Proposal of An Evaluation Method Using a Physiological Index in Navigator-Centered Education

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Abstract

We have been researching how to evaluate navigators' arts using their physiological and behavioural information in order to make a new index of human-centered education as carried out on a training ship. We need the evaluation for specialised merchant ships such as tankers, container ships, LNG carriers, etc., because the responsibilities and actions of the bridge teammates differ according to each ship's type. In this paper, we describe, using the frequency components of R-R interval data, responses in bridge teammates while aboard merchant ships.

Keywords: SNS, R-R interval, mental workload, merchant ship, teammate

1 Introduction

In Japan, a university or a maritime technology college, not a navy or a coast guard, controls the education for merchant ship navigators. Practical on-board education is conducted on a training ship, such as a power vessel or tall ship. Specialists who have a lot of experience educate students on the ship. However, the content of the practical on-board education is not always clear to the students, because real situations include all things, not just simple linear knowledge. In real life, complex situations are difficult for student navigators to understand. We need some evaluation indices of navigational arts/skills, which can form the basis of ship handling in on-board education, and these indices must be able to evaluate human behaviours.

We have been researching how to evaluate navigators' arts/skills using their physiological and behavioural information. We are using heart rate variability (R-R interval), nasal temperature, eye movement and gravity centre as quantitative indices [1, 2]. One of our recent main studies includes findings on the characteristics of the mental workload among ship's bridge teammates during navigational watch keeping. However, the vessels on which we always conducted the experiments were training ships, not commercial merchant ships. We need to evaluate navigators on merchant ships. The vessels are categorized according to their cargo properties (e.g., tanker, training ship, LNG carrier, etc.); consequently, the work of bridge teammates differs according to each ship's type. Additionally, the characteristics of bridge teammates' performances differ depending upon their nationalities.

The purpose of this paper is to determine whether we can find changes in teammates' mental workloads on the real bridge or not by the R-R interval. We evaluated the bridge teammates' performance on merchant ships rather than aboard training ships. The experiment was carried out at Istanbul Strait in Turkey using four kinds of vessels. We show the relationship between the bridge teammates' performance and the characteristics of their mental workload with SNS value [3], SNS=LF/HF, which is used to evaluate the mental workload in many study fields. LF consists of the frequency components between 0.04 and 0.15 Hz, while HF consists of the frequency components between 0.15 and 0.40 Hz. SNS value is influenced mainly by the physical conditions and the postures rather than by the mental workload. The navigator's responses give credence to our evaluation. In this paper, we confirm whether the navigator's responses to handling the ship in the busy Istanbul Strait are valid.

2 R-R Interval and SNS Value

We show an outline of the R-R interval in Figure 1. In Figure 1, the electrocardiogram consists of P, Q, R, S, and T waves, and the R-R interval is time interval from a peak R to the next peak. The R-R interval fluctuates according to physical and the mental conditions such as those in Figure 2. In this study, we use a frequency component of R-R interval data as a consistent measurement.

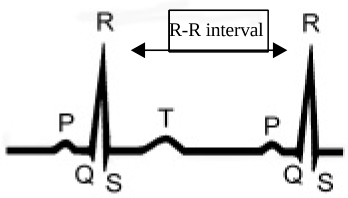

Figure 1: Outline of R-R interval.

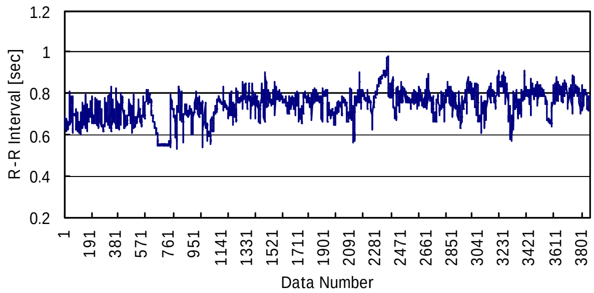

Figure 2: R-R interval data.

Our evaluation index in this study, the SNS value, can be calculated by using two frequency components of the R-R interval data. They are the Low Frequency component (LF) and the High Frequency component (HF). We calculate the SNS value by Equation (1) as follows:

$$SNS = LF / HF \quad (1)$$

LF consists of the frequency components between 0.04 and 0.15 Hz and reflects the sympathetic nervous system. HF consists of the frequency components between 0.15 and 0.40 Hz and reflects the parasympathetic nervous system. The SNS value can be used to evaluate the influence on the sympathetic and parasympathetic nervous systems simultaneously. Meanwhile, the SNS value is influenced by the physical conditions, the postures, etc. of the navigators excluding their mental workload. The recorded responses of the navigators lends credence to our evaluation [4, 5]. We tackled this problem [6], and we confirmed the responses to ship handling. However, we need more accurate research on the changes that occur in the SNS value.

3 Experiment

We measured the bridge teammates' R-R interval during navigational watch keeping on four kinds of vessels in Istanbul Strait (a star in Figure 3). Istanbul Strait is the narrow channel between the Black Sea and the Marmara Sea. We got good measurements of R-R interval data for the following navigational situations: entering port, leaving port and transiting the strait.

We observed the performance of the navigators using the Work-Sampling Method every second. The results were recorded on record sheets shown in Table 1. We also recorded their conversations with an IC recorder; checked and recorded sea/wind conditions; and recorded some target information, etc. on the navigational instruments.

Figure 3: Experimental area (Istanbul Strait).

Table 1: Work-Sampling data sheet.

Ship Name:					Date:	
PILOT-Name:					Start:	
Age/Weight/Height:					Finish:	
Time			Event-1	Event-2	Whom	Remarks
Hr.	Min.	Sec.				

On each Work-Sampling data sheet, we wrote the experimental vessel's name, type, length overall, gross tonnage, and dimensions. Then we recorded the names of the bridge teammates as well as the navigational situations. They were as follows:

1) *ATLANT*: Ro-Ro Fishing vessel, 76.7 m, 2,065 tons, Pilot and Captain, Entering port.
2) *WEISSHORN*: Container ship, 157.1 m, 12,029 tons, Pilot, Captain, and Helmsman, Entering port.
3) *ANKARA*: Container ship, 167.2 m, 14,865 tons, Pilot, Captain, and Helmsman, Leaving port.
4) *PARAGON*: Bulk carrier, 180.8 m, 17,153 tons, Captain, Chief Officer, Second Officer, Helmsman-a, and Helmsman-b, Transiting the strait.

4 Analysis

We used the SNS value in order to evaluate the bridge teammate's mental workload and calculated it in three steps:

1. We interpolated the R-R interval data every second with a Spline Function.
2. We calculated the spectrum of the interpolated R-R interval data by the Maximum Entropy Method (MEM) every thirty seconds.
3. We calculated the SNS value using Equation (1).

We analyzed the bridge team member's mental workload by comparing R-R interval data with the observation data, which we got using the Work-Sampling Method.

5 Results

We show the result of the *WEISSHORN* entering port in Table 2 and Figures 4 to 6. The bridge teammates of the *WEISSHORN* are the pilot, captain, and helmsman. Figures 4 to 6 show the results relating to the pilot, captain, and helmsman respectively, and these Figures show the relationship between real time and the SNS value. Table 2 shows seven events from A to G at which the SNS values increase dramatically.

Table 2: Seven events when SNS value increases (*WEISSHORN*).

	Hr.	Min.	Sec.	Events
A	10	20	0	Pilot on board
B	10	26	11	Ask the control station the distance from here to the berthing area
C	10	36	43	Talk with Captain about cranes
D	10	43	15	Go to starboard wing and give the berthing information to tug
E	10	53	52	A ferry is on the starboard and is drawing near the ship
F	10	58	12	Stop engine
G	11	25	2	Order tug to push at midship

In Figure 4, the pilot had six events: A, B, C, D, E and G. We describe the events in comparison with Table 1.

A) The Pilot went on board.
B) The Pilot asked the control station the distance from here to the berthing area, and gave information about berthing to captain.
C) The Pilot talked to captain about cranes.
D) The Pilot went to starboard side to give the information about berthing to tugboat.
E) A ferry pulls up on the starboard side for the crew to board. If he feels there is danger of a collision with her, he has to avoid her.
G) The Pilot ordered the tugboat to push the midship of the *WEISSHORN*. Then the pilot used the tugboat and the *WEISSHORN*'s engine to change the *WEISSHORN*'s position.

Based on the results, SNS values increase when the Pilot gets information for handling the ship.

In Figure 5, the Captain had an event: F. We describe the event in comparison with Table 1.

F) The Pilot slowed the forward speed of the engine and shifted it to astern to slow down her speed. The *WEISSHORN* had to reduce her speed because she was already near the berth.

Based on the results, SNS values increase when the Captain gets the information for handling the ship. This result is similar to the result obtained from the experiment with the Pilot.

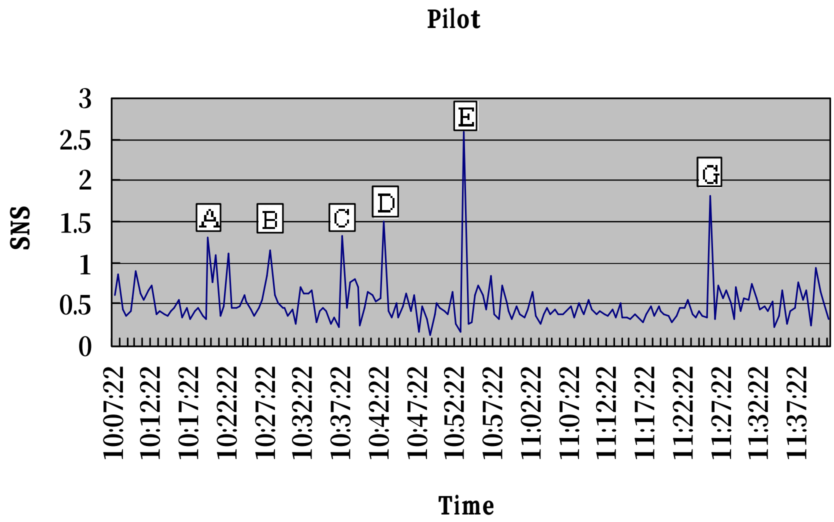

Figure 4: SNS value of the Pilot (*WEISSHORN).*

In Figure 6, the Helmsman had an event: C. We describe the event in comparison with Table 1.

C) The Pilot talked to the Master about cranes.

Based on the data, we couldn't find information about ship handling for the Helmsman. At that time, the Helmsman took part in the discussion with the Pilot. SNS values increase during talking, moving, etc. In this case, SNS values increase during talking.

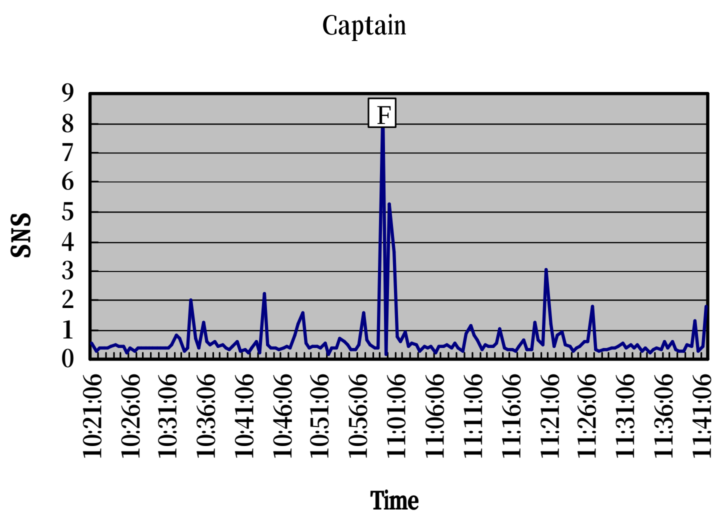

Figure 5: SNS value of the Captain (*WEISSHORN*).

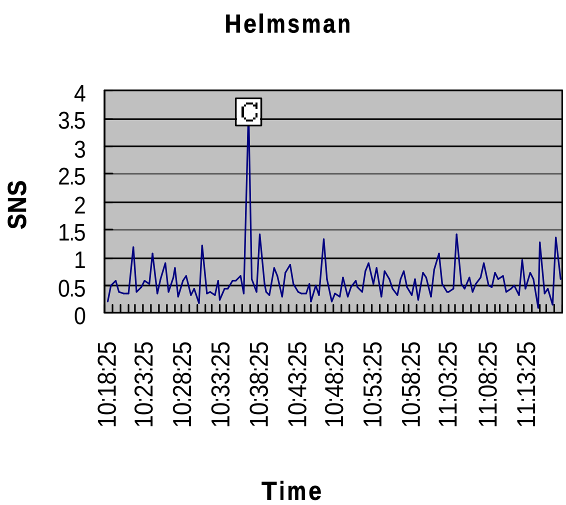

Figure 6: SNS value of the Helmsman (*WEISSHORN*).

From the Figure 4 to 6, we determined that there is a tendency for SNS values to increase when bridge teammates need to make judgments (brain work), and perform chart work (action); to give orders and to receive answers back (brain work and action). This tendency recurred in the results gotten from the *ANKARA*, the *ATLANT*, and the *PARAGON*. Moreover, these results matched those recorded aboard the training ship. In other words, we were able to confirm the efficacy of applying the SNS value to the navigators on the merchant ships.

6 Conclusions

We attempted to evaluate the mental workload for merchant ship bridge teammates using the R-R interval. The results showed that the SNS value was an effective tool in evaluating the mental workload of the navigators. The conclusions are as follows:

1) The bridge teammates maintained good mental balance during their turns at navigational watch keeping. Their mental workload increased when they needed to make judgments, perform chart work, give orders and receive answers back.
2) The SNS value was a good index to represent the performance of the bridge teammates for a merchant ship. We confirmed the same characteristics for the training ship; however, the particular performance of the bridge teammates differs according to each vessel's type. For example, on a training ship, the bridge teammates educate/train the students, and do not handle cargoes.
3) The SNS value sometimes increased when the navigator took actions or performed brainwork not related to ship handling.

Our future aims are:

1) to find the relationship between the performance patterns of every bridge team member and his response to the index;
2) to develop a framework for evaluating thoroughly the ship navigator's performance; and
3) to find a hybrid evaluation method using physiological indices.

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