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Experimental Approach to Effect Estimation of Decision Support Systems

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1. Introduction

Recently human error has been introduced as one of the serious causes of accidents in safety critical systems such as nuclear power plants (NPPs). In order to prevent human errors, many efforts have been made to improve main control room (MCR) interface designs and to develop decision support systems that allow convenient MCR operation and maintenance. For the advanced MCRs, various types of decision support systems have been developed, such as intelligent advisors, alarm systems, computer-based procedures, fault diagnostic systems and computerized decision support systems. It is very important to design highly reliable decision support systems in order to adapt them in actual NPPs. In addition, to evaluate those support systems and validate their efficiency and reliability is as important as to design highly reliable decision support systems, because inappropriate decision support systems or automation systems can cause adverse effects [1]. Research to experimentally estimate a decision support system's impact on the operator's performance has been previously reported in the literature. In most experimental studies, operator performance with decision support systems such as information aid systems is estimated by the quality and accuracy of a diagnostic performance [2] as well as by other various subjective or objective measurements. Subjective methods such as the NASA-Task Load Index (NASA-TLX) and modified Cooper-Harper (MCH) have been employed to measure the subject's mental workload [3].

In this work, target decision support systems are selected and evaluated by experiments. The target systems are an alarm system, a fault diagnosis system, a computerized procedure system, and an operation validation system. For the experimental evaluation, a prototype was implemented based on a micro-simulator.

2. Target Decision Support Systems

The prototype consists of four decision support systems: an alarm information system, a fault diagnosis system, a computerized procedure system, and an operation validation system. In the alarm information system, the alarm information is provided with occurrence time. Currently activated alarms are highlighted with the color red. If a subject clicks an alarm in the list, the trend graph of the related parameter of the selected alarm is displayed in the left side of the window. This system is expected to support the recognition of occurred alarms and the observation of abnormal patterns. The fault diagnosis system provides possible faults for the current state with a certainty factor and expected symptoms. Alarms data and related plant parameters are used as inputs for calculation of the certainty factors and the certainty factors are computed every second. In this system, if subjects click one possible fault, then they can obtain a list of expected symptoms of the fault which are elicited from operating procedures of NPPs. The computerized procedure system provides checkoff provisions. The system has database for a simplified version of the emergency operating procedure (EOP). Also, an information aid function for the computerized procedure system was implemented. If the information aid function is utilized, the values of the parameters related to the steps are displayed to the left of the steps. Subjects can determine required parameters for executing steps more easily from this function. When a subject attempts to execute an inadequate operation which is not included EOPs, a warning window pops up. If the subject clicks the 'Execute' button, the operation will be executed. If the subject clicks the 'Cancel' button, the operation will not be executed.

3. Experimental Evaluation

3.1 Evaluation Setup

The subjects were 17 graduate students of the Department of Nuclear and Quantum Engineering at KAIST. They ranged in age between 23 to 39 years and had more than three years of nuclear engineering experience. This experiment used a FISA2/PC real time micro-simulator [4],[5].

Subjects were asked to identify seven events: 1) Loss of coolant accident (LOCA), 2) Steam generator tube rupture (SGTR) of steam generator (SG) A, 3) SGTR of SG B, 4) Feed line break (FLB) of Loop A, 5) FLB of Loop B, 6) Steam line break (SLB) of Loop A, and 7) SLB of Loop B. All of the events are accidents wherein some pipes or tubes are broken and, consequently, coolant is leaking. Thus, in order to identify the events, subjects should deduce the events from the change of the values of the plant parameters, because those events do not produce any change of systems or components in this simulator.In the experiment, the subject is required to diagnose an event. If the subject diagnoses the event as LOCA or SGTR, then he/she is asked to perform corresponding operations according to the simplified EOPs. The simulator cannot cover all steps in EOPs, because it is a micro-simulator. For example, instruments regarding the radio activity in the containment are not considered in this simulator. Therefore, a simplified version of the EOPs consisting of 28 steps was used in the experiment.

3.2 Evaluation Results

The results of the experiment are represented by the subjects' workload and the accuracy of operations. The average values of the subjects' workload for the case of a LOCA event are shown in Figure 1. The workload in the case of no aid was reduced by about 4 by using all the decision support functions. The average values of the subjects' workload for the case of a SGTR event are also shown in Figure 1. In this case, the workload in the case of no aid was considerably more reduced by all aids: it was reduced by about 7. This result could be interpreted by the study of Kim and Seong, who represented operation tasks with the amount of information flow [6]. Operation tasks are analyzed by an information theory model, and the amount of information flow for each case is calculated in the paper. According to the paper, the amount of information flow of a LOCA event is 18.34 bits and that of a SGTR event is 30.69 bits. That means the SGTR event is much more complex task than the LOCA event, and thus subjects must handle and consider more information. With consideration of the amount of information flow for each event, the result shows that a decision support system could be more efficient in more complex and highly workloaded situations.

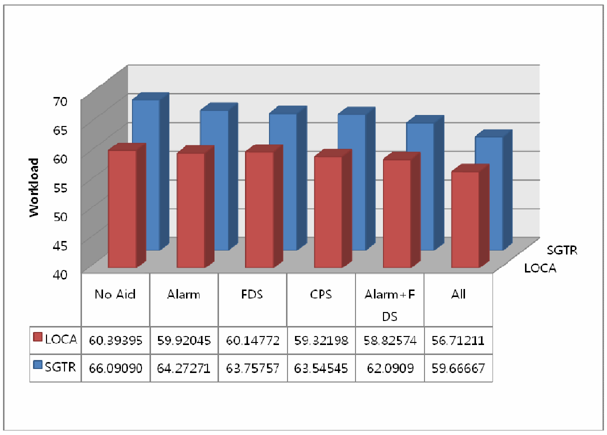

Figure 1. Workload in the cases of LOCA and SGTR event

The accuracy of an operation is measured by two errors: the diagnosis error and the operation error. A subject with no aid committed the diagnosis error 0.88 times on average during 8 events. The diagnosis error was reduced to 0.59 times by adding the alarm information function and reduced to 0.65 times by using the fault diagnosis function. When both the alarm information function and the fault diagnosis function were applied, the subject failed to diagnose an event 0.47 times during 8 events. The subject omitted a step 0.30 times and misjudged conditions 0.24 times on average during 16 steps without the computerized procedure function. When the computerized procedure function was provided, the error to omit a step was decreased to 0.12 times and the error to proceed to a wrong step was also reduced to 0.12 times. A wrong action execution occurred 0.29 times during 9 control actions without the operation validation function, but was reduced to 0.06 times with the operation validation function. This result also reflected the positive effect of cooperative support functions. The failure probability without aid is roughly 21%, and decreases to about 8% by using all the decision support functions.

4. Conclusion

In In this work, the effect of decision support systems was estimated experimentally. The results of the experiment showed that the decision support functions reduce the subjects' workload and failure probabilities. In the case of more complex tasks, the effects of the support functions were greater. In the results, the effect of the support systems in the case of the SGTR event was much greater than for the LOCA event. This could be a result of the SGTR event having a much greater amount of information flow than the LOCA event.

However, the scenarios considered in the experiment were relatively straightforward. Because the used simulator was a simple micro-simulator, simplified operating procedures and only twenty indicators were used. It is thought that if more complicated scenarios were considered by using a full scope simulator, more reliable conclusions could be obtained. In more complicated tasks, the decision support systems may show a more positive effect.

REFERENCES

[1] H. Yoshikawa, Human-machine Interaction in Nuclear Power Plants, Nuclear Engineering and Technology, Vol. 79 pp. 151-158, 2005.

[2] J. Raaumakers and W. Venduyn, Individual Differences and the Effects of an Information Aid in Performance of a Fault Diagnosis Task, Ergonomics, Vol. 39, pp. 966-979, 1996.

[3] J. H. Kim and P. H. Seong, The Effect of Information Types on Diagnostic Strategies in the Information Aid. Reliability Engineering and System Safety, Vol. 92, pp. 171-186, 2007.

[4] H. Seok and H. C. No, Development of a Software for the Micro Simulator for Kori Nuclear Power Plant Unit 2, Nuclear Technology, Vol. 106, pp. 384-396, 1994.

[5] Y. R. Sim, M. G. Na, and H. C. No, Development of a Small-Scale Simulator for Designing Advanced Control Algorithms at Nuclear Power, Proc. of KNS Autumn Mtg, Yongpyung, 2002.

[6] J. H. Kim, and P. H. Seong, A Quantitative Approach to Modeling the Information Flow of Diagnosis Tasks in NPP, Reliability Engineering and System Safety, Vol. 80, pp. 81-94, 2003.