Application of HERA for a qualitative error analysis of an emergency scenario

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1. Introduction

According to the need for data for a human reliability analysis (HRA), a number of data collection efforts have been undertaken in several different organizations [1, 2]. The Human Event Repository and Analysis (HERA) system [3] developed by Idaho National Laboratory for the US Nuclear Regulatory Commission (NRC) is also one of them. This paper summarizes the process and results of the HERA analysis including discussions about the usability of the HERA system for a human error analysis of simulator data. Five simulated records of a steam generator tube rupture (SGTR) scenario were analyzed with the HERA analysis process to scrutinize the causes and mechanisms of the human related events.

2. HERA Analysis

The overall process of this study can be summarized as follows.

- Step 1: task analysis on the emergency tasks stipulated in the procedures
- Step 2: protocol / timeline analysis on the five simulator records
- Step 3: HERA analysis (using HERA Worksheets A and B)

2.1 Task Analysis

In order to understand how the crews responded to the event under the simulated scenario, first a task analysis was performed for the procedures of the reference plant that the crews should follow in emergencies [4]. All the procedural tasks to be carried out by the crew during the simulations were analyzed and summarized as follows.

1. A main steam line break and a coincident SGTR occur
2. Crew checks alarms and plant status
3. Reactor trips
4. Crew enters emergency operation procedure (EOP) E-0, carries out step 1 through step 25
5. At Step 25, the crew can make a decision for further response and diagnose the event by taking one of three following responses:
   a. Wait until pressurize level goes up 6% at step 25 (but this would take a long time, and as a result, is not the most appropriate response)
   b. Re-diagnose the event after implementing the remaining steps of E-0 (from step 27 to step 35). The event can be diagnosed at step 28 (level of any SG goes up uncontrollably)
   c. Diagnose the event through the procedure of re-diagnosis (ES 0.0) at step 25 or any other step in E-0.

2.2 Protocol/Timeline Analysis

In order to identify the crews' behaviors in chronological order, protocol and timeline analyses [5] were performed on the five simulator records. All the communication protocols among the members of crews were recoded along with the procedural tasks that were already identified from the task analysis. Additionally, time information, such as when they started or finished a certain procedural step, could be derived from the timeline analysis. Through the protocol and timeline analyses, the analyst identified or at least presumed all the information to be processed and undertaken by the crew, which was critical information to complete HERA Worksheet A.

2.3 Human Error Analysis

After fully understanding what the task and context of the simulator record were, the analyst started to complete Worksheet A. Based on the results of the protocol and time line analysis, all the crews' responses were summarized into the Section 3 (event timeline) of Worksheet A in chronological order. All the subevents were coded according to the guideline of the HERA system [6]. All human fault or success subevents (XHEs or HSs, respectively) were identified based on the predefined recommended response paths. Finally, the analyst selected the XHE and/or HS subevents that qualified for a further detailed analysis in Worksheet B among the identified human failure or success events.

Each selected XHE or HS event received a detailed PSF analysis according to the guideline of the HERA system. Contributing factors that affected a human event either positively or negatively were identified in detail, and the relevant cognitive processes and error types were also identified using the systematic taxonomies supplied by using HERA Worksheet B.

3. Analysis Results

From the HERA study on the five simulator records, a total of 133 subevents and 62 human subevents were identified (9 human fault events and 53 human success events). Among them, 19 subevents (9 XHEs and 10 HSs) were analyzed in detail to scrutinize the cause and mechanism of the events according to Worksheet B.

Table 1 summarizes the events defined in the HERA study.

Table 1. Events defined in the HERA study

Crew ID	# of subevents	# of human failure events (XHEs)	# of human success events (HSs)
A	27	3	9
B	28	0	11
C	28	5	8
D	24	0	12
E	26	1	13
Total	133	9	53

In Table 2, we have summarized the error types and related performance shaping factors (PSFs) (in other words, contributory factors) that were identified from the HERA analysis. Four types of error were observed during five simulations: misdiagnosis, two different types of omission, and delay. Two misdiagnosed events were observed in crews A and C, and five errors of omissions, whereby crews skipped a procedural step, were identified in crews C and E. As for crew C, they made several omission errors consecutively after losing their control over the situation. There was another type of omission error in crew A, skip the whole procedure of the CSF status tree, which is required to be carried out independently when they move to another procedure from the E-0 procedure. One delay error was observed in crew A.

Table 2. Error types and relevant contributory factors

Error types	Major negative contributory factors	Relevant XHEs
Misdiagnose the situation & event	• Time pressure to complex task • High stress • Information fails to point directly to the problem, presence of multiple faults • Not familiar/well practiced task • Procedure/reference document technical content LTA (less than adequate) • Alarms/annunciators LTA • Procedure adherence LTA, poor understanding	A-XH1, C-XH2
Omission (skip a procedural step)	• Time pressure to complete task • High stress • Work practice or craft skill LTA • Self-check LTA • Crew interaction style not appropriate to the situation	C-XHE1, XHE3, XHE4, and XHE5, E-XHE1
Omission (omit to start CSF tree procedure)	• Information fails to point directly to the problem, presence of multiple faults • Not familiar/well practiced with task	A-XHE3
	• Inadequate staffing/task allocation, procedural adherence LTA	
Delay action (late reporting)	• Information fails to point directly to the problem, presence of multiple faults • Not familiar/well practiced task • Alarms/annunciators LTA • Recognition of adverse condition/questioning LTA • Team interactions less than adequate	A-XHE2

4. Conclusions

A human performance analysis on a set of simulator records was undertaken, using the HERA system. Five simulator records of an SGTR complex scenario were analyzed to identify the human success/fault events and to scrutinize the relevant PSFs along with the contributory factors according to the analysis process and structure of the HERA.

This study confirmed that the HERA was a useful tool to qualitatively analyze human performance from simulator records. It was possible to identify the human related events in the simulator records, affecting the system safety not only negatively but also positively, and to scrutinize the PSFs and relevant contributory factors with regard to each identified human event. Since it provides a systematic analysis process and a comprehensive taxonomy to support human performance analysis, it is expected that users could apply it to build a database as a technical basis supporting both an HRA and human factors management in NPPs. Additional research and modification efforts in the area related to the taxonomy of the contributory factors might further enhance HERA's usability and consistency.

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