Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

An Attentional Resources-effectiveness Measure in Complex Diagnostic Tasks in NPPs

Jun Su Ha and Poong Hyun Seong
Department of Nuclear and Quantum Engineering, KAIST
373-1, Guseong-Dong, Yuseong-Gu, Daejeon, South Korea, 305-701

1. Introduction

The main role of the human operators in main control rooms (MCRs) of nuclear power plants (NPPs) is generally to supervise and operate the system. The operator's tasks in NPPs are performed through a series of cognitive activities: monitoring the environment, detecting data or information, understanding and assessing the situation, diagnosing the symptoms, decision-making, planning responses, and implementing the responses [1]. In NPPs, there are a lot of information sources that should be monitored but the operators have only limited capacity of attention and memory. Because it is impossible to monitor all information sources, the operators continuously decide where to allocate their attentional resources. This kind of cognitive skill is called selective attention. In order for operators to effectively monitor, detect, and thus understand the state of a system, the operator should allocate their attentional resources to valuable information sources. Hence, the effectiveness of selective attention is expected to be able to reflect the effectiveness of monitoring, detection, and eventually understanding. In this study, an attentional resources-effectiveness measure is proposed which based on cost-benefit (or resource-effectiveness) principle.

2. An Attentional Resources-effectiveness Measure

The stages of information processing depend on mental or cognitive resources, a sort of pool of attention or mental effort that is of limited availability and can be allocated to processes as required [2]. Through selective attention, one can effectively perceive or understand the state of the environment. When an abnormal or accident situation occurs, operators usually first recognize it by the onset of salience such as alarm or deviation in process parameters from the normal condition. Then, they develop their situation awareness or establish their situation model by selectively attending the important information sources. The maintenance of their situation awareness or confirmation of their situation model is accomplished by iterating the selective attention. How effectively operators allocate their attentional resources to valuable information sources can be measured by applying cost-benefit principles, which is translated to resource-effectiveness principle. Two principles appropriately interpreted from cost-benefit analysis provide the foundation for the resources-effectiveness evaluation [3-5]. The first principle is that the measure of the resource-effectiveness is the relative attentional resources spent on an information source divided by the relative value (or importance) of the information source. The ratio is the basic attentional resource to the value of the information sources ratio (AVR), as follows;

$$\mathrm{AVR} = \frac{\text{Relative Attentional Resources}}{\text{Relative Value of Information}} \tag{1}$$

In this study, this AVR is more specified with some practical measures. The number and duration of eye fixation on information sources are considered as the attentional resources. The relative importance of the information source for the relevant task is considered as the value of the information source. Consequently, Eq.(1) is transformed into Fixation to Informationanal importance Ratio (FIR), as follows:

$$\mathrm{FIR} = \frac{\text{Relative Nuber/Duration of Eye Fixation}}{\text{Relative Informational Importance}} \tag{2}$$

The second cost-benefit principle is that to maximize the resource-effectiveness, the relative attentional resources (e.g., # or duration of eye fixation) should be equal to the relative value of information source (e.g., informational importance). Consequently, the AVR or FIR should be unity in order to maximize the resource-effectiveness. The number or duration of the eye fixation can be obtained from an eye tracking system. The relative informational importance can be obtained using the Analytic Hierarchy Process (AHP) [6] based on the dynamics of the relevant NPP.

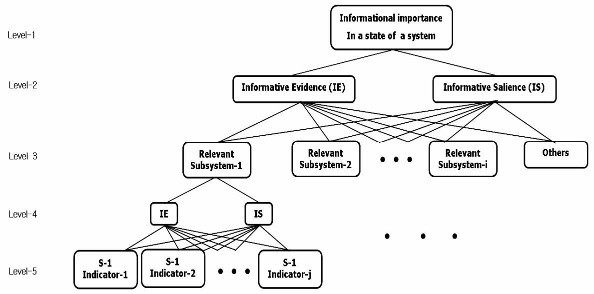

Figure 1. Setting up the hierarchy

It is generally accepted that information sources changing most frequently and likely to change give the greatest information. In this study, the attribute representing "the frequent change of the source" is referred to as "informative salience" and the attribute representing "the likelihood of the change" as "informative evidence". Hence, the hierarchy of informational importance can established as shown in Figure 1.

4. Application & Results

Eye fixation data obtained from an experiment with FISA-2 simulator during diagnostic tasks are used to investigate the feasibility of the proposed measure. Data from 2 subjects (high expertise level and low expertise level) are used for comparative purpose. Diagnostic tasks such as LOCA, SGTR, SLB, and FLB are randomly given to the subjects. The values of the informational importance of indicators in each of the accidents are described in Table 1.

	Prz.	S/G(A)	S/G(B)	Others
LOCA	0.5357	0.2024	0.2024	0.0595
SGTR(A)	0.2545	0.442	0.2545	0.0491
SLB(A)	0.1964	0.4822	0.2679	0.0536
FLB(A)	0.1964	0.4822	0.2679	0.0536

Table 1. Subjects Information

The FIRs for the information sources are calculated with the informational importance and the eye fixation data. An example in the case of LOCA and the high expertise subject (HES) is shown in Table 2.

LOCA : HES

Indicators	Pzr_Indicators	S/G(A) indicato	S/G(B) indicator	Others
Fix. #	26	11	6	8
Rel.Fix.#	0.5098	0.2157	0.1176	0.1569
Fix. Dur.	11.1	3.88	2.83	2.82
Rel.Fix.Dur.	0.5381	0.1881	0.1372	0.1367
Info.Impo.	0.5357	0.2024	0.2024	0.0595
FIR(#)	0.9517	1.0656	0.5813	2.6363
Abs(FIR(#)-1)	0.0483	0.0656	0.4187	1.6363
FIR(D)	1.0044	0.9292	0.6778	2.2974
Abs(FIR(D)-1)	0.0044	0.0708	0.3222	1.2974
FIR(I)	0.9780	0.9974	0.6295	2.4669
Abs(FIR(I)-1)	0.0220	0.0026	0.3705	1.4669

Table 2. An example result of FIRs

Theoretically FIRs should approach 1 for the best effectiveness. Hence, to investigate the effectiveness, the difference between FIR and unity are calculated, which are represented as the absolute values of (FIR-1). The absolute values should therefore approach zero. The lower the absolute values are, the more effective the selective attention is considered as. The averaged values of the absolute values over the indicators are summarized in Table 3. The subject with high expertise shows better effectiveness in the selective attention in all cases.

Participants	LOCA	SGTR(A)	SLB(A)	FLB(A)
High Expertise Subject	0.4655	0.1791	0.0786	0.2071
Low Expertise Subject	0.7655	0.4618	0.4296	0.6398

Table 3. The attentional resources- effectiveness results

4. Discussions and Further Study

Generally, the subject who has good mental model (high expertise) is expected to more effectively monitor and detect the state of a relevant system than a subject who has bad mental model (low expertise). The proposed measure is though to be able to reflect this characteristic and thus to represent the attentional-resource effectiveness in the monitoring and detecting tasks. By applying the resource-effectiveness principle, we can provide some advice or recommendation about subjects' monitoring and detection pattern based on the resource-effectiveness principle (FIRs → 1) and thus trained as well. For example, In Table 2, the subject is recommended to shift his attention to the S/G(B) indicator based on the resource-effectiveness principle (FIRs → 1). As a further study, an experiment will be followed to validate the proposed measure.

ACKNOWLEDGEMENT

This work is supported by "The Development of the HFE V&V System for the Advanced Digitalized MCR MMIS" project.

REFERENCES

[1] M. Barriere, D. Bley, S. Cooper, J. Forester, A. Kolaczkowski, W. Luckas, G. Parry, A. Ramey-smith, C. Thompson, D. Whitehead, J. Wreathall, Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis (ATHEANA), Rev.01, NUREG-1624, US NRC, 2000.

[2] C.D. Wickens and J.G. Hollands, Engineering Psychology and Human Performance, 3rd edition, Prentice Hall, 2000.

[3] E.J. Mishon, Cost benefit analysis, New York: Praeger Publisher, CBS Educational Division, 1976.

[4] S.C. Maurice, C.R. Thomas, C.W. Smithson, Managerial economics, Boston: Richard D. Irwin, 1992.

[5] D.G. Newman, B. Johnson, Engineering economic analysis, San Jose: Engineering Press, 1995.

[6] T.L. Saaty, The analytic hierarchy process. New York: McGraw Hill; 1980.