction

Technological developments have shifted the role of humans from direct control to supervision of complex automated systems. Rather than single persons who are responsible for several subparts of the system, one or two operators supervise the entire system. The operator monitors (a large part of) the system and intervenes when a non-normal situation occurs.

Automation undeniably has a number of advantages. Computers can, for example, assist the human operator in highly complex tasks, such as mathematical operations. However despite these opportunities, automation has also resulted in major problems. One of the main problems of automation mentioned with regard to supervisory control is that operators experience a greater distance to the system (Wiener, 1985). Because of automation, the operator has less overview of what exactly is going on at a detailed level. In case an intervention is required it may be difficult for the operator to build up an accurate model of the situation (Sheridan, 1988).

Intervention is mostly required when a disturbance occurs. A disturbance is a non-routine situation and because subsystems are often related, a
disturbance is likely to propagate through the system. As a consequence, the operator faces a complex situation, where there are multiple disturbances to be dealt with. The system deteriorates fast and since the consequences are often very negative (think of a power station) the operator experiences time pressure.

In complex situations where operators have to deal with more than one disturbance at the same time the dynamics of the system are highly important. Due to the system dynamics the system can change in such a way during fault handling that in other parts of the system disturbances occur that are more urgent. In that case the operator should interrupt his current activities to switch to a disturbance with a higher priority. However, operators are often reluctant to stop ongoing activities and to focus on another task.

Moray and Rotenberg (1989) used the term ‘cognitive lockup’ for this phenomenon, which they referred to as the tendency to focus on only a limited part of the system while ignoring the rest of it. Operators tend to zoom in on a single fault and do not provide enough attention to other parts of the system. However, when during the handling of this fault other faults emerge that appear to be more urgent they remain unattended.

There are many examples, especially in shipping and aviation, where, in hindsight, accidents could be ascribed to cognitive lockup. One such example is the air crash of flight 173 of United Airlines in December 1978. The captain of the flight focused entirely on a landing gear malfunction and ignored monitoring the aircraft’s fuel state. As a consequence, the captain did not react to a decreasing fuel supply. The plane ran out of fuel and crashed (National Transportation Safety Board, 1978).
In addition, cognitive lockup has been found in experimental studies where the experimental task consisted of a simulation of a supervisory control system. Moray and Rotenberg’s data (1989) showed that participants were reluctant to attend to additional faults. This finding was replicated by Kerstholt, Passenier, Houttuin and Schuffel (1996) who found that the first fault received attention much sooner than subsequent faults.

Even though cognitive lockup has been successfully demonstrated in experimental studies, no founded explanations for this phenomenon have been provided to date. A possible explanation that has a strong intuitive appeal is that of human capacity limitations. People are simply unable to deal with more than one task at the same time and consequently will attend to the environment only after the task has been ended.

This explanation has particularly been investigated in the PRP (Psychological Refractory Period) paradigm where two simple S-R tasks overlap: the second stimulus is presented after the first stimulus but before a response is given. The typical finding in this paradigm is that the second task overlapping the first task takes more time to finish as compared to the situation where the second task is executed in isolation.

Within the PRP research, researchers have distinguished two different notions for this so called PRP effect. The ‘classical’ notion assumes that processing the first task fully “captures” human processing capacity so that processing the second task can only begin after the first one is terminated. The claim on the information processing system made by the first task prevents the second task from being attended, at least till the moment the first task is completed and the information processing system is no longer occupied. As a result, the reaction time of the second task increases.
A more recent notion assumes that there is also a strategic component involved in dual task performance. That is, people seem to have flexible control over the order in which tasks are executed. De Jong (1995), for instance, showed that under some conditions participants were able to process the second stimulus presented first. Other studies, also conducted within the same PRP paradigm, provided additional evidence for flexible control over the moment a second task is processed (Meyer and Kieras, 1997; Meyer, Kieras, Lauber, Schumacher, Glass, Zurbriggen, Gmeindl and Apfelblat, 1995 and Schumacher, Lauber, Glass, Zurbriggen, Gmeindl, Kieras and Meyer, 1999).

These two notions on people's capability to handle tasks simultaneously have been investigated with simple reaction-time tasks. For more complex tasks such as supervisory control this issue has never been addressed. The purpose of the present research is therefore to investigate which of the two notions can explain the findings of cognitive lockup in supervisory control tasks. Are operators unable to deal with more than one fault simultaneously due to capacity limitations, or do they make a deliberate choice not to deal with a second fault before ending the first fault?

We addressed the first explanation - cognitive lockup is due to capacity limitations - in the second experiment of this thesis. In this experiment we manipulated the mental workload of the first fault by increasing diagnosis complexity. A limited capacity explanation implies that cognitive lockup occurs when the processing system is saturated. In this line, it is expected that as the complexity of the first fault increases, the system will be closer to saturation and less 'residual' resources will be available for dealing with subsequent faults. As a consequence, the increase of the first fault's complexity results in a stronger tendency to deal with faults in a strictly sequential manner.
The second explanation - a controller that deliberately allocates resources to a specific task - is investigated in the third experiment. According to this notion, the controller makes a trade-off between the anticipated costs and benefits of reassessing the situation the moment a second disturbance occurs. The controller decides on the basis of the outcome of this trade-off whether to reallocate attention or not. So, operators refrain from a reassessment not because they are not able to, but rather because they think the costs of a reassessment do not outweigh the benefits. To test this hypothesis we decreased the costs of reassessing the situation in order to make the outcome of the trade-off clearly in favour of reassessment. If operators indeed make a trade-off between the anticipated costs and benefits, the tendency for cognitive lockup will decrease as the costs of a reassessment are less than the benefits.

Summarized, in the present chapter we will investigate two different explanations for cognitive lockup: limitations in human information-processing capacity and a controller that refrains from allocating resources to the reassessment of priorities because he considers the costs of reassessment too high. In order to test these explanations we used the simulation of the shipping control task.

Experiment 2
In this experiment we investigated whether cognitive lockup can be explained in terms of limited information-processing capacity by manipulating the complexity of the diagnosis process. Increasing the complexity of diagnosing the cause of a fire places a higher claim on the human information processing system. As a consequence, we expected that there would be less residual capacity to deal with additional fires, increasing cognitive lockup.
The most interesting scenarios in this respect are those where a fire starts at the point the operator is already involved in a diagnosis process. In these cases the human information processing system is occupied the moment a second fire starts. If people's tendency to deal with faults sequentially can indeed be ascribed to a limited information processing human capacity, we would expect cognitive lockup to increase when the diagnosis process becomes more complex.

This in contrast with scenarios where two fires start simultaneously. In these cases the operator can first assess priorities and set out a strategy before entering the diagnosis process. In these cases, we would not expect any effect of complexity of the diagnosis process on cognitive lockup.

**Method**

*Participants*

Twenty-seven participants voluntarily participated in the experiment. They were all first year students at the University of Utrecht. The experiment lasted about two hours and they were paid Dfl. 70 (approximately € 32).

*Experimental task*

The same experimental task was used as in the first experiment

*Procedure*

The procedure was the same as in the first experiment.

*Design*

A 2 * 3 (Presentation mode, Complexity) factorial was used. Both factors were manipulated within subjects. The experiment was made up of three blocks, each block representing a different level of complexity. The order of blocks was counterbalanced across participants. Participants were given 5
minutes rest between blocks. One manipulation in this experiment was the presentation mode of two fires: a sequential presentation and a simultaneous presentation. The second manipulation was the complexity of the diagnosis process, which comprised three conditions. In the least complex condition, one tree of questions had to be walked through to determine the appropriate treatment. In the middle condition, there were two different trees: one for fires starting at the two upper decks and one for fires starting at the two lower decks. In the most complex condition there were four different trees, one for each separate deck.

The resulting design consisted of 6 cells each containing 18 scenarios. In each cell there was an equal number of scenarios where the first fire had priority, the second fire had priority and the first and second fire had equal priority. (Note that in the simultaneous condition there was no ‘first’ or ‘second’ presented fire, since both fires started at the same time.) The cells were also balanced for the number of questions that needed to be answered in order to determine the correct treatment for a fire.

108 scenarios were constructed in this way. In order to prevent participants from anticipating a second fire, 54 scenarios were added in which only one fire occurred.

Dependent variables
As in the previous experiment the following variables were measured:
- Performance: number of burn downs;
- Strategy: moment of switch and request of priority information
Results

Performance

Figure 3.1 presents the mean percentage of scenarios that ended in a burn down for the sequential and simultaneous scenarios as a function of task complexity.

![Graph showing mean percentage of scenarios that ended in a burn down as a function of presentation mode and task complexity.]

There was no effect of presentation mode ($F(1,26) < 1$). There was an effect of complexity: as the complexity of the diagnosis process increased, more scenarios ended in a burn down ($F(2,52) = 8.54, p < 0.01$).

There was no interaction between Presentation Mode and Complexity ($F(2,52) < 1$), implying that for all levels of task complexity the number of burn downs was equal for the sequential and simultaneous condition. An increasing level of task complexity did not have a stronger effect on performance in sequential scenarios.
Strategy

Figure 3.2 shows the percentage of scenarios in which the second fire was detected after the correct treatment of the first fire had been selected.

![Graph showing the percentage of scenarios in which the second fire was detected after the completion of the first fire as a function of task complexity and presentation mode.]

The figure shows a difference in strategy for the sequential and simultaneous condition ($F(1,26) = 40.76$, $p < 0.01$). For the sequential scenarios the second fire was detected in most cases after the first one was completed. For the sequential scenarios the second fire was detected before the first fire in half of the cases and after the first fire in the other half of the cases. In other words, the tendency to handle faults one after another is much stronger in the sequential condition.

There was no effect of Complexity ($F(2,52) < 1$) nor an interaction effect between Complexity and Presentation mode ($F(2,52) < 1$). This implies that an increasing degree of complexity did not have any effect on participants' strategy.

Figure 3.2: Mean percentage of scenarios in which the second fire was detected after completion of the first fire as a function of task complexity and presentation mode.
Figure 3.3 presents for each level of complexity the percentage of scenarios priority information was requested for the first fire.

![Graph](image)

**Figure 3.3:** Mean percentage of scenarios in which priority was assessed for the first fire detected as a function of task complexity and presentation mode.

In the sequential scenarios participants requested significantly less priority information than in the simultaneous scenarios ($F(1,26) = 25.74, p < 0.01$).

There was no effect of complexity ($F(2,52) < 1$) nor an interaction between complexity and presentation mode ($F(2,52) < 1$). For each level of complexity much more priority information was asked in the simultaneous condition than in the sequential condition.

**Discussion**

The purpose of this experiment was to investigate whether cognitive lockup could be explained in terms of limited information-processing capacity. The workload of dealing with the first disturbance is assumed to be so high that
no resources are left for reassessing the situation. In this experiment we varied the claim on the operators’ information-processing capacity when dealing with the first fault. We did so by manipulating the complexity of the diagnosis process. We reasoned that if people’s tendency for cognitive lockup could be ascribed to limited information-processing capacity, higher levels of complexity would result in more instances of cognitive lockup.

The data showed however that an increasing level of complexity had no effect on the moment the second fire was detected nor on the frequency of priority assessment in either mode of presentation. Since different levels of complexity in diagnosing the first fire didn’t affect participants’ tendency for cognitive lockup, we can not attribute the lockup phenomenon to limits in the human information processing system.

As in the first experiment we found that a difference in strategy between the sequential and simultaneous condition was not reflected in the performance data. We ascribed this effect to the fact that the assessment of priorities required more time than we had expected so that the assessment of priorities did not always outweigh the information that was obtained. Task complexity did have an effect on the performance data. This finding can be considered as a manipulation check. Since more complex tasks resulted in more burn downs, we may assume that more complex tasks did indeed demand more resources.

In all, the experiment replicated people’s tendency for cognitive lockup that was found in the previous experiment. However this tendency can not be explained in terms of limitations in human information-processing capacity. Therefore, we turned to another explanation for cognitive lockup in the next experiment.
**Experiment 3**

As stated earlier, recent research in the realm of the PRP-paradigm, demonstrated that people are able to process a second task presented first, at least in certain conditions. This finding suggests that people have strategic control over the order of processing. The third experiment was conducted to investigate whether this notion was also valid for more complex tasks such as process control. This would mean that in case of cognitive lockup, operators make a deliberate choice to start with the second fault after having completed the first fault.

In the third experiment of this thesis we investigated the explanation that participants make such a deliberate choice on the basis of a trade-off between costs and benefits. The reluctance to reassess the situation could result from the anticipated costs for reassessing the situation. In our fire control simulation, a reassessment is required the moment a second fire occurred. Participants then are assumed to make a trade-off between the anticipated costs and benefits of priority assessment. If cognitive lockup occurs because the benefits of assessing priority do not outweigh the costs, we expected that as the anticipated costs of assessing priority would decrease, participants would become more inclined to interrupt the ongoing task and enter the task of priority assessment.

In order to test this explanation, we designed an experiment in which we manipulated the costs of priority assessment. We reasoned that if operators indeed make a trade-off between costs and benefits of priority assessment, the tendency to reassess the situation increases when the costs are lowered while the benefits remain the same.

For that reason we replicated the first experiment of this thesis. This condition formed the baseline condition. We added two conditions where the costs of assessing priority were substantially lower. In the second
condition the costs were only minimal. Participants needed to click only one single button to assess a fire’s priority. In the third condition participants didn’t even need to take action themselves. The system reassessed the situation, which implied that there were no costs for the participants. Compared to the baseline condition, we expected a decline of cognitive lockup for the second condition and a further decline for the third condition.

**Method**

**Participants**
Thirty participants voluntarily participated in the experiment. They were all first year students of the University of Utrecht. The experiment lasted about two hours and participants were paid Dfl. 70 (approximately € 32).

**Experimental task**
The same experimental task was used as in the previous experiments.

**Procedure**
As in the previous experiments there were two training sessions: a training session for the assessment of priority and training session for the selection of the correct treatment. Since participants in the Button and Window condition did not need to ask questions to assess priorities, this training session was left out for participants in these conditions.

**Design**
A 2 * 3 (Presentation, Priority assessment) factorial was used. The first factor was manipulated within subjects and the second factor between subjects. The presentation of fires could either be simultaneous or sequential. There were three between-subjects conditions that each comprised of ten participants: the Questions condition, the Button condition and the Window condition.
The second factor that was manipulated in this experiment was the way priority could be assessed. There were three conditions of Priority Assessment: the Questions condition, the Button condition and the Window condition.

1. Questions: as in the first experiment answering a fire’s priority could be assessed by answering questions. A tree-structure determined which questions had to be asked and, at the end of the tree, which priority a fire had. Answers were provided with a one-second delay.

2. Button: a fire’s priority was generated by clicking one single button that provided immediate priority information.

3. Window: priority information was presented on a window. This window popped up out on the screen the moment two separate fires raged the ship. In this condition priority information was therefore provided when additional fires occurred. By clicking on it the window closed, enabling participants to proceed solving the fires.

Each condition of priority assessment consisted of 72 scenarios: 27 sequential scenarios, 27 simultaneous scenarios and 18 single fire scenarios. The sequential and simultaneous conditions contained an equal number of scenarios in which the first fire had priority, the second fire had priority and the two fires had equal priority. The conditions were also balanced for the number of questions that were required in order to diagnose a fire.

**Dependent variables**

As in the previous experiments we measured the *number of burn downs*, *moment of switch* and *request of priority information*.
Results
Again, we subdivide the results in two sections: in the first section performance data are provided and in the second section strategy data.

For each condition of priority assessment, participants had 35 seconds for the high priority fire, 50 seconds for the low priority fire and 50 seconds for both fires when priorities were equal. The assessment of priorities required more time in the Questions condition than in the Button and Window condition. Because the assessment of priorities takes relatively little time in the Button and Window condition, more time is left for the diagnosing process and, as a consequence, more scenarios will be completed successfully. In other words, the burn downs in the Questions condition are disproportional high. In order to make the three conditions comparable for the number of burn downs, we computed the overall time on priority assessment in the Questions conditions and added this amount to the total time participants spent on each trial in the Button and Window condition. If for a scenario the total time exceeded the time limit, it was counted as a burn down.

Performance
Figure 3.4 presents the percentage of burn downs for the three different conditions of priority assessment for both the sequential and simultaneous scenarios.
Figure 3.4: Mean percentage of scenarios that ended in a burn down as a function of presentation mode and priority assessment.

An ANOVA showed that there was a main effect of Presentation Mode ($F(1,27) = 6.27$, $p < 0.05$). Overall, in the sequential condition more scenarios ended in a burn down than in the simultaneous condition.

There was also a main effect of Priority Assessment ($F(2,27) = 14.33$, $p < 0.01$). A post hoc analysis revealed that in the Questions condition significantly more scenarios ended in a burn down than in the Button and in the Window condition ($p < 0.01$). A decrease in costs for the assessment of priorities resulted in better performance.

Though the figure shows a different pattern for the Questions condition in comparison with the Button and Window condition, there was no interaction between Priority Assessment and Presentation Mode ($F(2,27) =$
2.10, p > .1). A reduction in costs did not have a differential effect in the two conditions of presentation.

**Strategy**

It was recorded whether the second fire was detected before or after completion of the first fire and how much priority information was requested.

Figure 3.5 presents the percentage of scenarios in which the second fire was detected after the first fire was completed. This was done for the sequential and simultaneous scenarios, and for the different conditions of priority assessment.

![Figure 3.5: Mean percentage of scenarios in which the second fire was detected after completion of the first fire as a function of presentation mode and priority assessment.](image-url)
First, there was a main effect of Presentation mode ($F(1,27) = 5.43, p < 0.05$). In the sequential condition there were more scenarios in which the second fire was detected after completion of the first fire than in the simultaneous condition. So, overall, there was more cognitive lockup in the sequential presentation mode than in the simultaneous presentation mode.

Second, there was no significant effect of Priority Assessment ($F(2,27) = 2.30, p > 0.1$). However, there was a significant interaction between the different ways in which priority could be assessed and the presentation mode ($F(1,36) = 3.82, p < 0.02$). The effect that in sequential scenarios participants more often detected the second fire after completion of the first fire than in simultaneous scenarios was present for the Questions condition ($F(1,9) = 5.26, p < 0.05$) and the Button condition $F(1,9) = 11.08, p < 0.01$) but not for the Windows condition ($F(1,9) = 2.47, p > 0.1$). There is, in other words, a tendency for cognitive lockup in the Question and Button condition, but this tendency is absent in the Window condition.

The second variable indicating participants' strategy was the percentage of scenarios for which priority information was requested for the first fire detected. Figure 3.6 presents the percentages for two different conditions of priority assessment. Since participants in the Window condition did not need to request priority information actively, this variable could only be registered for the Questions and Button Condition.
Again, there was a main effect for Presentation Mode \( (F(1,18) = 15.50, p < 0.01) \). In the simultaneous condition more priority information was requested than in the sequential condition. There was also a main effect of Priority Assessment \( (F(1,18) = 15.25, p < 0.01) \) implying that in the Button condition significantly more priority information was requested than in the Question condition.

There was no interaction effect between Priority Assessment and Presentation Mode \( (F(1,18) < 1) \). The reduction of costs from asking multiple questions to clicking a single button had the same effect on either mode of presentation: a decreasing tendency to process fires in a serial way. This implies, as can also be gathered from figure 3.6, that for the Button-condition participants' tendency to process fires sequentially and to refrain from assessing priorities is still more prominent in the sequential condition.
**Discussion**

The purpose of the third experiment was to investigate whether cognitive lockup could be explained by a controlling function that allocates attention on the basis of a trade-off between costs and benefits of reassessing the situation. Following this line of reasoning, cognitive lockup is due to a perception of high costs. To test whether participants refrain from reassessing the situation because they consider the costs too high, we manipulated the costs that accompany the reassessment. We hypothesized that if participants indeed make a trade-off between costs and benefits of a reassessment, a decline in costs would result in a weaker tendency for cognitive lockup.

The data of the third experiment provided support for the notion that the costs of reassessing the situation affect operators' switching behavior. When the costs were reduced to clicking a single button, cognitive lockup decreased as well. In case there were no costs and the system reassessed the situation for them, cognitive lockup appeared to be absent. So it seems that operators indeed make a trade-off between the costs and benefits of reassessing the situation. A decrease in costs results in an outcome of this trade-off that is more in favor of reassessing the situation.

A closer look at the separate conditions of priority assessment provides some additional information on cognitive lockup. First, the effect of cognitive lockup in the first and second experiment was replicated in the present experiment for the condition where priority information could be assessed by asking multiple questions. Again, in the sequential scenarios, operators showed a stronger tendency to deal with faults sequentially than in simultaneous scenarios. Cognitive lockup in other words, is a robust finding.
In case the costs of assessing priorities merely consisted of clicking a single button, we found a decline in the number of scenarios in which operators dealt with fires in a sequential order (even though we still found some degree of cognitive lockup in the sequential scenarios). Apparently, operators decide to reassess the situation only when the benefits clearly outweigh the costs. Evidently, there is an asymmetry between the way the costs and benefits are evaluated.

The finding that participants sometimes incorrectly estimate certain costs is in line with earlier findings reported by Kerstholt (1994). In dynamic environments such as process control, people generally use a strategy to request information rather than apply actions, also in conditions where an action-oriented strategy is optimal. In another study, Kerstholt (1995) found that people can use a action-oriented strategy but only when the costs of information clearly outweighed the costs of applying actions.

It is an interesting question why operators still do not reassess the situation when the costs for a reassessment are lower than the benefits. There are a number of plausible reasons. One possible reason is people’s difficulty in estimating time durations. The costs and benefits in the present task are expressed in terms of time. Reassessment of the situation costs valuable time, but there are also benefits in terms of time. A reassessment of the situation provides information about a possible change in priorities. Participants can apply this information to effectively rearrange their available time. However, since people find it difficult to estimate time durations, they can not adequately make a trade-off between costs and benefits.

Another possible reason is that participants may be aware that, with the present design, the odds are only one against three that the second fire has higher priority. Participants may be less prepared to spend effort into reassessing the environment when the probability that it pays off is only
0.33. In general, people choose a strategy so that a sufficient level of accuracy is reached for the lowest possible level of mental effort (Payne, Bettman and Johnson, 1988). In other words, because there is a high chance that one’s effort will be in vain, one is less prepared to invest energy in reassessing the situation.

For the other condition of priority assessment, there are practically no costs to the assessment of priorities. In this condition, in which participants are forced to interrupt their ongoing activities in order to take notice of priority information, cognitive lockup is absent. The fact that participants in this condition do not return to the diagnosis process of the first fire when this fire has low priority suggests that they do not strictly hold on to the first fire. The moment they are detached from the diagnosis activities of the first fire, they are able to make a new decision that takes into account the change in the environment.

**General Discussion**

In supervisory control tasks, human decision making can become very complex when disturbances occur. Since disturbances have to be dealt with within a certain time limit and the consequences of exceeding this limit are often dramatic, there is a very high level of time pressure. Moreover, because disturbances often propagate through the system, operators have to deal with multiple tasks at the same time. Accident analyses have reported that in these critical situations operators have the tendency to focus on a single disturbance and ignore the rest of the system. A consequence of cognitive lockup is that other, more urgent disturbances remain unattended, resulting in a break down of the system.

The rationale of the research in this chapter was to investigate the reasons why operators are locked up in a subpart of the system. We suggested two
possible explanations. One explanation was that operators lack sufficient information-processing capacity to deal with subsequent disturbances. The other explanation was that cognitive lockup is the outcome of a trade-off between anticipated costs and benefits of reassessing the situation. The former explanation was investigated in the second experiment and the latter explanation in the third experiment.

The data provided evidence for only the latter explanation. The second experiment showed that a higher workload, realized by an increase of complexity, did not result in a stronger tendency for cognitive lockup. In the third experiment cognitive lockup appeared to be affected by the anticipated costs of a reassessment. When we lowered these costs, cognitive lockup decreased substantially. This implies that - when confronted with a second fault – operators make a trade-off between the costs and benefits of a reassessment.

Cognitive lockup occurs because operators perceive the costs of a reassessment too high relative to the benefits. Operators seem to be able to break through the tendency for cognitive lockup when the benefits of a reassessment are very high relative to the costs. Nevertheless, in the sequential scenarios cognitive lockup is still present whereas in the simultaneous scenarios participants practically always decided to reassess the situation, even when the priorities are absolutely clear.

Why do operators in sequential scenarios still decide not to reassess the situation when the benefits are high and the costs low? In other words, what drives operators to continue with the first disturbance in spite of the fact that they know it is better to reassess the situation? The answer may be found in the realm of human decision making.
In decision making literature there is a similar class of phenomena, all reflecting people's tendency to stick to their initial plan, even if the outcome of that plan is clearly negative (e.g. the sunk cost bias and escalation of commitment). A number of explanations have been suggested to explain these phenomena (e.g. Arkes and Blumer, 1985; Brockner, 1992; Kahneman, Knetsch and Thaler, 1990). However, these explanations have been investigated with static, highly hypothetical scenarios. In the next chapter we will investigate to what extent these explanations can account for cognitive lockup as observed in a dynamic supervisory control task.

The results of the experiments in this chapter have important implications for the design of decision support systems. To date, most support systems are constructed to relieve operators from a high workload. The overall idea is that operators make mistakes because of limitations in their cognitive capacity. The data of the experiments make clear that sub-optimal performance due to cognitive lockup can not be overcome by reducing workload. Operators do not refrain from reassessing priorities because they have reached their limits of information-processing capacity.

A decision support system that seems more productive is one that makes the costs and benefits of switching more explicit. At the moment a second fault turns up, operators make a trade-off between the costs and benefits of making a reassessment of the situation. These costs and benefits are not apparent in most supervisory control tasks. Operators often lack information concerning the costs and benefits of a reassessment, which makes it difficult for them to make a trade-off. Therefore operators should be assisted assessing the costs and benefits of a reassessment in order to make an accurate trade-off.
To conclude, in order to prevent operators from becoming locked up in a subpart of an automated system, we recommend designers of decision support tools to change their focus from relieving cognitive load to providing operators with means to facilitate a reassessment of the situation.