CHAPTER 7

PLANNING SKILLS UNDER DECISION SUPPORT: COMPUTER-AIDED NURSE SCHEDULING

7.1 INTRODUCTION

The present chapter is about the influence of computer-aided nurse scheduling on the task performance. Roth and Woods (1989) had also investigated the effects of decision support based on a cognitive task analysis. They found that decision support improved the task performance, and second, that the variety of possible solutions for a specific problem increased.

A task presented in a computer-aided situation differs from that in the manual situation (Waern, 1989). The scheduler thus has to perform a ‘new’ nurse scheduling task. It is divided between the scheduler and the computerized system whereas in the manual situation the task performance was completely done by the scheduler. The fact that the computer-aided nurse scheduling can be regarded a new problem-solving situation, implies that the demand on domain knowledge along with the problem-solving processes may change. The main purpose of this study is to explore to what extent the problem-solving processes underlying the task performance change under the influence of decision support. In the manual situation it was found that the task decomposition, the task arrangement, and the use of domain knowledge comprise the greatest part of the problem-solving for making a schedule. The role of these aspects underlying the task performance will be investigated along with whether decision support also places specific demands on the scheduler. Therefore an experiment with the ZKR system that was based on the results of the cognitive task analysis discussed in chapters 4, 5 and 6, was designed to investigate the task performance by experts and novices in a decision-aided situation.

7.2 COMPUTER-AIDED NURSE SCHEDULING: THE ZKR SYSTEM

The task performance under decision support was investigated by using the ZKR nurse scheduling system developed within the project DISKUS. In the framework of this thesis the ZKR system is therefore considered as a tool for doing
research. This needs to be distinguished from the original aim within the project DISKUS, namely, the development of a computerized system that aims at supporting the scheduler in making schedules. ZKR is an abbreviation of ‘ZieKhuisRoostering’ (nurse scheduling). The design of the ZKR system was grounded on the results of the cognitive task analysis (see chapter 4, 5 and 6) from which the results are discussed in this thesis since this sets up a background for the development of knowledge-based systems (Waern, 1989). After the phases of knowledge acquisition and knowledge structuring, by which a thorough understanding of the nurse scheduling task was acquired, and which are part of the cognitive task analysis, the next phase in building the ZKR system was the knowledge representation. This phase comprises the representation and the implementation of the structured knowledge resulting from the preceding phases, according to a particular formulation that consists of production rules (IF... THEN...) and structured objects (frames). They are both used in the expert shell Nexpert which comprises objects and classes along with rules. It results in a computerized system that needs to be tested and evaluated in the next phase. Although the performance of the ZKR system depends for a large part on the nature of the knowledge representation and the implementation, the usability of the system is also fixed by the nature of the interaction between the user and the system. This is shaped for the ZKR system by associating it closely with the manual way of working by a scheduler. In this way, the semantical distance between the scheduler and the system becomes smaller. Moreover, this is in line with a design principle for decision support from cognitive psychology. Another characteristic is the modular set-up of the system by which the different tasks of the nurse scheduling task can be performed in each random sequence. In addition, the ZKR system offers the user different types of support. It is possible to work interactively in cooperation with the system, as well as to adapt generated schedules manually. Moreover, it is the responsibility of the scheduler to decide on the final schedule (Mietus & Oldenkamp, 1992). The ZKR system was further elaborately described in several reports concerning design considerations, the modelling, technical and software aspects (see Jorna, 1992; Mietus & Oldenkamp, 1992; Oldenkamp, 1991, 1992). In the meantime it is being further developed for practical use in hospitals. In the present paragraph the functions of this system are discussed from the human problem-solving perspective.

The functions offered by the ZKR system

The functions of the ZKR nurse scheduling system resemble for the most part the several tasks found in the cognitive task analysis and discussed in chapter 5 which concern administration, problem solving and evaluation at the aggregate level. Below, they are discussed in detail.
Administration

The administrative function of the ZKR system aims at the specification of the nurse scheduling problem for the planning period scheduled by preparing data needed to be processed in the problem solving. It concerns introducing and updating if necessary the administrative data, such as personal data, wishes, courses, vacations, etc. After choosing a specific planning period, the relevant administrative data is automatically placed on the schedule within the user interface. For instance, the wishes, courses, and vacations are recognizably represented in the schedule by colouring those cells related to a specific combination of a day and a staff member (see figure 7.1). For instance, a vacation of a nurse is represented by the colour red. By means of clicking on a staff member, all available personal data of that staff member is shown in a window. The system also automatically computes the historical data. An overview of the updated historical data can optionally be obtained. After finishing the computer-aided making of the schedule, the administrative data can again be updated in order to deliver a complete overview of the scheduled planning period.

Problem solving

The problem-solving function of the ZKR system aims at the generation of (partial) schedules. It contains the scheduling of the day, evening and night shift that is separately performed by the system. These three tasks are sufficient to generate a complete schedule for one planning period of four weeks. An important difference between these tasks is the division of the planning period into smaller parts that are separately scheduled. The night shift is entirely scheduled for four weeks at once whereas the scheduling of the day and evening shifts are performed per week. The user is free to choose the sequence in scheduling these three shifts. The system does not impose a specific task arrangement in the scheduling of shifts. The ZKR system computes solutions for the chosen shift on the basis of scheduling knowledge and rules captured in the system by using techniques from the field of Artificial Intelligence supplemented with Operational Research techniques. From the computed solutions of each shift the five best solutions are presented to the user. They are all acceptable solutions for the schedule, but the first solution is the ‘best’ and the fifth is the ‘poorest’ solution. This so-called ‘best solution’ is the first one presented in the schedule but the other four solutions can be examined separately. For example, the user
could jump from the fifth to the third solution and then decide that the second one was the most suitable solution for the specific shift being handled. The user may run through all five solutions as often as needed according to his/her personal view. After making a final choice, the scheduled shift is presented in the schedule as depicted in figure 7.2.

Within the problem solving the counting of the number of scheduled shifts per staff member as well as counting the quantity of staffing in a shift is automatically done by the ZKR system. The results of this counting are presented in the schedule and are immediately available to the scheduler. By performing the counting the system relieves the scheduler of this time-consuming task.

Moreover, it is always possible for the user to adapt the solutions manually if for any reason the user prefers to overrule the computed solution. Lastly, the days off and short-time days need to be manually scheduled.

**Evaluation**

The evaluation of the generated schedule needs to be performed manually by the user. It is always possible to make slight changes in the schedule by manually resolving parts of the schedule. The possibility of manual adaptations is important because the scheduler may consider that some changes lead to a better schedule despite the captured knowledge and rules in the ZKR system, the so-called emergence of ad hoc goal functions.

Below, an overview of the functions and the related tasks are given.

<table>
<thead>
<tr>
<th>administration</th>
<th>introducing personal data</th>
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<tbody>
<tr>
<td></td>
<td>introducing wishes</td>
</tr>
<tr>
<td><strong>problem solving</strong></td>
<td>introducing courses and vacation etc.</td>
</tr>
<tr>
<td></td>
<td>looking after historical data</td>
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<tr>
<td></td>
<td>scheduling the night shift</td>
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<tr>
<td><strong>counting</strong></td>
<td>scheduling the evening shift</td>
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<tr>
<td></td>
<td>scheduling the day shift</td>
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<tr>
<td></td>
<td>the quantity of staffing</td>
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<tr>
<td></td>
<td>the number of work days of a staff member</td>
</tr>
<tr>
<td><strong>manual</strong></td>
<td>adapting the days off and short time days</td>
</tr>
<tr>
<td><strong>evaluation (manual)</strong></td>
<td>evaluating and resolving, if needed, specific parts of schedule</td>
</tr>
</tbody>
</table>

The functions such as presented by the ZKR system resemble the three aggregate tasks along with their subtasks distinguished in the task performance when performing the task manually. The user or scheduler is free to choose which task is
going to be executed by the system. In this way the schedule is created little by little instead of wholly by the cooperation between the user and the system.

7.3 A CHANGING ROLE FOR THE SCHEDULER IN A DECISION-AIDED SITUATION

The ZKR system takes over a part of the task performance that normally would be done by the scheduler him/herself in the manual situation. The cooperation between the ZKR system and the scheduler is discussed from the task performance perspective. The scheduler still has to perform a part of the administration by updating the wishes, courses, vacation etc. However, historical data are now computed by the ZKR system and processed in computing solutions of the schedule.

The task decomposition as part of the problem solving is represented by making a choice from among the day, evening and night shift. In this regard the scheduler should be content with this task decomposition, although the scheduler has to arrange the sequence of executing them since the ZKR system does not impose a fixed order. This implies that the scheduler gets the opportunity to perform his/her preferred scheduling strategy, (for instance, a scheduler may prefer to schedule the evening shift after a day shift) and not be hampered by difficulties of a problem-solving nature. In the manual situation the scheduler often scheduled the day shifts as the last one. In this sense the ZKR system offers more flexibility in arranging the tasks.

The scheduling procedure, when executed, leading to a solution of the schedule, is completely performed by the system. This means that the counting, searching for personnel available for a shift, ranking the availability pool, composing teams satisfying the quantity and quality of staffing does not need to be done any more by the scheduler. In addition, it implies that all the burdensome extra control activities can be omitted in the making of a schedule. Moreover, automated counting would not bring about as many mistakes as occurred in the manual situation. However, the scheduler does have to judge the five presented solutions and choose one of them in the end. This is a new aspect of the nurse scheduling task under the decision-aided situation. Of paramount importance is that the scheduler is able to judge the solutions by the different aspects significant for nurse scheduling, such as the different goals. In this regard the effort of the scheduler may shift to the judgment of the nurse scheduling goals away from performing complex problem-solving processes. When the scheduler does not agree with one of the offered solutions as a whole, he/she may overrule them partly or entirely by making changes manually. In this way, the responsibility lies with the scheduler: the judgment of the scheduler remains essential
in the making of the schedule when using the ZKR system. It may be obvious that the role of the scheduler changes with decision support and along with that it is expected that the nature of the problem solving underlying the task performance will differ as well. Below an overview of the division of labour between the scheduler and the ZKR system is presented.

<table>
<thead>
<tr>
<th>division of labour</th>
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<tbody>
<tr>
<td><strong>administration</strong></td>
</tr>
<tr>
<td>introducing personal data</td>
</tr>
<tr>
<td>introducing wishes</td>
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<tr>
<td>introducing courses and vacation etc.</td>
</tr>
<tr>
<td>looking after historical data</td>
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<tr>
<td><strong>problem solving</strong></td>
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<tr>
<td>scheduling the night shift</td>
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<td>scheduling the evening shift</td>
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<tr>
<td>scheduling the day shift</td>
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<tr>
<td><strong>evaluation</strong></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>counting</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>manual</strong></td>
</tr>
<tr>
<td>scheduling the days off and short-time days</td>
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</table>

The changing role for the scheduler will become significant in the problem solving. In order to understand the nature of the changes a closer investigation on the task performance by experts and novices is needed. An experiment is designed therefore with the ZKR system, though it deviates slightly from the methodological aspects related to the manual situation discussed in chapter 3. Some methodological issues are discussed first in the paragraph following.
7.4 METHODOLOGICAL ASPECTS OF THE EXPERIMENT UNDER DECISION SUPPORT

7.4.1 Subjects

The same persons participated in the experiment under decision support as in the experiment in the manual situation. There was a long time (one year) between these two sessions, so that they would not remember that the scheduling problem offered in both situations was the same problem. This implies that there is not a learning effect in the subjects. However, the distinction between the two novice groups expired because the subjects from the novice-np group had in the meanwhile become second-year student nurses, which means that they had acquired two years of practical nursing experience when the experiment took place. In this sense they were now comparable with the novice-p group.

7.4.2 Procedure

The experiment was run either in the private offices of the head nurses or, for the novices, in a quiet classroom at school. All subjects were asked not to exchange any information about the ZKR system and the presented schedule problem during the period the experiments took place.

Every experiment started by running a tutorial which instructed the subjects how to interact with the ZKR system by the use of a mouse. After reading the user manual carefully, all subjects were adequately prepared to perform the scheduling task on the computer. This took about twenty minutes. Then, a written schedule problem (the same as within the manual condition) was presented and all participants were asked to make a conclusive schedule by using the system.

The information concerning the scheduling history of each employee such as the recent weekend and night shifts worked, courses and personal wishes, were already included in the nurse scheduling system. This differs from the other session in which these data were presented on small cards and the subject had to write it down on the schedule by him/herself. The automatically generated schedule for each consecutive shift, which had to be judged, presented the names of the scheduled nurses on screen, as well as the results of the counting of the quantity of staffing for the actual shift. This also differs from the manual session in which the scheduler had to perform this by him/herself. It was possible to make manual corrections in the schedule.
Each subject had as much time as was needed for making his or her definitive schedule. During the task performance the subjects were asked to think out loud and this was recorded on tape at each session. The experiment ended with a short interview on their experience with the nurse scheduling system. The results obtained were regarded as confidential. Below an overview of the different aspects forthcoming within the making of a schedule is presented.

<table>
<thead>
<tr>
<th>manual</th>
<th>decision support</th>
</tr>
</thead>
<tbody>
<tr>
<td>data needed for the administration presented on small cards</td>
<td>data needed for the administration already implemented in the ZKR system</td>
</tr>
<tr>
<td>counting by scheduler</td>
<td>counting by system</td>
</tr>
<tr>
<td>quantity of staffing to be computed by the scheduler</td>
<td>quantity of staffing presented automatically on the user interface</td>
</tr>
<tr>
<td>scheduling by scheduler</td>
<td>scheduling by system</td>
</tr>
</tbody>
</table>

7.4.3 Measures

A log file implemented in the ZKR system registered a chronological record of the different tasks and investigated solutions of a scheduled shift undertaken by each subject while working on the scheduling problem. Each shift under consideration was registered as well as each solution that was evaluated. This results in a precise overview of different steps performed by the scheduler, along with the time needed for each separate activity that was also recorded in the log file.

Also, a protocol analysis was performed on the tape-recorded data in order to reveal the cognitive processes while working with the system.

The effects of decision support on task performance were measured by the following variables which included the sequence in shifts (scheduling strategy), the judgment of the five solutions and the choice made from one of the five solutions proposed by the nurse scheduling system, and the required time for the task performance to schedule the day, evening or night shift. Only the sequence of shift referring to the task arrangement was also measured in the manual situation. The others are new under decision support.
7.5 PROBLEM SOLVING UNDER DECISION SUPPORT

Problem solving under a decision-aided situation, in particular the ZKR system, is discussed by examining the task performance as shown when making a schedule. As far as it is possible the same aspects put forward in the problem solving in the manual situation are considered in the decision-aided situation as well (see 7.3.3). However, the form of the nurse scheduling task has been changed under decision support compared with the manual situation, implying that the task environment differs between the two situations and accordingly the demand on the problem solving can differ as well. This means that the aspects to be examined have a slightly different meaning depending on the task environment under consideration. For instance, the task decomposition in the ZKR system is based on the manual task decomposition of the administration, problem solving and evaluation, but is fixed for the scheduler, unlike in the manual situation, and is therefore not examined here.

The arrangement of the tasks

Along with the task decomposition, the other problem-solving principle in dealing with a planning task is the task arrangement. This means that tasks are ordered to be executed sequentially, thereby making the task performance manageable for the scheduler. Making a schedule supported by the ZKR system the user is still challenged by choosing the order in which tasks are going to be executed, with the difference that the type and the number of tasks can no longer be freely chosen any more since they are now part of the functionality of the ZKR system. The task arrangement as performed by the ZKR system but imposed by the subjects is investigated since it may change compared to the manual way of scheduling. Each single task is now offered by the ZKR system: the scheduler becomes less dependent on the problem-solving processes related to the task decomposition, and the scheduling strategy can now be performed more flexibly. This means that the scheduler gets more freedom of choice to fix the scheduling strategy. It is therefore expected that the schedulers will reveal more variety in their task arrangement by tuning the arrangement of the tasks more to the schedule's present state; we expect in particular that the fixed order of scheduling the night shift first, then the evening shift and then the day shift, will not be obeyed strictly. The task arrangement under decision support is investigated in this respect by looking at the sequence of shifts. Each choice of a shift can be considered a single task to be executed by the ZKR system. When all these choices are placed in sequence, each subject exposed a specific scheduling strategy, for instance, a scheduling strategy consisting of the
sequence evening shift, night shift, day shift.

The results of the task arrangement are depicted table 7.1. The ‘standard’ sequence of night-evening-day is set off against all the other possible sequences which are: day-evening-night; day-night-evening; evening-day-night; evening-night-day; night-day-evening.

<table>
<thead>
<tr>
<th></th>
<th>night evening day</th>
<th>not (night, evening, day) all others</th>
</tr>
</thead>
<tbody>
<tr>
<td>experts (n=6)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>novices (n=8)</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

The Fisher-exact test revealed a significant difference (c = 0.16, df = 1, alfa = 0.025) between the experts and novices, implying that they differ in the task arrangement; that is, the experts chose the sequence night-evening-day while the novices performed another sequence deviating from the experts', for instance, the sequence day-evening-night. The experts' scheduling strategy was still the same as had been revealed in the manual situation, while for the novices the finding that they reveal hardly any sequence is similar to the manual situation as well. However, two experts attempted to experiment with their sequence in shifts in order to attune it with their view that the day shift is the most important one. From the previous investigations on the domain knowledge of nurse schedulers it was known that the day shift was denoted as the most important shift in a nurse schedule because most of the workload of patient care is focused in the daytime. Therefore, all experts designated their preference for the day shift as the shift to start with when a schedule had to be produced. An expert scheduler gave the reason for this by saying:

I should actually say it the other way round, the day shift has priority. Only because there are so many problems with the evening and night shifts do I tackle them first. But that is scheduling technically; as regards quality, you really should schedule the other way round, you should begin with the day shift and what’s left over [schedule] for the evening and night shift.

This result suggests that some of the expert schedulers did indeed adapt their
scheduling strategy to their preference. They tried out whether it was possible to make a schedule on the basis of domain knowledge only. Tentatively speaking, the effect of decision support on the task performance may be a change towards the shift considered the most important one to be scheduled first. In this respect it seems that under decision support the use of domain knowledge dominates a more general problem-solving skill such as the task arrangement. This means that the scheduler called less upon their procedural experience of how to perform the nurse scheduling task. The other experts said that they prefer to schedule the day shift first but that they did not take the opportunity to do so with the ZKR system. In fact, they commenced with the night shift. Moreover, this was in contrast to the novices, most of whom also started with the day shift. Although this difference can be explained by differences in knowledge and skills between experts and novices, the rigid manner in which the experts started with the night shift and handled the sequence of shifts, as they were commonly used to, was not necessary under the present conditions of decision support. This was illustrated by the finding that the novices, who started with an alternative shift and consequently handled a different sequence of shifts than the experts, also succeeded in the accomplishment of their task. The novices took decisions which were not based on already acquired procedural experience in the domain of nurse scheduling, but they succeeded in the application of interactive scheduling with the system. The novices had not yet learned scheduling, whereas the experts had a disadvantage when working with the ZKR system since they first needed to ignore the scheduling strategy they were used to. Further practice with the system is needed to observe possible changes in the scheduling strategy in experts.

Choosing a solution

The next aspect to be dealt with in cooperating with the ZKR system, after the choice of a task, is the five solutions presented. The ZKR system displayed five alternative solutions in which personnel are assigned to the chosen shift. They are all acceptable solutions for the schedule, but the first solution is the ‘best’ and the fifth is the ‘poorest’ solution. This so-called ‘best solution’ is the first one presented in the schedule though the other four solutions can be examined separately. The possibility of choosing from these potential solutions introduces a new aspect of the nurse scheduling task under decision support, in comparison with the manual situation, in which the scheduler concentrates on finding just one solution. The task performance demanded by the system requires, ideally speaking, that the scheduler needs to judge each single solution, then compare them with each other, before a final decision can be taken. The first issue is whether the scheduler makes use of the number of solutions offered, the second question is on which criteria are the solutions judged, and lastly, which solution is finally chosen by the scheduler. Each question
is further discussed below.

The way the schedulers dealt with the facility of several solutions is investigated by means of the following categories. The first one is that a scheduler considers all five solutions, the second one is that two to four solutions are considered, for instance, solutions one, three, and four were considered. The scheduler does not need to follow the fixed sequence from one to five. It is also possible to go back to a solution already considered. The third category is that the scheduler considers just one solution (the first presented solution); that can only be solution one. All solutions considered for a shift by the subject were registered in the log file which is scored by means of the three categories for each subject. The results are given in table 7.2.

The Mann-Whitney U test revealed a significant difference between the experts and the novices for the category ‘one solution considered’ for the day and evening shift: the experts considered one solution only more often than the novices, who passed through several of the five solutions. Moreover, a similar tendency can be seen within each subject group for all three shifts. Both groups, however, make use of the five solutions presented to a great extent, though the experts prefer to consider one solution only later on and the novices keep considering all five solutions. By regarding several potential solutions of a shift more information is processed in order to take a decision. Judging one solution did not cause much difficulty, though performing a comparison among the different solutions was rather demanding, because it was sometimes hard to remember a solution since just one solution was presented in the user interface. An example of a part of an expert's log file is given, revealing the task performance for the evening shift in a particular week of the planning period:
Table 7.2  NUMBER OF SOLUTIONS CONSIDERED FOR THE DAY-, EVENING-, AND NIGHT SHIFT FOR THE TWO GROUPS OF SUBJECTS

<table>
<thead>
<tr>
<th></th>
<th>day shift</th>
<th></th>
<th></th>
<th>evening shift</th>
<th></th>
<th></th>
<th>night shift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 s</td>
<td>2-4 s</td>
<td>1 s</td>
<td>5 s</td>
<td>2-4 s</td>
<td>1 s</td>
<td>5 s</td>
</tr>
<tr>
<td>novices (n=8)</td>
<td>7.38</td>
<td>6.81</td>
<td>5.50</td>
<td>8.00</td>
<td>6.25</td>
<td>5.75</td>
<td>7.75</td>
</tr>
<tr>
<td>z</td>
<td>-0.13</td>
<td>-0.79</td>
<td>-2.59</td>
<td>-0.52</td>
<td>-0.52</td>
<td>-2.01</td>
<td>-0.32</td>
</tr>
<tr>
<td>p</td>
<td>0.89</td>
<td>0.42</td>
<td>0.01</td>
<td>0.59</td>
<td>0.15</td>
<td>0.04</td>
<td>0.74</td>
</tr>
</tbody>
</table>

legend: 5 s = five solutions  
2-4 s = two - four solutions  
1 s = one solution

the results have been averaged over the subjects (mean rank)

<table>
<thead>
<tr>
<th>considers all five solutions first</th>
<th>considering solution one</th>
</tr>
</thead>
<tbody>
<tr>
<td>starts with solution one again,</td>
<td>considering solution two</td>
</tr>
<tr>
<td>weighs solution one and two</td>
<td>considering solution three</td>
</tr>
<tr>
<td>decides to consider another</td>
<td>considering solution four</td>
</tr>
<tr>
<td>solution</td>
<td>considering solution five</td>
</tr>
<tr>
<td>decides not to choose solution</td>
<td>considering solution one</td>
</tr>
<tr>
<td>five, weighs solution three and</td>
<td>considering solution two</td>
</tr>
<tr>
<td>four</td>
<td>considering solution three</td>
</tr>
</tbody>
</table>

accept solution three
Although at a first glance it appears to be a rather complicated process, it took less than ten minutes to accept solution three finally. The scheduler jumps quickly from one to the other after controlling the presented solution on nurse scheduling goals considered particularly important for nurse scheduling. The judging process of the solutions is discussed below.

**Judging the solutions presented by the ZKR system**

For computing solutions different aspects of the nurse scheduling problem are taken into account by the ZKR system. These aspects, abstracted from the results of the cognitive task analysis performed within this study, were designated as important in the making of a schedule manually. The question is whether the scheduler still processes such criteria in the interpretation of the solutions. Therefore the tape-recorded data of each subject, with the verbally justified decisions while working on the schedule problem, were written down on paper. A protocol analysis was performed on these texts in order to understand the major criteria used to make the final decision for each shift by the experts and the novices.

Generally speaking, both the experts and the novices applied their domain knowledge in the judgment of the solutions. Both experts and novices were especially focused on checking the achievement of goals, for instance, they checked the quality of staffing of a shift. They hardly make any comments on the constraints and the quantity of staffing of the three shifts. This is explained by the fact that the experts and novices easily recognize that those aspects of nurse scheduling were taken into account by the ZKR system. This is also illustrated by their protocols. An expert states why she checks the quality of staffing:

I look at their experience. It's not a problem, it's just curiosity.

The expert again:

I find the evening shifts and the night shifts the hardest ones to schedule. So I'll do that first. Then you could say that you should have the most continuity in the day shift. I am going to do that first, that means a lot of fuss for me. I'm going to do the day shift first, how much continuity ...

An expert judged the solutions on the continuity goal:

What I like about this. Every time there is an overlap, a shift. So if I start those two that there is still one from the evening before, I think that's a really good system.
The advantage for the experts is that they only have to check the goals which can be done separately for each goal. Moreover, this is done per week. In the manual situation, on the other hand, the bottleneck was first to realize such a solution in which all goals were attained. The scheduler then checks the achievement of the nurse scheduling goals until the evaluation of the whole schedule, thus, after finishing the problem solving.

The goal under consideration in the novice group largely depended on the observable features of that part of the schedule which agrees with the manual situation, despite the fact that the ZKR system contains more goals. This was illustrated in the protocol analysis where the novices often pointed to the schedule pattern which successively determined their decisions.

Vleugel has planned evening shift, then a day off and then work again. Gul does have the evening shift, is supposed to then rotate early, has got off. I don't like this choice one so much. This one is a bit better since Gul can now have those days off. And then she could rotate to day shifts. Duis also gets off and begin on Monday with the evening shift and the weekend after that off again too. She really should be off then. It works out well for Noot, has off, could also get off then again, has 6 days off. And the evening shift after that. Sonja has 2 days working, 3 off and 4 working. So does Water. The drawback is then Juul. Otherwise choice 3 is really quite good.

The novice paid a lot of attention to the schedule pattern, especially to the tuning of shifts and the total number of working days, although some of the novices mentioned continuity in the day and evening shift. This suggests that novices can acquire knowledge of goals on the basis of the solutions. In the protocols it can be seen that both the experts and the novices considered the honouring of the wishes and the quality of staffing in the night shift important compared with the day and evening shifts. Domain knowledge acquired is thus applied in the judgment of the solutions of the ZKR system for the day, evening and night shift. In this sense domain knowledge remains important in the making of the schedule despite computer-aided nurse scheduling. Moreover, it underlines the fact that the scheduler needs to be supported instead of replaced by a computerized system.

**The chosen solution**

The key point is which one of the five solutions is finally chosen for the definitive schedule by a scheduler. From the view of the ZKR system the first solution is the best solution whereas the fifth solution is the worst solution. An expert
should be able to recognize the nature of the differences among the solutions since they are based on the experts' scheduling knowledge. The first solution agrees more with an optimal processing of the experts' knowledge than the others. It is therefore expected that the expert group would choose the first solution more often than the novice group. Since it is here the definitive solution chosen, the related part of the task performance is only considered in the log file. This means that those solutions resulting in the final schedule of four weeks are under consideration. The chosen solutions by the subjects are categorised on the basis of the ‘first solution chosen’ and ‘the second to fifth solution chosen’. However, a solution could not be computed by the ZKR system for every week because of technical problems in the software. At the time of this study the ZKR system used was not a fully operational system. The results somewhat may be flattering since not every subject could finish the making of the schedule. The results are depicted in table 7.3.

<table>
<thead>
<tr>
<th>Table 7.3</th>
<th>THE SOLUTION CHOSEN FOR THE DAY-, EVENING-, AND NIGHT SHIFT FOR THE TWO GROUPS OF SUBJECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>day shift</td>
</tr>
<tr>
<td></td>
<td>f</td>
</tr>
<tr>
<td>experts (n=6)</td>
<td>10.58</td>
</tr>
<tr>
<td>novices (n=8)</td>
<td>5.19</td>
</tr>
</tbody>
</table>

Legend: f = first solution  
s-f = second-fifth solution

The Mann-Whitney test revealed a significant difference between the experts and the novices for the day and evening shift (resp. \( z = -2.66, p = 0.007; z = -1.79, p = 0.07 \)) implying that the experts chose the first solution more often than the novices. The experts were thus able to distinguish the first solution from the second to fifth solutions, whereas the novices did not make such a distinction. No such significant result was found for the night shift. The experts recognized their criteria in the first solution which they had denoted as important in making a schedule manually. A within-group comparison reveals the same pattern for all three shifts: experts chose more often the first solution and the novices chose more often one
from the second to fifth solutions. If the experts had only chosen the first solution then obviously, an ‘optimal’ solution could be defined; however, they sometimes preferred one of the other solutions. A choice for one of these refers to the possibility that factors other than the criteria elicited from the experts may play a role. Such factors may be prompted by a personal motivation or they may come into perspective during the problem solving itself. Offering several solutions by a computerized system meets the needs of and is beneficial to a scheduler in the making of a schedule.

Although the results discussed are encouraging from a cognitive point of view for computer-aided nurse scheduling, they need to be tentatively interpreted. By being supported the scheduler is relieved of a lot of problem solving, thereby reducing the memory load and freeing more of the scheduler's attention for judging the solutions. Moreover, the ZKR system stimulates a more structured way of working compared with the manual situation. Both the experts and the novices were aided by the system. They were able to perform a task arrangement according to their personal preference. In this sense the ZKR system enabled a flexible scheduling strategy. The experts, and the novices as well, examined a considerable number of solutions each time a decision needed to be made for a specific shift. Moreover, in judging the solutions the schedulers made greater use of their domain knowledge. According to Roth and Woods (1989) by providing a broader range of variation in attaining possible solutions, the overall task performance may improve, which may lead to a better decision making in the end.

**Time investment.**

Nurse scheduling is considered a time-consuming task in practice. One of the requirements a computerized system is desired to fulfil is saving time. The time needed to schedule a shift by the scheduler or user consists of judging the solution, jumping between solutions and finally choosing one of the solutions. This was recorded in the log file. Each measurement started immediately after the appearance of the first offered solution on the screen and ended when a definitive choice was made. The time required by the experts and the novices to decide which solution fit best for the actual shift handled, before proceeding to the next one, was obtained from the log file. All attempts were taken into account independent of whether all solutions were considered, and in which sequence the solutions were considered, along with whether it led to the final schedule. Thus each shift scheduled by the system and judged by the user is regarded as a serious attempt. The time needed by the ZKR system to compute solutions for the scheduling of a shift was excluded. Table 7.4 reveals the results.
Testing revealed a significant difference (F-value = 4.96, df = 11, p < 0.077) between the experts and novices for the night shift only, implying that the novices needed less time for scheduling the night shift than the experts. The amount of time needed for scheduling the day and evening shift is more or less equal between the two groups. It should be noted that judging the solutions for scheduling the night shift could take more time because of the four weeks scheduled for the night shift than the day and evening shifts, which were scheduled per week by the system. These findings need to be tentatively interpreted since within both groups the subjects revealed rather dispersed time scores for all three shifts. Tentatively speaking, the results reveal that scheduling the day, evening and night shift can be finished in a restricted amount of time, within one hour, with support from the ZKR system. However, the scheduling of these three shifts does not deliver a complete schedule. In this sense the time needed is a little bit flattered since the processing of the administrative data was not taken into account and the scheduling of days off has to be done manually in this prototype. Also the time needed to evaluate the final schedule was not considered here. These aspects of decision-supported scheduling need to be added in order to get a more complete view on the time investment. Moreover, in practice, negotiation with personnel on a ward about assigning a shift still has to be done by the scheduler and unexpected things could always happen that need to be processed into the schedule. However, in comparison with the manual situation all these aspects may not need more time. The performance of the administration is shortened for the scheduler since many data are immediately available, and historical data is automatically computed. Moreover, no counting needs to be performed any more by the scheduler. In a computer-aided situation this

<table>
<thead>
<tr>
<th></th>
<th>experts (n=6)</th>
<th>novices (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>time spent on the day shift per week</td>
<td>2.41</td>
<td>3.59</td>
</tr>
<tr>
<td>time spent on the evening shift per week</td>
<td>2.14</td>
<td>3.57</td>
</tr>
<tr>
<td>time spent on the night shift for four weeks</td>
<td>6.43</td>
<td>4.38</td>
</tr>
</tbody>
</table>

the results have been averaged over the subjects

Table 7.4  NUMBER OF TIME (IN MINUTES AND SECONDS) SPENT ON SCHEDULING THE DAY-, EVENING-, AND NIGHT SHIFT BY THE SCHEDULER
decreases the time needed for making a schedule.

7.6 CONCLUSION

The role of decision support in the task performance of the experts and novices was investigated in the present chapter. Some experts and most of the novices made use of the function of the system to impose a sequence in performing the tasks scheduling a shift tuned to their personal preference. It is concluded that the task arrangement as part of the scheduling strategy is, to for the most part, directed by domain knowledge. This implies that the role of procedural experience, significant in managing the task performance manually, is changing. It will become less important since a part of the procedural experience has been taken over by the ZKR system by offering a number of tasks in a structured way. The manual task performance has been analyzed in order to be implemented in a computerized system. Moreover, the expertise related to the task decomposition is embedded in the system. The use of decision support on the task performance, in particular the scheduling strategy, is considered fruitful. The performance of the three aggregate tasks still consists of the sequence administration, problem solving and evaluation. However, the updating of the administrative data, in particular the historical data, is more quickly available. The evaluation, however, still needs to be performed explicitly. The other problem-solving aspect when using the ZKR system are the five solutions presented. This is a rather new aspect of the problem solving. In the manual situation, the scheduler routinely converges to one solution and rarely compares possible alternatives at the same time. This is because many repetitive tasks such as counting and checking are such a major component of the cognitive demand that examining separate solutions simultaneously exceeds the working memory capacity (Newell & Simon, 1972; Anderson 1983; Newell 1990). The experts only considered one solution more often than the novices, especially for the day and evening shifts. When judging the solutions both groups appealed to their domain knowledge. This may explain the fact that the experts immediately chose the first solution after some experience with judging the other four solutions, since it is more similar to the experts' knowledge. Moreover, the results did indeed reveal that they chose the first solution more often than the novices, although the experts also preferred one of the other solutions sometimes. Deciding on the five solutions revealed that it is important that a computerized system leave the responsibility to the user in making a schedule. An advantage revealed by the results was that making a schedule in cooperation with the system will lead to a time-saving. Although this is very important, other advan-
tages can be tentatively indicated as well. The counting performed automatically by the system gives a reduction in miscalculations, improving the problem solving along with saving time. The ZKR system aims at the support of the manual task performance since parts of the schedules referring to a specific shift instead of an entire schedule are offered. By this means, the scheduler can focus on a specific part of the scheduling problem so that more solutions can thoroughly be weighed, which results in better decisions. In the final chapter a comparison between the scheduling task with and without decision support is discussed.