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Identifying objective criterion to determine a complicated task – A comparative study

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ABSTRACT

A reliable estimation on the likelihood of human error is very critical for evaluating the safety of a large process control system such as NPPs (Nuclear Power Plants). In this regard, one of the determinants is to decide the level of an important PSF (Performance Shaping Factor) through a clear and objective manner along with the context of a given task. Unfortunately, it seems that there are no such decision criteria for certain PSFs including the complexity of a task. Therefore, the feasibility of the TACOM (Task Complexity) measure in providing objective criteria that are helpful for distinguishing the level of a task complexity is investigated in this study. To this end, subjective difficulty scores rated by 75 high-speed train drivers are collected for 38 tasks. After that, subjective difficulty scores are compared with the associated TACOM scores being quantified based on these tasks. As a result, it is observed that there is a significant correlation between subjective difficulty scores rated by high-speed train drivers and the associated TACOM scores. Accordingly, it is promising to expect that the TACOM measure can be used as an objective tool to identify the level of a task complexity in terms of an HRA (Human Reliability Analysis).

1. Introduction

There is no objection to the fact that the safety of large process control systems extensively depends on the performance of human operators. For example, the results of Probabilistic Safety Assessment (PSA) showed that a human performance related problem (e.g., human error) is determinant for the safety of Nuclear Power Plants (NPPs) in the Republic of Korea (KEPCO, 1997). In addition, Baysari et al. (2008) pointed out that about 50% of railway accidents and/or incidents in Australia are attributable to human error. Operation experience of other industries (including chemical plants, petro-chemical plants, marine and aviation industries) have shown similar insights (Helmreich, 2000; Kariuki and Lowe, 2007; Kim and Kim, 2015; Ren et al., 2008). Therefore, it is very important to reduce the likelihood of human error (i.e., Human Error Probability; HEP) as much as possible pertaining to important tasks that are able to significantly degrade the safety of the whole system (Yang, 2014). In this regard, various kinds of Human Reliability Analysis (HRA) methods have been developed for several decades (Forester et al., 2009; Hirschberg and Dang, 1996; IAEA, 1990; Pyy, 2008). In the context of the PSA, Forester et al. (2009) articulated the roles of the HRA as follows: (1) identifying accident scenario contexts and associated human actions, (2) quantifying the failure probability of each relevant human action, and (3) when necessary, identifying ways to improve human performance. These roles indicate that the quality of HRA results is very sensitive for evaluating the safety of NPPs.

However, it is not easy to obtain reliable HRA results because of several obstacles. One of them is the variability of HRA results. In order to explain this issue more clearly, for example, let us consider the catalog of important Performance Shaping Factors (PSFs) being included in two kinds of HRA methods, such as the Standardized Plant Analysis Risk – HRA (SPAR-H) method developed by US NRC (Nuclear Regulatory Commission) (Gertman et al., 2004), and K-HRA (Korean standard HRA) method developed by KAERI (Korea Atomic Energy Research Institute) (Jung et al., 2005).

Based on the catalog of PSFs, an HRA practitioner who would like to use either the SPAR-H or the K-HRA method needs to decide the level of each PSF based on the context of each human action being considered. For example, in the case of the SPAR-H method, the HRA practitioner has to determine the level of the *Procedure* through clarifying the following criteria (Gertman et al., 2004): (1) whether or not there are procedures specifying what has to be done by human operators (e.g., *Not available*), (2) whether or not the technical contents of procedures are complete (e.g., *Incomplete*), and (3) whether or not the format of procedures is

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appropriate and easy to use (e.g., *Available, but poor*). Similarly, from the point of view of the K-HRA method, the *Procedure* can be categorized into three levels along with the following criteria (Jung et al., 2005): (1) the goal and decision-making aspects, the sentence structure for situation assessment and planning, and the required actions of a task, including relevant warnings and/or cautions are so clearly described that human operators can easily understand them (e.g., *High*), (2) the goal and decision-making aspects, the sentence structure for situation assessment and planning, and the required actions of a task, including relevant warnings and/or cautions are briefly described or roughly presented such that human operators are required of some degree of judgment to understand them (e.g., *Medium*), and (3) the goal and decision-making aspects, the sentence structure for situation assessment and planning, and the required actions of a task, including relevant warnings and/or cautions are so poorly described or presented that human operators cannot easily understand them (e.g., *Low*). This means that the variability of HRA results originating from a subjectivity in identifying the level of the *Procedure* may be less significant because it can be determined by direct observables with relatively firm decision criteria.

In contrast, in terms of the *Complexity* of a task to be conducted by human operators, which is one of the common PSFs emphasized in both HRA methods, it is somewhat troublesome to determine its level due to a lack of baseline substantiated by one or more direct observables. The following definitions on the level of the *Complexity* being considered in the SPASR-H method are helpful for understanding this claim (Gertman et al., 2004).

- "*Highly complex* – very difficult to perform. There is much ambiguity in what needs to be diagnosed or executed. Many variables are involved, with concurrent diagnoses or actions (i.e., unfamiliar maintenance task requiring high skill).
- *Moderately complex* – somewhat difficult to perform. There is some ambiguity in what needs to be diagnosed or executed. Several variables are involved, perhaps with some concurrent diagnoses or actions (i.e., evolution performed periodically with many steps).
- *Nominal* – not difficult to perform. There is little ambiguity. Single or few variables are involved." (p. 29)

Similarly, the K-HRA method provides the following definitions to determine the complexity level of a task to be conducted by human operators (Jung et al., 2005).

- *Simple*: Simple and straightforward actions;
- *IF-THEN*: Procedure-guided tasks actions with IF-THEN rules;
- *Complex*: Continuous control tasks or tasks requiring the comparison and/or integration of several sources of information.

These definitions imply that additional guidance and/or criteria are indispensable for reducing variability in determining the *Complexity* level because it appears to be subjective and ambiguous to be actually used. For example, in the case of the SPAR-H method, HRA practitioners are apt to understand differently the meaning of several expressions, such as 'very difficult', 'somewhat difficult', and 'not difficult'. In addition, it is uncertain to apply the criteria of the K-HRA method if a required task demands human operators to carry out a lot of information comparisons and/or integrations that are included in a couple of *IF-THEN* rules.

Although many researchers have tried to provide more detailed criteria for several decades (Whaley et al., 2012), they also appear to be insufficient. A more serious issue is that most HRA methods regarding the *Complexity* as one of the significant PSFs are also faced with a similar obstacle. In this vein, Podofillini et al. (2013) pointed out that "Indeed, the application of current HRA methods is largely based on subjective evaluations (coming in at different stages of the analysis and to different extents, depending on the specific method and analyst knowledge/experience)." (p. 152) Subsequently, in order to reduce the variability of HRA results, the development of an objective criterion for determining the level of each PSF may be one of the most plausible countermeasures. It is to be noted that, for the sake of convenience, this issue will hereafter be referred to as a *task complexity issue in conducting an HRA*.

For this reason, Podofillini et al. (2013) investigated the feasibility of the TACOM (Task Complexity) measure as a promising tool for resolving *the task complexity issue in conducting an HRA*. To this end, they compared the TACOM scores of procedure-guided tasks to be conducted by human operators working in the Main Control Room (MCR) of NPPs with corresponding HEPs that are observed from the International HRA Empirical Study (Bye et al., 2010; Lois et al., 2009). The results of these comparisons are quite promising, in spite of a large uncertainty, because both the relative difficulty rankings and empirical HEPs of given tasks seem to increase in accordance with the increase of the associated TACOM scores. If the TACOM measure is meaningful for explaining the change of human performance, then it is expected that objective criteria to determine the level of a task complexity can be established in terms of TACOM scores.

In this study, in order to scrutinize this expectation in detail, task difficulty scores rated by high-speed train drivers are compared with the associated TACOM scores. In other words, if a similar tendency is identified from human operators who are working in entirely different task environments, then it is anticipated that the TACOM measure can be regarded as an objective tool for clarifying what a highly complex and moderately complex task are. To this end, in total 75 high-speed train drivers are asked to subjectively rate the difficulty level of 38 tasks, which is evaluated by using a five-point Likert scale. All of the respondents are male, and they are working in the same railway company in the Republic of Korea. As a result, it is observed that there is a significant correlation between subjective difficulty scores rated by high-speed train drivers and the associated TACOM scores. Since it is believed that human operators may feel a difficulty in conducting a complicated task, this result can be thought of as an important clue supporting that an objective criterion to distinguish complicated tasks will be determined along with a sound technical underpinning.

The remainder of this paper is organized as follows. As the background of this study, brief explanations on both the TACOM measure and the International HRA Empirical Study are given in Section 2. Then detailed processes pertaining to additional data collections from high-speed train drivers are explained in Section 3. Based on these data, the results of comparisons between subjective difficulty scores rated by high-speed train drivers with the associated TACOM scores are interpreted in Section 4. Finally, a brief conclusion is drawn in Section 5 with some discussions based on existing literature supporting the result of this study.

2. Background

As already mentioned in the previous section, it is necessary to develop additional criteria that allow HRA practitioners to properly decide the level of significant PSFs under the context of a given task. From the point of view of representing the level of a task complexity, one promising attempt could be the use of the TACOM measure.