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A Comparison of Human Error Probabilities Collected from the HuREX and SHEEP Frameworks

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INTRODUCTION

Collecting the human reliability data needed for estimating human error probabilities (HEPs) is a major research topic in human reliability analysis (HRA). Recent studies have focused on collecting such data by having actual operators licensed for nuclear power plants run a full-scope main control room (MCR) simulator. Currently, the largest such efforts are being led by the U.S. Nuclear Regulatory Commission (U.S. NRC) and the Korea Atomic Energy Research Institute (KAERI). Both organizations have collected HRA data from full-scope MCR simulators and actual operators via the Scenario Authoring, Characterization, and Debriefing Application (SACADA) [1] and Human Reliability Data Extraction (HuREX) [2] research projects, respectively.

Idaho National Laboratory (INL) has its own approach for collecting HRA data. Rather than using full-scope simulator studies, INL collects HRA data using the Simplified Human Error Experimental Program (SHEEP), which depends on student participants operating simplified simulators [5] (e.g., Rancor Microworld [3] and the Compact Nuclear Simulator [4]). The SHEEP framework, which is intended to complement—not replace—full-scope studies such as HuREX or SACADA, mainly collects HRA data for estimating nominal/basic HEPs needed in the HRA quantification process.

This paper discusses how the HEPs collected from the HuREX and SHEEP frameworks are seen to differ. This study is a foundational research for inferring full-scope HRA data based on the data collected from the SHEEP framework. For the comparison, we used HEPs in the HuREX database published in KAERI-TR-6649 [6]. These HEPs were collected from actual licensed operators manipulating MCR simulators of the Westinghouse type or Optimized Power Reactor (OPR1000) type in South Korea. On the other hand, the HEPs based on the SHEEP framework were collected from both actual licensed operators and students, using a simplified simulator (i.e., Rancor Microworld).

THE HUREX FRAMEWORK

Table I shows every task type suggested in the HuREX framework. It collects 20 task types, categorizable into five cognitive activity types: (1) information gathering and reporting (IG), (2) response planning and instruction (RP), (3) situation interpreting (SI), (4) execution (EX), and (5) other (OT). Details on these task types are provided in KAERI-TR-6649 [6]. For this technical report, 223 experiment records were analyzed in order to estimate HEPs.

Table I. Task Types in the HuREX Framework [6]

Cognitive Activity	Task Type
Information Gathering and Reporting (IG)	IG-alarm
	IG-indicator
	IG-synthesis
	IG-value
	IG-comparison
	IG-graph
	IG-abnormality
	IG-trend
Response Planning and Instruction (RP)	RP-entry
	RP-procedure
	RP-step
	RP-information
	RP-manipulation
	RP-notification
Situation Interpreting (SI)	SI-diagnosis
Execution (EX)	EX-discrete
	EX-continuous
	EX-dynamic
	EX-notification
Other (OT)	OT-manipulation

THE SHEEP FRAMEWORK

The SHEEP framework consists of three steps: (1) identification of HRA items collectible in a simplified simulator, (2) treatment of these HRA items based on experimentation, and (3) integration of the data into a full-scope database for deployment in HRA methods.

The first step classifies all HRA data items collectible in any type of simulator into two groups: (1) items collectible in both simplified and full-scope simulators, and (2) items only collectible in simplified simulators. The second step suggests how experimentation can be used to treat the relevant HRA items classified in the first step. For those HRA items that are collectible in both simplified and full-scope simulators, this step involves differentiating the participant type (i.e., operator vs. student) and simulator complexity (i.e., simplified vs. full-scope). This study design sets the stage for collecting the data needed to develop full-scope inference models in the next step. In the case of the HRA items that are only collectable in a simplified simulator, this step contributes to gathering new HRA data missed by full-scope simulators. The last step entails integrating experimental data obtained in the previous step into the HuREX database and potentially incorporating them into HRA methods.

In this paper, HEPs from 240 experiment records collected from 20 operators and 20 students, all using Rancor Microworld, were employed for the comparison. Details on the experimental design are found in the author's previous research [5, 7].

Table II. Comparison of HEPs from the HuREX and SHEEP frameworks

Cognitive Activity	Task Type	HUREX Study		SHEEP Study (Using Rancor Microworld)			
		HEP (EOO)	HEP (EOC)	HEP (EOO) - Student	HEP (EOC) - Student	HEP (EOO) - Operator	HEP (EOC) - Operator
Information Gathering and Reporting (IG)	IG-alarm	2.208e-3	-	-	-	-	-
	IG-indicator	8.764e-4	-	-	4.380e-03	-	-
	IG-synthesis	-	-	-	-	-	-
	IG-value	-	8.264e-3	-	-	-	-
	IG-comparison	-	1.519e-2	-	-	-	-
	IG-graph	-	-	-	-	-	-
	IG-abnormality	-	-	-	-	-	-
	IG-trend	-	1.790e-2	-	-	-	-
Response Planning and Instruction (RP)	RP-entry	3.205e-3	-	-	-	-	-
	RP-procedure	3.953e-3	-	-	4.545e-02	-	2.222e-02
	RP-step	5.634e-2	-	2.014e-03	7.049e-03	9.165e-03	6.110e-03
	RP-information	3.466e-3	1.386e-3	-	-	-	-
	RP-manipulation	4.819e-2	1.566e-2	-	-	-	-
	RP-notification	1.721e-2	1.912e-3	-	-	-	-
Situation Interpreting (SI)	SI-diagnosis	-	2.667e-1	-	-	-	-
Execution (EX)	EX-discrete	1.545e-2	2.809e-3	1.490e-03	-	1.512e-03	-
	EX-continuous	-	-	-	4.137e-02	8.850e-03	2.124e-02
	EX-dynamic	-	6.667e-3	-	5.000e-01	-	3.488e-01
	EX-notification	5.859e-3	5.859e-3	-	-	-	-
Other (OT)	OT-manipulation	-	-	-	-	-	-

HUMAN ERROR PROBABILITY COMPARISON BETWEEN THE HUREX AND SHEEP FRAMEWORKS

Table II represents a comparison of error rates taken from the HuREX and SHEEP studies. The errors are divided into errors of omission (EOOs) and errors of commission (EOCs). EOOs are caused by omitting a task, whereas EOCs correspond to 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) [8].

An HEP comparison between the operator group and the student group reveals all the values to be within a difference of approximately five times. Representatively, in the SHEEP study, the EOO HEPs for students (2.014e-3) and operators (9.165e-3) for RP-step show the largest difference: 4.55 times more errors. Second, regarding the HuREX data, the EOO HEP for RP-step, the EOO HEP for EX-discrete, and the EOC HEP for EX-dynamic are comparable to the Rancor Microworld data. The students' EOC HEP for EX-dynamic shows the largest difference (approximately 75 times more errors) when compared to the operators' error rates.

When we compare the number of EOOs and EOCs counted, the student and operator data collected from Rancor Microworld reflect more EOCs than EOOs, though the opposite is true for the HuREX data. In fact, the reason behind the lower number of EOOs in the Microworld data is straightforward, since the system's reduced complexity lends itself to lower likelihoods in order to omit certain tasks. However, the number of EOCs seems relatively high in both groups when using the simplified simulator. In the Microworld data, we saw that most EOCs observed in the experiment corresponded to "Rule Violations." As a representative example, Student #1, Student #11, and Operator #6 in the experiment moved to the next step, though the current step they were on had not been finished—reactivity did not reach 20% in Scenario 1 (i.e., fully automated startup [0–100%]). Although difficult to conclude without additional experimentation regarding simulator complexity, transitioning from a full-scope simulator to a simplified one may result in a larger number of violations than omissions. Thus, it may be inferred that using a simplified simulator contributes to reducing the number of EOOs but increasing the number of EOCs.

CONCLUSION

This study represents an ongoing effort to provide additional data to support and complement full-scope studies. The outcomes of this study will contribute to understanding the differences in human performance and error between different data collection frameworks, as well as inferring full-scope data based on the data collected from the SHEEP framework.

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