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Operator performance and signs of sleepiness during day and night work in a simulated thermal power plant

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Abstract

The objective was to assess operator performance, subjective and objective sleepiness in a simulated thermal power plant under realistic production conditions. Twelve experienced operators participated in two conditions, a night shift (2300–0700 h) and a day shift (0800–1600 h), in a balanced design. The work tasks were constructed to get maximum realism. The simulator logged the state of the processes. This information was used to calculate indicators of operator performance in 2-h blocks: deviation from pre-planned production of heat and electricity, the net profit made, the time to acknowledge warning signals, the time to stop and restart a coal mill and the number of errors made. Subjective sleepiness was rated every 20 min. Electrophysiological (EEG and EOG) signals were recorded continuously. In spite of higher sleepiness during the night shift, as indicated by subjective ratings and to some extent by electrophysiological recordings, operator performance was not negatively affected. In fact, performance tended to be worse during the day. It is concluded that the performance of experienced operators may not deteriorate during night shifts in control room work of the present type, probably due to lower workload during the night, lack of monotony and to the processes being relatively inert and forgiving to minor operator errors.

Relevance to industry

The impact of working time arrangements, especially those including night work, on operator performance in control room environments is of great importance to safety and productivity.

Keywords: Shift work; Sleepiness; Performance; Electroencephalography

1. Introduction

Night work is associated with increased subjective and objective sleepiness, for instance, changes in the electroencephalogram (EEG) indicating drowsiness or light sleep have been observed in train drivers (Torsvall and Åkerstedt, 1987), truck drivers (Kecklund and Åkerstedt, 1993), and control room operators (Torsvall et al., 1989). However, studies describing the actual performance during work are, with a few exceptions, scarce. Bjerner et al. (1955), in an early study, observed that the number of errors in reading gas meters in a gas works was higher during the night compared to the day. Studies of performance in more complex work situations are, however, lacking. At an increasing rate complex, industrial processes are being controlled from

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computerised control rooms. There are few studies comparing performance differences between day and night in control room work. Andorre-Gruet et al. (1998), for example, found lower supervisory activity during the night shift in the control room of a chemical plant. One reason for this relative lack of studies may be the difficulty to obtain reliable measures of performance in real-life settings. However, modern technology has made realistic simulators possible. Within the power industry such simulators are used to train operators in normal production as well as in handling emergency situations. The purpose of the present study was to compare performance, as measured by central production parameters, and sleepiness between day and night work, using professional power plant operators as subjects.

In most realistic shift work situations, the type and intensity of work may differ between day and night, most often with lower intensity during the night. This, in particular, applies to thermal power plants since the demands for electricity and heat are lower during the night. Hence, it was decided to take these day and night shift differences into account in the design of the study in order to maximise the realism.

2. Methods

2.1. Subjects

Twelve control room operators from a thermal power plant in Sweden were recruited as subjects. Twelve (out of 18) was the number of operators that the company could take out of production for participation in the experiment. They were all men, with a mean age of 41 years (range 32–54 years). They were highly experienced and had worked at the power plant for an average of 18 years (range 9–31 years) with a mean experience of control room work of 8 years (range 1–25 years).

2.2. Design

Each of the subjects participated twice, with one night shift (2300–0700 h) and one day shift (0800–1600 h) in a counterbalanced order. The shifts in the simulator replaced a similar shift in the normal shift sequence. The night shift was the first after a sequence of three or four consecutive afternoon shifts. The day shift was the first in a sequence of 7 day shifts after three days off.

2.3. Simulated task

The simulator was a thermal power plant trainer, TPP2000-200 MW-ws (NOR-Control, Norway) which closely simulated the production unit of the thermal power plant in which the subjects normally worked. The main difference was that the simulator was entirely operated from computer displays and keyboards, whereas the actual production unit was operated from a mixture of computer displays and more traditional control desks.

A thermal power plant produces heat for district heating and electricity in amounts that depend on the demand for energy which, in turn, depends on environmental temperature, time of day and the price of electricity. The goal is to produce the optimal amount of heat and electricity—producing more or less has negative economical consequences. Before each shift a production plan of electricity is made. The plan is based on a forecast of the need for electrical energy. The production plan for the morning shift is rising from the start of the shift to high levels during the afternoon. The production during the night is lower than during the day but rises towards the morning. Hence, two scenarios were constructed, which involved typical production plans for both the day and the night shift. These production plans were given to the subjects at the start of the shift. The subjects were instructed to adhere to the production plan as closely as possible. However, since the production plan normally is revised during a shift as a response to changes in the price of electricity this was also simulated. For the day shift, the changes involved an earlier increase in the level of production than what was prescribed in the plan. For the day shift, the production was cut back towards the end of the shift. The subjects were told these changes in production an hour in advance. The simulated environmental temperatures that were added to the two scenarios were typical for