

Can We Measure Operating Team's Situation Awareness with Verbal Protocols?

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1. Introduction

Today's systems are complex, focused on not just physical tasks, but on elaborate perceptual and cognitive tasks as well. Hence, humans in many complex and dynamic systems are required to act as effective and timely decision makers. Situation Awareness (SA), which is used within human factor research to explain to what extent operators of safety-critical and complex real systems know what is going on the system and the environment, is considered a prerequisite factor for effective decision making and performance [1]. Thus, the need for operators to maintain SA in complex and dynamic environments is frequently cited as a key to effective and efficient performance. In terms of understanding SA, much effort has been devoted to the development of a measurement method of SA. Thus far, however, various studies have been limited to addressing the SA of individual operators. However, many complex systems are operated by teams. It is typical of complex systems that they require more than one operator. The purpose of this study is to develop team SA measurement method using verbal protocol data..

2. Background

Here, the SA concept of Endsley is adopted to describe team SA. SA, as Endsley formally defines it, is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future." There are three generic aspects in the definition of SA that are related to cognition : *perception, comprehension, and projection*. Level 1 SA, which implies perception, Level 2 SA, which implies comprehension Level 3 SA, which implies projection forms a three-level hierarchy with level 1 as the lowest basic level and level 3 as the highest level.

Although Endsley's SA concept was originally developed to describe individual SA, it was considered that team SA also involves the team's assessment (perception, comprehension, and projection) of the current situation. Team SA is considered to have three levels of SA according to Endsley's SA concept.

3. Development of a Framework for Team SA Measurement

In complex and dynamic systems where teams operate, the team's cognitive behavior is reported by observing verbal protocols. For example, it was reported in the aviation industry that team

communication, particularly verbal communication, supports the knowledge-building and information-processing activities that lead to team SA construction [2]. Many studies stress the strong link between team communication and team SA. Based on this standpoint, team communication was considered as a starting point of developing a framework for team SA measurement, as the strong link between these two factors implies that team communication reflects team SA. Elucidation of the elicitation of logical connections between these two is pursued hereafter.

In the field of naturalistic decision making, researchers have struggled to show how the decision-making activity proceeds. Rasmussen developed a decision ladder template based on earlier research in which he used verbal protocols to study the decision-making process of experienced workers at thermal power stations [3]. Important insight from this model is that the information-processing activities, as one of cognitive activity can be observed from verbal protocols. Thus, the cognitive activities to be considered in this study are selected from the decision ladder model and include the following: *activation, observe, identify, predict, evaluate options, define, formulate, and execute*.

Based on the consideration that cognitive activities can be derived from verbal protocols, we attempted to create logical connections between the cognitive activities derived from verbal protocols and those for team SA measurement.

In railway systems where cognitive tasks by the driver are required, research that attempts to understand how all of the elements in the driver's environment interact and affect what is likely to happen next was conducted. A SA model was developed as a high-level model of the tasks that the driver has to perform, and each of the individual tasks within the high-level model was then described [4]. An important finding from this research was that certain cognitive activities are required before each level of SA is gained. The results of this research were considered in selection of the cognitive activities for each level of team SA. It was found that the cognitive activities of 'observe' for Level 1 team SA, 'identify' for Level 2 team SA, and 'predict', 'evaluate', 'define' for Level 3 team SA were required.

We developed logical connections between team communication and team SA by deriving cognitive activities required for each level of team SA. However, we still need to know how to measure these cognitive activities so as to understand each level of team SA.

When analyzing the cognitive activities for each level of team SA from team communications, a verbal protocol analysis was implemented. However, to conduct a verbal protocol analysis, it is vital to develop a well-defined speech act coding scheme with which the nature of verbal protocol data can be properly distinguished [5]. Among various speech act coding schemes, the speech act coding scheme [6] developed by the Korea Atomic Energy Research Institute (KAERI) is adopted here.

The types of elements in a speech act coding scheme that have a relationship with the cognitive activities required for each level of team SA should also be determined. To derive this relationship, research results from Hollnagel [3], which shows a schematic diagram of various internal data processing mechanisms is adopted.

Based on the mapping result between the cognitive activities for team SA and the speech act coding scheme, specific elements in the speech act coding scheme for the corresponding cognitive activities required for team SA were derived. These are shown in Table 1. With Table 1, each level of team SA can be measured in a verbal protocol analysis.

Table I: Mapping result for measuring each level of team SA

Level of team SA	Cognitive activities for team SA	Speech act coding schemes
Level 1	Observe	Inquiry, Announcement
Level 2	Identify	Judgment, Announcement
Level 3	Predict, Evaluate, Define	Suggestion

4. Preliminary Analysis

A preliminary analysis is performed here with this framework. The purpose of this preliminary study was to determine the feasibility of the suggested method. It was considered that team SA is also linked to team performance. It was shown that teams with high team SA tend to perform better as teams, with the result that team SA is a consistently good predictor of team performance [7]. Hence, the method developed in this study should have correlations between team SA and performance to ensure its feasibility. To perform the preliminary study, verbal protocol data collected by KAERI was used [5]. Based on this data, each level of team SA was measured by counting each speech act coding scheme shown in Table 1. As developing a total team SA measure is beyond the scope of this research, each level of team SA was simply added to calculate the total team SA score. To determine the feasibility, the performance score of the operation team is required. This data was adopted from KAERI/TR-4159/2010 [5].

Figs. 1 and 2 show the results of this preliminary analysis. As shown in these figures, a high level of correlation exists between the total team SA score and the number of correct actions by the operation team. Although a number of data is very limited, these results

imply that the total team SA as measured using the proposed method reasonably infers the operation team SA and thus shows a fair level of feasibility.

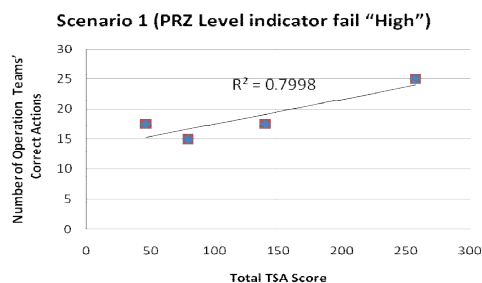


Fig. 1. Result of preliminary analysis (Scenario 1)

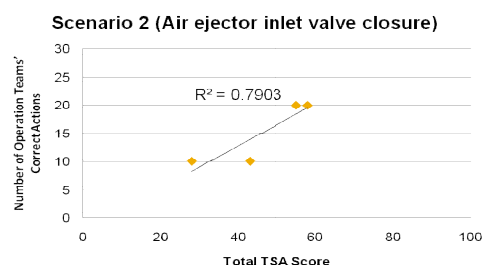


Fig. 2. Result of preliminary analysis (Scenario 2)

3. General Conclusions

A method of measuring each level of team SA is developed here. While developing a total team SA measure is beyond the scope of this research and requires more effort, it can be considered from the results of the preliminary analysis that this method reasonably infers an operation team's SA. Despite the fact that a preliminary analysis was performed with this study, more case studies are necessary. These case studies should contain more scenarios that require an operation team's diagnosis. After more case studies, theoretical and experimental studies are required to develop a total team SA measure.

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