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Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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Bumjun Park[a], Sungheon Lee[a], Seungheon Kim[a], Jeongtaeg Kim[b], Jooyoung Park[c], Ronald L. Boring[c], Jonghyun Kim[a*]

[a] *Department of Nuclear Engineering, Chosun University, 309 pilmun-daero, Dong-gu, Gwangju, 501-709, Republic of Korea*

[b] *Korea Hydro & Nuclear Power Co.LTD., 1655 Bulguk-ro, Gyeong-ju, 38120, Republic of Korea*

[c] *Idaho National Laboratory, 2525 Fremont Avenue, Idaho Falls, ID, 83402, USA*

[*] *Corresponding author: jonghyun.kim@chosun.ac.kr*

1. Introduction

Human reliability analysis (HRA) is a method for evaluating human errors and estimating human error probabilities (HEPs) for application in probabilistic safety assessment [1]. To estimate error probabilities with a high degree of quality and reliability, most HRA methods are based on sets of human reliability data collected from actual recorded measurements, expert judgments, simulator studies, or experimental studies. Typically, the earliest HRA methods (i.e., the Technique for Human Error Rate Prediction) [1] proposed evaluating HEPs using expert judgment data, with additional input from sparse empirical and experience-based data.

Currently, most studies rely on full-scope simulators and actual licensed operators [2-3], since simulators come nearest to representing actual reactor conditions. In this regard, efforts are being led by the U.S. Nuclear Regulatory Commission and the Korea Atomic Energy Research Institute to collect data from full-scope simulators using the Scenario Authoring, Characterization, and Debriefing Application database [3] and the Human Reliability data Extraction (HuREX) framework [4], respectively. However, researchers experienced difficulty in collecting various items and gathering enough data to support HRA.

In a complementary approach to full-scope research, this study compares human performance between actual operators and students using Rancor Microworld, developed by Idaho National Laboratory. Rancor Microworld is a simplified nuclear process control simulator for collecting HRA data. The ultimate aim of this study is to use the HEPs of students operating in Rancor Microworld as a basis for developing a method to estimate the HEPs of actual operators in the real world. Six human performance measurements—(1) time, (2) error, (3) workload, (4) situation awareness, (5) attention patterns, and (6) number of manipulations—were measured via experiments conducted on 11 operators and 20 students (so far).

2. Overview of Rancor Microworld

The Rancor Microworld simulator [5] was used for this experiment. Rancor Microworld is a simplified simulation environment designed to reproduce the important characteristics of real-world situations while leaving open the possibility of manipulation and experimental control [5]. It investigates theoretical and practical concepts related to process control, and provides a graphical user interface that fosters a general way for researchers to create a process control system [5]. Fig. 1 shows part of the Rancor Microworld interface.

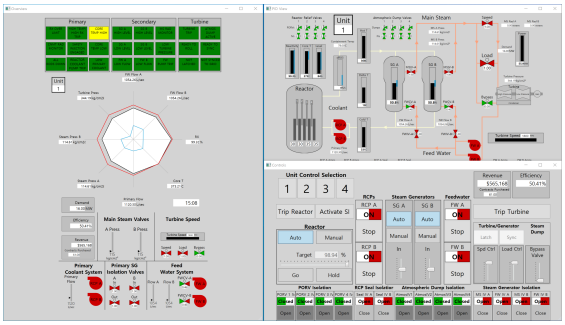

Fig. 1. Rancor Microworld interface.

3. Experimental Design

In this study, a randomized factorial experiment was designed to compare the differences in human performance between students and actual operators. Details of the experimental design are as follows.

3.1 Subjects

The subjects are divided into two groups: students and actual operators. Subjects in the "actual operators" group consist of operators with operating licenses for Korean nuclear power plants (NPPs), while subjects in the "students" group consist of college students who study nuclear engineering and areknowledgeable about NPPs and their operations.

3.2 Scenarios

Scenarios were categorized as either non-events or events. Non-event scenarios are operations performed under normal operating states (i.e., start-up, shutdown, or full-power operations). In these scenarios, subjects may not feel the stress or time pressure associated

with event scenarios. Event scenarios consist of several important actions that must be completed within a limited timeframe and positively or negatively impact the future state of the plant. Emergency or abnormal situations are examples of event scenarios. Such variables may help us determine the means of collecting event-based data using simulated scenarios.

Table Ⅰ: List of experiment scenarios and procedures.

Type of Scenario	Specific Scenario
Non-event	Start-up operation (0% to 100%)
	Shutdown operation (100% to 0%)
	Manual rod and feedwater pump control as part of start-up operation
Event	Reactor coolant pump failure during full-power operation
	Control rod failure during full-power operation
	Feedwater pump failure during full-power operation
	Abnormal turbine trip during full-power operation
	Steam generator tube rupture with indicator failure for the steam generator level
	Loss of feedwater

3.3 Human Performance Measurements

In this study, six human performance measurements were evaluated: time, error, workload, situation awareness, attention patterns, and the number of manipulations. The following is a summary of each performance measurement:

Table Ⅱ: Human performance measurement summary.

Human performance	Description
Time	The time to complete a scenario and the average time to complete an instruction.
Error	When operator task performance strays from the procedure.
Workload	Estimated by the modified Cooper-Harper rating scale (MCH) questionnaires. Eye-trackers estimate the relationship between blinking rates and workload.
Situation awareness	Estimated by Situation Awareness Rating Technique (SART) questionnaires.
Attention patterns	An eye-tracker estimates the ratio of attention focused on major information within the microworld interface.
Number of manipulations	How often subjects manipulated the Microworld interfaces.

4. Preliminary Results

To date, the experiment has been conducted for 20 students and 11 operators. In regard to performance measurements, the analysis results for SART and MCH are presented in Table Ⅲ. For identical types of scenarios, the ANOVA test indicated operator workloads to be lower than those of the students (see Fig. 2). In addition, the SART result demonstrated that the operators had better situation awareness than did the students (see Fig. 3).

Table Ⅲ: ANOVA result for MCH & SART.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Subject	MCH	41.173	1	41.173	6.385	.012
	SART	251.654	1	251.654	4.788	.030
Scenario	MCH	1.971	1	1.971	.306	.581
	SART	8.652	1	8.652	.165	.685
Subject * Scenario	MCH	1.455	1	1.455	.226	.635
	SART	20.910	1	20.910	.398	.529
Error	MCH	1173.652	182	6.449		
	SART	9565.329	182	52.557		
Total	MCH	3907.000	186			
	SART	77253.000	186			

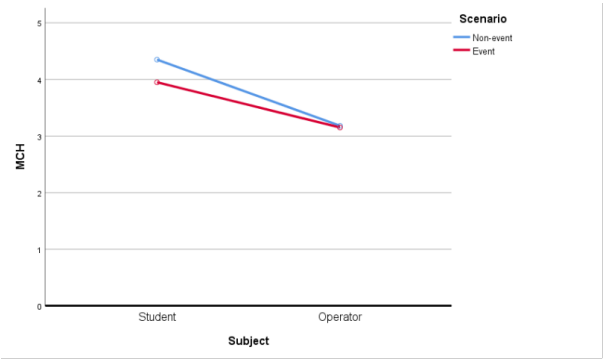

Fig. 2. Experiment results for MCH.

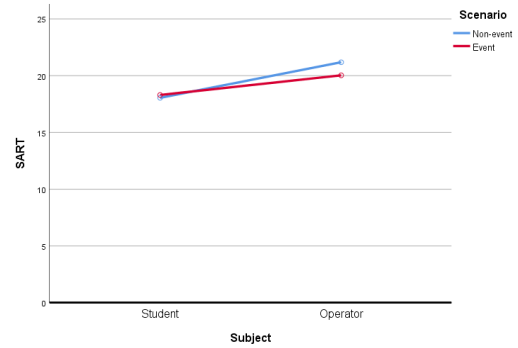

Fig. 3. Experiment results for SART.

5. Conclusion

This paper described an experiment using the Rancor Microworld simulator to probe into the differences in human performance between students and actual operators. Even though it may sound somewhat obvious, the results show actual operators' performance to be better than that of students operating in Rancor Microworld. Additional experiments and analyses will be conducted. Further experimental studies using Rancor Microworld are expected to result in additional data perhaps missing

from full-scope studies, and to contribute to items that can support HRA data.

Acknowledgement

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