An Empirical Study of Situation Awareness Measurement Methods Based on Crew Simulator Training

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Abstract

Objective: The purpose of this study was to quantitatively analyze the situation awareness (SA) of a crew in the engine-room. Background: The crew in a ship's engine-room ensures normal navigation of the ship by managing the equipment in the ship. Therefore, the measurement of the SA among these crew members is crucial for the safety of the ship, but there is currently no quantitative method for measuring SA. Method: Empirical research based on the actual training process of the crew was conducted. The Low-Event Task Subjective Situation Awareness (LETSSA) technique was chosen as the measurement method of the crew's SA. The LETSSA questionnaire was distributed to participants before and after crew training, which took place in the liquid cargo simulation ship at Shanghai Maritime University. Results: The SA of 33 students majoring in marine engineering and 31 crew members was measured. The results of the questionnaire showed that the two groups of participants had different level of SA before and after the training. The results of the measurements were in agreement with the actual situation. Conclusion: Within the margin of error, the LETSSA technique can quantitatively measure the SA of crews in a ship's engine-room. Application: Provide reference for improving the SA of marine crews in training and education, and provide a basis for the development of maritime policy by the International Maritime Organization (IMO).

Keywords

Situation awareness, Engine-room Resource Management (ERM), Low-Event Task Subjective Situation Awareness (LETSSA).

1. Introduction

Situation awareness (SA) is a psychological concept that was originally introduced when the US Air Force studied how to improve F15 fighter pilots' perception of a rapidly changing environment (Endsley, 1998). The concept of SA was proposed by Endsley (1988), who deemed that SA was the perception, comprehension and projection of various factors in the environment at a particular time and space. Originally, studies on SA were mainly focused on aircrew members (Orasanu, 1995). Then, SA was introduced in other fields, such as medical care (Olson, 2013), offshore drilling (Roberts et al., 2015), submarine track management (Loft et al., 2018), etc. Do not number your paper: All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question.

SA was introduced into Engine-room Resource Management (ERM) by the Manila Amendments to the Seafarers' Training, Certification and Watchkeeping (STCW) Code (International Maritime Organization [IMO], 2010). However, there is currently no method of quantitatively measuring SA in education, training and testing in ERM, as SA is only assessed qualitatively through subjective assessment.

A variety of measurement methods for SA have been proposed in recent years. Stanton, Salmon, Rafferty, Walker and Baberet (2013) concluded that there are more than 30 different methods of measuring SA. These methods can be divided into two classes: subjective measures and objective measures.

The subjective techniques of measuring SA are based on the opinions of the operator or observer (Endsley, 1995a). Objective techniques include measuring various physiological indicators in the human body, external performance indicators, etc. According to the relationship between these indicators and SA, the degree of SA can be determined. Objective methods can provide values independent of the subjectivity of the assessor. However, because different people have different reactions to the same stimulus, scores for different testers are difficult to compare point-by-point. In ERM, this problem is more pronounced, especially when the crewmembers are from different countries and have different cultural backgrounds. Moreover, the cost of objective methods of measurement is larger than that for subjective methods, and the process is inconvenient. As most of the seamen come from developing countries, it is difficult to popularize objective methods in their countries.

Rose, Bearman and Dorrian (2018) demonstrated that, in actual situations, the measurement of SA is usually conducted using subjective methods. The main advantage of a subjective measurement method is that it is a direct assessment method that relies on mental load, is simple to assess and easy for the operator to accept. Due to the adoption of a unified measure dimension, subjective measures are comparable across different situations and different operators. Moreover, it can be deployed after the task is carried out and, thus, is not intrusive to the task.

Currently, the most widely used subjective measurement method for SA is the Situation Awareness Rating Technique (SART), which consists of ten facets and is divided into three parts: the demand for attention resources (instability, complexity and variability of the situation), the supply of attention resources (awakening, concentration, distraction and abundant energy), and the understanding the situation (information quantity, information quality and familiarity) (Taylor, 1990). Although the SART is the most commonly used measurement method for measuring SA, Endsley (1993) argued that the SART cannot predict objective SA because of its lack of predictability, and its high correlation with workload.

For this reason, when using subjective methods to measure SA, researchers have attempted to evaluate SA by other means. For example, using task analysis, Wilson et al. (2001) compiled a questionnaire, Low-Event Task Subjective Situation Awareness (LETSSA), to measure the SA of railway signalers. Research conducted by Rose et al. (2018) showed that the LETSSA technique could measure participants' SA under low-event tasks and predict the objective and subjective performance of participants without being affected by workload.

In contrast to the high-event tasks, a low-event task refers to a task for which the working environment is not constantly changing; thus, the psychological load is not high (Luther, Livingstone, Gipson, & Grimes, 2005). In normal operating conditions, the crew members in a ship's engine-room do not need to pay much attention to many factors. This can be regarded as a low-event task. Therefore, we considered using the LETSSA to measure the SA of the crew in the engine-room

2. Determining situation awareness model

The SA can be divided into two types: individual SA and team SA. Endsley (2015b) demonstrated that individual SA plays an important role in ensuring safety. When we comprehend SA from a system perspective, individual operators rely on their own SA to make decisions in most dynamic tasks. Thus, individual SA is more important for a system (Rose et al., 2018). Additionally, it is important to guarantee that the operator has a good SA in regard to the safety of the operation (Endsley, 2015a). Therefore, the focus of this paper is on individual (crew member) SA.2.2 Page Numbers.

In our experiment, we examined experienced crewmembers as well as undergraduates majoring in marine engineering. Their abilities, experience, long-term memory and short-term memory are different and are influenced by the external environment. Based on Endsley's (1995b) SA model, a corresponding analysis model was established. The analysis model of participants' SA is shown in Figure 1.

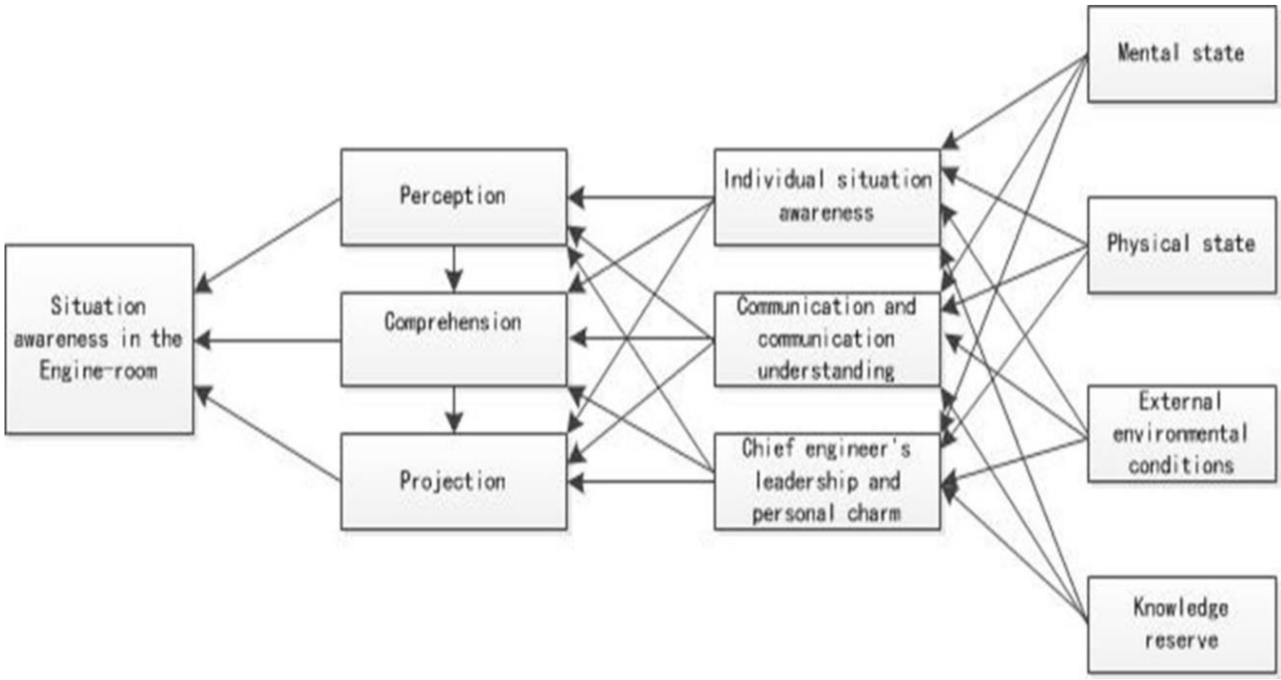

Figure 1. Theoretical model.

3. Method

3.1 Design of LETSSA questionnaire

Rose et al. (2018) pointed out that the LETSSA questionnaire can be used in any simulation task. Building on the literature (Rose et al., 2018), the author designed the questionnaire according to participants' SA model (see *Figure 1*) and crew-training syllabus.

We invited training teachers and senior marine chief engineers from maritime colleges to pretest this LETSSA questionnaire for the purpose of confirming the clarity of the expressions/words and the completeness of the questions. The complete questionnaire consists of 13 questions, the responses to which are divided into 10 different levels: 1 for strong disagreement and 10 for strong agreement. These numbers also represent the corresponding scores.

Participants indicate their agreement with each question. High score indicates a high level of SA. The questionnaire was administered in paper form. Each participant was given a questionnaire before and after the training.

3.2 Design of LETSSA questionnaire

There were 33 students in this study. They were aged between 21 and 24 years (M = 22.2, SD = 0.81), and were all male. They had no prior onboard-working experience, participation was voluntary and no remuneration was given.

Thirty-one crewmembers participated, all of whom were male, aged 28–58 years (M = 39.6, SD = 8), with experience ranging from 7 to 28 years (M = 14.9; SD = 7.7). Twenty-one participants were working as senior crewmembers, and 10 participants were working as ordinary crewmembers.

The crew training was carried out on the "Wu song," a combined liquid cargo simulation ship belonging to Shanghai Maritime University. The "Wu song" is dedicated to teaching and research on large oil tankers, bulk chemical tankers, LPG ships and LNG ships. The combined liquid cargo simulation ship is 60.8 m long and 10 m wide, meeting the requirements of the Manila amendment to the STCW convention for special training of tanker crews (IMO, 2010). A photograph of the "Wu song" is depicted in Figure 2.

*Figure 2.*The appearance of "Wu song".

The internal layout of the "Wu song" is shown in Figure 3: In the first row, from left to right: are the engine-room area, cargo oil pump and tank-washing pump area, engine-room simulation pump room, and oil-fired boiler. In the second row, from left to right: are the combustion inert gas system (IGG), IGG control panel, engine-room hydraulic platform pump, and oil-fired boiler control panel.

*Figure 3.*The interior of the "Wu song"

Crew training is divided into three parts: basic training for oil tankers and chemical tankers, advanced training for tanker operations, and training for crew knowledge updates. The students and the crewmembers had the same conditions and objectives for the training, such as training content, training methods, training time, training instructors, training goal, etc. Each part of the crew training can be divided into two subparts: theoretical training and practical training. Figure 4 shows (in the first row): crewmembers and students attending theoretical training; and (in the second row): crewmembers and students attending practical training.

*Figure 4.*Crew training.

4. Results and discussion

The scores for the students and crewmembers are shown in Table 1 and Table 2

Table 1: Student Scores

	Questionnaire score			
	Lowest score	Highest score	Total score	Average score
Before training	69	80	2475	75
After training	71	85	2640	80

As shown in Table 1, students' scores after training were obviously improved with respect to the lowest score, the highest score, the total score and the average score. This demonstrates that the SA of students after training was generally improved.

Table 2: Crewmember Scores.

	Questionnaire score			
	Lowest score	Highest score	Total score	Average score
Before training	70	85	2480	80
After training	75	100	2790	90

As shown in Table 2, as with students' scores, crewmembers' scores after the training were obviously improved with respect to the lowest score, the highest score, the total score and the average score, showing that the SA of crewmembers after the training improved in general.

Score Comparison

According to the questionnaire data, we can find the score of participants before and after the training, as shown in Figure 5..

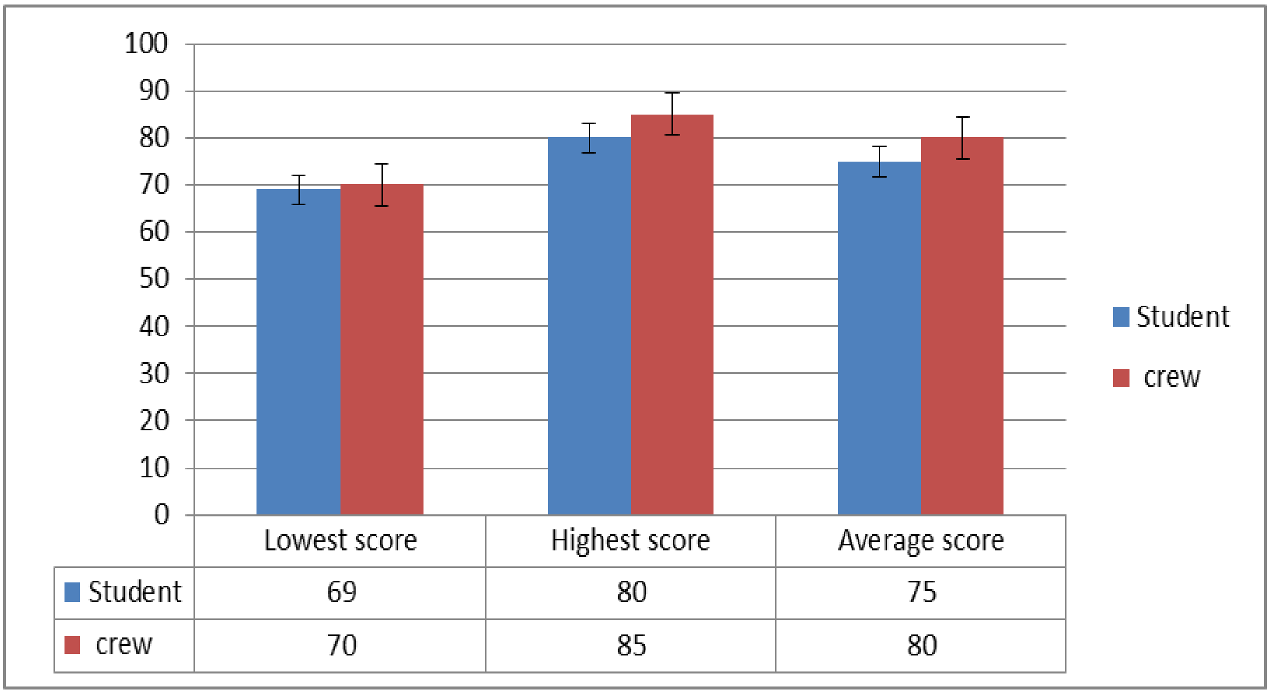

Figure 5. LETSSA questionnaire score before the training

Before the training, the crewmembers' scores were higher than those for the students, indicating that the level of the crewmembers' SA was higher than that of the students before the training.

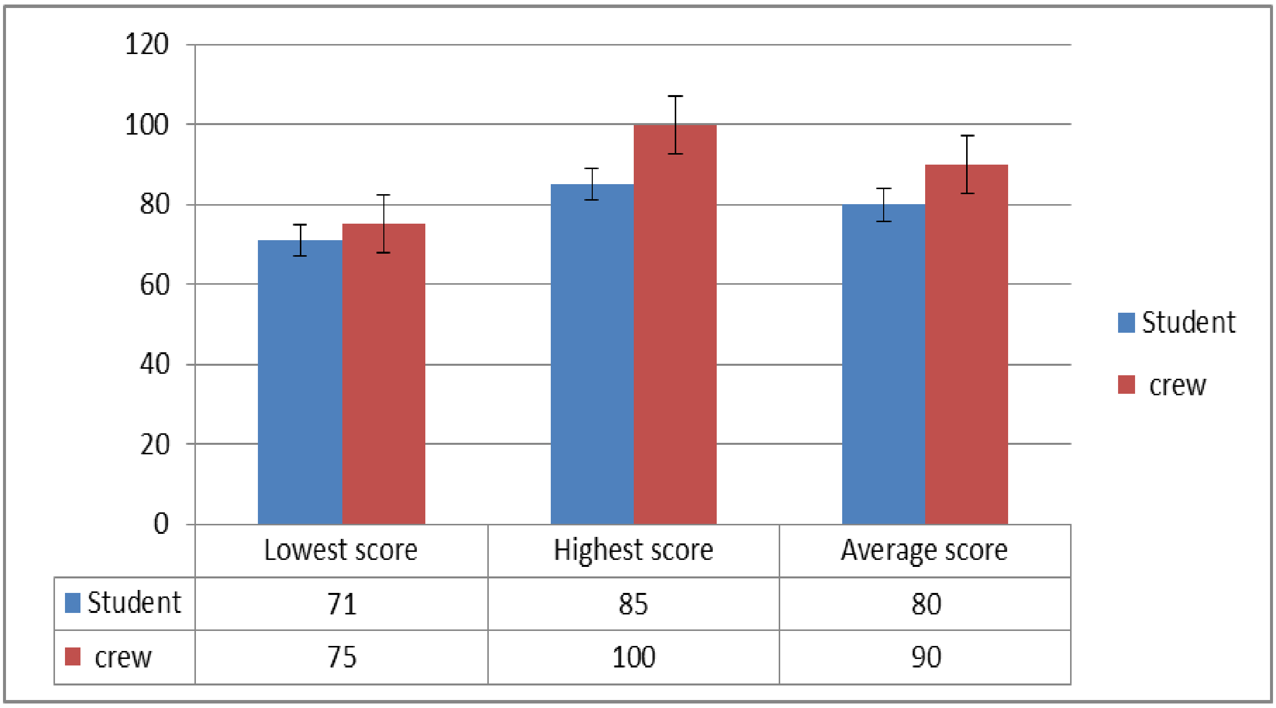

Figure 6. LETSSA questionnaire scores after the training.

After the training, the score of the students and the crewmembers were both improved, showing that their SA improved after training. The crewmembers' scores after training were higher than those of the students, showing that the SA of the crewmembers was still higher than that of the students.

Analysis of Total Scores

A trend chart of the total scores before and after training is depicted in Figure 7.

Figure 7. Total scores before and after training.

The SA of both crewmembers and students improved after training. However, the increase in the SA for the crewmembers was greater than that of the students. This further proves that the LETSSA technique method can detect differences in SA between crewmembers and students. Consequently, the LETSSA technique is suitable for the measurement of crewmembers' SA.

5. Conclusions

This paper attempted to solve the problem of quantitatively measuring marine crewmembers' SA by introducing the LETSSA technique to the field of ERM. At present, in the education and training of marine crewmembers, assessors only provide qualitative results with regard to SA. The result of our quantitative analysis indicates that the LETSSA is suitable for the quantitative measurement of SA in ERM. In addition, the quantitative analysis method that we conducted is worthy of being promoted in other crew-training countries, because it has the advantages of being low-cost and consistent with qualitative judgment.

However, if the measurement results are used to determine whether marine crewmembers can pass the assessment, they may falsify their responses. In that situation, we can-not obtain accurate results. In future research, this aspect should be taken into consideration. Furthermore, it is important to determine the relationship between the results of subjective and objective methods by means of a comparative study, so that a more comprehensive and accurate concept of SA can be attained.

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