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Changing the World's Energy Future

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Comparison of Error Rate Depending on Operator Expertise and Simulator Complexity

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1. Introduction

Generally, human reliability analysis (HRA) methods estimate human error probabilities based on human reliability data. Inappropriate data causes an increase in the uncertainty of HRA and a decrease in the quality of probabilistic safety assessment, which is a comprehensive safety assessment method for nuclear power plants (NPPs) [1]. So, securing sufficient and appropriate data is critical in HRA field. Currently, many HRA data collection studies use full-scope simulators and actual licensed NPPs operators.

Idaho National Laboratory (INL) has suggested a method to obtain human reliability data using simplified simulator environments, i.e., Simplified Human Error Experimental Program (SHEEP) framework. It is a method of collecting HRA data through simplified simulators and non-expert operators. This framework enables HRA data to be collected using the fewer resources than full-scope study. In previous studies, INL and Chosun University confirmed that the data collected through SHEEP framework can support full-scope data collection study [2], and compared performance differences based on operator expertise when using a simplified simulator [3].

As a part of the SHEEP framework, this paper analyzes operator's error rate depending on the expertise and simulator complexity. The experiment uses two simulators, i.e., the Rancor Microworld, a simplified simulator developed by INL and the Compact Nuclear Simulator (CNS), a less simplified simulator developed by the Korea Atomic Energy Research Institute (KAERI). A total of 72 operators and students participated in the experiment, and the error rate was analyzed using analysis of variance (ANOVA) test.

2. SHEEP Framework

Fig. 1 summarizes the SHEEP framework, which consists of three steps: 1) identification of HRA items collectible in simplified simulators, 2) treatment of the HRA items based on experiment, and 3) integration of the data into full-scope database and HRA methods.

The first step classifies HRA items into two groups: 1) HRA items collectible from simplified simulator and full-scope simulators, and 2) HRA items only collectible from simplified simulators. The second step suggests how the HRA items can be measured in experiments. The third step integrates the experimental data collected in the previous step into a full-scope database.

This study focuses on the second step, which treats HRA items that are collectible in both simplified and full-scope simulators. This study aims to understand the differences stemming from the expertise (i.e., actual operator vs. student) and simulator complexity (i.e., Rancor Microworld vs. CNS) by collecting error data through experiments and then analyzing error rate via statistical analysis methods.

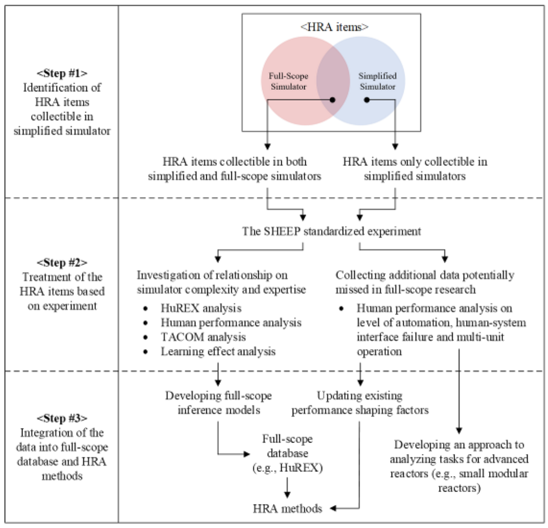

Fig. 1. SHEEP framework [3]

3. Experimental Design

A randomized factorial experiment was designed to compare subjects' error rates depending on expertise and simulator complexity. Table I summarizes the randomized factorial experiment design used in this study.

Table I: Randomized Factorial Experiment Design

	Non-expert (i.e., Student)	Expert (i.e., Actual operator)
Less simplified simulator (i.e., CNS)		
More simplified simulator (i.e., Rancor Microworld)		

3.1 Independent Variables

3.1.1 Expertise.

This variable is divided into the operator and student groups. A total of 72 subjects participated in the experiment: 36 actual operators and 36 students. The operators are currently employed at Korean NPPs. They are licensed operators or experts with considerable experiences. The students are undergraduate or graduate students at the department of nuclear engineering, Chosun University. They have a basic knowledge of NPPs system and operation.

3.1.2 Simulator Complexity.

This variable is divided into two groups: 1) a more simplified simulator (i.e., Rancor Microworld), and 2) a less simplified simulator (i.e., CNS). The Rancor Microworld is a simplified simulator developed by INL [4]. This simulator is based on a reduced-order thermo-hydraulics model that follows a simplified Rankin cycle reminiscent of small modular reactors. This simulator reproduces the main characteristics of actual NPP operation.

The CNS, a simplified simulator developed by KAERI, is based on the Westinghouse 900MWe [5]. This simulator has more complicated plant model and human-system interface than the Rancor Microworld.

3.2 Scenarios

For this experiment, ten Rancor Microworld scenarios and 4 CNS scenarios were developed. Scenarios can be divided into non-event scenarios and event scenarios. Non-event scenarios simulate normal situations such as start-up and shutdown. On the other hand, event scenarios simulate abnormal situations such as component failures or emergency scenarios.

3.3 Error Measurement

An error was defined as a deviation from the the procedures. Errors are divided errors of omission (EOOs) and errors of commission (EOCs). EOOs includes omitting a task, while EOCs are selection errors (e.g., selecting the wrong control), errors of sequence (e.g., conducting tasks in the wrong order), time errors (e.g., too early or too late) or qualitative errors (e.g., too little or too much).

4. Results and Analysis

As shown in Fig. 2, this study carried out four comparisons of error rates: 1. Different expertise in Rancor Microworld, 2. Different expertise in CNS, 3. Different complexity in students, and 4. Different complexity in operators. Tables II shows the error rate and ANOVA results for four different comparisons. The red number means that there is a significant difference as a result of the ANOVA test.

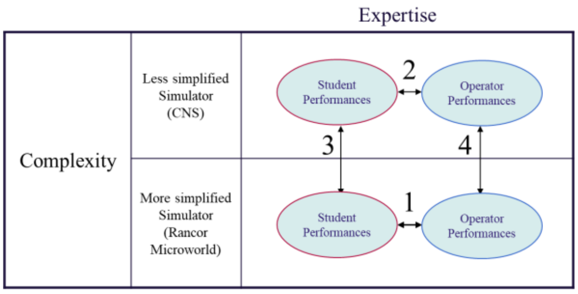

Fig. 2. Data groups to be compared

Table II: Comparison of Human Performance based on Simulator Complexity

	Student group	Operator group	p-value for different subjects
CNS	0.01679	0.00507	0.001
Rancor Microworld	0.00947	0.00594	0.046
p-value for different simulators	0.025	0.551	

4.1 Different expertise in Rancor Microworld

Fig. 3 shows the error rates for two subjects' groups when using Rancor Microworld. The ANOVA results indicate that there is a significant difference in error rates depending on the expertise. The student group showed statistically a higher error rate than the operator group.

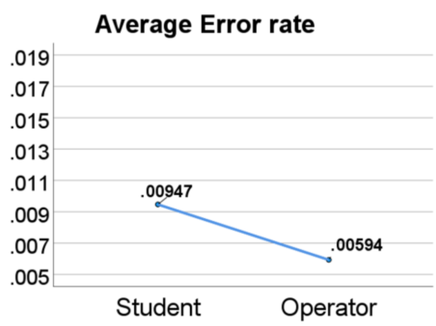

Fig. 3. The comparison between subjects in the Rancor Microworld

4.2 Different expertise in CNS

Fig. 4 shows the comparison of error rates between two subjects' groups when using CNS. The ANOVA results show that there is a significant difference in error rates depending on the expertise. The student group showed statistically a higher error rate than the operator group in the CNS.

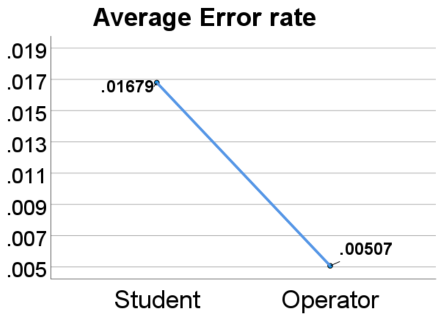

Fig. 4. The comparison between subjects in the CNS

4.3 Different simulator complexity in student group

Fig. 5 shows the comparison of error rates between two simulators when operated by the student group. The ANOVA results indicate that there is a significant difference in error rates depending on the simulator complexity. The student group showed statistically the higher error rate when using CNS.

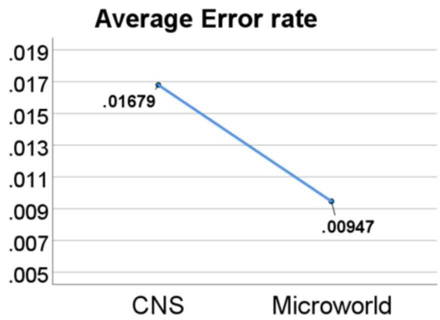

Fig. 5. The comparison between the simulators for the student group

4.4 Different simulator complexity in operator group

Fig. 6 shows the comparison of error rates for two simulators when operated by the operator group. The ANOVA results show that there is no significant difference in error rates depending on the simulator complexity.

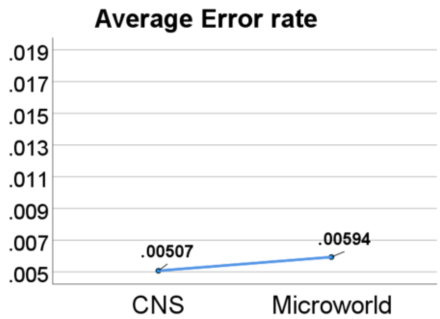

Fig. 6. The comparison between the simulators for the operator group

*4.5 Interaction: Expertise * Complexity*

Fig. 7 shows the interaction of error rates depending on the expertise and complexity. The ANOVA test indicates that there is an interaction between the expertise and complexity (p=0.021). The operators' error rate was not affected by the complexity, while the students' error rates are different depending on the simulators.

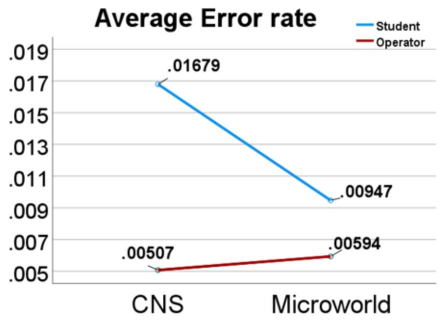

Fig. 7. Error rate of all participants

5. Conclusions

This paper analyzed the difference in the error rate that stem from the operator expertise and simulator complexity, as a study to implement the SHEEP framework. The results of this study are expected provide meaningful insights for the future work that aims to develop a model inferring full-scope study data from the student data using simplified simulators.

Acknowledgments

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