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An Experimental Design on the Use of Rancor Microworld Simulator: A Comparison of Human Performances between Actual Operators and Students

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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 (PSA) [1]. To estimate the error probabilities with high quality and reliability, most HRA methods have been developed on the basis of human reliability data sets collected from actual historical measurements, expert judgement, simulator studies, or experimental research. Representatively, the oldest HRA method, i.e., Technique for Human Error Rate Prediction (THERP) [1], has suggested on how to estimate HEPs with the data from expert judgement as well as sparse empirical and experience-based data.

Nevertheless, a lack of adequate data still has been highlighted as a major challenge in the field of HRA [2]. In fact, many HRA methods widely used by utilities and regulatory agencies for nuclear power plants (NPPs) have been developed based on THERP data, which was generated from the early 1970s until the late 1980s, mostly from non-nuclear experience. Although new technologies like digital main control rooms (MCRs) are already implemented on new or upgraded nuclear power plants, HRA methods still have been applied as is without modification to accommodate differences due to digital technologies.

For this reason, several institutes and researchers have attempted to collect HRA data from event reports, simulator studies, or multiple sources [3]. For most current studies, these are predominantly concentrating on collecting data from simulator studies with full-scope simulators. The largest current efforts are led by the U.S. Nuclear Regulatory Commission (U.S. NRC) and Korea Atomic Energy Research Institute (KAERI). These efforts are collecting data from full-scope digital MCR simulators using the Scenario Authoring, Characterization, and Debriefing Application (SACADA) database [4] and Human Reliability data Extraction (HuREX) framework [5], respectively.

In keeping with the need for human reliability data sources, Idaho National Laboratory (INL) has begun to collect HRA data using its simplified simulator, i.e., the Rancor Microworld simulator, in contrast to the U.S. NRC and KAERI using full-scope simulators. To be specific, INL's study has concentrated on offering and supporting additional data beyond what KAERI and U.S. NRC are collecting through full-scope simulator as well as collecting specific data for digital MCRs and dynamic HRA.

The present study represents as an early effort to collect HRA data using the simplified Rancor Microworld simulator. This study aims to experimentally investigate whether students could be used as subjects for collecting HRA data instead of actual operators. To achieve this goal, this study tries to compare human performance between actual operators and students measured across benchmark experiments. Six human performances measures—i.e., 1) average completion time per instruction, 2) the number of secondary tasks, 3) error rate, 4) workload, 5) situation awareness, and 6) patterns of attention—are measured from the experiments. Then, these are compared and analyzed using appropriate statistic methods.

2. Overview of the Rancor Microworld

The Rancor Microworld is a simplified simulation environment designed to reproduce important characteristics of real situations while leaving open the possibility of manipulation and experimental control [6]. It examines theoretical and practical concepts related to process control as well as providing a graphical user interface that would allow the researchers to create process control systems in a generic manner. Fig. 1 shows a part of the Rancor Microworld interface.

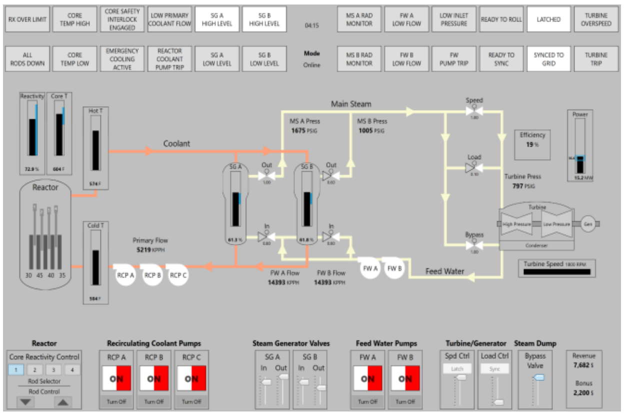

Fig. 1. A part of the Rancor Microworld interface

Experiments with simplified simulators like the Rancor Microworld have several distinguishing features in comparison with these full-scope experiments. For the full-scope studies, it is highly favorable to collect HRA data regarding high fidelity to actual NPPs, but the simulators as well as the participants like actual operators are rare and costly. Furthermore, the scenarios with full-scope simulators are relatively complex to set up, take a long time to be finished, and require professional expertise to be analyzed with high reliability. On the other hand, for the simplified simulator, it is possible to get large sample sizes by considering less experienced participants like non-licensed operators or students. Additionally, the simulator is simple to develop and customize for specific experimental conditions.

Fig. 2 indicates a data classification that can be collected at different levels of tasks and simulators. The Rancor Microworld collects data which is close to the minimum scenario level. As a simple simulator, Rancor focuses mainly on how operators use their perception to gather information and make decisions that are confounded by the complexity in full-scope simulator studies. How quickly the operators find information, or how they comprehend at a glance are the examples that can be observed with Rancor.

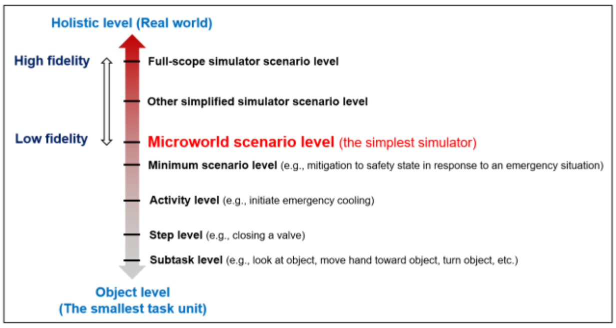

Fig. 2. A data classification that can be collected at different levels of tasks and simulators

3. Experimental Design

In this study, a randomized factorial experiment was designed to compare human performance between actual operators and students. The details of the experimental design include the following.

3.1 Independent variables

The experimental design is controlled by two independent variables, i.e., type of subject and scenario. Table I shows the experimental design based on randomized factorial experiment design. The type of subject is categorized into actual operators and students, which is a measure of experience, while the scenarios are classified into simple vs. complex.

Table I: Experimental design – a randomized factorial experiment design

Type of subject	Scenarios	
	Simple	Complex
Actual operators		
Students		

Several scenarios under start-up operation, abnormal operation and emergency operation are imbedded in the Rancor Microworld. Faults can be embedded into the scenarios, e.g., masking of indicators, to increase the complexity.

3.2 Human performance measures

This study measures the six human performance measures discussed previously, i.e., 1) average completion time per instruction, 2) the number of secondary tasks, 3) error rate, 4) workload, 5) situation awareness, and 6) patterns of attention. Following are brief explanations of each performance measure.

Table II: Brief explanation on each human performance

Human performance	Description
Average completion time per instruction	✓ Average time to complete a procedure instruction
The number of secondary tasks	✓ Interface management tasks such as configuring, navigating and arranging the interface
Error rate	✓ Deviation of operator task performances from the procedure
Workload	✓ Psychological and physical workload ✓ Estimated by the modified Cooper-Harper rating scale (MCH) questionnaires
Situation awareness	✓ Perception of elements in the environment within a volume of time and space, comprehension of contextual meaning, and the projection of the status of the elements in the near future ✓ Estimated by Situation Awareness Rating Technique (SART) questionnaires
Patterns of attention	✓ Proportion that focus on major information among alarm, primary system, steam generator and turbine system ✓ Estimated by eye tracking system

3.3 Subjects

The experiments will involve at least twenty subjects and one subject respectively participates in each scenario. For the subjects included in "Actual operators" group, they are composed of operators who have operating licenses for Korean nuclear power plants, while the subjects in "Students" group consist of university students studying in the Department of Nuclear Engineering at Chosun Univeristy.

3.4 Facility and data acquisition

As shown in Fig. 1, the Rancor Microworld simulator is used in experiments. It is portable because the software is installed on a laptop. The experiments could be performed at any place with a desk and a chair.

Operator performance data introduced in Section 3.3 are collected through observation, audio/video recording, eye tracking equipment, and simulator log data.

3.5 Experiment procedure

Each subject performs all the scenarios. Each scenario takes approximately 10 minutes, which is highly short compared with full-scope experiments. In addition, prior to conducting the scenarios, an introductory session is held to provide an overview of the experiment and ensure adequate baseline performance.

4. Discussion

This study aims to compare human performance between actual operators and students measured from the experiments, specifically to identify whether the students could be used as test subjects for collecting HRA data instead of actual operators. The outcome of this study is not included in this paper, but will be provided at the conference.

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