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Experiment for Investigating Human Performances in Diagnostic Task under Seismic Situation

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1. Introduction

Operator actions are critical in a Seismic Probabilistic Safety Assessment (PSA). The seismic load-induced stress can reduce the human task performance of nuclear power plant operators and generate a human error and the time delay for diagnosis and execution. However, researches that have investigated human performance in seismic situations up to date have not provided sufficient insights for analyzing human errors. NPPs have only a limited number of operator errors that occurred in the event of an earthquake. Therefore, the determination of HEPs in seismic PSAs generally relies on expert judgment [1].

This study is to design an experiment for investigating the relation of seismic effects with human performances for diagnostic tasks. This study develops the scenarios, the seismic magnitude, and the procedure for the experiment. Seismic simulation apparatus is used for the experiment. For human performances, time to complete, accuracy, situational awareness, and workload were measured. Then, the relation between the earthquake magnitudes and human performances is statistically analyzed.

2. Experiment Design

This study designs an experiment whose objective is to investigate the relation between the seismic magnitude and human performances in diagnosis tasks using a shaking table. A 3×3 factorial experiment repeating three times was applied. Table I shows the design of the experiment.

Table I: Experimental Design - A Randomized Factorial Design

No. Scenarios	Magnitude	Types of Accident
1	0g	LOCA
2	0g	SGTR
3	0g	MSLB
4	0.1g	LOCA
5	0.1g	SGTR
6	0.1g	MSLB
7	0.2g	LOCA
8	0.2g	SGTR
9	0.2g	MSLB

2.1 Seismic Magnitude

Three different seismic levels have been selected, i.e., 0g, 0.1g, and 0.2g. In Korean NPPs, 0.1g is the Operating Basis Earthquake (OBE). Above this magnitude, the operator should shut down the reactor manually. The Safe Shutdown Earthquake (SSE) is 0.2g above which the reactor is shutdown automatically. The higher magnitude is not used in this experiment due to the safety of subjects.

2.2 Task

The subjects are asked to diagnose emergency scenarios in the experiment. The emergency scenarios include loss of coolant accident (LOCA), steam generator tube rupture (SGTR), and main steam line break (MSLB), which have a relatively higher probability of occurrence in the earthquake.

2.3 Human performance

The following human performances were measured in the experiment.

Time to complete: it is duration from the initiation of an event to the completion of diagnosis.

Accuracy: It is a measure of the quality of performance. In this experiment, accuracy is determined by a successful diagnosis.

Situation Awareness (SA): SA is knowledge relevant to the task being performed. It is a critical factor of decision making and has been included in several models of decision making. This study uses a Situation Awareness Rating Technique (SART) of subjective measurement of SA. SART concentrates on measuring the operator knowledge in three areas: demands attentional resources, the supply of attentional resources, and understanding of the situation [2].

Workload: The workload has been suggested as a set of task demands, an effort, and as activity or accomplishment [2]. This study uses the modified Cooper-Harper rating scale (MCH) initially developed by the aviation industry to estimate the psychological and physical workloads of the operator. The operators answer the questionnaire after finishing the scenario.

Forehead temperature variation (ΔT): The temperature of the forehead is used as a physiological measure.

Increased blood flow leads to an increase in forehead temperature in relation to unstable conditions.

2.4 Invariants

Invariants are independent variables that are kept constant in the experiment. These include the frequency, i.e., 2.5Hz, vibration direction and vibration time. The vibration frequency was determined at 2.5 Hz in the X, Y and Z directions. And the seismic vibration time was decided by 10 seconds. This is because long vibration times can damage the simulator monitor.

2.5 Equipment

A nuclear power plant main control room earthquake simulator was used which is located in Korea Atomic Energy Research Institute (KAERI). It consists of a 6-axis drive system (SmartCue-60xx) and a seismometer (Digital Seismometer_AK-2000). Three axes oscillation was used for the safety of the participants. An earthquake recorder measures the strength of an earthquake from an accelerometer below the floor. The following Fig. 1 is an overview of the entire seismic apparatus. And Fig. 2 is NPP MCR Earthquake Simulator

An NPP simulator, i.e., Compact Nuclear Simulator (CNS) is used to simulate accidents. It was developed by KAERI. The reference NPP is Westinghouse 930MWe plant which is a three-loop pressurized water reactor (PWR). This interface is entirely digitized. Fig. 3 shows a snapshot of the CNS for the reactor coolant system.

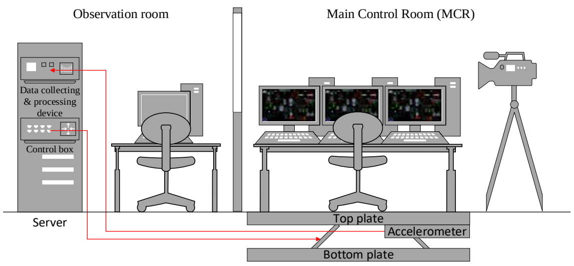

Fig. 1. Overview of the Entire Seismic Apparatus

Fig. 2. Nuclear Power Plant Main Control Room Earthquake Simulator in the KAERI

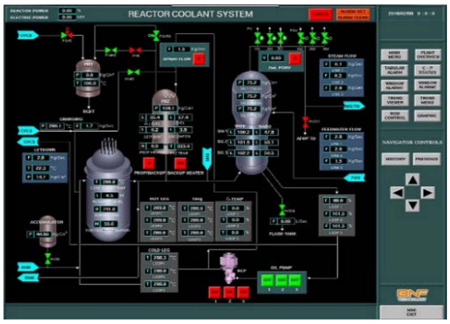

Fig. 3. CNS Interface

3.6 Participants and Training

Forty-three undergraduate students at Chosun University participated in the experiment. They were not informed in prior that an earthquake will occur. Participants were trained to be familiar with the CNS as well as NPP systems. A test after the training session was carried out to confirm their ability to perform diagnostic tasks.

3.7 Experiment Procedure

Fig. 4 shows the time frame of the experimental procedure. At the beginning of the experiment, a participant fills out the personal information in the general questionnaire. Then, the simulation and scenario are started. The participant is asked to perform the diagnosis of the situation. When the accident diagnosis is complete, the participant raises hands and then the

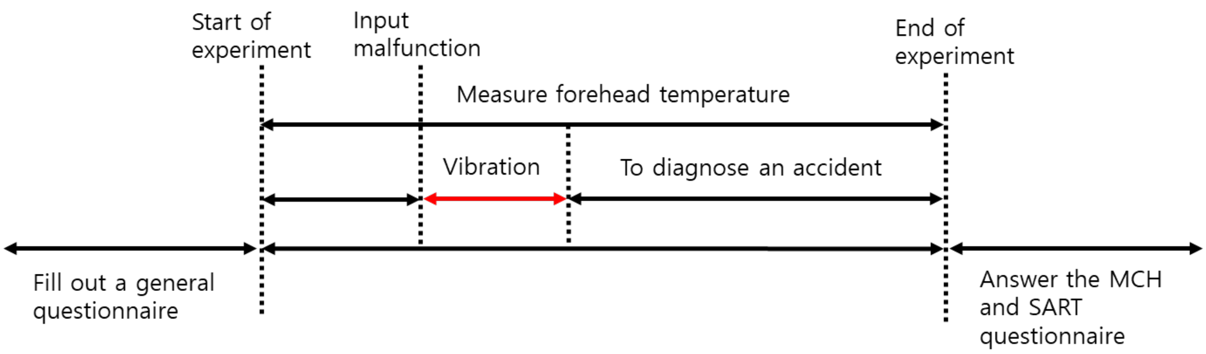

Fig. 4. Timeframe of experiment procedure

simulation is finished. Then, the participant fills out the questionnaires for SA and workload.

3. Result

This study performed statistical analyses on the experiment results. Table 2 shows the average values of performance measures.

Table II: Average Value of Performances

Seismic Level	Accuracy	Time to Complete	ΔT (High temperature)	Workload (MCH)	Situation Awareness (SART)
0g	0.6	80.9	0.49	6.15	17.5
0.1g	0.6	90.9	0.44	7.3	13.8
0.2g	0.82	92.1	0.57	4.55	14.82

Table III shows a summary of the results from the analysis of variance (ANOVA) test for performance measures according to the seismic magnitude. The result indicates that no difference in the performance measures was found among 0.0g, 0.1g, and 0.2g. Fig. 5 presents experiment results for time to complete, forehead temperature variation, workload, and situation awareness, respectively.

Table III: Summary of Result from ANOVA Test

	Human Performance				
	Accuracy	Time to Complete	Forehead ΔT (High temperature)	Workload (MCH)	Situation Awareness (SART)
Difference with seismic magnitude	No	No	No	No	No
P-value	0.45	0.74	0.57	0.14	0.21

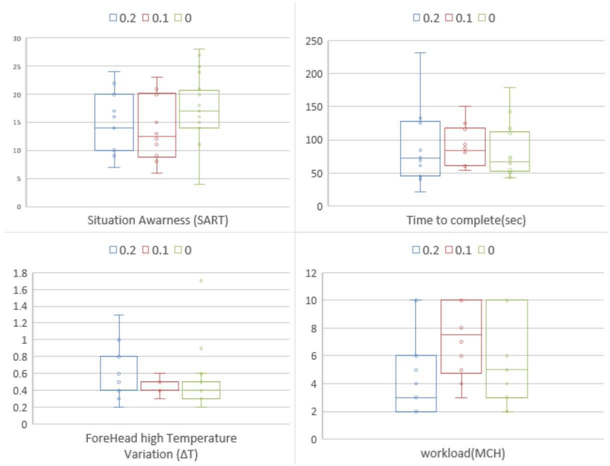

Fig. 5. Human Performance Result Graphs

4. Conclusions

This study presented an experiment to investigate the human performances in the diagnostic tasks under the seismic situation. It measured five human performances according to three seismic magnitudes. The experimental results showed that performance measures were not significantly different between the magnitudes of the earthquake (0g, 0.1g, and 0.2g).

Acknowledgment

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