Study on Performance Shaping Factors (PSFs) Quantification Method in Human Reliability Analysis (HRA)

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1. Introduction

Operation performance information systems (OPIS) database revealed that 127 (18.4%) among 690 incidents occurred because of human errors in nuclear power plants (NPPs) between 1978 and 2014 [1]. Human reliability analysis (HRA) seeks to evaluate the potential for, and mechanisms of, human error that may affect plant safety [2]. The purpose of HRA implementation is 1) to achieve the human factor engineering (HFE) design goal of providing operator interfaces that will minimize personnel errors and 2) to conduct an integrated activity to support probabilistic risk assessment (PRA). For these purposes, various HRA methods have been developed such as technique for human error rate prediction (THERP), simplified plant analysis risk human reliability assessment (SPAR-H), cognitive reliability and error analysis method (CREAM) and so on. In performing HRA, such conditions that influence human performances have been represented via several context factors called performance shaping factors (PSFs). PSFs are aspects of the human's individual characteristics, environment, organization, or task that specifically decrements or improves human performance, thus respectively increasing or decreasing the likelihood of human errors [3]. Most HRA methods evaluate the weightings of PSFs by expert judgment and explicit guidance for evaluating the weighting is not provided. The aim of the study is to suggest quantifying framework for PSF weightings by using objective data.

2. Existing methods to quantify PSFs

Human error probabilities (HEPs) can be increased or decreased due to the effect of context factors which are called PSFs such as operators' stress, training and so on. Accordingly, existing HRA methods have suggested their own PSFs with different definitions, their scope and different terminology. The suggested PSFs for each HRA method and evaluation approach are represented below.

- THERP [4]
  1) Suggested PSFs: Physiological stressors, Psychological stressors, Task and equipment characteristics, Organismic factors, Situational Characteristics, and Job and task characteristics
  2) Evaluation approach: THERP relies on the experience and judgment of human factors specialist to assess the impact of PSFs.

- HEART [5]
  1) Suggested PSFs: A channel capacity overload, A need for absolute judgments which are beyond the capabilities or experience of an operators, Operator inexperience, A shortage of time available, No clear, Direct and timely confirmation of an intended actions, and etc.
  2) Evaluation approach: The assessors judge the effect of error producing conditions (EPCs) in the contextual situation.

- SPAR-H [6]
  1) Suggested PSFs: Available time, Complexity, Procedures, Fitness of duty, Stress/stressors, Experience/training, Ergonomics/HSI, Work process
  2) Evaluation approach: PSF multipliers apparently based on the authors' observation/review of event statistics and on a comparison with data in existing HRA methods.

- CREAM [7]
  1) Suggested PSFs: Adequacy of HSI and operational support, Working conditions, Adequacy of organization, Adequacy of training and experience, and etc.
  2) Evaluation approach: The analyst assigns the ratings of the common performance conditions (CPCs) to calculate the combined CPC score and determine the most likely control mode.

As mentioned above, those HRA methods assess PSFs by expert judgment. In addition, most HRA methods like INTENT, ATHEANA and IDAC also assess PSFs by expert judgment [8-10].

3. A framework to quantify PSF weightings

The original baseline HEP can be obtained based on the differences in the PSF profile [11]. It is necessary to describe each human error datum according to its task context, and to describe it in terms of PSF. Each error datum should also ideally be described in terms of the same PSF, so that comparison and extrapolations can be made between data. Thus, it creates a PSF profile for each datum.

For example, let us assume that there are four tasks as shown in Fig. 1 and Fig. 2. Each task can be described by using PSF profile. In case 1, the only difference between task 1 and task 2 is "procedure" PSF. Thus, if task A has an error probability of 0.001 and task B has an error probability of 0.002, then the effect of "procedure" PSF can be expected as 2. Also, if task C has an error probability of 0.0014 and task D has an error probability of 0.01, then the effect of "training" PSF can be expected as 7.14. In this manner, it is possible to quantify PSFs.

Fig. 1. Example of PSF profiling: Case 1 – Different PSF profiles between Task A and Task B (Procedure)

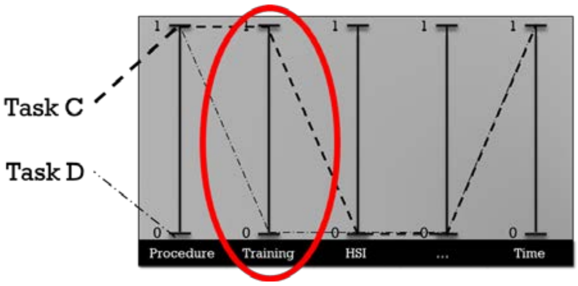

Fig. 2. Example of PSF profiling: Case 2 – Different PSF profiles between Task C and Task D (Training)

4. Case study

In order to apply the framework to quantify PSF weightings, case study was performed. We select eight tasks, its human error probability PSFs for all eight tasks were assessed.

We used human error probability data from [12] and calculated error probability by using zero failure probabilities [13] as shown in Table I.

Estimation of PSFs for each task was performed. We consider nine PSFs such as stress level, action type, experience, time constraints, situational characteristics, procedures, training, HSI, and teamwork. Based on human factor (HF) issues in main control room (MCR), we developed decision trees and its guidance to estimate PSFs to enhance consistency and minimize experts' subjective opinion in evaluation of PSFs. The result of PSFs estimation is presented in Table I.

Table I: The estimation result of PSF and HEP

	PSFs (stress level/action type/experience/time constraints/situational characteristics/procedures/training/HSI/teamwork)	HEP
Task #1	EH/SBS/skilled/Poor/ MCR/40/Normal/Good /Good	0.357
Task #2	MH/SBS/skilled/Good/ MCR/40/Good/Poor/ Good	0.214
Task #3	MH/SBS/skilled/Good/ MCR/40/Good/Good/ Good	0.500
Task #4	EH/SBS/skilled/Good/ MCR/40/Good/Good/ Good	0.357
Task #5	MH/SBS/skilled/poor/ MCR/40/Normal/Good / Good	0.071
Task #6	MH/SBS/skilled/Good/ MCR/20/Good/Good/ Good	0.928
Task #7	MH/SBS/skilled/Good/ MCR/40/Good/Good/ Good	0.071
Task #8	MH/SBS/skilled/Good/ MCR/40/Good/Good/ Good	0.071

The result of PSF profiles for eight tasks were shown in Fig. 3. From the analysis of PSF profiling, the prototypical rules were derived to calculate PSF weighting as below.

1. **IF** [Time constraint] is [less than 20 minutes], **THEN** HEP Ｘ22.3
2. **IF** [HSI] is [Poor], **THEN** HEP Ｘ 3
3. **IF** [Stress level] is [Moderately high], [Procedure] is [Poor], and [Time constraint] is [more than 40 minutes], **THEN** HEP Ｘ 5

In this way, it is possible to obtain the prototypical rules to assess PSFs. Due to insufficient data, we derived only three prototypical rules, but more rules can be obtained with sufficient data.

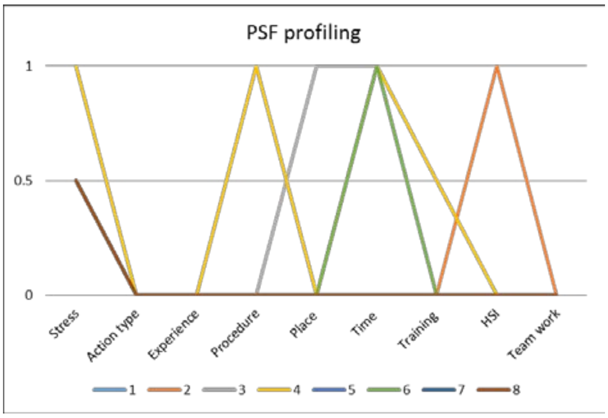

Fig. 3. The result of PSF profiles for eight tasks

5. Conclusion

It has been widely known that the performance of the human operator is one of the critical factors to determine the safe operation of NPPs. HRA methods have been developed to identify the possibility and mechanism of human errors. In performing HRA methods, the effect of PSFs which may increase or decrease human error should be investigated. However, the effect of PSFs were estimated by expert judgment so far. Accordingly, in order to estimate the effect of PSFs objectively, the quantitative framework to estimate PSFs by using PSF profiles is introduced in this paper. Also, we performed case study to apply the framework. With sufficient simulation data, it is expected that the realistic effect of PSFs can be estimated objectively.

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