Understanding planning for effective decision support
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CHAPTER 5

PLANNING SKILLS IN NURSE SCHEDULING

5.1 INTRODUCTION

The nurse scheduling task is a planning problem in itself. With an empty framework to start with and all necessary information available, the first planning problem faced is namely how to manage the scheduling task in general. All the necessary data have to be transferred to the appropriate places in the framework to form a well-organized and complete schedule. The planning nature of the nurse scheduling task implies that the challenging aspect in handling this task is the determination of tasks (Thierauf, 1982). Johnsons (1988) defines a task as ‘an activity that is undertaken by one or more agents to bring about some change of state in a given domain’ (p. 164). Dealing with the activities refers to the problem solving. Along with the task environment, investigating the problem-solving processes of an actor underlying the task performance in that environment is thus the other important aspect for understanding the making of a schedule (Newell & Simon, 1972). This merely refers to the deployment of different types of knowledge in order to achieve a goal that concerns task-, strategic-, and inference knowledge as distinguished within KADS (see chapter 3). Task knowledge acquired plays a dominant role in decomposing the task; strategic knowledge arranges the goals related to tasks resulting in an overall sequence; inference knowledge consists of rules directed to the execution of the task.

Dealing with the nurse scheduling task encourages the decomposition and arrangement of tasks. The decomposition of an ill-structured task needed to deal with the complexity of the task is a generic problem-solving principle (Newell & Simon, 1972). Decomposition is a process of refinement of tasks into smaller manageable subtasks (Jeffries, Turner, Polson & Atwood, 1981). Consequently, it unburdens the working memory load by making a more efficient use of the capacity. In this respect, an adequately performed task decomposition reduces the complexity of the task (Leplat, 1988). The performance of task decomposition, however, depends on the task knowledge and skills of a problem solver.

Since task decomposition results in a number of subtasks, it implies that an arrangement of subtasks is needed in order to perform the nurse scheduling task systematically. The arrangement of tasks is deployed by strategic knowledge that
results in a specific sequence in which the subtasks are going to be executed. The arrangement of tasks may depend on the nature of the task decomposition. A vertical task decomposition will impose a hierarchic structure among the tasks that are mutually interdependent. This implies that the sequence in tasks is more or less fixed. In contrast, a horizontal task decomposition reveals a sequence of tasks that are mutually independent, implying that the sequence of tasks is free. Moreover, it depends on preferences from a problem solver. Taken together, the process of decomposition into smaller directly executable subtasks and the arrangement of these subtasks in a specific sequence for successive execution indicate the scheduling strategy as seen in the task performance. Card, Moran and Newell (1983) pointed out that, in handling complex tasks, the decomposition as well as the arrangement are important to investigate for the understanding of the task performance.

The characterization of the scheduling strategy is understood by pursuing Cohen and Feigenbaum (1982) who consider human planning in two manners: script-based planning and opportunistic planning. Script-based planning consists of skeleton plans which are recalled from a store of plans instead of generated (Schank & Abelson, 1977). The plan guides the planning systematically. In opportunistic planning, however, the planner has no underlying plan, which implies that planning is performed less systematically. Hayes-Roth and Hayes-Roth (1979) characterize human planning as opportunistic and multi-directional as well, although the criticism of their research is that the subjects involved can be regarded as novices because the subjects do not have any experience in performing the presented task.

In order to understand the nurse scheduling strategy theoretically and empirically a general description of the several tasks in the nurse scheduling domain are abstracted from the thinking aloud protocols that are depicted in the task structure and next, a comparison between expert and novice schedulers with respect to their task performance is made. Lastly, the execution of tasks is discussed in relation to scheduling illustrated by some protocols. The questions addressed concern into which tasks the nurse scheduling task is decomposed by experts and novices. And in which strategic way do the schedulers organize the tasks?

5.2. THE TASK STRUCTURE OF NURSE SCHEDULING

Clancey (1985) distinguished several types of problems by heuristic classification. He made a generic distinction in synthetic tasks and analytic tasks. Planning is an example of a synthetic task whereas diagnosis belongs to the latter. Typical of a synthetic task is that it can be decomposed into different subtasks. This is, actually,
a process of categorizing. Following Clancey (1985) ‘The categorization is not based on purely essential features, but rather is primarily based on heuristic, non-hierarchical, but direct associations between concepts’ (p. 342). Heuristic classification is a description of how a complex task is solved by the problem solver that is independent of implementation in a computerized system. The different tasks and the relationships among them are represented in the task structure. A first step in the specification of a task structure is to indicate activities related to the domain entities discussed in chapter 4. The connection of a domain entity and an activity refers to a task within the nurse scheduling domain. These tasks can be clustered into groups which refer to more generic tasks at an aggregate level. It results in the following tasks. The task making a schedule for the ward resembles the goal of the nurse scheduling task in general. While the tasks determine the wishes for the planning period, determine the historical data, process the personal data and determine the fixed data for the planning period refer to administrative activities. This cluster is denoted as the aggregate task administration. The aggregate task problem solving is abstracted from the activities schedule personnel, schedule shifts, schedule planning period. The activity counting is part of the scheduling task as well as being performed within the problem solving and in the evaluation. Lastly, the activities which check the constraints and weigh the schedule goals refer to the evaluation of the schedule regarded as the aggregate task evaluation. The three tasks in relation to their subtasks are depicted in figure 5.1 and discussed next.

The aggregate task administration aims at the updating of information about personnel available on a ward, before starting with problem solving. The scheduler decides which data are relevant to the new schedule, where to obtain the relevant data and where these data need to be put in the schedule. Some data are put in a cell of the schedule, for instance the wish of a staff member or the courses of student nurses, while other data are placed on a separate piece of paper. The administrative task is a straightforward activity but time-consuming. For instance, the history of an individual staff member for the scheduled shifts is easy to compute but when it needs to be done for thirty staff members then it will take a lot of time. The administration is actually the preparation for the problem solving. The task administration results in a temporarily fractional schedule that is the starting point for the task problem solving.

In the problem solving decisions need to be taken on the assignment of staff members to shifts in the planning period, whereby the different constraints
are taken into account, along with attempting to achieve the schedule goals. The three distinguished tasks related to problem solving are not feasible as such, in contrast with the task administration which can be executed right away on the basis of their division. These tasks are further refined on the basis of the values of the dimensions. The refinement is depicted in figure 5.2.

A characteristic feature of these distinctive tasks is that they cover a specific part of the framework of the schedule instead of the framework wholly, that is to say, that such a smaller specific part of the schedule is lifted out and selected to be scheduled separately. The focus is on the selected part. The scheduling of one of the personnel types extends in the horizontal direction, while the scheduling of a part of the planning period extends in the vertical direction. For instance, executing the subtask schedule trainees means that one specific type of personnel that is placed as a group on the schedule is chosen to be scheduled. On the other hand, scheduling one of the shifts does not cover such a compact part of the schedule framework. Often, scheduling one of the shifts is therefore combined with a specific part of the planning period. The task decomposition required within the problem solving results thus in feasible, well-structured tasks that make dealing with the complexity of the task possible. For problem solving this means that the problem space is more restricted and easier to deal with and consequently, the number of possible solutions decreases, so that less searching
is needed to achieve the final solution. For instance, when scheduling the student nurses only, all solution paths with registered nurses can be excluded. The execution of these tasks results in a complete schedule for personnel on a ward. However, some of these subtasks may overlap in the part of the schedule they cover, which means that it is not necessary to perform every task in order to complete the whole schedule. The easiest subtask will be that task which covers the smallest part of the schedule, and that is, scheduling the staff members one by one, since this task reveals the smallest problem space. Days off, short time and special leave are credited as time worked although these are off-duty shifts. Scheduling these shifts is summarized in the task schedule the off-duty shifts.

The smaller tasks related to the problem-solving part of the nurse scheduling task are executed according to the same scheduling procedure; moreover, the execution of the scheduling procedure is the scheduling itself. The scheduling procedure contains the following activities or tasks: select personnel, rank selected personnel, assign a shift and build a pattern around the shift. Thus, the assignment of personnel to a shift happens within the scheduling procedure. The aim of the activity select personnel is to sort out from the whole set of personnel a subset of personnel who are in principle available for that specific part of the schedule. Herewith disallowable solutions are excluded. Next, a decision has to be made about
who is preferred for a shift assignment. This is done by the activity rank selected personnel, in which a hierarchic structure is imposed on the availability set. The activity assign shift chooses the ‘best’ person, who is then assigned to a shift. Lastly, a schedule pattern tuned to the assigned shift is constructed around the assigned shifts of an employee. Finally, these four activities result in a scheduled part of the schedule. Within these four scheduling activities it is often necessary to count the number of staff of a specific shift as well as the number of scheduled shifts of a particular staff member required in order to be in line with the labour percentage. Suppose that an average ward contains about twenty employees which need to be checked. It can be expected that counting consumes much time and moreover, mistakes can be easily caused by miscounting. The scheduling procedure is depicted in figure 5.3.

Figure 5.3 THE TASKS OF THE SCHEDULING PROCEDURE

However, it is difficult to keep a general overview of the schedule when all tasks are executed separately. Therefore the aggregate task evaluation is an important task in the making of a schedule. The evaluation of the schedule is more a diagnostic task which searches for less desirable solutions which need to be improved. The scheduler examines the schedule by weighing the several nurse scheduling goals and checking on the constraints. It is therefore diagnostic because the schedule is checked on less desirable solutions or on violating the constraints which the scheduler attempts to adapt to more acceptable solutions. Also, counting is performed in order to check the quantity of staffing as well as the number of shifts assigned to a staff
member for the whole schedule. After the performance of the task *evaluation* the scheduler will reschedule a part of the schedule, if necessary, by backtracking. The task *evaluation* is depicted in figure 5.4.

In conclusion, the three aggregate tasks reveal a mutual dependency. The results from the first task handled are necessary to perform the next one. The function of the aggregate task *administration* is the preparation of data needed to be processed in the task *problem solving* that is in fact the core of the planning problem. Feedback on the outcome of this task is the main function of the task *evaluation*. The three generic tasks are depicted in figure 5.5.

The subtasks related to the aggregate tasks are depicted in the task structure in figure 5.6. The task structure reveals that a planning task consists, most importantly, of designing tasks and activities in order to solve this complex task. The scheduler proceeds through the task structure by choosing tasks to be executed. Passing through the task structure depends on problem-solving processes, namely, the task decomposition and the task arrangement, as performed by the scheduler. Moreover, the sequence of tasks is indeterminate and not all tasks need to be performed to achieve a complete schedule. In the next two paragraphs the task decomposition and the arrangement of tasks by expert and novices schedulers as revealed in their thinking aloud protocols, is reported.
5.3 COMPARISON OF THE TASK DECOMPOSITION BETWEEN EXPERTS AND NOVICES

The protocols were traced to identify the tasks resulting from the task decomposition by expert and novice schedulers when making a schedule. Tables 5.1 to 5.3 depict the results concerning the decomposition of the tasks administration, problem solving and evaluation by the experts and the two novice groups.

All the experts performed the four tasks belonging to administration, and the novices also revealed a comparable task decomposition, with the exception of the task determine the historical data. Half of each novice group did not perform this task, while the other half of the novices noticed the relevance of this task in nurse scheduling. The determination of historical data appears to be less recognizable in the nurse scheduling task in comparison with the other three tasks belonging to the administration part of nurse scheduling. Personal data, wishes and established data are easily recognized as being relevant in the nurse scheduling task because these data are coupled with the personnel. Because of the considerable similarities between experts and novice schedulers in the task decomposition of the administration tasks, it is concluded that this will not cause difficulties in the performance of the nurse scheduling task.

The heart of the overall nurse scheduling task is the problem solving task. The task decomposition as regards this task reveals a less homogeneous picture. The results are depicted in table 5.2.
Chapter 5

1 making a schedule
2 administration
3 problem solving
4 evaluation

2.1 process personal data
2.2 determine fixed data
2.3 determine historical data
2.4 determine wishes

3.1 schedule a shift
3.2 schedule personnel
3.3 schedule the planning period
3.1.1 schedule the day shift
3.1.2 schedule the night shift
3.1.3 schedule the evening shift
3.1.4 schedule the off-duty shift
3.2.1 schedule the head nurse and assistant head nurse
3.2.2 schedule the deputizing
3.2.3 schedule the trainees
3.2.4 schedule the responsible qualified nurse
3.2.5 schedule the part-timers
3.2.6 schedule one staff member
3.3.1 schedule a weekend
3.3.2 schedule a week
3.3.3 schedule a day

5 select personnel
6 rank selected personnel
7 assign a shift
8 build a schedule pattern

Figure 5.6 TASK STRUCTURE OF THE NURSE SCHEDULING TASK
All the experts consent to the four tasks belonging to the task *schedule a shift*. However, more variety in task decomposition among experts is shown for the task *schedule personnel* and the task *schedule a planning period*: for instance, not every expert prefers to schedule trainees separately. Thus, together with a resemblance among experts in task decomposition, expert schedulers also develop their personal preference for decomposing a task. The two novice groups reveal comparable results in their task decomposition. They agree in the task decomposition of the task *schedule a shift* and partially in the decomposition of the two other tasks. The differences between the two novice groups are rather small.

A comparison between the expert and novice schedulers for the task decomposition revealed the following results. According to the Kruskal-Wallis test statistic, there is no significant difference among the three groups, Chi-square = 2.26, n.s., for the task *schedule a shift*. This implies that the experts and novices reveal the same task decomposition. There was no significant difference found among the three groups, neither for the decomposition of the task *schedule personnel*, Chi-square = 3.04, n.s., nor for the task *schedule the planning period*, Chi-square = 2.43, n.s. Obviously, the differences between the experts, the novices-p and the novices-np are not very overwhelming in their task decomposition, although a closer inspection of the task decomposition reveals that novices decompose the tasks *schedule personnel* and *schedule the planning period* into smaller tasks in comparison with experts, as illustrated by the tasks *schedule one staff member* and *schedule one day*. This task decomposition is only performed by the novices and not by the experts. What these two tasks have in common, is that they comprise the smallest separate part on the dimension personnel and planning period of the schedule, which are the easiest tasks to

<table>
<thead>
<tr>
<th></th>
<th>experts (n=6)</th>
<th>novices-p (n=6)</th>
<th>novices-np (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>process personal data</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>determine fixed data</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>determine historical data</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>determine wishes for planning period</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
These results reveal that problem solvers decompose a task into smaller tasks until he/she is able to manage the task. Comparable results are found by Jeffries et al (1981) who investigated a design task by letting novices and experts design a computer program. Apparently, novices are less competent than experts, who are able to manage more complex tasks than novices. This difference between experts and novices reveals that cues from the perceivable dimensions of a schedule appear to

<table>
<thead>
<tr>
<th>schedule</th>
<th>experts (n=6)</th>
<th>novices-p (n=6)</th>
<th>novices-np (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a night shift</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>an evening shift</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>a day shift</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>off-duty shifts</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>head nurse and assistant head nurse</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>the deputizing</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>the responsible qualified nurse</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>trainees</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>the part-timers</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>one staff member</td>
<td>-</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>a weekend</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>a week</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>one day</td>
<td>-</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5.2 THE DECOMPOSITION OF THE PROBLEM SOLVING PERFORMED BY EXPERTS AND NOVICES
govern the task decomposition for the novices (Forbus & Gentner, 1986). Novices addressed more the layout of the empty framework of the schedule, while the experts had acquired task knowledge on a more abstract level, which can be seen in that they are able to schedule bigger parts of the schedule. Their knowledge is packed more in so-called chunks. A chunk is any stimulus that has become familiar, hence recognizable, through experience (Schank & Abelson, 1977). Despite the great resemblance between the experts and the novices in their task decomposition, the organization of the novice's task knowledge has not achieved that of the experts.

The decomposition of the task evaluation by the schedulers is depicted in table 5.3

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Experts (n=6)</th>
<th>Novices+p (n=6)</th>
<th>Novices+np (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counting the working days and days off</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Counting the quantitative staffing of each shift</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Weigh the goals</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Check the constraints</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The experts and the two novice groups hardly differ in the decomposition of the task evaluation of the schedule. The experts and the novices both perform the two types of counting tasks, whereas it is more difficult to recognize the evaluation of the achievement of goals and of satisfying the constraints as distinctive tasks in the task performance of the schedulers. The experts perform these two evaluation task by inspecting the schedule generally during scheduling. Often the evaluation by means of counting is performed during the problem-solving task as well. Counting the shifts and days off, or counting the quantitative staffing of a shift, in particularly the day shift, is regarded a control mechanism on the results of the problem solving. The conclusion of these results is that all experts and novice schedulers reveal a comparable decomposition of the nurse scheduling task into the task administration, the task problem solving and the task evaluation. The task decomposition into administration, problem solving and evaluation is derived from the input/output data.
relation among these tasks. The output of the administration is further processed in the task problem solving and the input for the evaluation is the result of the task problem solving.

The task decomposition of the problem-solving part as seen in the experts and novices reveal a number of tasks in which the experts and novices agree: schedule a night shift, schedule an evening shift, schedule a day shift, schedule the off-duty shifts and schedule the head nurse and deputy. The task problem solving was thus primarily performed by executing the subtasks from the task schedule a shift. The common task decomposition among experts and novices is considered the invariance of the task performance in nurse scheduling. The utility of recognizing invariance in the task performance is pointed out by Simon (1990, p. 2) who stated: ‘Psychology does not much resemble classical mechanics, nor should it aim to do so. Its laws are, and will be, limited in range and generality and will be mainly qualitative. Its invariants are and will be of the kinds that are appropriate to adaptive systems. Its success must be measured not by how closely it resembles physics but by how well it describes and explains human behaviour’. Moreover, the invariance of scheduling behaviour therefore needs to be processed in designing decision support because it may be displayed and recognized by other schedulers as well.

The task decomposition reveals some differences among experts and novices as well. Some tasks are only performed by either an expert or a novice. Such a difference between experts and novices refers to the role of knowledge and skills in the task decomposition. Experts decompose the task personnel into schedule the deputy and even some of the experts prefer to schedule the trainees, the responsible qualified nurse and the part-timers separately. Such tasks are more related to an expert level while the tasks schedule one day and schedule one staff member are salient at the novice level since these tasks were only performed by novice schedulers. That novices acquired less knowledge and fewer skills also makes it clear that their task decomposition is based on cues from the nurse scheduling task, particularly the schedule itself. It is concluded from the results that within the task decomposition an expert and novice level are indicated, along with an invariant part of the task decomposition.

5.4 THE ARRANGEMENT OF THE DIFFERENT TASKS

In the present paragraph the task performance of the scheduler is held up against the empirical task structure with respect to the sequence of tasks performed, that is, the arrangement of tasks. Schedulers may differ in their opinion of the
successively performed tasks and thus in their scheduling strategy. Such an arrangement of different subtasks of the nurse scheduling task is discussed for the experts and the two novice groups.

All subjects agree on the sequence administration first, problem solving next and evaluation last. The arrangement of tasks related to each aggregate task is discussed in the following section.

5.4.1 The task administration in experts and novices

The protocol analysis revealed that the experts and the novice-p group started with the aggregate task *administration* and they executed all the relevant tasks before another task was selected. Thus, they first refine and perform the administrative task. This is depicted in table 5.4.

<table>
<thead>
<tr>
<th></th>
<th>experts (n=6)</th>
<th>novices-p (n=6)</th>
<th>novices-np (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>gathered</td>
<td>6</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>dispersed</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
</tbody>
</table>

On the other hand, the novice-np group executed the administrative tasks more dispersedly. They performed these tasks, when they realized that the data provided by one of the administrational tasks, are needed for making a schedule. The dispersed performance of the tasks was due to their lack of strategic knowledge into conceiving that it would be beneficial to know the administrative data ahead of time. The planning behaviour of the novices-np indicates opportunistic planning. Hayes-Roth and Hayes-Roth (1979) investigated planning by subjects having to plan a day's errands. They pointed out: ‘We assume that peoples's planning activity is largely *opportunistic*. That is at each point in the process, the planner's current decisions and observations suggest various opportunities for plan development. The planner's subsequent decisions follow up on selected opportunities’ (p. 276). The novices-np follow a bottom-up strategy which means that their problem-solving processes are directed by the presentation of the schedule currently available. The bottom-up way
of planning is a significant aspect of opportunistic planning, although, problems with scheduling may arise further on. Then the scheduler has to backtrack, which involves replanning from the point that failed (Cohen & Feigenbaum, 1982, p. 520). It will take extra cognitive effort by the scheduler.

5.4.2 The task problem solving in experts and novices

The task schedule a shift

To investigate the strategic aspects of the task schedule a shift a quantitative analysis was performed with the following variables. The order in which the different day, evening and night shifts were handled is denoted as the sequence of tasks. The total number of alterations among the different tasks is denoted as the number of tasks. First the results with respect to the task schedule a shift are discussed. In table 5.5 the results concerning the sequence of tasks are depicted.

As can be seen in this table the expert group as well as the novice-p group started with the task schedule a night shift. Experts argued their choice to schedule the night shift first based on the tightness of the night shift, namely the strict constraints of the night shift and the fact that a night shift covers seven days sequentially and two days off, which should coincide with a weekend. They explained that these two things are hard to satisfy when the evening and day shift have already been scheduled. Moreover, it is easier to change a scheduled evening or day shift than a night shift. In problem-solving terms, the night shift has a quite strict number of allowable solutions in comparison with the evening and day shift. A solution path will sooner be found when the problem space is not curtailed by already scheduled shifts. Although it was elucidated from the investigations into the domain knowledge of nurse schedulers that schedulers considered the day shift as the most important shift to schedule because most of the workload of patient care is focused in the daytime and therefore the scheduler prefers the qualitative staffing in a day shift to be above the minimal norm, the achievement of the staffing in a shift is more difficult for the shift which is scheduled last. Thus, there seems to be a discrepancy between the preference and the planning abilities of the scheduler.
The novice-p group defend their choice by stating that they experience the night shift as an unpleasant shift for personnel. The novice-np group is in this sense unbiased since they have still not worked in the hospital. They chose a shift at random just to start with. They were not able to state the reasons for their opportunistic choice.

The question still remains whether the three groups really made a strategic choice based on their first task to schedule. This was further investigated by looking at the sequence in which the night, evening and day shifts were handled. All subjects in the expert group as well as the novice-p group used the same strict sequence in shifts, namely night, evening and day shift. It seems that the novices-p really did acquire strategic knowledge. Two illustrations of expert protocols with respect to the arrangement of tasks within their scheduling strategy are given below.

**Example protocol of an expert: illustration of transformations between tasks in his/her strategy.**

All the wishes are filled in. Now I'm going to see who worked the night shift... (scheduled the night shift). I've finished planning the night shifts. Now, just the late starts and week-ends off. (pattern around the night shift). Now I'm going to plan the evening shifts in the same way.

**Example protocol of an expert:**

I move on to the second week. First the weekend... I have two evening

<table>
<thead>
<tr>
<th></th>
<th>experts (n=6)</th>
<th>novices-p (n=6)</th>
<th>novices-np (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>no fixed sequence</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>day → evening → night</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>day → night → evening</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>evening → day → night</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>evening → night → day</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>night → day → evening</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>night → evening → day</td>
<td>6</td>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>
shifts completed. The rest are day shifts. Who all do I have? ... So, that's it for this week. Next week. Let's just see again how we're doing with the evening shifts...

In these protocols the consequent reasoning of the experts is revealed in their task performance in finishing a task and choosing the next task.

The novice-np group reveals no such strict sequence in scheduling shifts. They perform the task scheduling a shift in an opportunistic way since no sequence can be abstracted from their protocols. The differences between the two novice groups are striking because they only differ in the amount of practical experience working in hospitals. None of them had ever made a schedule.

<table>
<thead>
<tr>
<th>Table 5.6 THE MEAN NUMBER OF-shifts SCHEDULED SEPARATELY</th>
</tr>
</thead>
<tbody>
<tr>
<td>experts (n=6)</td>
</tr>
<tr>
<td>mean number of shifts</td>
</tr>
</tbody>
</table>

The acquisition of strategic knowledge would not only lead to a strict sequence in scheduling shifts but also, as is expected, to a restricted, compact number of performed tasks. An experienced scheduler will finish the scheduling of the night shift before performing a new task, although, within the general scheduling strategy tasks can be repeated iteratively, for instance, scheduling the day shift per week. The total number of separately scheduled shifts are counted and this number is called the size of the scheduling strategy. This is depicted in table 5.6.

From table 5.6 it is concluded that novices reveal a less compact manner of scheduling compared with the experts. Novices do more repetitions in scheduling the same shift. Surprisingly, the novice-p group did not achieve as much as the experts. Despite the strict sequence by the novices-p, they were not able to keep their strategy under control. This may be due to the fact that they failed to keep their attention fixed on scheduling one shift before skipping to the next. For the novices-np it was even more difficult. Lesgold et al. (1988) discussed a comparable result for novices in their research as well. In this respect the cognitive demand is rather burdensome, which is reflected in the novice's scheduling strategy, which reveals disorderly, i.e. opportunistic, repetitions in scheduling the day evening, and night shifts. An example of such a sequence of shifts is given in figure 5.7.
On the basis of a systematic strategy it was expected that the scheduler would schedule the evening shifts either in sequence for four weeks or per week. The novice skipped to the day shift during the scheduling of the evening shift and skipped back to the evening shift. In addition, the novice scheduler thought aloud in the protocol to schedule the day shift and decided further on that the day shift had to be scheduled for four weeks but changed some things for a person and began again with the day shift. The scheduler who was scheduling the day shift took the opportunity to schedule one staff member and then started again with the task schedule a day shift. Again, this illustrates that the task performance of the novices can be regarded as opportunistic planning.

It is concluded from the discussed results that the arrangement of tasks by novices is directed for the most part by the nature of opportunistic planning, while the experts perform the arrangement of tasks within the task scheduling a shift straightforwardly. They performed, in order, the tasks night, evening and day shifts. The task performance of the experts is explained by script-based planning. A so-called planning script underlies their task performance. Schank and Abelson (1977) defined a script as ‘a predetermined, stereotyped sequence of actions that defines a well-known situation’ (p. 41). They explained the concept of a script by the well-
known example of the restaurant script. The acquisition of knowledge will thus be stored in a script. It contains the outlines for solving the nurse scheduling task. An important function of the planning script is thus to provide a background in which the nurse scheduling task is carried out (Schank & Abelson, 1977, p. 49). Consequently, when an experienced scheduler has to make a new schedule, this script will be accessed. Novices have acquired less-developed scripts, which explains the differences between experts and novices in their task performance. Cohen and Feigenbaum (1982) showed that script-based planning is a top-down approach which means that during problem solving the abstracted actions in the script are filled with knowledge from the particular situation. Thus, the expert planning behaviour in the task *scheduling a shift* is called script-based planning while the novice planning behaviour for this task is called opportunistic planning.

**The task schedule personnel**

A well-organized arrangement of the tasks related to the task *schedule personnel* was not found in the scheduling strategies. The expert group perform first the task *schedule the head nurse and the assistant head nurse*, and then the task *schedule the deputizing*. These tasks were mostly performed at the beginning of the scheduling strategy, after the task *administration*, while the other tasks such as *schedule the responsible qualified nurse, schedule the student nurses, schedule the part-timers and schedule one staff member*, are optionally performed. This means that these tasks were either not positioned in a particular place within the scheduling strategy or were not even performed by the expert scheduler. These so-called optional tasks are considered a further refinement preferred by an individual scheduler in order to handle the complex scheduling task. In this sense it is referred to as the variant part of the task structure. In other words, these tasks can be positioned anywhere among the other tasks belonging to the invariant task structure. For instance, one expert scheduled the part-timers last to complete the schedule. More or less, she used the variable working days of part-timers to fill up the empty places in the schedule. Thus, there was no overall strategy in arranging the optional tasks by the experts. The results are depicted in figure 5.8
The novices did perform the task *schedule the head nurse and the assistant head nurse* but they did not do it in a systematic way within their scheduling strategy, and they hardly ever performed the other tasks. The novices focused for the most part on the task *schedule one staff member* within their scheduling strategy. An example is given in the following protocol:

I'll put Isabel in the evening shift. No, I won't do that, I'll put a student in the evening shift. She's on evening duty and then Isabel a late start. And Juul gets a day off. This remains early day shift, and that too. Floor has a late start and Sonja has a late start, Isabel a day off, Juul has early day shift. Hillie a day off. Boukje from early day shift to... Door, what percentage does she work again? 50%. Door is also off-duty. Floor goes to the night shift, no to the evening shift. So! Hillie gets an early day shift or no, she [gets] the... And that stays the same, and this becomes off-duty. Renske again in the evening shift and this also remains evening shift. Anna has ADV and Boukje? Day shift? Christa and Floor, Door... this stays the same. Isabel stays in early day shift. Juul gets night duty. Renske stays in the evening shift. Then Saturday-Sunday. Sonja: two day shifts. Now, who's on night duty? Juul stays on night duty on the weekend. Then Floor again on evening duty. Then I have enough for the early day shift and evening shift and night shift. And the rest are off-duty. And the Sunday I do exactly the
same schedule.

This novice reveals a consistent way of planning: each person to whom shifts were assigned is directly based on a previous day. Hereby the focus is on the visible parts of the schedule. The novices have more difficulty executing a scheduling strategy thoroughly than the experts.

The task schedule the planning period

The arrangement of the tasks related to the planning period is investigated per scheduler since the decomposition of the task schedule the planning period as depicted in figure 5.2 revealed too many differences among the schedulers in the expert group. Each individual scheduler performed a specific arrangement consistently; for instance, a scheduler consistently schedules the Monday to Friday periods after completing the weekends. To give a second example, an evening shift is first scheduled only for the weekends for the whole planning period and then the rest will be scheduled. The several possibilities of the arrangement in task structure concerning the dimension planning period are depicted in figure 5.9.

Often, a part of the planning period was tuned to the dimension shift depending on the preference of the scheduler; for instance, the night shift was always scheduled for four weeks or the days off were coupled with the weekends.

The novices did not acquire any systematism in handling the planning period. Often, they schedule per day, starting with the first day and working through the last day of the planning period. An example of scheduling per day is given in the following protocol:

Schedule per day

Then I have Monday finished! She's off, her too. Tuesday, I start with the day shift. We have 5 of them, 1,2,3,4,5. There also has to be a late day shift. I had her yesterday, so today I'll give her a... Let's see, evening shift, code 5. One, two, so I have that, and two night shifts: one, two. So I have that too, the rest are off... Now Thursday, 1,2,3,4,5. Evening shift, here a 5, there a 5. Night shift, one, two. So, I have that too, so I'm finished fast. Friday...
The cognitive demand of the nurse scheduling task is illustrated in the example. By scheduling per day the novice scheduler is able to control this task, which is not the case for a more complicated task, such as schedule the day shift. The novices started with the more complicated tasks but did not succeed, which is one reason why they plan opportunistically. The performance of scheduling per day also illustrates that the memory load is reduced because the results of the problem solving cover a small part of the schedule, implying that they also have more control over the outcomes.

5.4.3 The task evaluation in experts and novices

The task evaluation is achieved by performing the distinguished tasks *weigh the goals* and *check the constraints* and *the counting* at the end. These tasks are interrelated, since a goal may be checked by counting the shifts. This implies that, on the one hand, weighing the goals may be rather invisible in the protocols, and on the other hand, that the arrangement of the evaluation tasks is not performed in a specific sequence. Note that counting is also done many times within the scheduling itself. The task counting in particular is performed by all experts as part of the
evaluation. The two novice groups did not explicitly perform the task *evaluation* as such at the end. This does not mean that they assumed that their schedule was a feasible one. The task evaluation is an extra control on the results of the scheduling.

In conclusion, the results concerning the arrangement of tasks within the nurse scheduling task agree with the comparable observation in performing a planning task by Hayes-Roth and Hayes-Roth (1979) who state that the arrangement depends on characteristics such as decomposition, individual differences and knowledge and skills.

5.5 CONCLUSION TASK DECOMPOSITION AND TASK ARRANGEMENT

The task performances of the schedulers reveal some common aspects with regard to the decomposition and arrangement of the different tasks. This concerns first, the decomposition of the task *administration* together with the arrangement that these tasks are performed in the beginning of the whole nurse scheduling process. Second, the decomposition of the task *schedule personnel* into *schedule head nurse and assistant head nurse* and the task *schedule the deputy*. These tasks are performed after the administration activities. Third, the task *scheduling a shift* is decomposed and arranged respectively into the night, evening and day shifts. Fourth, the off-duty shifts (day off, short time and so on) will be scheduled and fifth, the task *evaluation* is performed by counting at the end. All six experts revealed a similar way of planning while the novices were only somewhat similar in this regard. This common part indicates therefore the invariant part of the task structure in nurse scheduling. From the results we can tentatively conclude that the novices acquired the invariant task structure first. Therefore, the common aspects of the task performance are abstracted to form one generic scheduling strategy. In figure 5.10 the generic scheduling strategy is depicted.

It can be seen in this figure that the first, second and last step contain more than one task because these tasks were always performed before the following tasks and were therefore considered as one step. However, the order of these tasks showed some variety among the experts. Logically, the other tasks that are left fall under the variant part of the task structure.

The distinguished scheduling strategy in the task performance refer to script-based planning guided by a plan. Schank and Abelson (1977) explain this as follows: ‘Plans are where scripts come from. They compete for the same role in the understanding process, namely as explanations of sequences of actions that are intended to achieve a goal. The difference is that scripts are specific and plans are
general. Both are necessary in any functioning system’ (p. 72). A plan is a representation of the scheduling strategy underlying the task performance, whereas a script is filled with context-specific knowledge like typical things on a ward. When a script is available, it will be chosen; otherwise a plan is chosen. Both guide problem-solving activity in the nurse scheduling task.

Figure 5.10 THE GENERIC NURSE SCHEDULING STRATEGY

The function of a plan is explained by Hoc (1988) who distinguished three main features of a plan: ‘Guidance is heuristic. It can orient activity rapidly in the most promising directions without requiring fine or laborious analysis of the situation’ (p. 116) The heuristic nature of a plan means that the knowledge stored in a plan can be used in new situations and besides that, this knowledge is easily accessible. Second, ‘The guidance provided by planning allows for optimal use of the limited processing capacities of the human cognitive system’ (p. 116). Plans serve to reduce the cognitive load by storing knowledge in meaningful patterns and anticipating the required processing of a task by structuring it. Third, ‘Guidance raises the control level of activity’ (p. 116). A plan strictly guides the sequence of tasks performed.

Task decomposition and task arrangement are thus important problem-solving
processes in dealing with the complex planning task. However, the aim of the nurse scheduling task, assigning personnel to the schedule, has still not been attained. The task decomposition and the task arrangement form a preparation for the actual scheduling of personnel since this results in manageable tasks. The execution of such a task forms the real scheduling activity as was briefly reported when the aggregate task problem solving was discussed. It is further discussed in the following paragraph.

5.6 THE SCHEDULING ACTIVITIES

Scheduling is the problem-solving process in which the assignment of personnel to shifts takes place on the schedule. It consists of the following activities: select personnel, rank selected personnel, assign a shift and build a pattern around the shift. The activities are executed by applying inferences on domain knowledge (see KADS). The attention is focused on a specific part of the schedule for each activity. Within the selection and the ranking of selected personnel the focus is on the vertical dimension of the schedule. Whereas within the assignment of a shift and building a pattern around the assigned shift the focus is on the horizontal dimension of the schedule.

The activity select personnel aims at sorting out those staff members from the whole set of personnel who can be in principle available for that specific shift under consideration --since they could not be available for several reasons: a labour agreement would be violated, a student nurse has a course or a nurse has a vacation, because of a person's labour contract, and so on. The result is a subset containing those staff members who can be scheduled. Herewith the impossible solutions are excluded. Thus, by selecting staff members systematically a scheduler prevents difficulties in generating solutions later. The selection of personnel takes place by applying inference rules. These inferences are represented as production rules. A production rule contains two parts, namely: ‘if ... and then ...’. The first part after IF describes relations among domain entities. After THEN an action is performed. This approach to solving the task is characterized by ‘narrowing the set of possibilities’ rather than ‘searching through the set of possibilities’ (Greeno & Simon, 1988, p. 627). A few examples of inferences that select personnel are given below.

| Examples of inferences select personnel |
IF a labour agreement is not violated for a staff member
THEN select this staff member

IF a night shift was scheduled more than four weeks ago for a staff member
THEN select this staff member

IF none of the other types of shift has been scheduled for a staff member
THEN select this staff member

IF wish pronounced by a staff member
THEN select this staff member

IF a staff member may not be scheduled for a specific shift on the basis of a labour contract
THEN do not select this staff member

IF established data (course, vacation) belongs to a staff member
THEN do not select this staff member

The processing of these inferences results in new data: the created subset of personnel is considered the availability pool of staff members for a shift. The advantage of an overview of the availability of staff members is that the scheduler knows whether the number of persons in the availability pool are enough to fulfil the quantitative and qualitative staffing. If the size of this pool is too small, the scheduler has then identified a first possible problem which needs to be solved before starting again with a different task from the scheduling task. For instance, it can be solved by either weakening some inferences if this is allowed, or a practical solution is to ask nurses from a different ward to assist or to hire nurses from an employment agency.

In the next step a decision has to be made about whom is preferred for the assignment of a shift. This is done by the activity rank selected personnel which means that a hierarchic structure is imposed on the availability set by applying inferences. The highest staff member in the ranking will get the highest priority to be scheduled. Examples of these kind of inferences are given below.

**Examples of inferences rank selected personnel**

IF wish for a shift pronounced by a staff member
THEN a high position in ranking
IF it was a long time ago that the shift was scheduled for a staff member 
THEN a high position in ranking

IF two or more days off before a shift for a staff member
THEN a high position in ranking

IF both wish and history of a staff member are relevant for a shift
THEN a very high position in ranking

IF wish was pronounced for another shift by a staff member
THEN a low position in ranking

Ranking is a complicated factor of the scheduling task because combinations of staff members needed to fulfil the quantity and quality of staffing also need to be taken into account. The point is that a specific combination may lead to a higher priority in the ranking despite a lower priority of an individual. A scheduler therefore has to weigh several combinations within the problem-solving reasoning. Within the activity ranking selected personnel the achievement of the scheduling goals directs the final solutions. The scheduling goals are transformed into inferences which are part of the reasoning in scheduling a shift. When a scheduler thus acquires poor knowledge of goals, he/she may not perform the ranking activity very much.

In the next step decisions have to be made about the assignment of personnel to a shift whereby the ranking should be taken into account. This is the activity assigning a shift. Within this activity the combination of individual staff members is the leading factor, because the combination of nurses and trainees has to satisfy at least the constraints of quantitative and qualitative staffing of a shift. This implies that some combinations may even be impossible or less desirable according to the scheduler. Finally, those combinations with a high priority are assigned to the shift. A few examples of inferences are given below.

**Examples of inferences assign a shift**

IF a team consists only of trainees in a shift
THEN do not assign a shift to this team

IF a team contains a number of persons which is less then the required minimal quantity
THEN do not assign a shift to this team
The execution of the activity *assign a shift* results in an overview of assigned shifts for a staff member. Assigning implies that the focus is on comparisons among personnel, which differs from the last part to be performed namely, constructing a scheduling pattern for each individual staff member. Hereby the scheduler focuses horizontally on just one nurse. Thus, after assigning a shift to a nurse or trainee, a schedule pattern around the shift will be constructed. This is indicated as the activity *build a pattern*. Examples are given below.

### examples of inferences *build a pattern*

<table>
<thead>
<tr>
<th>IF</th>
<th>THEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>a shift has been assigned to a staff member</td>
<td>build a pattern around that shift consisting of a block size of two or more for that shift</td>
</tr>
<tr>
<td>a night shift and weekend off is scheduled for a staff member</td>
<td>build a pattern consisting of a day shift as the next shift</td>
</tr>
<tr>
<td>a sequence is a day shift followed by a day off for a staff member</td>
<td>build a pattern consisting of an evening shift as the next shift</td>
</tr>
<tr>
<td>a course is scheduled for a staff member</td>
<td>do not build a pattern of an evening shift as the next shift</td>
</tr>
<tr>
<td>a weekend has been scheduled for a staff member</td>
<td>build a pattern of same shifts on Saturday and Sunday</td>
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</tbody>
</table>

The result is *a scheduled pattern for a staff member* and herewith has the scheduling itself attained the end state. The examples of inferences underlying the four subtasks are not meant to be exhaustive but are given as an illustration of knowledge at the inference layer.
In the performance of the different activities the role of domain knowledge is very important. Along with that, counting is also significant in checking the quantity of staffing for a shift. The four activities all together form the inference structure of scheduling that is depicted in figure 5.11.

The sequence in performing respectively selection, ranking, assignment and construction is more or less settled. The execution of them transforms the initial state of making a schedule into several problem states and finally, into the goal state: the nurse schedule. The number of possible solutions is decreased by following this line of reasoning because it operates further on data as the result of a previous action. Each new solution can easily be checked as to whether it is a better solution.
Actually, the scheduler starts with an enormous amount of possibilities and is narrowing his/her view by excluding solutions and focusing on the final solutions. Illustrations of scheduling by experts and novices are presented in the following paragraphs.

**Examples of how the empirical data is categorized**

The first protocol reveals the problem-solving processes underlying the scheduling of a night shift while the second example reveals the scheduling of the evening shift. The different scheduling activities are denoted.

**Protocol of an expert: scheduling the night shift**

*select*

*wish*  
In week 10 there's nobody who wants to take the night shift. Here I had three people who wanted to do the night shift.

*wish*  
The problem with her is that she wants to have that weekend off.

*fixed data*  
And she has requested vacation then, so she can't be on night duty.

*remarks*  
What I would like is for these two to stay in week 11. For week 10, I have one already. It's a matter of choosing. I'll just pick one. I'll just mark it yellow.

*quality*  
That's an experienced nurse with a student. That's all right.

*remarks*  
Two night shifts for her that week. I'll put her on night shift and just try it since otherwise you could just keep on planning. I'm curious as to what kinds of problems might come up later.

*fixed data*  
That student can't go on night duty, because she has to go to a course.

*rank*

*wish*  
You're able to give the people a weekend, but sometimes you can't do anything else. I'll try to find a possibility. I'll look to see when I was on night shift. Or Sonja and then not grant the weekend.

*history*  
I look to see how long in the past she has done a night shift. Sonja hasn't had any night shifts.

*quality*  
She can work with Mies, because she's experienced.
I also look at how many weekends off she's had. I do want to take that into account. She has had 8 weekends off, so she should be able to work two weekends in a row and I won't give her the weekend of the 10-11.

She's going on night shift. The weekend after that she has off and she's going on a course and can't go on night duty.

I have three weeks for night duty scheduled. That one's already on it. This one's coming off, because I already have two.

She has worked relatively many night shifts and only works 50% and has already asked for a lot of shifts, it's E. so I'll take her off and then I'll schedule the other ones definitively. So Klaske and Lydia.

It's a bit of a shame to put two experienced people in the night shift. I could also put a student on the night shift. Then I'll move that night shift one week back. You also have to make sure you have properly qualified personnel left over.

I look to see when Klaske and Lydia did the night shift. Lydia in week 5 and Klaske in week 8. So it's Lydia's turn first and then Klaske.

I'm scheduling Paula for a late shift, she hasn't requested anything and can do them four in a row. So can I.

I'm not scheduling anything definitively yet, because something could come up.

After a night shift, I assign Gerrie an evening shift.
wish on Wednesday through Friday, she didn't ask for anything.

select

Hillie has the weekend off, Klaske also has the weekend off and I'm here for evening shifts too.

weekend off

assign quantity

Wednesday, I have two of them. Just Thursday and Friday, I'm giving those to Lydia,

work/day off

her birthday is Saturday. She works 80% and has a bit more time off.

The sequence of the four activities is recognizable in both protocols of the experts. Selecting more than one staff member is a condition for ranking them. If no selection of a person took place then only the activities assign and build are relevant. The reasoning processes for the activity select and rank are more complex inferences. In these reasoning processes the expert makes remarks which refer to goals in the nurse scheduling domain. The expert anticipates what will further happen during scheduling. Experts’ reasoning is more extensive and more elaborate than that of the novices (Lesgold et al., 1988, p. 317), as can be seen in the novices’ protocols below, the novices’ reasoning is less extensive and more fragmented.

When a novice focuses on one person, then the activities select and rank are skipped and the emphasis is on the activities assign and build. The activity build spreads out over more than one week, sometimes the whole planning period. This is in accordance with the fact that novices schedule around the observable schedule. Novices may forget some aspects of the domain: they forget to schedule the head nurse and deputy, they have problems taking all such aspects into account simultaneously, which means that their domain knowledge is less organized compared to that of experts. A poor performance is due to their lack of attention to constraints in the domain (Greeno & Simon, 1988). Novices lack the greater formulations that characterize the expert scheduler with specialized scheduling knowledge. This is illustrated by the following protocols from novices.
Examples of inferences by novices derived from their protocols.

Protocol of a novice-p

**select**

*personal data* Floor works 100% and the other one 50%.

*wish* Isabel would like a couple of evening shifts.

**build**

*pattern* If she gets a lot of evening shifts she's off the rest of the week. Door 4 evening. First week.

*quantity* I just have the problem that 3 get evening shift on March 15.

*pattern* 60% who get(s) another day off. Thursday evening and then off.

*pattern of one person* I take Door 5 evening in 2 weeks. The weekend of March 3-4 she gets late duty. I wanted her to work the weekend and then she has the whole week off and the 4 days working and then 4 again. I have her here Thursday, Friday, weekend and Monday, 5 days working. She still has the rest of the week off. And she works two weekends and is already off two weekends.

**select**

*counting* Evelien works 50%, 10 days, counting.

*pattern* Vacation days and off duty. Floor three evening. Gerrie comes off duty. Renske should here also. Isabel. Hillie first works only 50%. Has regulated 8 days' work then she has to do two more. She also has two weekends off.

**assign**

*counting* Juul works 9 days so she can go off, counting.

*evening shift* Isabel evening on the weekend, Floor an evening. 5 evening shifts seems like a lot to me. Is that normal? So that's all the late ones.
### Protocol of a novice-p

**assign**
- **wish**: Continue with Hillie, she hasn't asked for any night duty.

**history**
- Worked most recently up to February 8. She could work again March 8, if necessary. Hillie, she can't go here. Would she be able to do night duty here this week?

**quality**
- Then too I already have a graduate. Maybe she can go at the end of this, I don't yet have anybody. And there I already have three people in the night shift. I'll start by putting her in for the last week.

**history**
- Isabel that's a graduate, latest night shift on February 8, so she can't go in again until March 8. Then she has one week vacation... Now I'll just see what percentage she works.

**fixed data**
- Now I've still got the night shift, I'm not really happy with it. If I can find a solution for that, since I still have to give short time days. No, I really think I have no other... I just don't know how I always get this...

**build**
- **pattern**: She has to have three days off, one way or another. Since you come out Thursday, so you should have Friday, Saturday, Sunday free no matter what after the night shift. So I'm going to work on those short time days.

**remarks**
- I'll just continue now with the evening shifts.

**quantity**
- I have two here for every day. I have two here.

**assign**
- **quality**: Now on to Saturday, Sunday. What if I put a student in there? Renske, she's dependent, but she is very experienced, so that could work. I've got to put Renske here in the evening shift,

**build**
- **patterns**: then she's worked 1,2,3,4,5,6,7 days. I'll give her two evening shifts, that would work. Let's see. Monday, Tuesday nobody's

**select**
- **wish**: asked for anything, I can just schedule it myself.
She didn't work..., she did the night shift, she just had the evening shift.

She has vacation. Floor already has a lot of evening shifts,

Gerrie still doesn't have any evening duty, works 100%, so I can schedule her in. There she's also on vacation, so I can give her an evening shift here. Gerrie is also experienced, she's not very experienced, so Isabel..., then I could give her here 2,3 evening shifts.

Let's see if I get the day shifts to turn out. You have to take so many things into account. I think this week is all done. It's terrible, you really should take a course for it. Christa, she still has days left open, so I wanted to give her a day shift, because she's matched with Sonja and that's a first-year student.

But there are so many day shifts that day, so I'm giving her it off.

The novices will continually check by counting the number of employees whether the quantitative staffing requirement has been complied with. Ranking was not much performed by novices. They concentrate on the building patterns. They possess a less developed procedure in executing the activities of the task scheduling, however, the aggregate sequence is consistent with the inference structure. It can be seen in the task performance that novices skip some parts of the scheduling inference structure.
5.7 CONCLUSION AND DISCUSSION

In this chapter the task performances of expert and novice schedulers are compared in making the schedule. The significant part of dealing with the planning task revealed in the task performance, the task decomposition, the task arrangement and the scheduling itself were investigated. The results concerning the task decomposition reveal only marginal differences between the experts and novices. They decompose the nurse scheduling task in a similar way, in particular the administration and the tasks schedule a shift, schedule the head nurse nurse and the deputy. The novices, however, were not able to perform the tasks resulting from the task decomposition successively and so they decomposed them further into smaller manageable tasks. Moreover, differences were found among the experts in the task decomposition of the task personnel.

More differences were found between the experts and the two novice groups for the arrangement of tasks. The novices revealed an opportunistic task arrangement in contrast with the experts who followed a coherent scheduling strategy. They acquired an adequate script for solving the nurse scheduling task. The result that novices did not perform the scheduling strategy systematically is comparable to the result found in the diagnostic strategy of novices investigated by Schaafstal (1991). The common part of the task decomposition was arranged in a similar way by the experts. Naturally variety in task arrangement among experts was seen in the other tasks as well. The explanation for acquiring the scheduling strategy seems to be a problem-solving reason related to the cognitive limitations, though further experimental research is needed to shed more light on this. The finding that in making schedules not only an expert level can be distinguished from the novice level but also that within the expert group variety in task performance can be discerned is interesting for designing decision support. Obviously, there is not just one way of performing the nurse scheduling task.

The execution of the several tasks from the scheduling strategy is actually a scheduling problem. The experts' scheduling procedure consisted of four different activities. In the first two activities they concentrate on the selection and ranking of personnel, then in the last two activities they assign a shift to an individual staff member and finally build a pattern containing more of the same shifts or days off. The novices' scheduling procedure was less thorough, since they may skip one of the four scheduling activities, in particular, the ranking of personnel. Both experts and novices often cite the quantity of staffing of a shift or the number of assigned shifts of a staff member in order to justify their choices. They achieve the aim of the activity by applying inferences to their domain knowledge. The experts revealed more elaborate reasoning than novices by weighing different nurse scheduling goals.
The experts among each other, however, may also differ in the tuning of the goals, though more insight into the hierarchy of goals and the weighing of domain knowledge in the scheduling is needed to clarify the differences among the expert schedulers.

The results discussed in this chapter have implications for designing decision support. When starting the design of decision support from the human perspective, one should rely on the problem solving as revealed by schedulers. Coupled with that, the interesting results regarding the task decomposition and arrangement need to be included in the starting point for the design. The distinction between the invariant and variant parts of the scheduling strategy means that the computerized system should support the different tasks in order to keep the arrangement flexible. Along with that the inference rule underlying the scheduling activities can be easily implemented, which means that less searching is needed to assign personnel to the schedule by the scheduler. Moreover, novice schedulers can also have the expert knowledge at their disposal. By incorporating these aspects into the design, it is then adapted to the scheduler by making the problem less complex, as explained by Timmermans (1991). Decision support aims then at compensating for cognitive limitations.