Recent Empirical Studies on Influential Factors in the Diagnosis Reliability of Operators

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1. Introduction

A diagnosis, which implies the identification of the most plausible causes of off-normal events, has been recognized as an important task for securing system safety [1]. Many HRA (human reliability analysis) methods have thus presented the models to quantify the human error probability (HEP) of a diagnosis. In this paper, we reviewed the influential factors considered in the HRA methods and examined the findings of recent empirical studies. Based on the findings of empirical results, the implementation of traditional HRA methods is discussed.

2. Diagnosis Errors in HRA Methods

2.1 THERP, ASEP & K-HRA

The nominal diagnosis failure model, which is represented by a time-reliability curve, was proposed in the THERP method (refer to as Fig. 1), and this model has been also employed in the ASEP and K-HRA methods [1-3]. Although the authors of the THERP handbook understood that there are the wide range of cognitive activities in the operations of plants, the diagnosis of off-normal events was regarded as an only cognitive behavior owing to a lack of empirical data and the usefulness of the application. It is also supposed that the diagnosis failure model involves failures in the perception, interpretation, diagnosis, and a portion of the decision-making.

The time required is the most influential factor in the diagnosis HEP; however, the THERP and ASEP methods allow an adjustment of the diagnosis HEP based on training experience or task familiarity [1, 2]. In addition, the HEP can also be recalculated by the stress and expertise levels. The K-HRA method has different additional factors. The priority of the task, man-machine interface, procedure quality, training/experience level, and degree of decision-making burden are the adjusting factors of the diagnosis HEP.

2.2 SPAR-H

In SPAR-H method, the diagnosis error is the main aspect of the HEP quantification [4]. The diagnosis task defined in this method entails the entire spectrum of cognitive processes including an interpretation of the plant information, an understanding of the ongoing situation, and the formulation or decision to execute counter-measures. Although 1.0E-2 was assumed as a nominal HEP of the diagnosis, eight factors were presented for multiplying the nominal HEP of the diagnosis: the available time, stress/stressors, complexity, experience/training, procedures, ergonomics/interface, fitness for duty, and work processes.

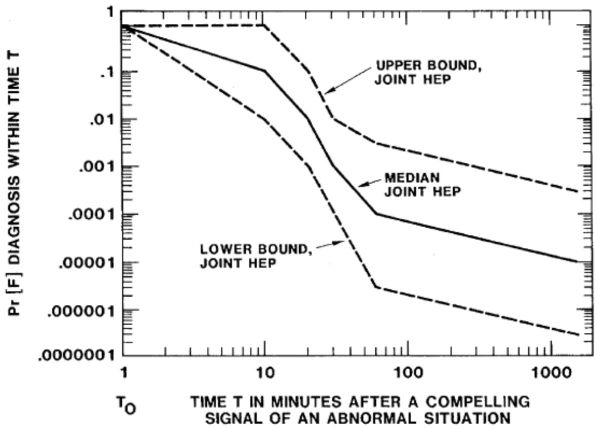

Fig. 1. The diagnosis HEP model estimated based on the response time [1].

2.3 CREAM

The extended version of the CREAM method provides a set of generic failure types with their basic HEPs [5]. The faulty diagnosis is one of the generic failure types that belongs to a cognitive activity, interpretation. CREAM also presents influential factors and their weights to the HEPs for each cognitive activity. The influential factors in the interpretation activity are (1) working conditions, (2) number of simultaneous goals, (3) available time, (4) time of day, (5) adequacy of training and preparation, and (6) crew collaboration quality.

2.4 HCR/ORE and CBDTM

Although the HCR/ORE and CBDTM developed by EPRI to estimate the failure rate in initiating a timely and correct response do not distinctively categorize a diagnosis error, it is assumed that the correct initiation response encompasses diagnosis activities of an operator [6]. The HCR/ORE provides another type of time-reliability curve for this kind of HEP; hence, the time is the only influential factor of the HEP. However, the CBDTM considers the interactions between the plant situation and operator response, and the interactions between the procedures and operator responses when the operator should make a decision of a correct action. Lots of factors for the decision making process were included, such as the indicator accuracy, training experience, workload, alarm annunciation, formal communication, and procedure quality and clarity.

3. Recent Empirical Studies

3.1 OPERA Database

A statistical analysis of the OPERA database obtained by the HuREX framework showed that the diagnosis HEP can be affected by the time pressure [7,8]. In these data, however, it was also revealed that most cases in the urgent situation, which leads to lots of unsafe acts (failure: 6; success: 2), is also correlated with the unfamiliarity and absence of a procedural cue. In other words, the operators encountered a scenario that have never been seen before, and the procedure provided possible causes except for the inputted malfunction. On the other hand, during an abnormal situation where more than 30 minutes remain to cope with the situation, sixteen attempts were successful while two operators conducted unsafe acts. The four operators under an emergency situation found the leak location of systems when they had to follow a procedure.

3.2 Full-Scope Simulator Study-1

Kim et al. estimated the diagnosis HEPs based on the data obtained from both domestic full-scope simulator experiments and Halden Human-machine Laboratory experiments [9]. Based on the counted number of errors with the available time, it can be inferred that the diagnosis HEP is not relatively high when the task is urgent. For example, many operators inadequately performed the two kinds of urgent tasks. However, these tasks were also coped with low-quality procedures. In other cases, one of the most urgent tasks (available time = 4 min.) were satisfactorily conducted by all seven operators. Moreover, there is a task that no operator successfully performed during a lengthy available time (100 minutes). Kim et al. reported that this task was performed when insufficient information is provided from the procedures and indicators.

3.3 Full-Scope Simulator Study-2

Park et al. collected the human performance data from a computer-based full-scope simulator [10]. From this experiment, whose factors among the operator experience, time urgency (more than 30 minutes or not), and task complexity have an impact on the following human performance indices: the completion time, HEP including cognitive or executive error rates, workload, situation awareness, and so forth. From the statistical analysis, it was found that the operator experience was associated with the performance indices including HEPs, the task complexity was influential in terms of situation awareness, and the time urgency was not related with any performance index. This result does not mean that the time urgency is insignificant to the human reliability, but other factors to be included also exist.

4. Considerations for HRA Application/Research

Because deriving concrete findings from empirical data requires lots of samples and results in various environments, it is necessary to be careful when concluding the influential factors in terms of diagnosis reliability. However, from the brief survey of the HRA methods and the empirical studies, we deduced some considerations of a HRA application regarding the diagnosis task.

The definition of a diagnosis can be differently interpreted according to the purpose of HRA research and applications. For example, some HRA methods assumed a diagnosis error as a failure of the response to the cognitive cues requiring operational behaviors. It was assumed that the related cognitive processes (e.g., perception, diagnosis, and response planning) pertain to a failure of the cue response. Some other researches have focused on a failure to attribute a likely cause for the given symptoms where the procedures or other cues explicitly require the diagnosis task. When any diagnosis HEP is assessed, the definition of the diagnosis of the HRA method should be carefully understood.

While many HRA methods mainly rely on the time information when a diagnosis HEP is determined, the empirical studies tend to emphasize the other kinds of factors such as the procedure, task familiarity, and operator experience. Some results might be interpreted as the time factor having inter-relative effects with other factors instead of driving effects of the human error. In particular, because the diagnosis HEP model of THERP is highly speculative, an adjustment of the model or the development of a new model is desirable [1, 11]. For example, a method that allows supplementary factors to adjust the diagnosis HEP can be developed such as the K-HRA. Another promising solution is the mixed usage of the time-dependent model and context-dependent model such as HCR/ORE and CBDTM methods. The EPRI recommends HRA practitioners to calculate the two cognitive HEPs using both methods and take a higher HEP from them [6].

We are also collecting empirical data for the operators in computer-based control rooms and plan to establish a diagnosis HEP model from the collected data.

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