The Effect of Cognitive Complexity Factors on Operators' Performance in Conducting Emergency Operating Procedures

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1. Introduction

According to the previous study, it has expected that two kinds of cognitive complexity factors – the abstraction level of knowledge (AL) and the level of engineering decision (ED) could impair operators' performance in the course of conducting emergency operating procedures [1]. However, without an experimental evaluation, this expectation cannot be properly confirmed. Thus, in this study, the effect of cognitive complexity factors on operators' performance is experimentally verified.

2. The meaning of AL and ED

When operators who are working in the main control room (MCR) of commercial nuclear power plants faced with an emergency event, they have to follow a set of procedural steps that have been stipulated in emergency operating procedures (EOPs). Unfortunately, carrying out the activities included in procedural steps is not just a rule following behavior because: 1) operators need a detailed knowledge for many processes and/or systems, and 2) operators need to establish a proper decision criterion that can be varied with respect to the situation they are faced with [1]. Accordingly, it is feasible to expect that operators' performance could be affected by both the amount of knowledge to be processed by operators and the level of intricacy in establishing decision criteria. In this vein, based on the Rasmussen's abstraction paradigm of knowledge representation [2], four levels are suggested to represent the level of knowledge to be processed. They are: 1) component function (CF) level, 2) system function (SF) level, 3) process function (PF) level and 4) abstraction function (AF) level. In addition, four levels are considered (from ED-1 to ED-4) in order to represent the level of intricacy in establishing decision criteria [1].

3. Experiment

As stated earlier, the purpose of this study is to confirm the effect of AL and ED on operators' performance experimentally, when they have to follow a procedure. Therefore, the following experiment is considered.

3.1 Experiment tool

As for the experiment tool, the simple simulator shown in Fig. 1 is used [3]. This simulator was designed so that it can emulate brief functions for the secondary side of a nuclear power plant. This simulator has the following key features.

- All the valves and pumps included in the simulator can be dichotomously controlled (i.e., on-off control).
- Several valves and pumps are implemented so that they can be continuously controlled.
- The simulator can generate warning alarms (refer to 'Alarm window' in Fig. 1) for several important process parameters.

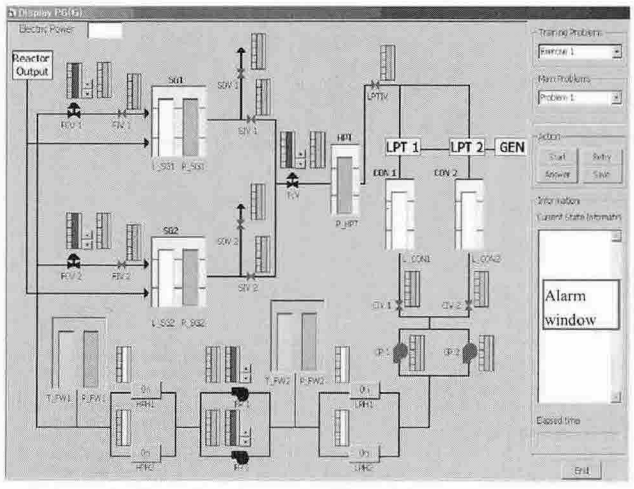

Figure 1. The simulator used in this experiment.

3.2 The subjects

In total 32 undergraduate students of Korea University of Technology and Education participated in this experiment. All subjects were male, and their age was 27.9 years in average.

3.3 Method

The subjects are asked that they have to maintain the whole process as longer as possible, because this simulator will be shut down when any process parameter exceeds its operating range. If a process parameter comes close to a predefined operating range, the simulator provides a warning alarm with the subjects. According to the warning alarm, the subjects

have to stabilize the process parameter under jeopardy by conducting an alarm response procedure. That is, if the subjects successfully conduct all the activities included in an alarm response procedure, then the generated alarm will disappear.
Here, in order to distinguish the change of operators' performance due to the different levels of AL and ED, four kinds of alarm response procedures are prepared for each warning alarm. In addition, the subjects are randomly classified into four groups, and then they are asked to follow a dedicated alarm response procedure when a warning alarm occurred. That is, for a given alarm, there are four alarm response procedures that are described in the level of [CF, ED-1], [CF, ED-3], [SF, ED-1], and [SF, ED-3], respectively. In addition, different types of alarm response procedures are assigned for four groups. As an example, Fig. 2 shows four different alarm response procedures for "L_SG1 is approaching to Min." alarm.

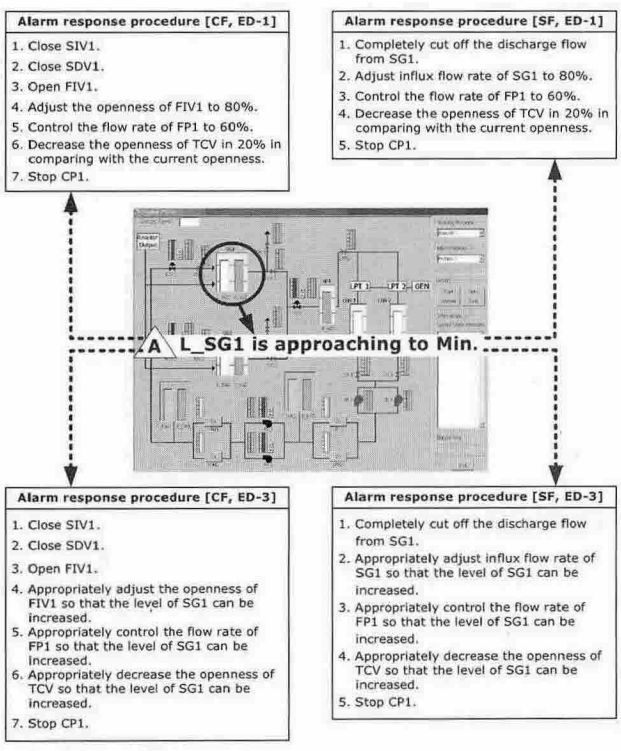

Figure 2. Four different alarm response procedures for "L_SG1 is approaching to Min." alarm.

3.4 Performance measure

Clearly, the subjects' performance can be measured by the total process retaining time, since the subjects are asked to maintain the whole process, as longer as they can, by conducting different kinds of alarm response procedures.

3.5 Result

Experiment result strongly support to the fact that the subjects' performance seems to be degraded along with the increase of levels of AL and ED. Table 1 shows the change of the subjects' performance (retaining time) with respect to the change of levels of AL and ED.
As can be seen in Table 1, when they have to use alarm response procedures that contains a higher level of AL and ED, the subjects seem to have a difficulty in retaining the whole process.

Table 1. Averaged retaining time.

	Averaged retaining time (second)
[CF, ED-1]	563.2
[CF, ED-3]	330.5
[SF, ED-1]	586.3
[SF, ED-3]	250.1

4. Conclusion

In this study, the effect of cognitive complexity factors (i.e., AL and ED) on the change of subjects' performance is experimentally investigated. As a result, cognitive complexity factors seem to be meaningful, since the subjects' performance is affected by the change of levels of AL and ED. In other words, it is expected that the subjects who have to follow a procedure that requires a higher level of AL and ED feel a difficulty in conducting it. Thus, without a logical jump, it is reasonable to draw the following conclusion – the increase of levels of AL and ED could impair the operators' performance, since it can create a difficulty in conducting procedures.

Reference

1. Jinkyun Park, Kwangsup Jeong and Wondea Jung, A study on the identification of cognitive complexity factors related to the complexity of procedural steps, Proceedings of the Korean Nuclear Society Spring Meeting Gyeong ju, Korea, May 2004.
2. J. Rasmussen. Information processing and human-machine interaction: an approach to cognitive engineering, North-Holland, New York, 1986.
3. Dong-Han Ham and Wan Chul Yoon, The effects of presenting functionally abstracted information in fault diagnosis tasks, Reliability Engineering and System Safety, Vol. 73, p. 103-119, 2001.