Effect of Procedure Types and Operator's Experience on Human Performances

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1. Introduction

Performance shaping factors (PSFs) in the human reliability analysis (HRA) refer to any factor that influences human performance [1]. To perform an HRA, it is necessary to identify PSFs that are most relevant and influential in the task analyzed. Generally, those PSFs are used to adjust basic human error probabilities (HEPs) in the nominal condition to calculate the final HEP in the condition of analyzed task.

Many PSFs, such as training, procedure, stress, and complexity of task, have been suggested by HRA methodologies up to date. However, the selection of PSFs and the estimation of influence of PSFs in most HRA methodologies rely on expert judgments rather than the knowledge from actual experiments and observations. Therefore, it is not an easy work for HRA practitioners to decide whether a PSF really influences operator's performance or how much it contributes to the occurrence of error.

This study experimentally investigates impacts of procedure types and operator's experience on human performances. This study selects two performance shaping factors, i.e., procedure types and operator's experience on the human-system interface (HSI), especially, digital main control room (MCR). Then, an experiment has been designed to investigate these two PSFs on the step completion time of procedure.

2. Experiment Design

2.1 Performance Shaping Factors

2.1.1 Procedure Types

This study defines four types of emergency operating procedures, i.e., Standard Post Trip Action (SPTA), Diagnostic Action (DA), Optimal Recovery Procedure (ORP), and Functional Recovery Procedure (FRP) [2]. As shown in Fig. 1, when reactor trip occurs, operators initiate the SPTA that checks safety functions. Then, the DA is entered to diagnose plant status.

When operators identify an event that can be handled by the ORP, i.e., event-based procedure, they open a corresponding ORP. If any specific event is not diagnosed or a combined accident of more than two emergency events occurs, the FRP needs to be followed, focusing on recovering critical safety functions.

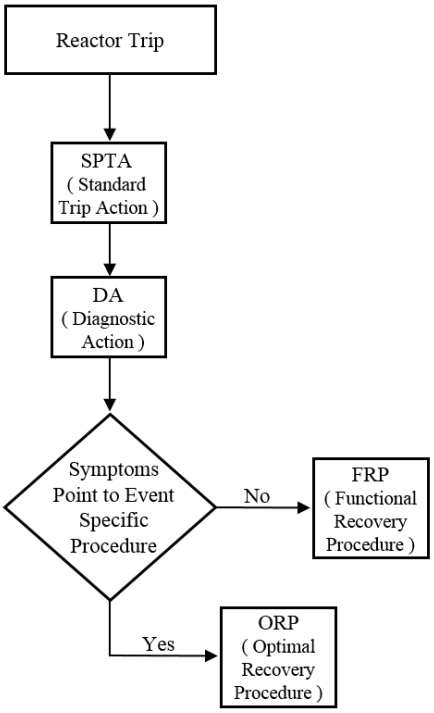

Fig. 1. Information flow maps for procedures after Reactor Trip.

2.1.2 Operator's experience on the HSI

Operator's experience or familiarity on the HSI has been selected as another PSF. Subjects are divided into two groups: more experienced and less experiences groups on the digital MCR. The more experienced group is operators who have operating license of APR1400. The less experienced group is also licensed operators, but other types of reactors. Thus, they have sufficient knowledge on nuclear power plants, but less experience on the use of digital control room.

2.2 Experiment Design

A randomized factorial experiment has been designed as shown in Table 1. Six scenarios are carried out by each shift as follows:

- Loss of offsite power
- Steam generator tube rupture with N-16 failure
- Small break loss of coolant accident (SBLOCA) with safety injection failure
- Interface system SBLOCA
- Excessive steam dump event with N-16 failure
- Loss of all feedwater

KINGS simulator is used as an experiment facility as shown in Fig. 2. The simulator contains a plant model of APR1400 which has a fully digitalized MCR. The simulator is operated by three operators and each operator has three screens for monitoring and control.

Step completion time of procedure is measured during the experiment. Step completion time is measured by observers as well as simulator log data.

Up to now, three shifts, i.e., two for the more experienced group and one for the less experienced group, participated in the experiment. One shift consists of three operators.

Table Ⅰ: Experimental design

	More Experienced	Less Experienced
SPTA		
DA		
ORP		
FRP		

Fig. 2 KINGS simulator

3. Results

3.1 Effect of procedure types on step completion time

First, this study analyzes the effect of procedure types on the averaged step completion time. Table II shows the ANOVA test result on the averaged step completion time depending on the procedure types and operator's experiences. X1 and X2 indicate the operator's experience and procedure types, respectively. The result indicates that the averaged step completion time is statistically different between procedure types ($p<<0.01$). It means that the averaged step completion time of at least two procedure types are different. A Tukey test ($p<0.01$) shows that

- The averaged step completion time of the FRP is longer than that of the SPTA, and
- The averaged step completion time of the FRP is longer than that of the DA.

Table Ⅱ: Analysis of variance of the result

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	143,5	1	143,54	0,38	0,5402
X2	16534,8	3	5511,59	14,61	0
X1*X2	1911,9	3	637,3	1,69	0,1816
Error	18489,5	49	377,34		
Total	39956,4	56			

3.2 Effect of experience and training on step completion time

Table II shows that the step completion time is not statistically different along with the operator's experience on the HSI. However, when we take a look at the result about each type of procedures, a difference can be found.

Tables III to VI show the ANOVA results about the averaged step completion times of SPTA, DA, ORP, and FRP, respectively, depending on the operator's experience on the HSI. The result indicates that, in the SPTA, the averaged step completion time by the more experienced group is statistically shorter than that by the less experienced group ($p<0.01$). However, in the other types of procedures, there was no statistical difference between two groups.

Table Ⅲ: ANOVA: Averaged step completion time in the SPTA

Source	SS	df	MS	F	Prob>F
Groups	975,21	1	975,209	13,3	0,0022
Error	1173,33	16	73,333		
Total	2148,54	17			

Table Ⅳ: ANOVA: Averaged step completion time in the DA

Source	SS	df	MS	F	Prob>F
Groups	7,353	1	7,3531	0,13	0,7259
Error	923,839	16	57,7399		
Total	931,192	17			

Table Ⅴ: ANOVA: Averaged step completion time in the ORP

Source	SS	df	MS	F	Prob>F
Groups	1206,5	1	1206,5	2,7	0,1241
Error	5802,52	13	446,35		
Total	7009,02	14			

Table Ⅵ: ANOVA: Averaged step completion time in the FRP

Source	SS	df	MS	F	Prob>F
Groups	449,8	1	449,82	0,17	0,7013
Error	10589,8	4	2647,46		
Total	11039,7	5			

4. Conclusion

This study conducted an experiment to investigate the relationship between operator's performance and PSFs. Actual operators and NPP simulator are applied in the experiment. The result indicates that the step completion time differed statistically depending on the procedure types and operator's experience. This study is an on-going research that is collecting the data on the effects on the operator's performances by different PSFs. It is expected that this study will contribute to realistic estimation of human error probabilities when it can continue to collect more data.

REFERENCES

[1] US NRC, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG-1278, 1983.
[2] Kim, Seunghwan, Jinkyun Park, and Yoon Joong Kim. "Some insights about the characteristics of communications observed from the off-normal conditions of nuclear power plants." Human Factors and Ergonomics in Manufacturing & Service Industries 21.4 (2011): 361-378.