SCHEDULING OF ACTIVITIES AND RESPONDING TO ALARMS IN THE CONTROL OF A COMPLEX SYSTEM

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ABSTRACT

Decision-making in a complex environment cannot be described by a simple model. Both normative and the descriptive models find it difficult to describe the complicate relations between the processes of the main system, monitoring these processes, and the operator who tries to keep the main processes running in an optimal way. The tools these two different models use to describe the decision-making process can hardly be implemented in real complex environments because of the difficulty in describing the decision process, in drawing decision trees, and calculating the optimal decision that should be taken at each point.

The present study attempts to suggest a new perspective on operators' decision-making processes in complex systems. To describe the main forces that affect the operator's decision-making process I introduce a conceptual model. Focusing on the main factors that affect the decision-making process will assist in the design of new complex systems in the future.

Two research approaches were used to construct the suggested conceptual model. First, I conducted structured observations in the complex environment of the Neonatal Intensive Care Unit (NICU) of the Soroka Medical Center. Secondly, laboratory experiments were conducted of simulated control tasks. The NICU is a dynamic and overloaded working environment, often compared to a war room or a control room in a nuclear power station. The NICU was chosen as a typical environment where operators have to perform prescheduled tasks, while receiving information from alarm systems. Each nurse who operates in this environment is responsible for two to three neonates, whom she has to treat to improve their biophysical condition. The nurse receives information from many different sources including the alarm systems, which are known for their high false alarm rates, and have to perform many different tasks juggling them between the different stations they are responsible for.

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I performed three different types of observations in the NICU working environment, each focused on different aspects of the nurses' work there. The first observation series focused on the nurses' work with a single monitor, and provided detailed information on the different alarm types and the nurses' responses patterns. The second set of observations focused on all three monitors the nurse was responsible for during her working shift, showing the nurses' working patterns with all three monitors simultaneously. These observations were conducted using a program that generates an on-line communication line between the monitor and a PC desktop computer. The PC recorded all the alarms of the neonates' monitors, and combined this information in real time with information on the nurses' concurrent activities as recorded by a non-obtrusive observer. The observer watched the nurses throughout their shift and coded their activities into a recording device. The third set of observations focused on the nurse's entire working environment. For these observations I used a free sampling method in which an observer recorded the nurses' activities at any given moment during the working shift.

The laboratory experiments explored the main claim that complex system operators change their working patterns according to the system's warning validity and predictability. Participants in these experiments were presented with three "working stations" on a PC screen, and were required to maintain positive values in these stations. Their main task was to monitor the "stations" using an alarm system, and to intervene during the process in order to keep the station in positive value. This controlled environment allows testing different conditions, without the "noise" of additional tasks and commitments that interfere with the primary task in the real working milieu.

Findings of the NICU observations showed the high workload of the nurses in that environment. The present study supports previous ones showing that the nurses in the NICU have to perform many tasks simultaneously while the alarm systems generates many alarms most of which have low validity and low informative value. Yet, the nurses do not delay their response to the alarms because of their overload, but rather use them as additional source of information, integrating all the information from the different sources.

The present study is the first to propose a conceptual model to describe the unique working pattern the nurses use to perform their numerous tasks, and the findings support this model. The findings indicate that the nurses do not respond to all alarms, and that they adapt their work to their comprehensive load including the condition of the patients and the severity of the alarms they get.

Findings of the laboratory experiment show that the participants learned to schedule their interventions and initiate their tasks based on these schedules when the alarm system validity was low. In addition participants relied more on the alarm system and tended to respond to it when the changes in the stations they were monitoring were less predictable.

The present study combined the two different research approaches into one model that describes the decision-making process in complex environments. Integrating both aspects I suggest a model which is a coherent description of the operators' working pattern, based on the findings from the two research approaches.

The model describes the operator's decision making as a two-level process: a local and a general. At the local level the operator has to decide what his next action will be, while at the general level he has to choose a working pattern based on the systems' characteristics.

The former level calls the operators to use a Natural Decision Making pattern to dynamically decide their next move. At the general level the operator adopts special working patterns to maintain the complex system intact. The operators' working pattern combines two action patterns: they have to watch out and respond to events that require their immediate intervention while at the same time perform tasks they initiate in a certain frequency. This working pattern is based on the characteristics of the system they are working with which are determined by two main factors - the validity of the warning system and its predictability. These two dimensions can generate four possible working patterns:

1) Versatile – a valid warning system with a predictable rate of change. The operator has a complete spectrum of working patterns to choose from– from relying on the warning system and intervening only as a response to an alarm, to self-initiated actions following his scheduling.

2) Initiating – a low validity warning system with a predictable rate of change. At the self-initiated end the operator relies solely on an internal timing or sequencing mechanism to guides him when performing an action.

3) Responding – a valid warning system with an unpredictable rate of change. At the respondent end of the continuum operators essentially perform a vigilance task looking out for indicators that point at the need to perform an action.

4) Sampling – a low validity alarm system with an unpredictable rate of change. The only working pattern the operators can adopt in this case is to sample the working system. Thus he has to inspect the system from time to time to assess its status and decide if it requires an intervention to maintain it intact.

The operator chooses a working pattern from a continuum spanning from "responding" at its one end to "scheduling" at the other end. He then combines the two forms into one working pattern that involves both responding to alarms and initiating actions. His position on the continuum is affected by the two system dimensions.

The principal finding of this study is that, though operators change their actions dynamically, they work according to an overall structure based on the system characteristics. Another finding shows that the operators in the two research approaches rely on the warning system to some extent, tending to respond to the alarms more when their validity is high, and when the system is less predictable.

The implications of these findings should be considered by designers of complex systems as well as managers of similar working environments. These implications will support the design of a better working environment, which should lead to improve the operators' performance. The alarm system should be designed to fit the operators' ability to respond to all the alarms. Special attention has to be drawn to low predictability systems, and less so to systems with a higher need of interventions. The most important components of the complex system are the operators. Special attention should be awarded to the experience of the operators, since more experienced persons are more effective in working in such complex environment than novices.