Review on Situation Awareness Experiments in the Nuclear Power Plant

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1. Introduction

Modern control room design in the nuclear power plant (NPP) weights plant operators' situation awareness (SA) as one of the important design goals [1]. The Advanced Power Reactor 1400 (APR1400) built by Republic of Korea also aimed to improve and maintain the operators' situation awareness to help their plant operation.

To evaluate operator's SA in the main control room (MCR), many human factors experiments were done during MCR integrated system validation (ISV) test periods.

This paper discusses a SA data, which were collected using Situation Awareness Control Room Inventory (SACRI) [2] method, and propose a review method that eliminates some outliers of the results based on the concepts of signal detection theory (Green and Swets, 1966). Thus the evaluation results of SA can be more realistic and meaningfull.

2. SACRI Measures

During past a few years, the APR1400 MCR designers in Korea conducted many experimental tests to know design efficiency for the sake of the SA. The SACRI technique is selected as one of the SA test methods.

The SACRI were considered as one of intrusive SA test methods that does not significantly impact operator's primary task performance. [3]

2.1 Data Collection

Full scope plant simulator is used for the testbed and qualified operating staffs are attended as test participants. Sets of ISV test scenarios are developed for the test. Each scenario has anticipated abnormal event for transients and one design base accident. In the middle of the scenario the simulator is frozen, and each operator is quizzed with SACRI questionnaire to measure SA performances.

Operator's ability to discriminate signal and noise is denoted as "sensitivity (A')" in the signal detection theory (SDT), and the sensitivity is used as a SA index in the SACRI technique.

SA sensitivity is calculated as following equation [2],[4]:

$$A' = 1 - 0.25\left[\frac{P(HIT)}{P(FA)} + \frac{[1 - P(HIT)]}{[1 - P(FA)]}\right]$$

Where, P(HIT) is the probability of a person answers correctly when the signal present, and P(FA) is the probability of a person answers incorrectly when signal is not present. The SA sensitivity is expressed as a function that only depends on P(HIT) and P(FA).

2.2 Experimental Results

Figure 1 shows an example of one experimental score of the SACRI questionnaires [5] for one operating staffs using response operation characteristic (ROC) plot [4].

As shown in the figure, many scores are located on the left vertical line and upper horizontal line. Some points are located on or below diagonal line.

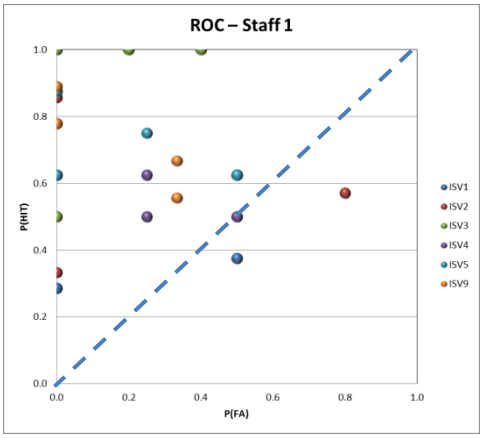

Figure 1. ROC of original SA data

2.3 Review on the Results

From the Figure 1 results review, following outlier data exclusion methods are considered;

1) Data on the diagonal line is treated as random signal. The data below the diagonal line is very suspicious in nature (i.e., noise is greater than signal). Thus, these values are treated as outliers and can be removed.
2) Dada on the upper horizontal line (P(HIT) = 1) or left vertical line (P(FA) = 0) also has suspicious in nature (i.e., operator always answers correctly or there may be no noise signal). Thus, these values are treated as outliers and can be removed.

Figure 2 shows the results of outliers were removed using data exclusion methods described above.

The average of SA sensitivity shown in Figure 2 was calculated as 0.67, and the average of SA sensitivity results before outlier elimination for Figure 1 was

calculated as 0.8. Result of Figure 2 is more conservative than result of Figure 1.

As shown in this example, the outliers in SA value may come from several reasons in the test.

To eliminate these outliers, the test designer should take more care in preparing and conducting test scenarios and SA questionnaires.

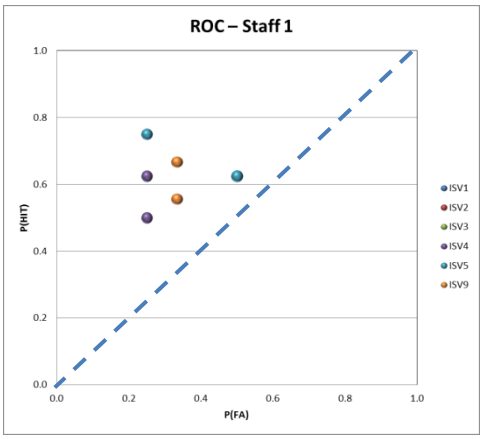

Figure 2. ROC of outlier removed SA data

3. Conclusions

The SA data collected through human factors ISV tests is reviewed, and the validity of the data is checked by the concept of SDT. The simple methods to exclude outliers in the data are suggested in this paper. The example shows more conservative result and less biased by outliers.

To get reasonable and conservative SA indexes, more careful test designs and tests should be prepared and conducted.

But due to the resource limitations (i.e., time, test participants, etc.) in most real design tests, a post-processing data analysis technique suggested in this paper can be used as one of effective SA score treatment methods.

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