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A Suggestion about Framework to Evaluate Operating Support Systems in NPPs

Moon Kyoung Choi, Poong Hyun Seong*
[a]*Department of Nuclear and Quantum Engineering, KAIST,*
373-1, Guseong-Dong, Yuseong-Gu, Daejeon, South Korea 305-701
**Corresponding author: phseong@kaist.ac.kr*

1. Introduction

The operating environment of an advanced MCR changed from that of the conventional analog to that of the digital type. The design of instrumentation and control (I&C) systems for various plant systems is also rapidly becoming fully digitalized I&C [1, 2]. Large display panels (LDP), soft-controls, computerized procedure systems, and advanced alarm systems were all applied to APR-1400(Advanced Power Reactor-1400) [3]. Thus, the role of the operator in advanced nuclear power plants shifted to suit more of a supervisor or a decision maker's role than that of a manual controller; hence the operator's tasks have become more cognitive oriented [4]

However, this shift in the operator's role may lead to a shift in type of workloads, from that of highly physical to that of more cognitive focused, demanded from the operators even though the overall workloads can be reduced. The operators performing alarm monitoring and identification tasks in nuclear power plants often suffer from heavy mental workload leading to many operating support systems being implemented to reduce stress and mental workload that the operator has to burden [4]. Generally the operating support systems in NPPs have been exclusively evaluated with subjective methods; therefore, there are no clear integrated evaluation method to determine whether an application of the support systems really assists the operators in reducing their mental workloads and their performances.

The method for evaluating operating support systems that will be used are performance, subjective, and physiological measurements.

2. Selection of assessment method

Performance measurement, subjective rating and physiological measurement have been considered as the three most general mental workload measurements [5, 6].

2.1 Performance measurement

There are two factors in measuring performance which are primary and secondary task performance assessments. Meister (1985) has developed a general taxonomy such as 'Accuracy', 'Time' that may be used to quantify primary and secondary task performance.

Accuracy is used for measuring the primary task performance index; in addition, performance completion time is also evaluated. If the real time spent for the completion of a goal in a test reduces, time performance of the personnel task is considered as acceptable [7]. Accuracy is the percentage of correct responses over the problems presented. Performance completion time is used for measuring the secondary task performance index.

2.2 Subjective measurement

A subjective rating is heavily indicative of the participants' internal experience. Subjective rating methods are most widely used for the evaluation of workers' workloads in various fields due to them having clear innate advantages over others such as being inexpensive, easily administrable, widely transferable, and having high face validity [8].

There are multiple methods of determining subjective rating such as using overall workload (OW) scale, modified cooper-harper scale (MCH), subjective workload assessment technique (SWAT), and national aeronautic and space administration task load index (NASA-TLX). In this study, NASA-TLX will be used to determine subjective rating because it is superior in terms of usability and validity compared to the other methods [8]. It is a recommended instrument for assessing cognitive workload by U.S. NRC. It divides the workload experience into the six components: mental demand, physical demand, temporal demand, performance, effort, and frustration. Among the components, performance component will be excluded because of a duplication.

2.3 Physiological measurement

For such as alarm-monitoring and identification tasks, which might experience fluctuations during a time period, the dependence of subjective rating on short-term memory might distort the workload rating for that period [9]. Therefore, physiological measurements that indicate biopsychic state are necessary for an evaluation of support systems.

Physiological measurements use the known features sensitive to operators' bio-status to measure the physiological aspect of the mental workload. Physiological status is highly sensitive to the cognitive requirements of a complex task, but can be objectively recorded continuously [10, 11]. In this study, EEG (electroencephalogram) and GSR (galvanic skin response) measurements are used. EEG was selected for EEG measurements which have shown to be sensitive to variations of mental workload during tasks such as inflight mission, air traffic control, and automobile driving etc. Measuring EEG of a subject was difficult in the past as it required the subjects to be stationary as EEG was and still is very sensitive to outside noise. However, with the advancement of technology to allow NPP operators to do tasks remotely from the main control room, noise interference during EEG measurement is not a problem.

Generally alpha, three kinds of beta, and gamma signals obtained from the EEG trials are analyzed to obtain valid measurements. It was demonstrated that resting alpha power and SMR power are increased under conditions that are associated with enhanced cognitive processing capacity or situations where subjects try to increase their capacity (e.g., during states of increased attention). Therefore relative alpha and SMR power will be used for physiological results analysis [12]. Incensement of sum of relative alpha power and SMR power means reduction of cognitive workload.

Measuring GSR is another way of objectively determining the physiological status of a subject by measuring the electrical conductance of the skin, which varies depending on the amount of sweat-induced moisture on the skin. It is used widely in psychological research due to its low cost and high utility. GSR (Galvanic Skin Conductance) measures arousal to a reliable degree (Andressi, 2000), a low skin conductance prior to performance and a high skin conductance during performance should relate to improved performance [13].

3. Suggestion of evaluation framework on operating support systems

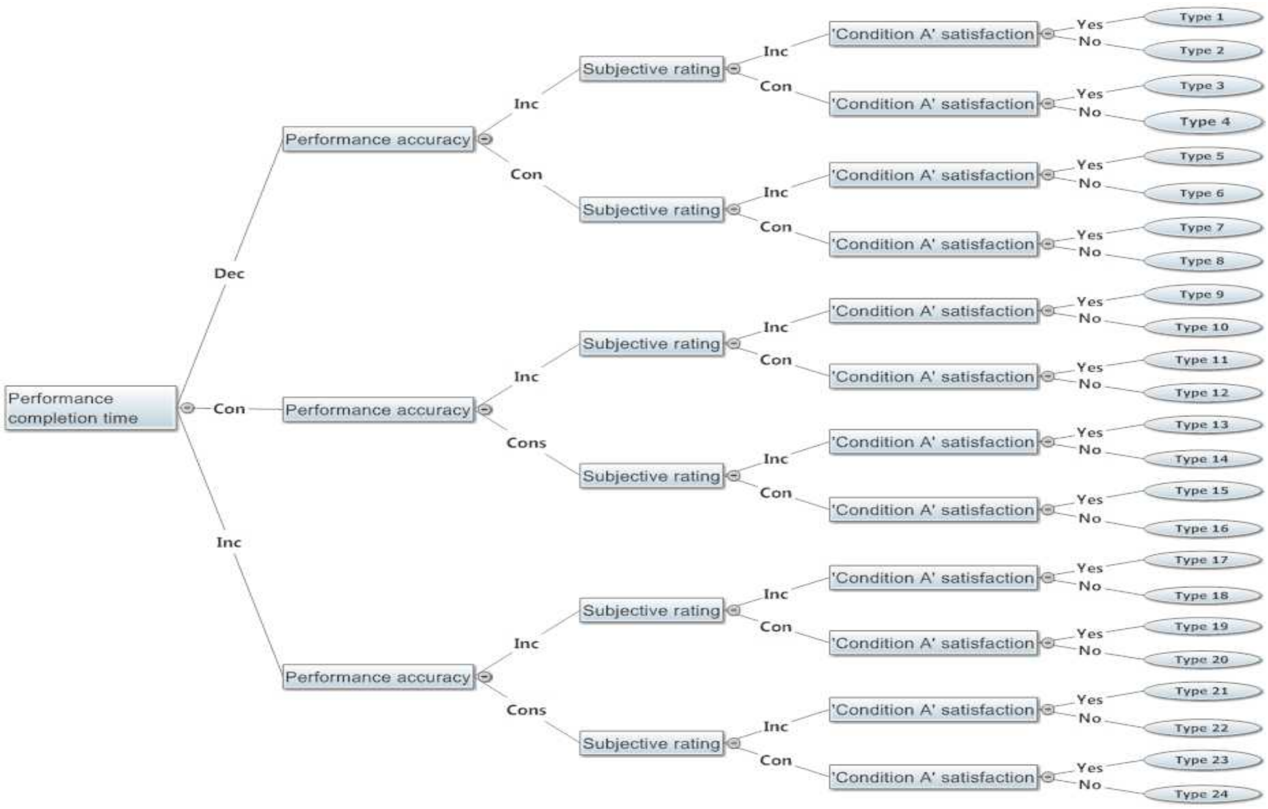

Fig. 1. Decision tree for an evaluation (classification) of operating support systems in terms of performance completion time, performance accuracy, subjective rating, and physiological results.
*Condition A: sum of relative alpha and SMR power (8~15Hz) increases, GSR decreases.

Fig. 1 is a classification of OSS types using decision tree. By using this tree, the type of operating support systems can be analyzed in detail. There are totally 24 types of operating support systems in terms of performance, subjective ratings, and physiological measurements. In view of safety of NPPs, performance accuracy is taken into consideration importantly so the case that performance accuracy decreases after application of OSS is exempted. The case that subjective rating decreases after application of OSS is also ruled out. The criteria for physiological measurements is set up as *Condition A. The sum of relative alpha and SMR power (8~15Hz) indicating reduction of cognitive workload should be increased and GSR should be reduced. Fig.1 will be gradually improved.

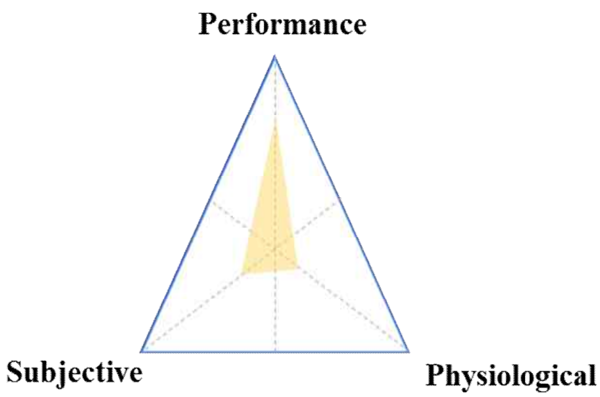

Fig. 2. Ternary phase diagram concept applied to an evaluation of operating support systems.

Ternary phase diagram concept is applied to operating support system evaluation. The triangular diagram has three vertices indicating performance, subjective, and physiological aspects of the evaluation. The center of the triangle indicates 0%, or no change, and the points of vertices indicate maximum improvement. Each criterion will be used for an overall evaluation of operating support systems. Through this evaluation method, aspects of improvement can be better understood with absolute and relative comparison (amongst the three factors) analysis. Fig. 2 shows an example evaluation result of a certain operating support system. Performance, subjective rating, and physiological have shown to all improve with the implementation of the support system. Performance aspect, especially, improved considerably. Subjective and physiological aspects, on the other hand, do not show as much improvement. Taking all this into account, it can be concluded that implementing this operating support system significantly improves operators' performances but it does not reduce operators' overall mental workload by much.

4. Conclusions

In order to evaluate operating support systems, performance, subjective, and physiological criteria were taken into consideration. Performance measurement will be determined by the accuracy and time factors, subjective rating will be determined using NASA-TLX and physiological measurements will be determined through EEG (sum of relative alpha and SMR power) and GSR data collection and analysis. It is expected that this suggested evaluation framework would become a useful tool in determining the effectiveness of operating support systems while minimizing unwanted bias. Furthermore, use of this framework could potentially be able to categorize support systems based on their strengths and weaknesses, e.g., operating support system type 1 is 'performance-focused support system' or 'Subjective rating-focused support system'. In order to make the evaluation framework about operating support system more precisely and concretely, experiments or researches will be carried out for improvement and verification. Ultimately an integral evaluation framework of operating support systems.

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