Can we determine the complexity level of a proceduralized task?

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1. Introduction

It is obvious that the safety of nuclear power plants (NPPs) is the most important prerequisite for their sustainability. In this regard, since the operation experience of NPPs has continuously emphasized that the degradation of human performance (e.g., human errors) is one of the significant causes deteriorating their safety [1]. Accordingly, it is necessary to reduce the likelihood of human errors (human error probability, HEP) in a systematic way. In this regard, determining the level of task complexities would be meaningful because the complexity of a task is recognized as a key performance influencing factor (PIF). In this study, the feasibility of determining the complexity level of a task is investigated based on existing empirical results.

2. Method and Results

2.1 Catalog of representative PIFs and complexity measure

Table I summarizes the catalog of representative PIFs being considered for investigating the performance of human operators working in the main control room (MCR) of NPPs.

Table I: Catalog of Representative PIFs

No.	Ref.[2]	Ref.[3]	Ref.[4]
1	Experience and training	Experience and training	Experience and training
2	Procedural guidance	Procedure	Procedure
3	-	-	Environment
4	HMI* and indication of conditions	Ergonomics and HMI	Ergonomics and HMI
5	Adequacy of time	Available time	Available time
6	Scenario and execution complexity	Diagnosis and execution complexity	Complexity
7	Stress	Stress and stressors	Stress and stressors
8	Crew (team) dynamics	-	Crew (team) dynamics and characteristics
9	Work process	Work process	Work process
10	Communication	-	Communication

*Human Machine Interface

From Table I, it is evident that the complexity of a task to be done by human operators is very important for understanding the performance of human operators (refer to a box highlighted by a dark color). For this reason, Park proposed a measure namely TACOM (Task Complexity) that allows us to quantify the complexity score of a task included in a procedure (i.e., proceduralized task) [5]. In brief, the TACOM measure can evaluate the complexity of a proceduralized task based on the integration of five submeasures: (1) step size complexity, (2) step size complexity, (3) step logic complexity, (4) abstraction hierarchy complexity, and (5) engineering decision complexity.

2.2 Comparing TACOM scores with human performance data

One of the benefits expected from the TACOM measure is that it allows us to objectively evaluate the complexity score of a procesuralized task based on its contents. In other words, the TACOM score of a given procesuralized task can be calculated by the layout of HMIs to be used for conducting the required task with the associated task descriptions. Due to this benefit, it is possible to compare the effect of task complexities on the performance of human operators available from other studies. It should be noted that the performance of human operators can be represented by three dimensions such as effectiveness, efficiency, and indirect dimension. In short, the effectiveness dimension denotes the accuracy (e.g., human errors) while the efficiency and the indirect dimension imply the amount of dedicated resources that are directly demanded by the task (e.g., task performance time) and the amount of mental efforts invested during the performance of a task rather than directly from the task requirements (e.g., workload), respectively [6, 7].

In this light, TACOM scores were compared with diverse human performance data, and it was observed that there are significant correlations with respect to three kinds of the human performance dimensions [8]. The more interesting point is that there is a certain range of TACOM scores, in which the performance of human operators is drastically changed. For example, in terms of the comparison between human errors and TACOM scores, it was recognized that the variation of HEPs follows a sigmoid shape around 4.0 of TACOM score (refer to a dotted box highlighted by a dark color in Fig. 1).

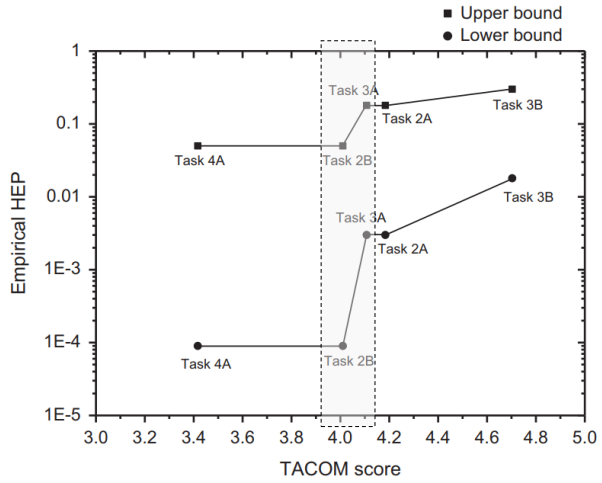
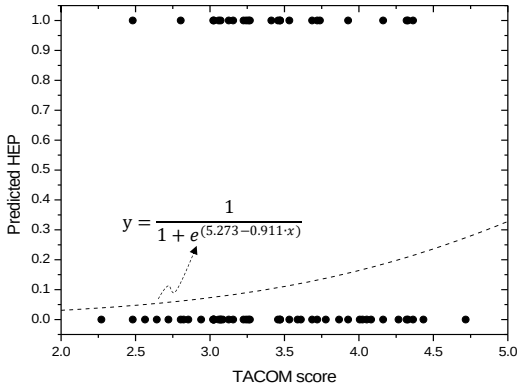


Fig. 1. Change of HEPs with respect to TACOM scores; modified from Ref. [8].

2.3 Additional comparison

As depicted in Fig. 1, if there is a specific range that distinguish the performance of human operators, it is expected that the complexity level of a proceduralized task can be soundly estimated in a systematic manner. In order to consolidate this expectation, additional comparison was conducted by using human error data that were classified by HuREX (Human Reliability data Extraction) framework developed by KAERI (Korea Atomic Energy Research Institute) [9]. Human error data were collected from the full-scope training simulator of NPPs, in which human operators working in a fully digitalized MCR have to deal with diverse simulated accident conditions [10]. Figure 2 shows the preliminary result of the logistic regression analysis pertaining to the number of human errors and the associated TACOM scores.



	Coefficients	Standard Error	p	Odd Ratio	Lower 95%	Upper 95%
Intercept	-5.273	0.768	6.511E-12	0.005	0.001	0.023
TACOM	0.9108	0.208	1.141E-05	2.486	1.655	3.734

Fig. 2. Result of the logistic regression analysis.

3. Conclusions

From Fig. 2, it is observed that there is a significant correlation between predicted HEPs and TACOM scores. Although this result should be elaborated with additional human error data, it is anticipated that the TACOM measure can be used to determine the level of task complexities. Conversely, if TACOM scores are sensitive to the complexity of proceduralized tasks, it is relevant to identify the catalog of error-prone tasks. For example, in the case of conducting PSR (Periodic Safety Review), one of the main concerns is to pick out the list of critical tasks that could result in human errors. Similarly, in the case of conducting ISV (Integrated System Validation) that is a part of HFEPRM (Human Factors Engineering Program Review Model), it is important to clarify newly designed HMIs are effective to support human operators who are faced with complicated tasks. In general, the selection of these tasks are largely based on the analysis of operation experience or the decision of subject matter experts. The TACOM measure can support this selection process by providing more objective and systematic decision criteria.

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