Ergonomic features of control room environments for improved operator comfort and support

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Ergonomic features of control room environments for improved operator comfort and support

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Process control operators need well-designed control room environments to focus better on tasks to be performed. The aim of this study was to evaluate if a high-end control room concept including the latest ergonomic features had any effects on operator comfort and alertness compared to a traditional control room. Twelve professional operators participated by running a paint factory simulation for three hours in each control room. Subjective estimations were given regarding perceived discomfort, stress-energy and emotional state. The results showed significant benefits of a supportive ergonomic control room environment on operator alertness, wellbeing and productivity, but they felt increased pressure to perform well in such a high-technology environment.

Keywords: Process control room, ergonomics, comfort, stress, emotion

1. Introduction

In order to control different industrial production processes in an optimal manner, operators need well-designed control room environments, to consider human machine interaction (Bligard, et al., 2008). A good design has to be based upon knowledge of ergonomics/human factors, meaning that the design should support the operators' needs, abilities and limitations from physical, cognitive and organisational perspectives, in order to optimize human well-being and overall system performance. By providing a good working environment, operators' comfort and performance will most likely increase (ISO 11064).

Recent research (e.g. Vischer, 2007) has focused on the physical environment and its effects on work performance. Research has also shown links between employee health and properties of the physical environment, such as indoor air quality, lighting and ergonomic furniture (e.g. Milton et al., 2000).

Research in ergonomics has shown the importance of variables like lighting, noise and noise control, furniture and spatial layout in offices. McCoy and Evans (2005) have suggested that stress can be triggered when properties of the physical environment interfere with plans and behaviour. A supportive physical environment should make it possible for operators to focus on the task to be performed without being preoccupied with environmental properties that interfere with the plans to be executed. Environmental comfort may, according to Vischer (1995), be a function of three hierarchically related categories: physical, functional and psychological. Physical comfort is defined as basic human needs, such as safety, hygiene and accessibility. Functional comfort is defined as ergonomic support for work tasks and psychological comfort deals with feelings of belonging and control over the workspace.

The purpose of this study was to examine how differences in the physical ergonomic design of the working environment in a process control room effects operator work experience. The aim was to evaluate if a high-end control room concept including the latest ergonomic features had any effects on operator comfort and alertness in terms of perceived discomfort, stress-energy and emotions during normal operation, compared to a traditional control room.

2. Methods

A total of twelve test subjects, eleven males and one female, participated in the study. They were all Swedish-speaking professional operators working at various process industries in western Sweden (pulp & paper, food processing, water cleaning, heat and power, chemical processing and oil refining). Their ages ranged from 26 to 53 years and work experience of process control from 2 to 35 years. Two control room environments were used in the study: a high-end conceptual control room with an optimised physical working environment including the latest ergonomic features such as large, and a traditional control room as often found in industry (Table 1). To achieve an operator-working situation that was similar to a real world industrial control room, a paint factory simulator was used. The choice of process was made with the intent to make it easy to interpret what was happening in the process, yet with the possibility to add complexity by changing the number of objects and recipes running at the same time. When mixing a paint batch, a number of parameters need to be set, e.g. water content, various colour pigments, thickening agents, binding agents and other additives.

Table 1 *Features of the two control room environments included in the study*

Features	High-end Control Room	Traditional Control Room
Area meter square	114	35
Operator workplace	ABB/CGM EOW-x3	Traditional desk
Adjustable work tables	Yes	No
Micro-ventilation in table	Yes	No
Curved table	Yes	No
Leather edges on table	Yes	No
Screens for interactive work	6 height-, tilt-, distance-adjustable screens	6 screens
Screens for monitoring	3 large height-adjustable screens in front of operator	3 large screens on the wall
Multi-client keyboard	Yes, with shortcuts	No
Office chair	Ergonomic adjustable	Standard adjustable
Reading light condition	Dimmable, 275-1000 lux	180-210 lux
Noise level	50-55 dB (A)	50-55 dB (A)
Temperature	20-25°C	20-25°C
Sound absorbents	Yes, on ceiling and walls	Yes, on screen wall
Windows	12 with adjustable blinds	3 large
Constant status light in ceiling	Normal green diode light. Emergency; red diode light.	No

Each test subject's working day started at 9 pm with a one-hour introduction of the control system of the paint factory. First, the test leader made an oral and visual presentation of the system, followed by giving the operator the opportunity to test the system and ask questions about the functionality. A few weeks before the test session, all operators had received written documentation about the simulator. Then each operator ran a three-hour shift in each of the two control rooms: one morning shift from 10 am to 1 pm and one afternoon shift from 2 pm to 5 pm. The conditions were randomly assigned to start working in either the high-end or the standard control room. A one-hour lunch break was taken between shifts. Every 30 minutes, the test leader gave the operator a paper-based questionnaire regarding their perceived comfort, stress and emotional state. To minimize intrusiveness, the test leader always asked the operator if it was okay to pause, allowing the operator to finish the current task or thought. The questionnaire took two to three minutes to complete. During this time the simulation was paused. After the second test session at the end of the day, an interview was also conducted with the operator.

To assess operator user experience in the two control rooms, comfort and alertness aspects were evaluated. These aspects were judged by subjective self-assessment ratings of *discomfort*, perceived *stress-energy* and *emotional state* during the test sessions. Interviews were also performed to get qualitative individual data regarding the operators' experiences of the two control room environments. The subjective assessments of experience were gathered via a three-page questionnaire (in Swedish) administered to the participants every 30 minutes during each three-hour shift, resulting in six questionnaires per shift (after 0, 30, 60, 90, 120 and 150 minutes). The questionnaire included one page for each of the three rating scales chosen; discomfort ratings (Osvalder et al, 2005), the Stress-Energy Questionnaire (Kjellberg and Wadman, 2007) and the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994).

The experimental study was conducted as a mixed factorial, within-subjects design, where all test subjects were exposed to the same factors; in this case the two control room concepts during morning or afternoon sessions. The non-parametric Mann-Whitney U test were used to analyse the hypotheses that the two control room environments would have significantly different effects on the operators' perceived discomfort, stress-energy and emotional states, respectively. To analyse the comfort ratings a one-way ANOVA was performed to study effects between the six discomfort parameters. For the 12 stress-energy items, statistical analyses were made for each subgroup, represented by *positive stress*, *negative stress*, *positive energy* and *negative energy* respectively. The emotional parameters *valence, activation* and *control* were analysed separately.

3. Results

The analysis showed that the total discomfort perceived by the operators was significantly lower ($p<0.05$) in the high-end control room than in the traditional control room regardless of time of day. However, in general, the discomfort ratings were low for all operators in both control rooms, and most operators rated discomfort in the high-end control room as nearly no discomfort at all. Furthermore, there was significantly ($p<0.05$) lower discomfort in the high-end control room for *stiffness, inconvenience*, *fatigue* and *pain*. For *numbness, pain* and *woody taste* no significant differences were seen between the two control rooms.

No significant differences were found in perceived discomfort between the morning and afternoon sessions in either of the control rooms. The perceived total discomfort increased over time in both control rooms during the test sessions. This result implies that the discomfort increased more the longer the working time in the traditional control room relative to the high-end control room. In the high-end control room the change over time was not as pronounced. Regarding energy ratings, the result showed that the positive energy was significantly higher ($p<0.05$) during the morning session than during the afternoon session. For the negative energy no significant differences were shown between the sessions. Regarding stress ratings, the operators were slightly more negatively stressed (*tensed, stressed* and *pressured*) during the morning session than in the afternoon. In the afternoon they were slightly more positively stressed (*rested, relaxed* and *calm*). A separate analysis of the parameter *stress* showed a significant difference ($p<0.01$) between the morning and afternoon sessions; the stress level was higher in the morning when the operators were exposed to the paint factory simulator for the first time. Neither of the stress or energy parameters showed a significant difference over time during a three-hour working session. The ratings were rather similar at all occasions during the sessions.

The emotion analysis showed no significant differences between the two control room concepts for any of the parameters valence, activation or control. Nearly all operators rated their valence as neutral on the scale from sad to happy in both environments, with a slight tendency toward happy. Regarding activation, the operators were calm and not excited during the working sessions. Regarding control, the operators felt they had control of the working situation during the whole session, and the ratings, especially at the end of each session, were high for control. Regarding time of the day, the emotional parameter control showed a significant difference ($p<0.01$) between morning and afternoon sessions. The control was higher in the afternoon when the operators ran their second session on the simulator, as they had become more proficient.

4. Concluding remarks

The purpose of this study was to examine how differences in the physical ergonomic design of the working environment effects operator work experience in the control room. The overall result showed that the perceived discomfort is lower in the high-end control room at all times of a working day. The operators preferred to work in the high-end control room and they also felt they might perform better in this environment, but they also sensed increased pressure to perform well. This result is of course in line with what could be expected when letting people compare a new and more sophisticated ergonomically designed environment with their daily working conditions, and therefore a discussion about bias in the study is relevant. However, the ergonomic features resulted in less *inconvenience*, *fatigue* and *pain* as well as it supported the work and increased the alertness in terms of activation and energy. All these parameters were actually possible to evaluate with the selected methods, which shows that they are appropriate tools for studying operator feelings and needs. The perceived discomfort did not increase much during a working session in the high-end control room compared to the traditional control room, which indicate that the working task is as important as the environmental features. Finally the high-end control room was experienced more attractive due to its possibilities to change working postures and thereby decrease discomfort, fatigue and pain.

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