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**Evaluation of Bridge Teammates'
Mental Workload for Simulator-based
Training Using Physiological Indices**

By

Tokyo University of Marine Science and Technology (TUMSAT)

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Evaluation of Bridge Teammates' Mental Workload for Simulator-based Training Using Physiological Indices

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Abstract *The physiological indices, heart rate variability (R-R interval), salivary amylase/nitric acid, and facial (nasal) temperature, are sufficient to evaluate the mental workload of a ship bridge teammate: a captain, a duty officer, a helmsman, and a pilot. The safe navigation keeps with bridge teamwork, and it is not only a duty officer. From this point, we need to evaluate bridge teammates together for understanding their mental workload. The evaluation of bridge teammates had been tried using heart rate variability with the collaboration of Graduate school of Maritime Sciences, Kobe University and Maine Maritime Academy, the college of the University of Maine in 2008. However, it is not using facial temperature and saliva yet. Each physiological index has unique characteristic; if we use multi-physiological indices, we could improve the accuracy of evaluating their mental workload.*

In this project, we attempt to evaluate the bridge teammates' mental workload using facial temperature, heart rate variability, and saliva together, and we read their characteristics of mental workload for the ship handling. Moreover, we confirm the response in the real situation.

Keyword: *Simulator Training, Common/Individual Skill, Team Work & Mental Workload.*

1. Introduction

The physiological indices, heart rate variability (R-R interval), salivary amylase/nitric acid, and facial (nasal) temperature, are sufficient to evaluate the mental workload of a ship bridge teammate: a captain, a duty officer, a helmsman, and sometime includes a pilot. The safe navigation keeps with bridge teamwork depends on Bridge Resource Management (BRM) [1],[2], and it means the ship maneuvering is not only by a duty officer. From this point, we need to evaluate bridge teammates together for understanding their mental workload. The evaluation of bridge teammates had been tried using heart rate variability with the collaboration research of Graduate School of Maritime Sciences, Kobe University and Maine Maritime Academy, the College of the University of Maine in 2008. However, it is not using facial temperature and saliva yet. Each physiological index has unique characteristics; if we use multi-physiological indices, we could improve the accuracy of evaluating their mental workload.

In this project, we attempt to evaluate the bridge teammates' mental workload using facial temperature, heart rate variability, and saliva together. We read their characteristics of mental workload for the ship handling. Moreover, we confirm their response in the real situation toward evaluating the on-board training.

We report the results of the five key points:

- 1) The Heart Rate Variability (HRV) is useful for evaluating the simulator-based training.
- 2) The multi-physiological indices, HRV, Facial Temperature (FT), and Saliva Amylase Activity (SAA), is fine for evaluating for the mental workload for the ship handling.
- 3) The physiological indices are useful for evaluating the bridge teamwork.
- 4) The new saliva index, Nitric acid (NO_3^-), is also fine for evaluating the mental workload for the ship handling.
- 5) The typical index, HRV, is fine for the real on-board situation.

2. Ship Handling Simulator

We have the ship handling simulator (simulator) in the school. The Kobe University (Kobe) [3], Tokyo University of Marine Science and Technology (Tokyo) [4], and California Maritime Academy (CMA) [5] use their simulator to be carried out the experiments. The measurement instruments of the physiological response are the same.

The all simulators are full mission simulator, and the international standard. Figures 1 and 2 show the image of bridge, and outline of the simulator. The simulator consists of visual-, bridge-, and operation-system. The visual system: 360 and 240 degrees horizontal view system is popular, and we use both of them. By projecting images on the screen makes it possible to pseudo-maneuvering. Navigational tools such as Radio Detection and Ranging (Radar) [6], Automatic Identification System (AIS) [7], Electronic Chart Display and Information System (ECDIS) [8], and etc., her instruments are installed. We make the scenario by own for each school. That is authorized by the pilots. The scenario has the same concept for all universities. The case of narrow passage, entering a port, and congested traffic that the navigator needs a lot of judgments is chosen.



Fig. 1. The image of bridge system



Fig. 2. The outline of simulator system

3. Physiological Index

We choose three physiological indices to evaluate the mental workload of bridge teammates. All of them, HRV, FT, and Saliva, are response of the autonomic nerve system [9]. We evaluate the mental workload from the responses and their performance.

In our research, the stress-less sensor which measures their response is best for the evaluation, because the measuring stress is noise.

3.1 Heart Rate Variability (HRV)

The heart beat consists of P, QRS, T waves. Figure 3 shows Electrocardiogram (ECG). We measure R-R interval. The R-R interval is the interval from the peak 'R' to the next peak 'R'. The R-R interval fluctuates. The amplitude of R wave is remarkable, and we are easy to detect the peak points.

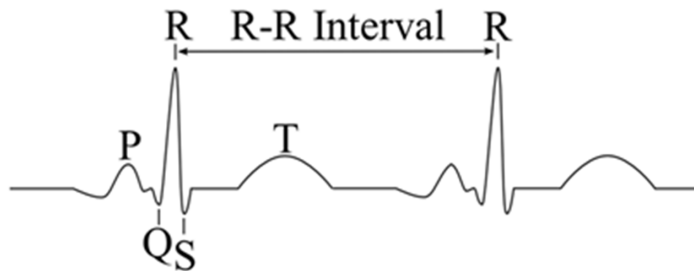


Fig. 3. ECG, R-R interval

Figure 4 shows an example of the measured R-R interval data, and it fluctuates 600 to 1,200 [msec]. We can calculate heart rate [bpm] in time domain, and LF/HF (Low Frequency: LF, High Frequency) value in frequency domain. The LF component is 0.04 to 0.15Hz, and the HF component is 0.15 to 0.40Hz. The LF is affected by the sympathetic and parasympathetic activity [10],[11]. The HF is affected by the parasympathetic activity. Especially, the HF is influenced by breathing. The LF/HF is typical index of sympathetic function for a lot of research fields [12]-[17].

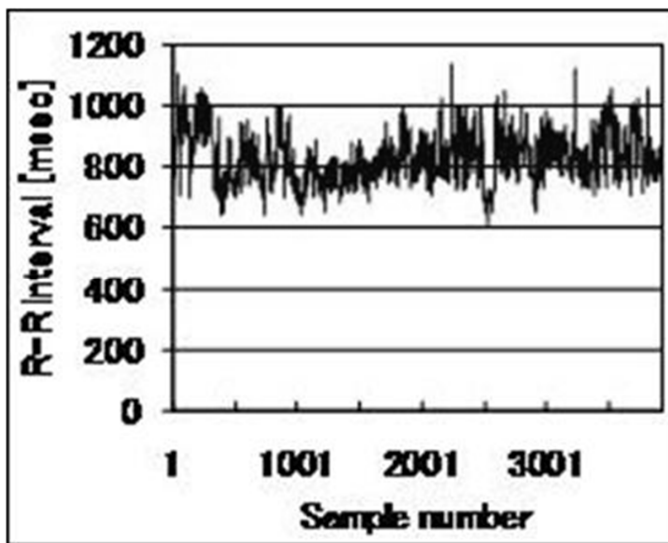


Fig. 4. The measured R-R interval data

We have Fourier Transform (FT) [18] by Fast Fourier Transform (FFT) [19] algorithm and Maximum Entropy Method (MEM) [20] in the frequency representation, and Short Time Fourier Transform (STFT) [21] and Wavelet Transform (WT) [22]-[24] in the time-frequency representation to calculate the frequency components (LF and HF) of R-R interval after interpolating using the cubic Spline function. In this project, we choose the MEM, and the interval time is 30 seconds [25]. The STFT, perhaps, is better than MEM. The STFT fixes the band of the frequency components, and it does not change like Autoregressive model (AR) order of MEM, but we choose the basic algorithm first in the frequency representation. The STFT has also consideration of window function. The Gabor function [26] is usual, but its accuracy is needed to confirm.

We use the Heart rate monitor (Polar RS800CX training computer, Polar Electro [27], Figure 5) to measure R-R interval. The Heart rate monitor consists of the wrist watch and the chest belt. The chest belt with sensor measures the R-R interval data, and transmits to the wrist watch with memory. The R-R interval is measured with the accuracy of 1 [msec]. The size of memory depends on the number of data, and we are able to measure the R-R interval data during the navigational watch (4 hours). We have sometime error data, high and low level (ex. 2,000, 300). We remove them if the error data appears, but it is only for a little. We give up the analysis if there are a lot of errors.



Fig. 5. The heart rate monitor, wrist watch and chest belt

3.2 Facial Temperature (FT)

We use the nasal and the forehead skin temperature of the facial temperature [28], [29]. The nasal temperature responds well, and the forehead temperature doesn't, because a lot of capillary vessel gathers at the nasal part, and the nasal temperature is sensible for the mental workload; however, the forehead temperature only depends on the body temperature. We use the nasal temperature or the difference between nasal and forehead temperature. The indoor simulator-based experiment is stable for the experimental conditions- air temperature, wind, humidity, noise, etc. It is enough to use the nasal temperature.

These temperatures can be measured by thermo-camera. The subject doesn't wear any sensor, and it is stress-less equipment for the subjects. Figure 6 shows the image of the measured data for bridge teammates: navigator and helmsman. We can measure their facial temperature at the same time, and get the

nasal and forehead temperature. The data number in the area of nasal and forehead temperature differs for each teammate, but we can analyse the data. Table 1 shows the specification of the thermo-camera.

Table 1. The specification of thermo-camera

Range [centigrade]	0.0 - 70.4
Accuracy [centigrade]	0.1
Resolution [line]	320
Scanning line [line]	240
Distance [meter]	20 - inf.
View [degree]	H:20.0 × V:15.0

Figure 7 shows how to decide the nasal and forehead areas from the thermo-image data. The nasal and forehead areas are decided utilizing the frame of eye glass. The subject wears the eye glass without the glass (only frame) if they don't wear it.



Fig. 6. The image of the measured thermo-data

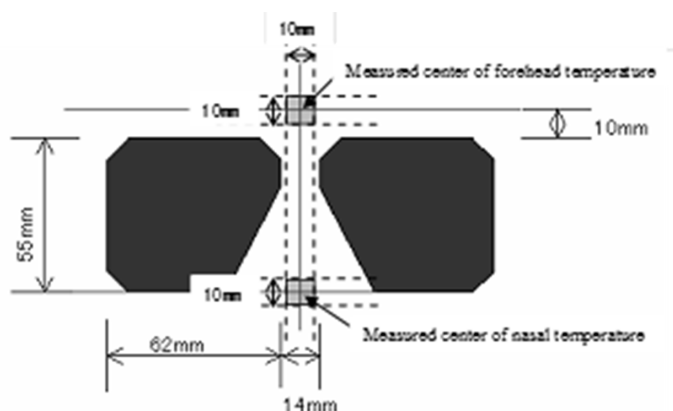


Fig. 7. How to decide the nasal and forehead areas from the thermo-image data

3.3 Saliva

We try two kinds of saliva indices: amylase activity and nitric acid ion (NO_3^-) [30],[31]. The both of them come from the blood, and the response time is fine. It responds into 30 seconds.

(1) Saliva Amylase Activity (SAA)

The Saliva Amylase Activity (SAA) measures by stress measurement devise (SMD) of Nipro Co. Ltd. [32]. The subject puts the tip under the tongue to take saliva for 30 seconds, and the SMD measures the SAA for 30 seconds. We need 1 minute for getting the measured data, and we prepare some SMDs to get the data of bridge teammates every 30 seconds. Figure 8 shows the SMD.

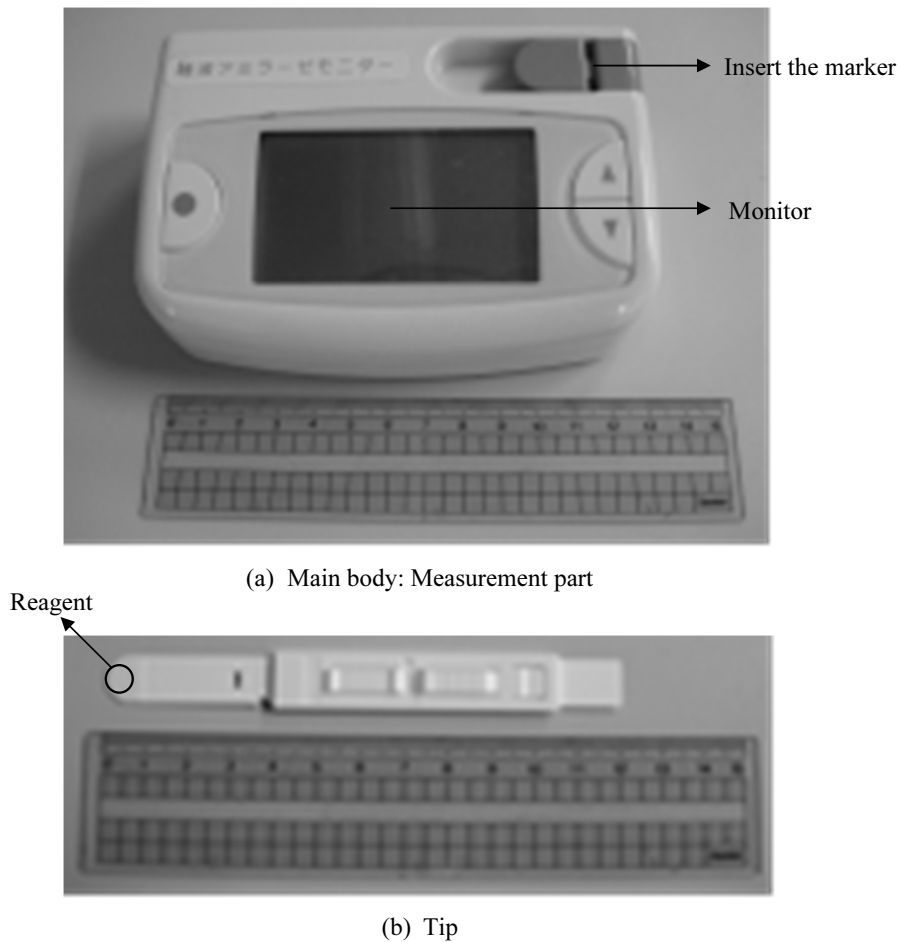


Fig. 8. The saliva amylase activity measurement devise

(2) Nitric acid ion (NO_3^-)

The salivary NO_3^- device is specifically designed by the National Institute of Advanced Industrial Science and Technology (AIST) [33]. The device utilizes pH checker [34]. The AIST has developed liquid film which changes pH value into salivary NO_3^- . Figure 9 shows the salivary NO_3^- measurement device consists of a measurement part and an electrode of liquid junction. The electrode is filled with NO_3^- solution, and has a hole connecting the solution with saliva (Figure 10).

The size of the measurement body is L: 143×H: 15×W: 28 [mm^3], and weight is 48 grams. The measured range is 0.0 to 14.0 [pH].

In regard to a relation between pH and NO_3^- value, pH 6.9 is the basis for one point calibration. It means NO_3^- is 10^{-3} mol [moles/l]. If pH value increases 1.0, it means NO_3^- is 10^{-2} [mol], and to decrease 1.0 means NO_3^- is 10^{-4} [mol]. The sensor part of the salivary NO_3^- measurement device is always immersed in NO_3^- solution of 10^{-3} [mol] just before every experiment, because we need to keep the sensor part stable during the experiments.

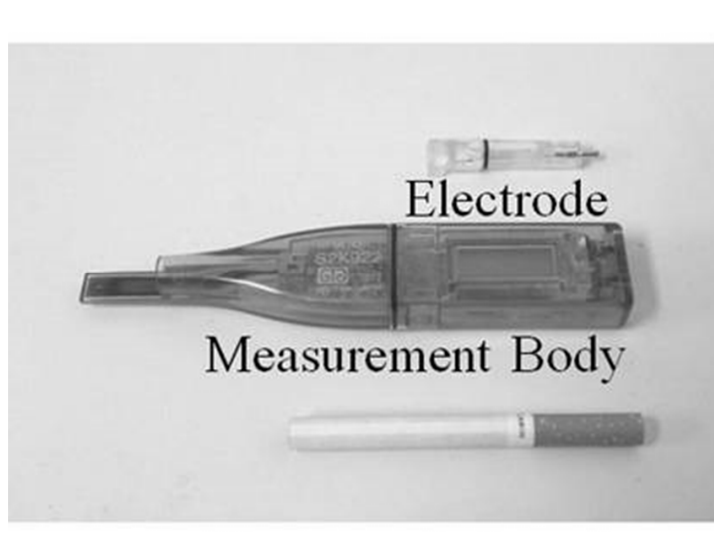


Fig. 9. The Salivary NO_3^- measurement device

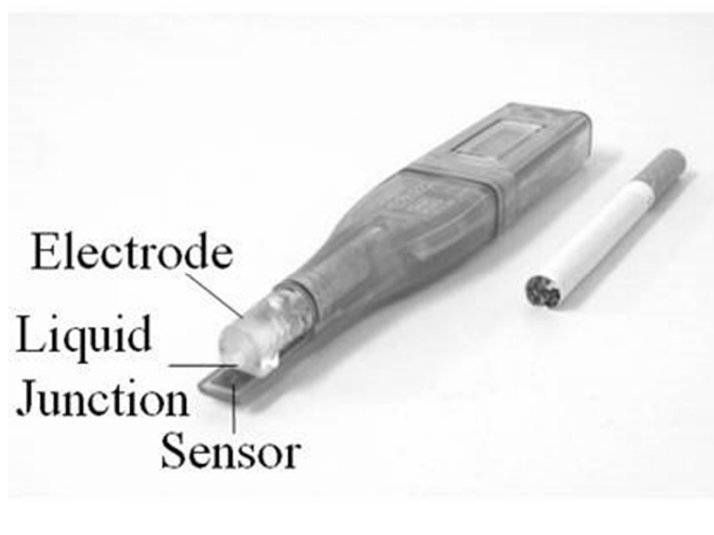


Fig. 10. The liquid junction and sensor parts of the measurement device

It might be afraid that NO_3^- solution in an electrode is mingled with KNO_3 solution of 10^{-3} [mol]; however, it is no matter for the sensor requirements, because the KNO_3 solution in the electrode is stronger than that of 10^{-3} mol. That is why osmotic pressure effects between two solutions, and we need not to worry about mingling two solutions.

We can get the salivary NO_3^- value in only 1 minute. The subject puts a metal spoon (spoon) under the tongue, and we measure the NO_3^- value to connect the sensors with the saliva. After every measurement, we need to sweep the saliva completely on the sensor and spoon using distilled water and paper waste. The spoon is prepared each subject.

4. Evaluation

We evaluate the bridge teammates' mental workload using physiological indices. It can be proposed as a quantitative evaluation. We show the relationship between the index of HRV, FT, Saliva and Mental Workload (MW).

4.1 Heart Rate (HR) and LF/HF value

(1) HR

- IF HR increase, MW is High
- IF HR decrease, MW is Low

The HR is influenced on the body activity, and we need enough consideration to read the response in comparison with the events of the performance.

(2) LF/HF

- IF LF/HF increase, MW is High
- IF LF/HF decrease, MW is Low

The LF/HF value takes care of the influenced on the parasympathetic nervous system, and we usual need enough consideration to read the response with the events of the performance, but the response of the navigator is remarkable and clear [35],[36].

4.2 Nasal Temperature (NT) and Forehead Temperature (FT)

- IF NT or $(NT - FT) < 0$ (decrease), MW is High
- IF NT or $(NT - FT) \geq 0$ (increase), MW is Low

The NT can lead the spot response and the tendency together.

The thermo-camera must be set up in front of the subject. This system is fine for evaluating the simulator-based training. The simulator space is limited, and it also limits the subject's performance. We can measure easily.

4.3 Saliva Amylase Activity (SAA) and NO_3^-

(1) SAA

- IF SAA increase, MW is High
- IF SAA decrease, MW is Low

The SAA allows that the subject takes water in the experiments, and it doesn't relate to the measured MW.

(2) NO_3^-

- IF NO_3^- increase, MW is High
- IF NO_3^- decrease, MW is Low

The NO_3^- is influenced on conditions of the mouse. The NO_3^- does not allow to take water because the pH value changes for it.

4.4 Performance

We record the behavior and voice by video camera and IC recorder, and check subject's performance by work sampling [37]. Moreover, we use the check sheet. Table 2 shows the check sheet.

Table 2. The performance check sheet

[illegible]

See reverse for grading definitions

The check items are Fundamentals, Technique, BRM, Integration, and Leadership. It does for bridge teammates: Mate, Radar observation, Navigator, and Helmsman. The evaluation of the individual performance is scored by the specialists. The score is five levels: VG 4.0, G 3.5, S 3.0, P 2.5, U 2.0.

5. Informed Consent

We need the informed consent for human research. The Kobe and CMA use the similar format. The Tokyo allows the permission of the Kobe's committee. We explain the experiment with oral and the informed consent form, and if they accept, we request to join in the research experiment as the subject. We show the basis informed consent form is below.

GRADUATE SCHOOL OF MARITIME SCIENCES, KOBE UNIVERSITY
5-1-1 FUKAEMINAMI, HIGASHINADA, KOBE, HYOGO 658-0022



**“Evaluation of Bridge Teammates’ Mental Workload for simulator-based training Using
Physiological Indices”**

Dr. Koji Murai, Principal Investigator

INFORMED CONSENT FORM

You are being asked to participate in a research study of the performance and mental workload on your heart rate (CMA, Kobe, Tokyo), facial temperature (Tokyo, Kobe), and saliva (Kobe) while you are operating the vessel. You have been invited to participate in this study because you are a professional mariner and are already familiar with human research.

We ask that you read this form carefully and ask any questions that you might have before agreeing to participate in the study.

Purpose of This Study

The purpose of this study is to evaluate bridge teammates’ mental workload (stress) and their performance. We will evaluate the mental workload (stress) by measuring heart rate variability (R-R interval), facial temperature, and saliva, and the performance. Once the data is analyzed and evaluated, we will be able to develop improved training for mariners preparing to go to sea where stressful conditions exist.

- Participants in this study are from the *Kobe, California, and Tokyo Maritime University*.
- The total number of subject is expected to be 10.
- Dr. Koji Murai will conduct the research. He is a professor at Kobe University, Graduate School of Maritime Sciences in Kobe. He is not receiving any remuneration or payment from an outside source or from you to conduct this research. Participation by students is strictly voluntary and there is no payment for participation.

Description of the Research Study Procedures

- If you agree to be in this study, we will explain the procedure in detail
- Outline of procedure
 - a. The researcher will ask you to place a heart monitor (a belt that goes around the chest underneath the clothes) on your chest by yourself.
 - b. The researcher will ask you to wear a special wrist watch with a memory chip in it which will record the information from the heart rate chest belt.
 - c. The researcher will ask you to take your saliva while you serve in a ship handling exercise.
 - d. The researcher will tape-record a picture by Video and Thermography while you serve in a ship handling exercise.

Risks of Being in Study

There are no risks because the heart rate chest belt, wrist-watch memory, thermography are external measuring devices. You will act normally, just as you would without the two or three measuring devices attached to you.

Benefits of Being in Study

Although there are no direct benefits to participating in this study, you will be contributing to the body of knowledge about the mental workload or stress mariners experience when they work on a vessel.

Payments

You will not receive any compensation for your participation in this study.

Costs

There is no cost to you to participate in this study.

Confidentiality and Privacy of Data

- The records of this study will be kept strictly private. The data will be stored in the navigation laboratory computer owned by Dr. K. Murai. Your name will be entered and a letter will be assigned to your name so that in any literature published about the study, you will appear only as “sub. A”, “sub. B”, and so on.
- Access to the records will be limited to Dr. K. Murai, if requested.
- In any report made, we will not include any information to make it possible to identify you.
- We will video-tape your performance on the vessel and will analyze the data from the tape. After ten (10) years, the videotape will be destroyed.
- After ten (10) years, we will destroy all the personal data collected.
- It is expected that the research study will be reported in an international journal, not yet determined. Your name or other identifying information will not appear in any publications of this study material.

Voluntary Participation

- Your participation is entirely voluntary. If you choose not to participate, it will not affect your current or future relations with Kobe University.
- You are free to withdraw at any time with no consequences to you.

Contacts and Questions

- The researcher conducting this study is Dr. Koji Murai (Principal Investigator). For questions or more information concerning this research, you may contact Dr. Murai (at murai@maritime.kobe-u.ac.jp).

Copy of Consent Form

- You will be given a copy of this consent form and one will be kept in our records file for future reference.



GRADUATE SCHOOL OF MARITIME SCIENCES, KOBE UNIVERSITY

Research Informed Consent Form

I have read the contents of this consent form and have been encouraged to ask questions. I have received answers to my questions. I give my consent to participate in this study. I have received a copy of this form.

Study Participant Name _____
(Please Print)

Signature of Participant _____

Date: _____

6. The Evaluation of Simulator-based Training Using LF/HF

The subjects, who wore the heart rate monitor, had trained for three months. We calculated LF/HF by cubic spline and MEM. In addition, we defined the reference value to evaluate as high condition of the mental workload. We think that the case of the calculated LF/HF value is more than the reference value is the stressful condition [38].

We counted the number of the stressful condition, and grouped the tendency of mental workload to compare with the contents of scenario.

The subjects were standing, and moved in the bridge while practice of simulator. The experiments were carried out the same scenario in a day. The following results were treated as failure.

- The deficit data for the malfunctioned the sensor.
- The data of the skipped number.

We measured the data at least 10 minutes of before/after the experiments to check the changing of the measured data. They had been operated the simulator-based vessel for 23 days. We got total 18 to 25 data every subject.

6.1 Scenario

Figures 11 to 13 show the ship's track. Figure 11 shows the turning around buoy. This is a basic navigation (Scenario A). The scenario A hasn't the dangerous situations- to avoid a target, and to control the ruder and speed. Therefore, it enables to maneuver stability. From Figure 12, we can see a lot of vessels, and that is a collision situation; moreover, it has a narrow passage route. We think they are stressful condition. We define this is the advanced navigation (Scenario B). In Figure 13, it is entering a port (Scenario C). In addition, in the scenario C, they must turn to the left hand along the way, and take up a berth with ship's right side along shore. This maneuvering is a difficult situation, and stressful condition.

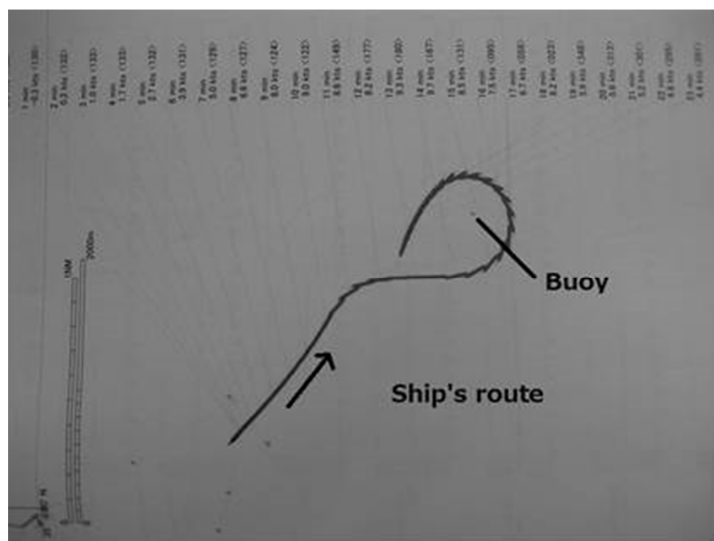


Fig. 11. Scenario A: Basic Navigation

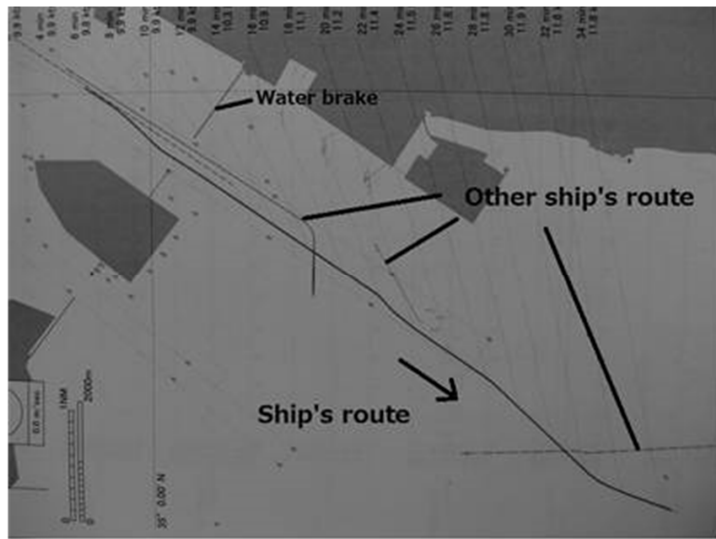


Fig. 12. Scenario B: Advanced Navigation

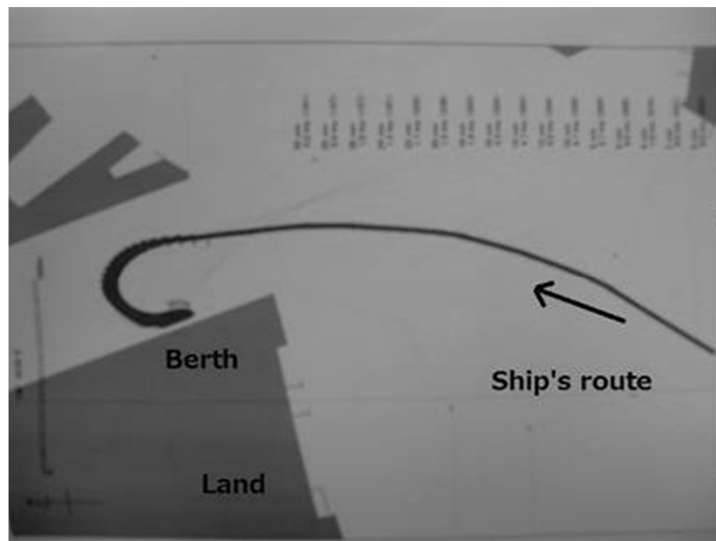


Fig. 13. Scenario C: Berthing

The scenario A is basic maneuvering such as go ahead and aback, emergency stopping, turning, tug boat, and other basic practices. The scenario B is advanced maneuvering that required to avoid other vessels. The scenario C is maneuvering to berth, entering and leaving a port.

In this project, we sorted all scenarios over three groups from feature of contents. We considered the changing of mental workload, and the tendency of alteration of the pattern from the transitions of scenario. Table 3 shows three kinds scenario.

The subjects are three cadets (S1, S2, S3). All of them have on-board experience (training ships) for 1 year; however, S3 has more 9 months for the patrol boat.

Table 3. Scenario

	Kind	Contents of scenario
A	Basic maneuvering	go ahead and aback, emergency stop, turning, treatment of tug boat
B	Advanced maneuvering	scenarios required to avoid other ships
C	Maneuvering at berth	scenarios contain entering or leaving port

6.2 How to Evaluation

We calculated mean of LF/HF for maximum 25 experiments for all subjects. In this project, we proposed the threshold as twice of mean for the mental workload as the reference value.

We compared the number of more than the threshold for 27 data, and investigated the alteration tendency of each. Moreover, we made an inquiry how different each them.

6.3 Results

Tables 4 and 5 show the total number of more than threshold for the experiments of each subject (S1, S2, S3). The total number of the experiment is 27 times (14 in Table 4, 13 in Table 5). Some part of blanks, ‘-’ in Tables, are failures of measurement, especially S2 had a lot of failures (7 times). The 13 experiments (Table 5, second stage) were carried out for three months later than the 14 experiments (Table 4, first stage). The subjects drilled on a real ship for the simulator scenarios between first stage (Table 4) and second stage (Table 5). We confirm subjects’ mental workload before and after the real ship training. The 26 kinds of simulator practice aren’t the same contents.

Table 4. The total number of more than threshold ($2 \times \text{mean of LF/HF}$) (First stage)

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Average
S1	-	9	33	33	20	20	4	14	14	7	5	9	4	8	13.85
S2	1	3	14	14	-	-	9	37	-	-	44	-	8	4	14.89
S3	3	5	4	1	0	0	28	45	51	1	3	4	2	0	10.50
Scenario	A	A	B	B	B	B	C	C	C	A	A	B	C	C	

Table 5. The total number of more than threshold ($2 \times \text{mean of LF/HF}$) (Second stage)

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	Average
S1	4	4	14	0	2	1	5	6	20	12	14	2	-	7.00
S2	9	-	7	3	-	7	12	9	6	10	4	12	8	7.91
S3	-	8	21	-	7	-	2	-	7	-	6	6	7	8.00
Scenario	B	C	C	B	C	B	B	C	C	B	C	B	C	

Figures 14 to 16 show typical results of LF/HF for each scenario (scenario A, B, C), subject 3 (S3). Figure 14 was the first experiment of the scenario A, basic navigation. The mean of LF/HF is 0.57. From Figure 14, the LF/HF increases dramatically at the part of circle, the subject handles the ship in turning. However, the most of the values is stable.

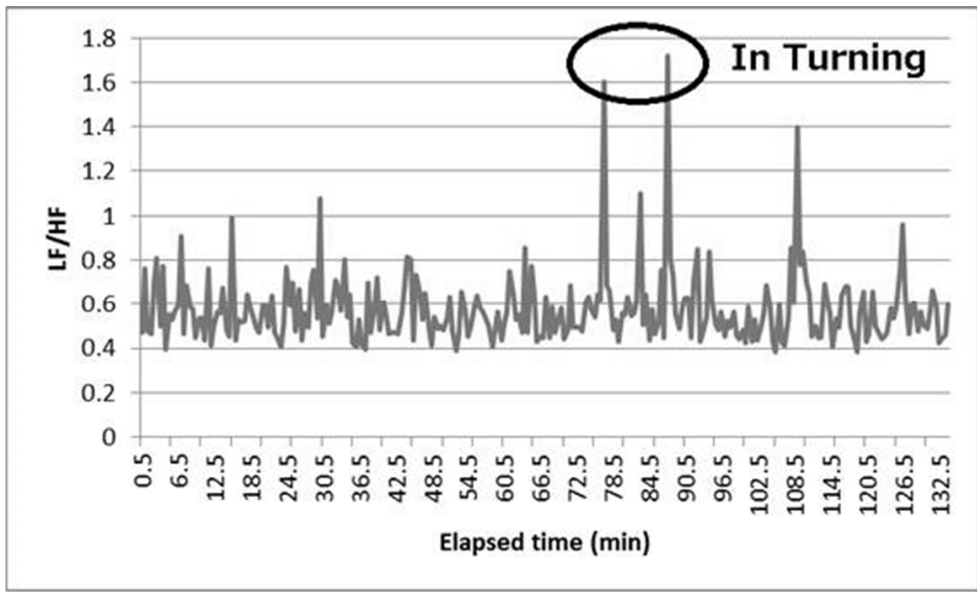


Fig. 14. LF/HF value of S3 (1st: scenario A), mean value 0.57

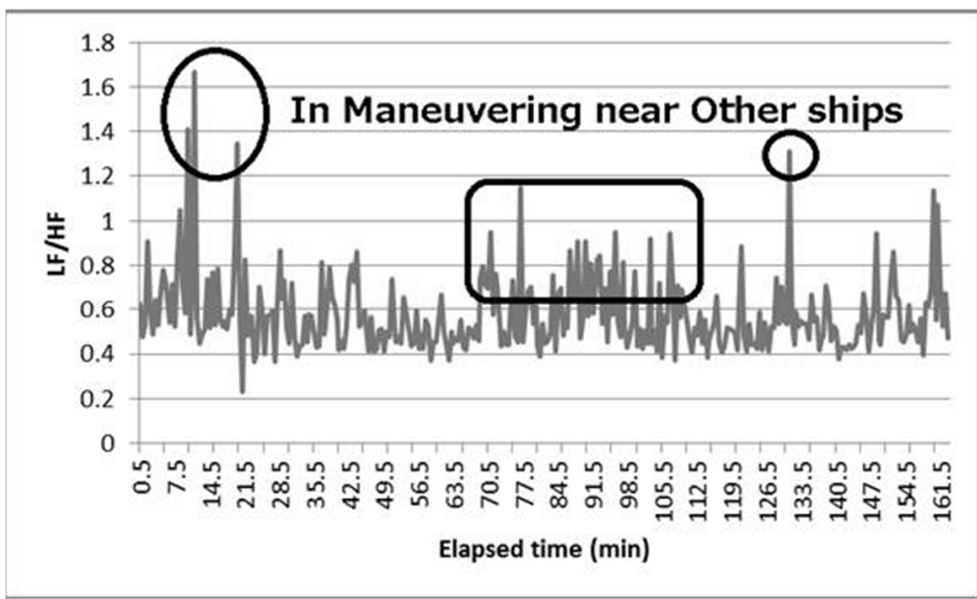


Fig. 15. LF/HF value of S3 (3rd: scenario B), mean value 0.58

Figure 15 shows third experiment of scenario B, advanced navigation. The mean of LF/HF is 0.58. We can see some spike responses (cycle parts in Figure 15) when the subject needed to avoid targets, and judge the change of own ship's course. The response time is also proportion to maintaining the dangerous situation.

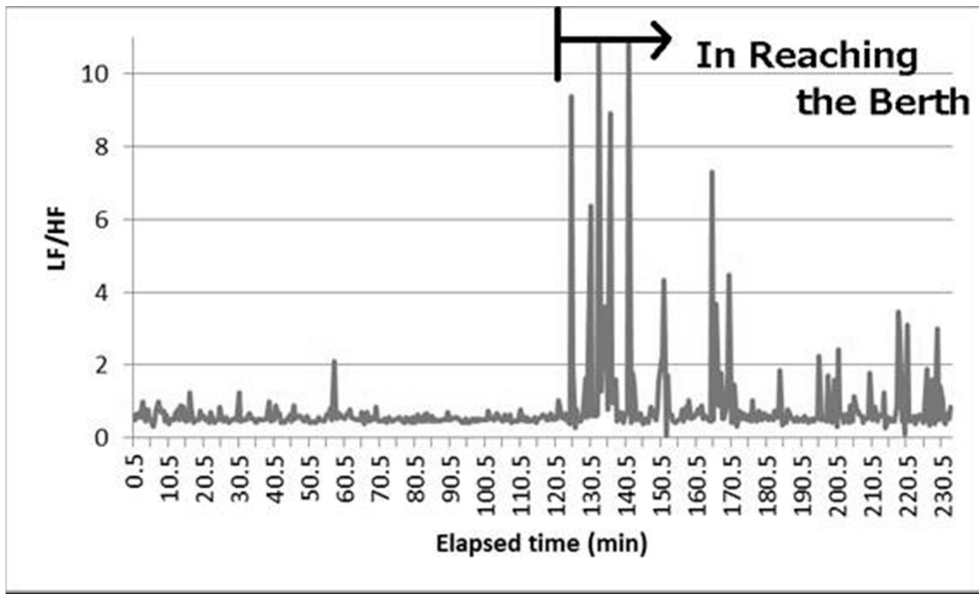


Fig. 16. LF/HF value of S3 (8th: scenario C), mean value 0.80

Figure 16 shows the results of eight experiment of scenario C, berthing. The mean of LF/HF is 0.80. It has highest mean values of three Figures. From Figure 16, the spiked response appeared when the subject controlled the ship's course and speed to approach to the berth.

6.4 Consideration

Tables 4 and 5 show the difference results for each subject who felt the difference kinds of mental workload. They quite differed. In other word, the simulator-based training has practical effects for matching the level of skill and ability. It is not only the common mental workload by training circumstance, but also difference mental workload to be given to each. If all of mental workload of subjects are nearly same, it is mental workload concerning to be given training; moreover, it can interpret to have no various sense of urgency to be taken by each scenario.

From the results of S1, there was the target ship which must be avoided to own ship in scenario B. It suggested that the target ship gives him the mental workload. However, in scenario C, maneuvering at berth, S1 put out the result to be able to do with better relax than anyone.

From the results of S2, it was marked a lot of failures, it showed that almost middle mental workload between them in the whole when we changed the content of scenario majorly. As an exception, we aren't clear the result of basic maneuvering 11th; therefore, the re-examination was required.

S3 had the lowest mental workload, but it made rising of mental workload more prominent in scenario C. In my understanding, it attributed to his carriers of boarding. Although S3 had many on-board training, but S3 hadn't any experience of berthing. The berthing usual does by Captain.

You can understand that the result in Table 4 differs from that in Table 5. One is total number (mental workload) variability decreases. We think that subjects can't regard simulator training as on-board experiences. The other is scenarios that subjects felt the change of mental workload. For example, subject 1 (S1) felt more mental workload in scenario C. This case revealed that subjects can do.

The tendency of changing mental workload had various feature from each subject. However, we can see a little relaxation of mental workload by their habituation over the whole. In scenario C of S3, its alteration was noticeable between three times after 7th and two times after 13th in Table 4.

From Figures 14 to 16, we can analyze the pattern of mental workload in each scenario. Figure 14, basic maneuvering, showed that it based on around 0.57 (mean value). By contrast, Figure 15, advanced maneuvering, indicated intermittent response for the mental workload. It was not able that subject had held comparatively high it with reactions during 70-110 minutes from beginning, although subject hadn't characteristics. It showed that the response became clear, and subject can't relax until passing danger of collision. Figure 16 at berthing also showed high mental workload, it appeared around at berth.

7. The Evaluation of Simulator-based Training Using LF/HF, Facial Temperature, and Saliva Amylase Activity

We evaluate the mental workload using three physiological indices. The cross-index needs accurate evaluation, and cross check.

The subjects were 6 students (male, 22-29 years old) who have the third grade navigator's license of ocean going vessel.

7.1 Scenario

The scenario is the narrow passage (Scenario D, Figure 17) and entering a port (Scenario E, Figure 18). The condition of scenario is below.

(1) Scenario D: Narrow passage

Own ship: Container ship- 20,000 Gross Tons, Length 201.0 meters, Breadth 27.1 meters, Course 000 (North) degrees, Speed 13.0 knots.



Fig. 17. Scenario D: Narrow passage

(2) Scenario E: Entering a port

Own ship: General cargo ship- 3,000 Gross Tons, Length 93.3 meters, Breadth 15.6 meters, Course 92 degrees, Speed 6.0 knots.

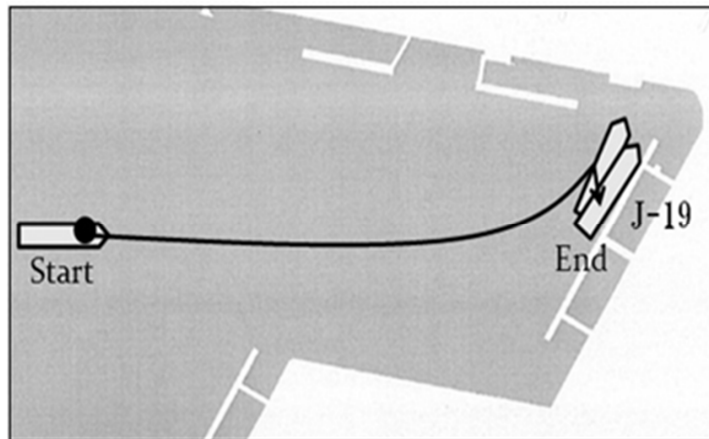


Fig. 18. Scenario E: Entering a port

The weather is blue and sky, the current and wind is calm. The subject did not need decision making for controlling the ship on the external forces. In Figures 17 and 18, 'Start' and 'End' shows initial ship's position and the goal of scenarios. The experimental time differs every subject.

7.2 How to evaluation

Three kinds of indices, LF/HF, the difference between Nasal and Forehead temperature (N-F temperature), SAA, change for the events of the scenarios. We evaluate the mental workload of the navigator using cross-index. If LF/HF and SAA increases and N-F temperature decreases, the navigator is stressful.

7.3 Results

We show the typical results of the measured LF/HF, N-F temperature, and SAA together for going a narrow passage (Figure 19) and entering a port (Figure 20). In Figures 19 and 20, SAA value is every 30 seconds and, 'A' to 'E' is remarkable events.

[Event]

- A) Decide own ship's course at 3, 9, and 23 minutes.
- B) Close to the fishing boats, crossing vessel, over taking vessel at 5, 11, and 25 minutes.
- C) Failure to communicate between pilot and helmsman at 18 minutes.
- D) Use engine motion and tugboat for changing course.
- E) Let go anchor (50 meters to berth).

The solid line, bold line and dotted line are N-F temperature, SAA value and LF/HF value respectively, and horizontal bold line shows SAA reference value (0.84 in Figure 17 (42[kIU/I]), 0.76 in Figure 18 (38[kIU/I])).

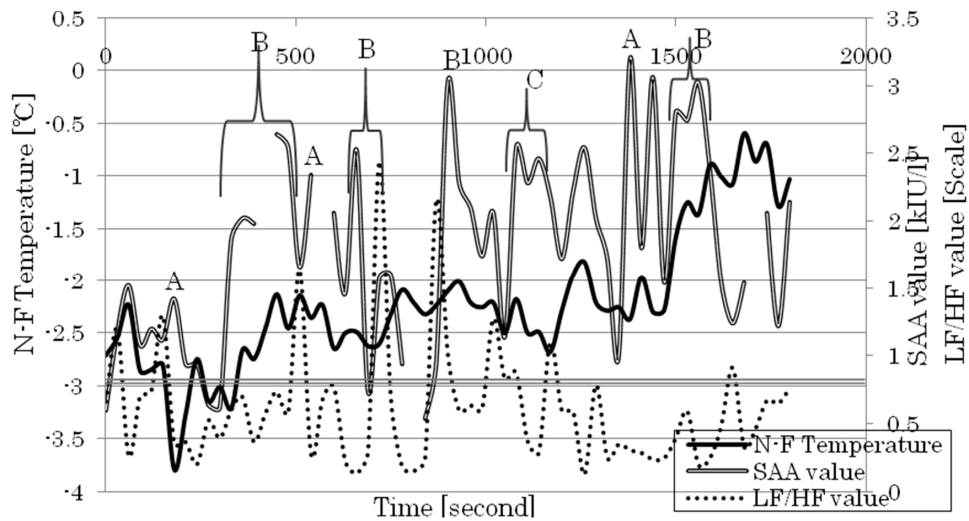


Fig. 19. The results of LF/HF, N-F temperature, and SAA (Narrow passage)

From Figure 19, most of SAA value was more than reference value. The student kept high mental workload while simulator training. Meanwhile, N-F temperature increased from start to end of the experiment gradually. We think that subject felt more stress at the start than the end of the training. SAA and LF/HF value increased when subject decide to change own ship's course for safe navigation (event A), and their values increased when subject need to avoid the collision to fishing boats and other vessels (event B). Moreover, their values increased when pilot fail to communicate with helmsman (event C).

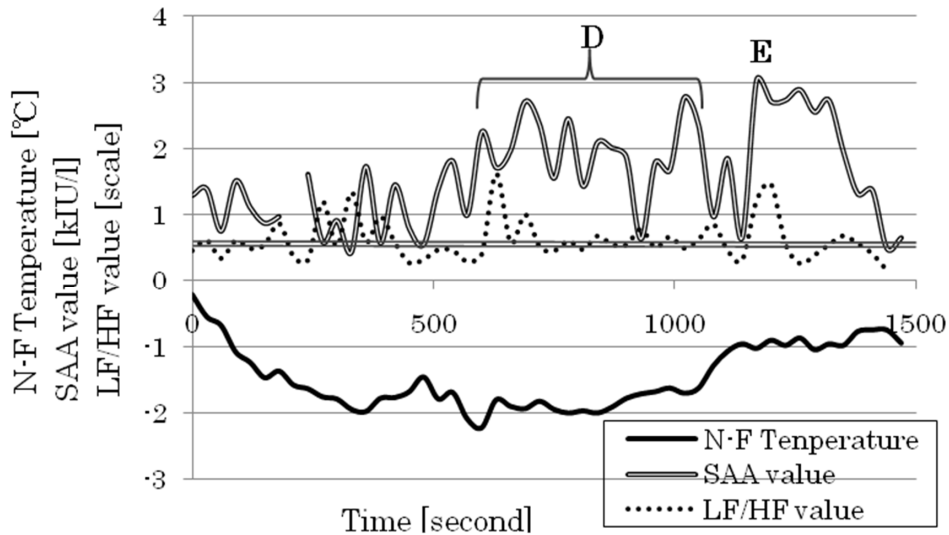


Fig. 20. The results of LF/HF, N-F temperature, and SAA (Entering a port)

From Figure 20, most of SAA value was more than reference value. N-F temperature decreased while simulator training, and showed large values at start and end of the experiment. The subject kept high mental workload while the experiment. SAA and LF/HF value increased when the subject used engine motion and tugboat for adjusting speed and course (event D) and let go anchor (event E). The results of narrow passage and entering port is similar, and all subjects shows same tendency like both of Figures.

We confirmed SAA value and LF/HF value are good indices at the spot, and N-F Temperature is also good at the tendency. The instructor of simulator training will be able to use heart rate variability, salivary amylase activity and facial temperature.

7.4 Consideration

We attempted to evaluate the student's mental workload for simulator training using SAA value, facial temperature and R-R interval. As the results, we confirmed the effect of SAA value, facial temperature (N-F temperature) and R-R interval (LF/HF).

The SAA value and LF/HF value increases, and the N-F temperature decrease when the navigator begins his mental workload for safe navigation- decision making for ship handling.

The SAA value and LF/HF value evaluates the mental workload of the ship navigator quickly on the spot, but N-F temperature shows the whole tendency.

We confirmed that the SAA value, the facial temperature and the LF/HF value are better cross-indices for evaluating the student's simulator training.

However, we need to evaluate the response time for the differences among individuals, and more data to get more accurate results.

8. The Evaluation of Bridge Teammates for Simulator-based Training Using HRV, Facial Temperature, and Saliva Amylase Activity

We evaluate the bridge teammates' mental workload using three physiological indices: HR, N-F temperature, and SAA. We tried to evaluate two bridge teammates, navigator (pilot) and helmsman, together.

The subjects were 7 students (Table 6). One of them (subject A) is a third grade pilot apprentice. Table 6 shows subjects.

Table 6. Subjects

Subject	Gender	Age	On-board experienced year
A	M	23	1 year
B	M	27	1year 10months
C	M	28	2 years
D	M	24	6 months
E	M	22	3months
F	M	21	3months
G	F	21	3months

8.1 Scenario

We choose the entering a port because we need a lot of stressful conditions to evaluate the bridge teamwork- the communication between the navigator and the helmsman. In case of the entering a port. The navigator needs a lot of judgments for handling the ship for short time, and the helmsman also is given a lot of orders from the navigator.

The scenario is the same as section 7.1, scenario E. Own ship: General cargo ship- 3,000 Gross Tons, Length 93.3 meters, Breadth 15.6 meters, Course 92 degrees, Speed 6.0 knots. The weather is blue and sky, the current and wind is calm.

8.2 How to evaluation

Three kinds of indices, HRV (R-R interval), N-F temperature, SAA, change for the events of the entering a port. We evaluate the mental workload of navigator (pilot) and helmsman using cross-index. If HRV and SAA increases and N-F temperature decreases, the navigator and the helmsman is stressful.

8.3 Results

We show the results of SAA value, HRV, and N-F temperature of the navigator and the helmsman, respectively.

(1) SAA value

We show typical result of SAA value for entering a port (Figure 21). The SAA value measured every 30 seconds. In Figure 21, the bold (black) and solid (gray) lines are pilot and helmsman SAA values each. The 'A', 'B', and 'C' are events.

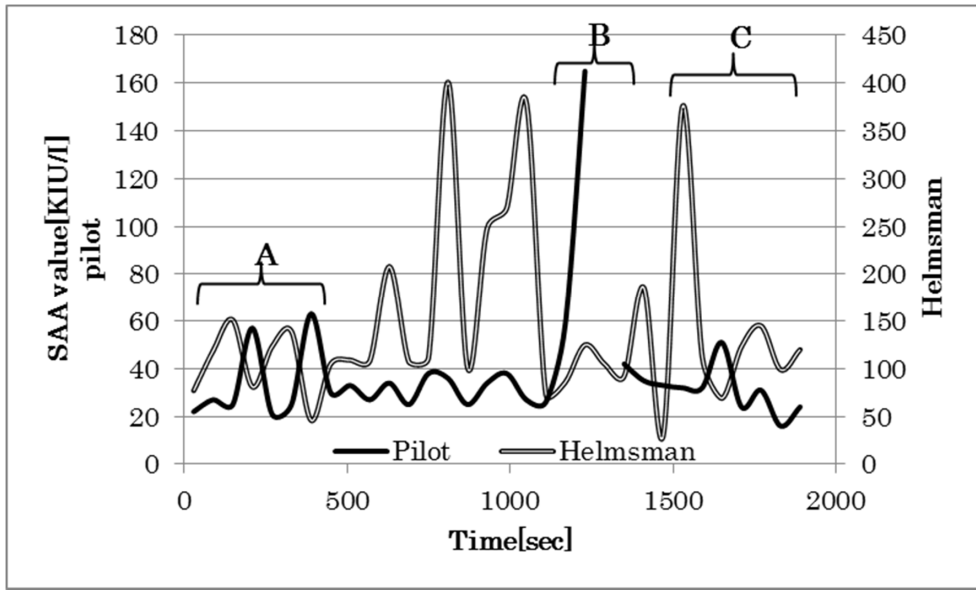


Fig. 21. The results of SAA value (Navigator and Helmsman)

[Event]

A: The pilot change course to the berth.

B: Let go anchor.

C: Berthing.

From Figure 21, the pilot's SAA value increased at events A and B, and the helmsman increases at events B and C. We think that the pilot needs decision making for approach to the berth (event A) and the key point of berthing (event B). Then, the helmsman needs a lot of rudder and speed controls before events B and C. Pilot felt more stress on the judgment. Moreover, there is difference of response time between pilot and helmsman. The helmsman follows the pilot's decision making. We confirmed same trends of SAA value for pilots and helmsmen.

(2) Heart Rate Variability (R-R interval)

We show typical result of R-R interval for entering a port (Figure 22). The bold and solid lines are pilot and helmsman R-R interval data each.

From Figure 22, pilot and helmsman R-R interval were short after event A in where pilot needs decision making for berthing and controlling the rudder and speed. This trend is similar to SAA value. Then, R-R interval fluctuates because of its responses appears immediately. The value decreases when the pilot and helmsman need the judgments for safe navigation. We confirmed same trends for all results.

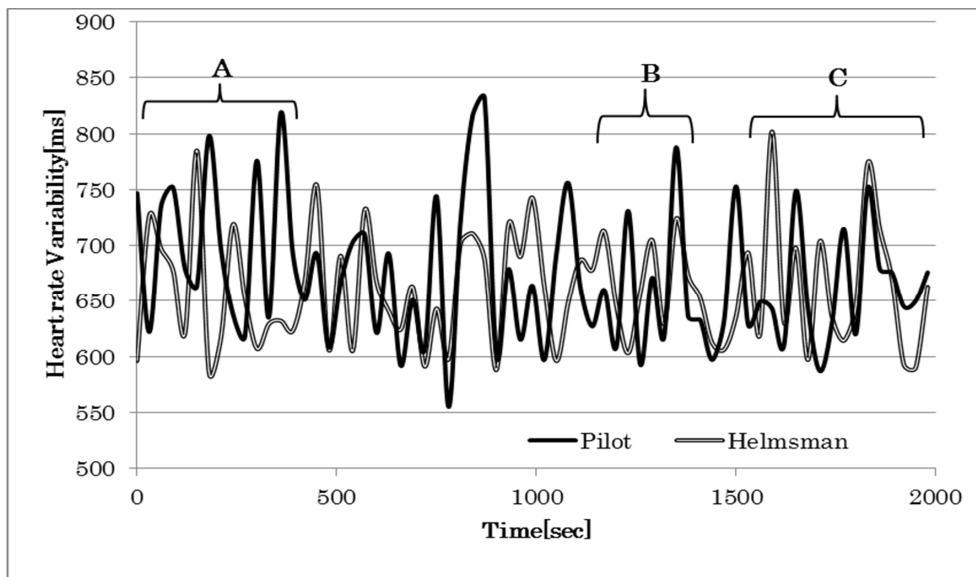


Fig. 22. The results of HRV, R-R interval (Navigator and Helmsman)

(3) Facial Temperature

We show typical result of facial temperature for entering a port (Figure 23). The bold and solid lines are N-F temperatures of pilot and helmsman each.

From Figure 23, pilot and helmsman N-F temperature decrease at event A than events B and C. We think subjects felt more stress at the beginning of the scenario than the end. This trend supports the planning of entering a port did before the navigation. Then, events A and B got the remarkable responses for the judgment of approaching and berthing. We confirmed same trends for all result.

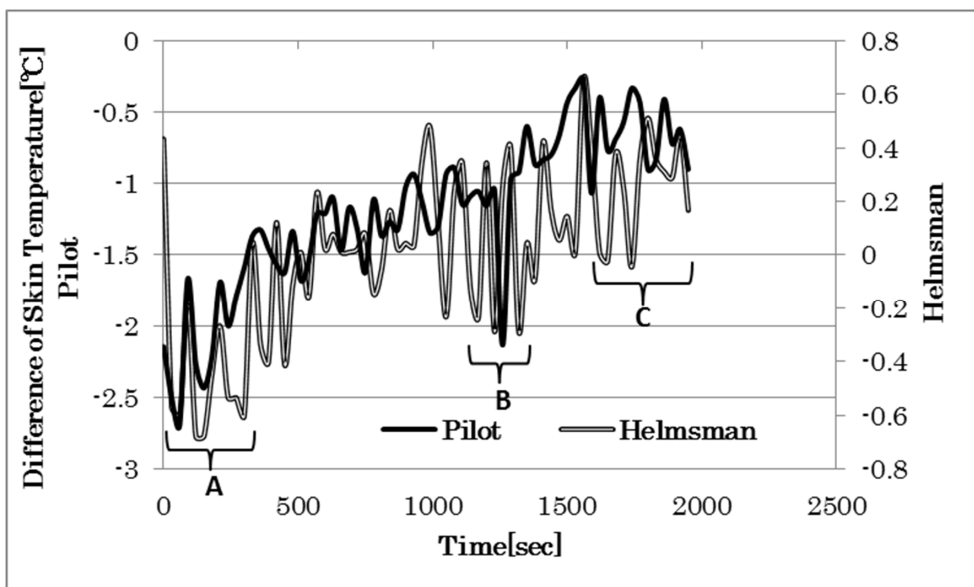


Fig. 23. The results of N-F temperature (Navigator and Helmsman)

From the results, N-F temperature is fine to clear the mental workload with both of response and trend, and it is easy to get in simulator is the limited space. The R-R interval is also fine to clear the response, but we can't get the trend of the mental workload.

8.4 Consideration

We attempted to evaluate the bridge teammates' mental workload for simulator-based training using SAA value, facial temperature, and heart rate variability (R-R interval). We confirmed same trends of physiological indices for pilots and helmsmen. Three physiological indices show the remarkable response to the judgement for ship handling. Three physiological indices is useful for evaluating the mental workload of bridge teammates.

9. The Evaluation of New Index: Saliva Nitric Acid (NO_3^-)

We confirmed the salivary NO_3^- responses for a ship handling as a new index. The simulator-based experiment is also the most important because the simulator makes it easy to control the experimental conditions; temperature, humidity, sound, brightness, and etc.; we can confirm the response, and develop the index for evaluating the mental workload.

Subjects' data is shown in Table 7. In Table 7, 'A' is a veteran navigator who has been a captain. 'B' has one year on-board experience and a seamanship license. 'C' and 'D' have a seamanship license, too. 'E' and 'F' don't have a license, and we consider they are representatives who have poor on-board experiments.

Table 7. Subjects

Subject	Gender	Age	On-board experiment [year]
A	M	59	more than 18
B	F	25	1
C	M	23	1
D	F	23	1
E	M	19	0.25
F	M	19	0.25

9.1 Scenario

We choose the entering a port and a narrow passage to keep the stressful condition in order to confirm the response of the saliva NO_3^- . The stressful condition is useful to get the response. The simulator experiment is also fine to easy control the experimental conditions.

9.2 How to evaluation

We evaluate the mental workload of navigator for entering a port and a narrow passage using the saliva NO_3^- . The saliva NO_3^- is available to evaluate the mental workload on the spot. This index is able to check the point of the events for the scenario. We also compare saliva NO_3^- with HRV (R-R interval) for the scenario of narrow passage route.

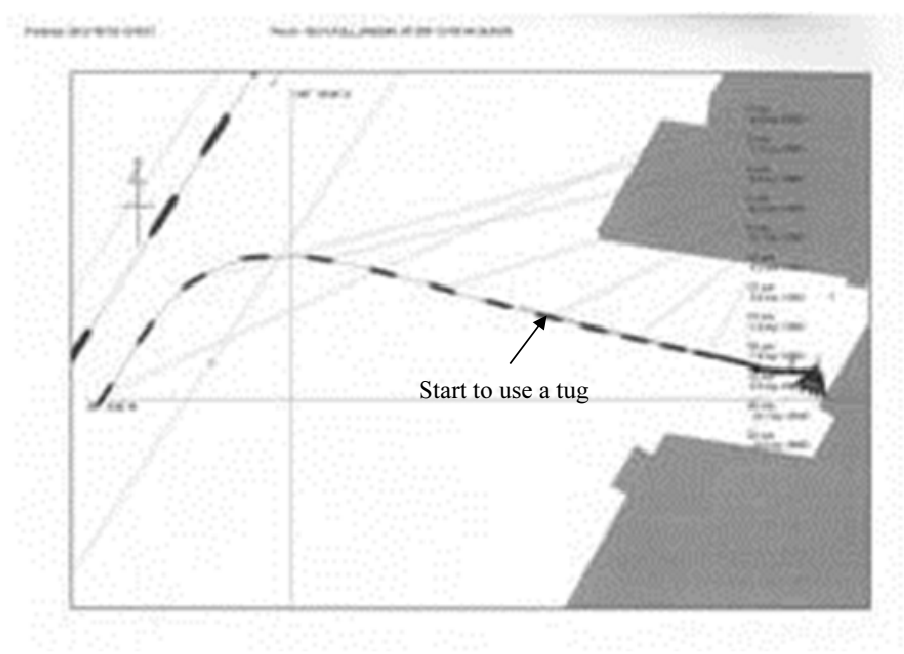
9.3 Results

We show the results of entering a port experiments for subject C in Figures 24 and 25. Subject C did an entering a port simulation twice. The scenario has no events except using a tug boat; however, subject C salivary NO_3^- reveals the same mental workload variability in both of experiments.

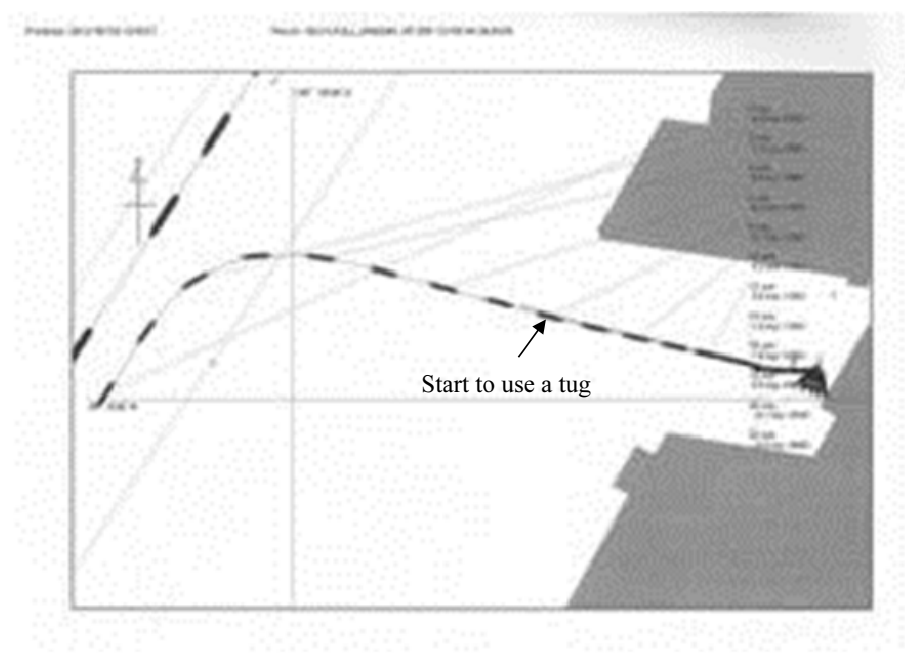
The general mental workload of first experiment is higher than second because of subject C inexperienced in a simulator experiment because I think tension felt by subject C is alleviated.

In Figure 24, dots of a ship shape show the ship's position every minute. Something white at the back of a ship is a tug boat. It can find ships start to use a tug boat 8 minutes after starting each experiment in Figure 24.

In Figure 25, at 8 minutes, both of the results reveal mental workload's rising. You know the trend of mental workload corresponds to the event of using a tug boat.

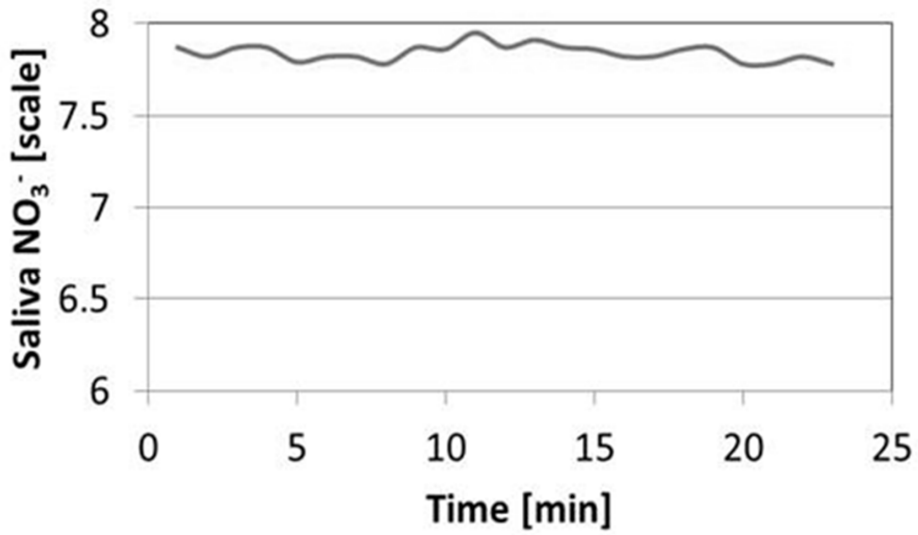


(a) First experiment

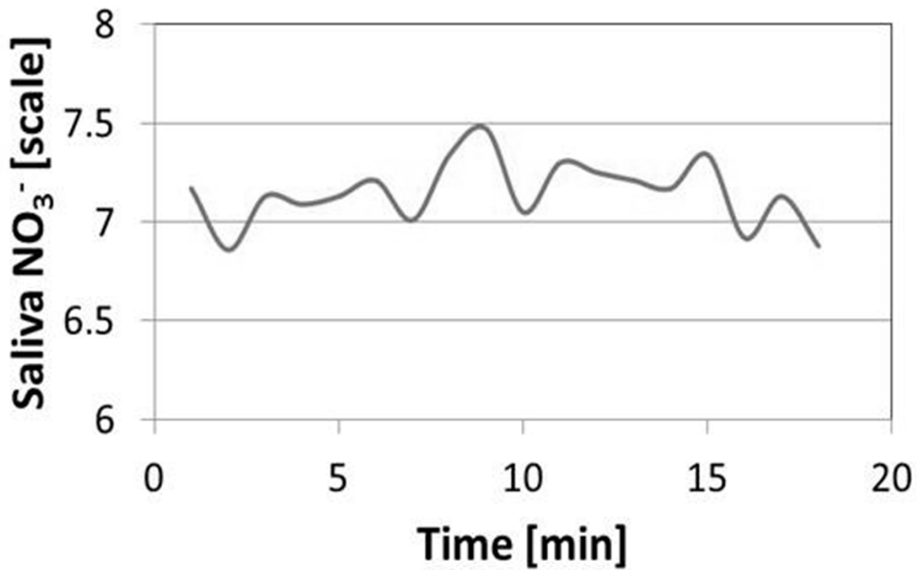


(b) Second experiment

Fig. 24. Ship's routes (Entering a port)



(a) First experiment



(b) Second experiment

Fig. 25. The results of measured salivary NO_3^- (Entering a port)

Figures 26 and 27 show the results of the narrow passage scenario experiment for subject E. The navigational event corresponds to mental workload. In other words, the low points in Figure 26 correspond to the higher peak in Figure 27. The peak point appear at except events

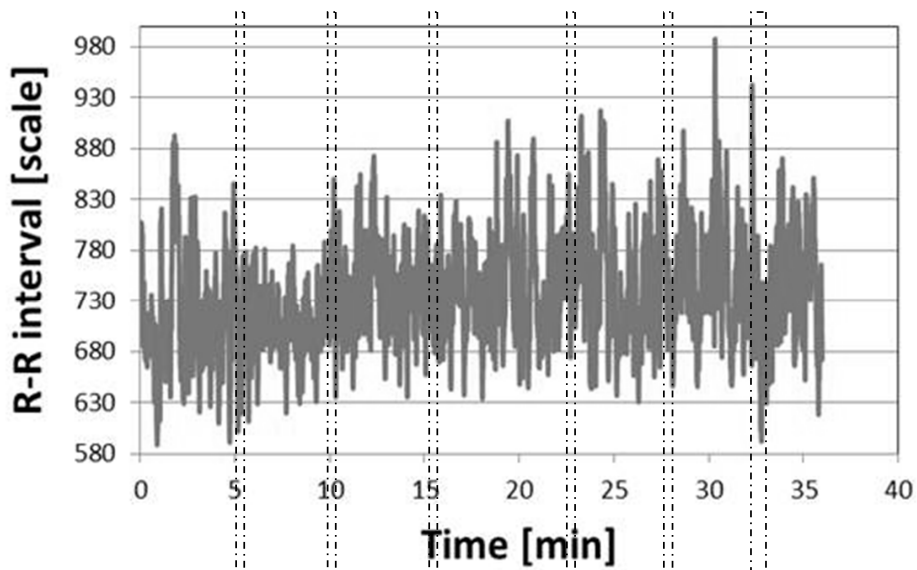


Fig. 26 . The results of measured R-R interval (Narrow passage)

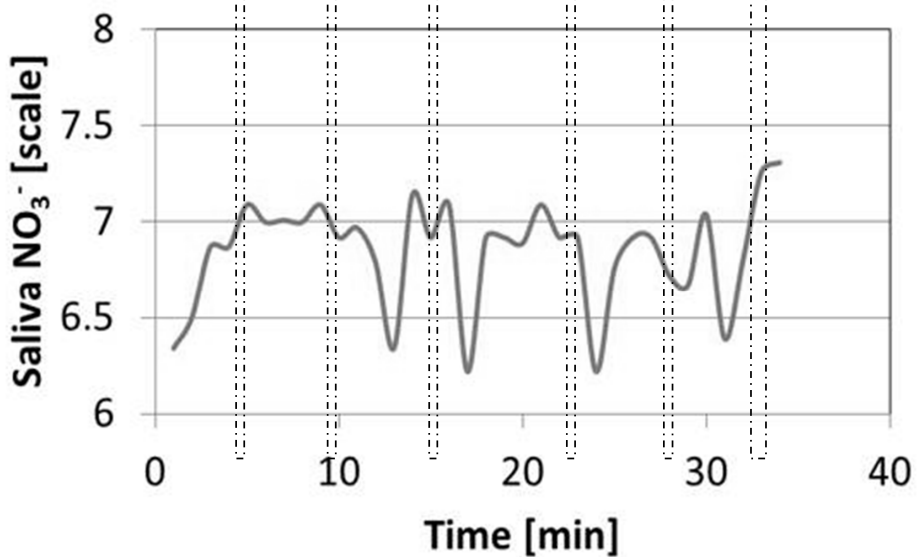


Fig. 27. The results of measured salivary NO_3^- (Narrow passage)

In Figures 26 and 27, the column written using dots shows us the event of the scenario; altering ship's course and coming close to other vessels and so on.

9.4 Consideration

We can find that salivary NO_3^- evaluates the mental workload for simulator-based experiment. We also confirm that lower peaks value of R-R interval correspond to the higher mental workload revealed by the salivary NO_3^- , and every column corresponds to every events.

We confirmed effects of the salivary NO_3^- value. The NO_3^- value reads newer and veteran navigator's mental workload on the spot in only a few seconds, corresponding to navigational events. We confirm the effectiveness of salivary NO_3^- to evaluate mental workload compared with R-R interval.

10. Try to Evaluate the Mental Workload in Real On-board Situation

We tried to evaluate the mental workload for the pilotage. There are two cases for boarding and leaving a vessel- entering a port, and going to open sea. On entering the port, the pilot, using a pilot boat, moves to the embarkation position determined for each sea area, boards the vessel using a pilot ladder which is prepared, steers the vessel safely, and finally leaves the vessel using a shore ladder at port. The characteristics of the pilot ladder are defined worldwide by International Maritime Organization (IMO) [39]-[43]. On the other hand, they undergo the inverse process for leaving the port- they board the vessel at the berth, guide it to the entrance of the bay or harbor, leave the vessel at sea, and return to the pilot boat.

Figure 28 is a snapshot of a pilot leaving/boarding a vessel at sea using the pilot ladder.

We chose *Hakata* bay, where is the Westside of Japan, as the experimental location, because the bay size is middle, it is better to be carried out the experiment- easy to move to ports, take some vessels, take some information of the port etc. In *Hakata* bay, the dis/embarkation point is located at harbor limit ('A' in Figure 29) or end of passage routes ('B' in Figure 29). The pilot takes/leaves the vessel at this point; the vessel sets the pilot ladder on the starboard or port side (lee side) to avoid the wind effect.



Fig. 28. The image of the experiment of real on-board situation, Pilotage

The speed is mostly 10.0 knots (18.5km/h) in *Hakata* pilotage. Figure 29 shows the dis/embarkation position in *Hakata* bay.

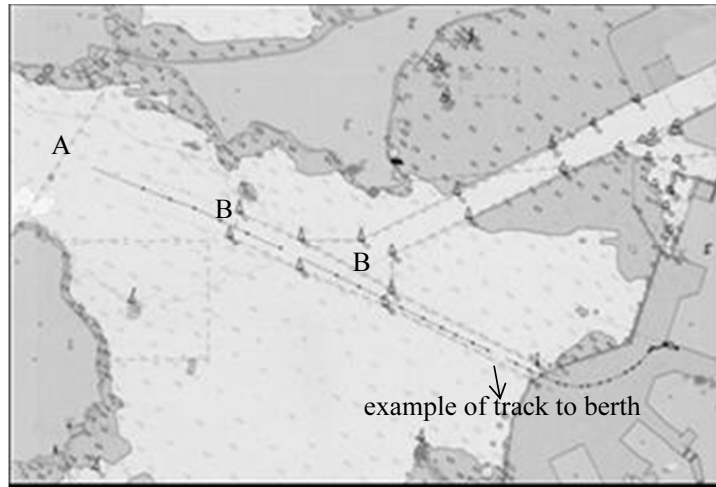


Fig. 29. The outline of Hakata bay

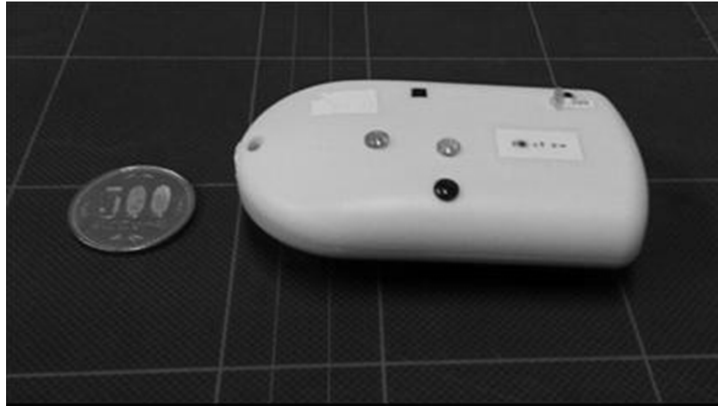
10.1 Experiment

Subjects wore a tri-axial accelerometer with atmospheric pressure sensor (Figure 30) at the waist, where is approximately body gravity center. The body gravity center is stable and the most suitable point for measuring the performance [44]. This was confirmed by on-board experiments [45]. Moreover, they wore a chest belt and a wrist watch to measure the HRV. The subjects dislike carrying unnecessary goods during their workdays. They take care while boarding and leaving the vessel at sea. In other words, the sensor never increases their workloads. The following conditions are the minimum requirements of the sensor:

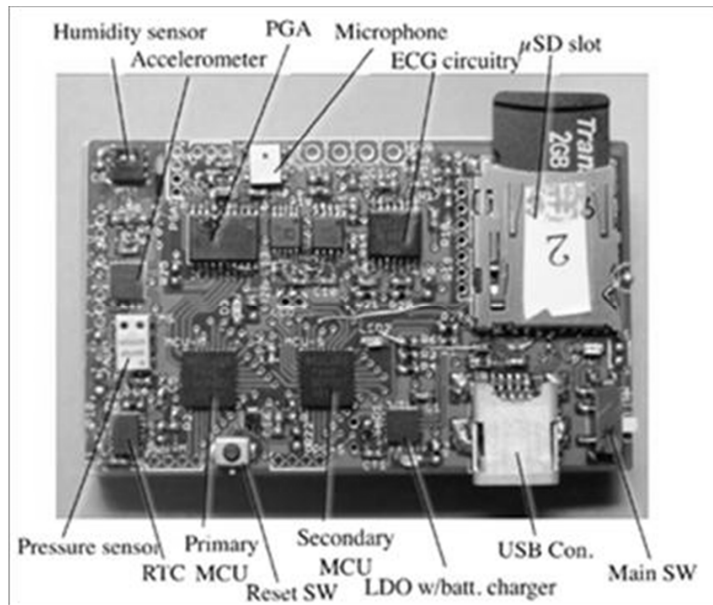
- Size - Small: sensor never adds to the workload.
- Weight - Light.
- Operation - Unnecessary: users must only push the start button before the experiment.
- Recording - Over 24 hours: the sensor has memory.
- Power source - Battery: memory is able to record over 24 hours.

The sensor (acceleration: LIS-3DH) is $W54 \times H39 \times D18 \text{ mm}^3$, range $(-)+10 \text{ G}$ (LSB 20 mG), weight 8 g, data sampling 125 Hz, and it measures the value for 3 axes every second. The sensor and battery are set in a plastic case. Moreover, we used a micro-SD card to record the data. We can record the data for each experiment without having to download to a PC.

The pilot moves a lot to the vertical direction- pilot ladder, elevator, etc. The monitoring of the performance is easy if the sensor is able to get vertical movement information. For this purpose, our sensor is equipped with an atmospheric pressure sensor.



(a) Outline of the outside of sensor



(b) Outline of the inside of the sensor

Fig. 30. The tri-axial accelerometer with atmospheric pressure sensor

The sensor is fixed at the waist on a belt. The relationship between the axes of the acceleration sensor and the body is shown in Figure 31.

In Figure 31, X: Up-Down; (+) up, (-) down; Y: Right-Left; (+) Left, (-) Right; Z: Fore-Back; (+) Fore, (-) Back.

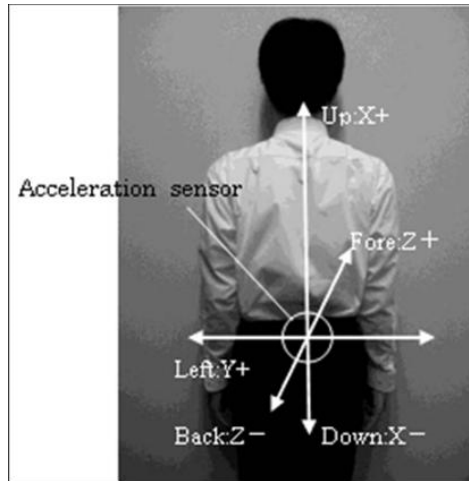


Fig. 31. Relationship between the acceleration sensor and body

The experiment was carried out at *Hakata* bay for a pilot and a navigator or cadets. The total measured data was 10 cases for the pilot (Table 8). The subjects were carried out different numbers of experiment. The kind of experimental vessel was Container, Pure Car Carrier, Bulk Carrier, etc.

Table 8. Subjects and number of measured data

Subject	Number of Data		
	Departure	Arrival	Total
pilot	7	3	10
navigator	5	1	6
cadet A	5	1	6
cadet B	1	1	2
cadet C	2	1	3
Total	20	7	27

We measured their body acceleration and pressure using a sensor (large model sensor), and HR using a heart rate monitor, and recorded the experimental situations and conversations using an Video Camera and IC recorder.

10.2 Results

Figures 32 to 34 show the results of body acceleration, atmospheric pressure, and HR for pilot and cadet respectively.

In Figure 32, X line is up-down, Y line right-left, Z line fore-back of the body. The letters 'A' to 'D' shows the active point corresponding to going up and down ladder, walking, etc.

From Figure 32, we see that a remarkable acceleration appeared while going down and up stair at the points of using ladder and walking, and the value is 1.5 to 2.0 G toward X up-down from the fluctuations. But, we need more data to analyze a detail individual character.

The range is large, (+)/(-) 10 G, because we estimated that larger acceleration values would appear, but the maximum value was similar, around 1.5 to 2.0 G. As the results, all measured values of piloting was sky rocket toward X up-down.

Figure 33 shows the results of atmospheric pressure while in Figure 32.

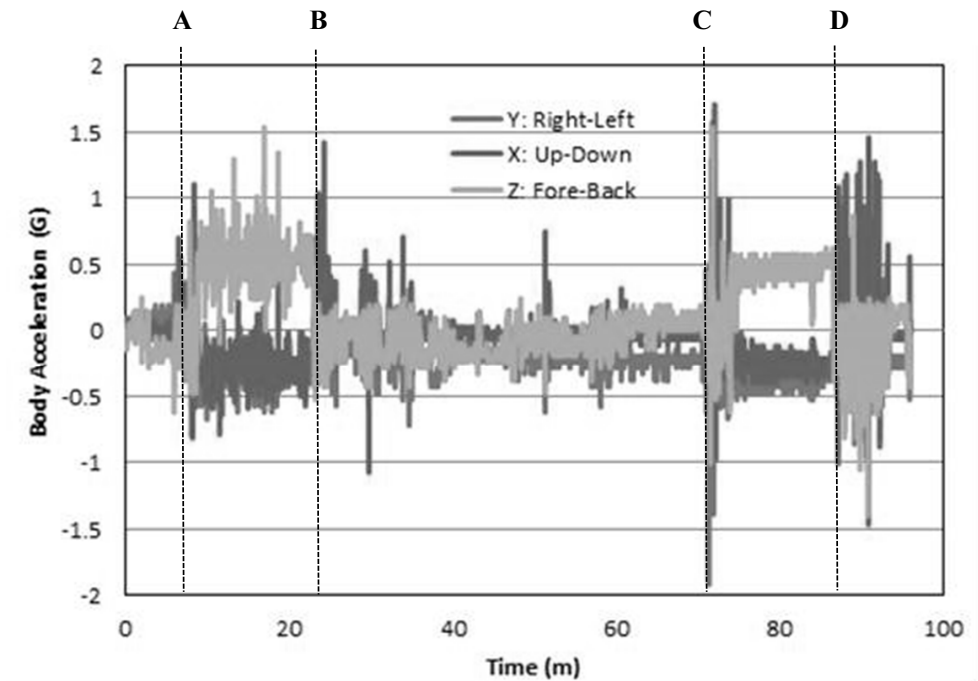
From Figure 33, the atmospheric pressure changed while moving from the deck to the bridge by the elevator and from the bridge to the deck (events E and G), and it is smooth without any change of height on the bridge (event F). The pressure sensor is useful to evaluate the performance changes with the height.

Figure 34 shows the results of the measured heart rate [bpm] was calculated by R-R interval.

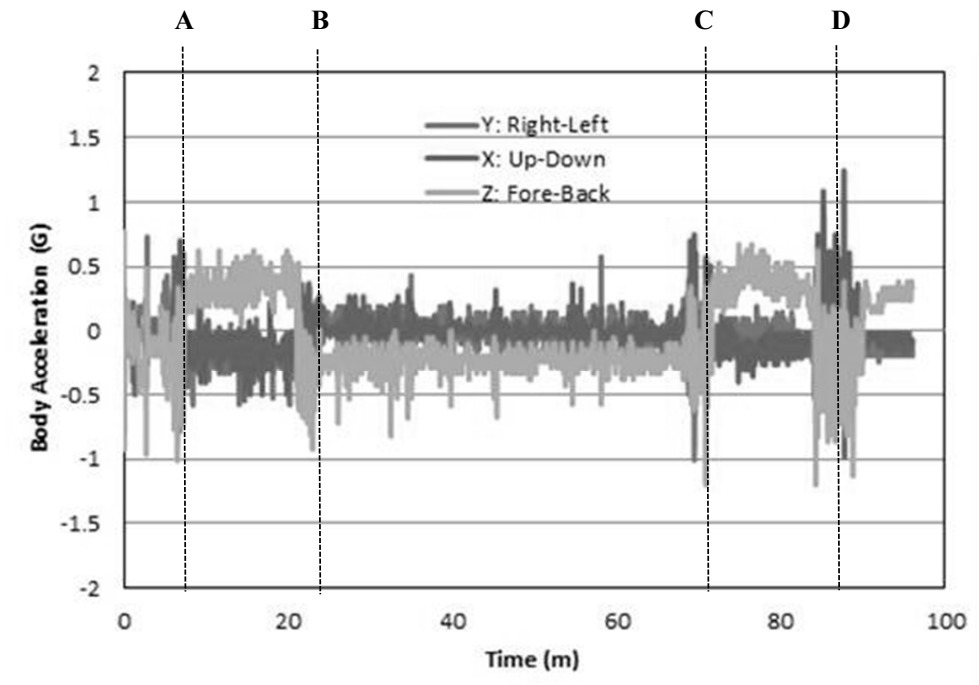
Moreover, the atmospheric pressure changes due to height changes can be detected well. The heart rate data appears the mental workload for decision-making for ship handling.

In Figure 34, the letters 'A' to 'D' are same events corresponding to the subject's performance in Figure 32, and 'H' corresponds to the decision-making for ship handling. Figure 35 shows the point of event 'H'. Figure 35 is AIS data.

From Figure 34, the most remarkable heart rate appeared while moving from the deck of vessel to the pilot ladder, and from the vessel to pilot boat, and walking at 25 (event B), 70 (event C) and 90 (event D) minutes. The value is maximum (B) that appeared when they had transferred to the vessel and go to the bridge.



(a) Pilot



(b) Cadet

Fig. 32. The results of measured body acceleration

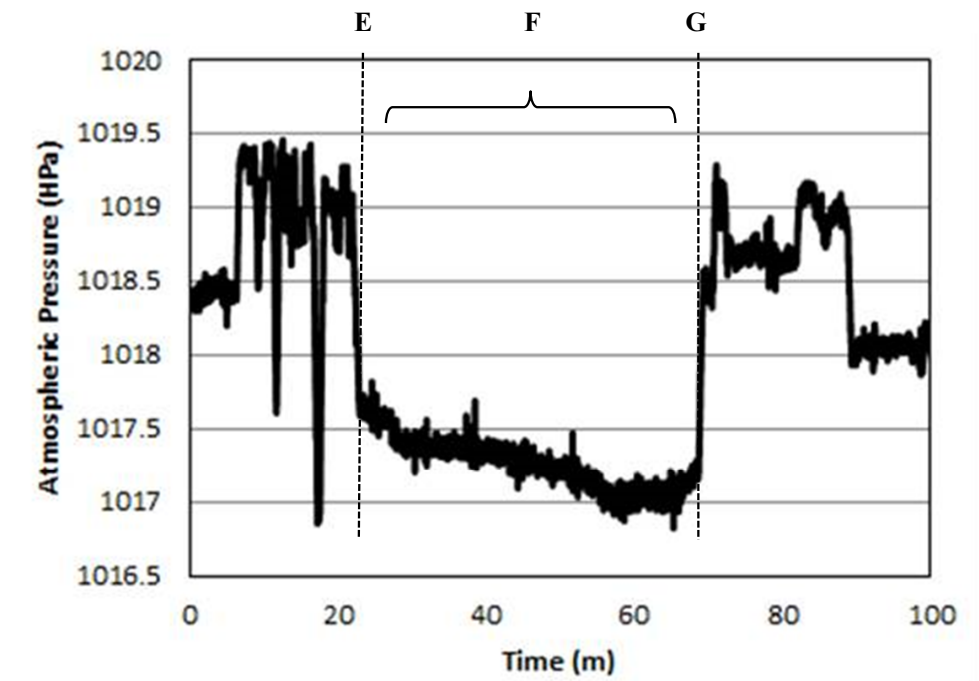
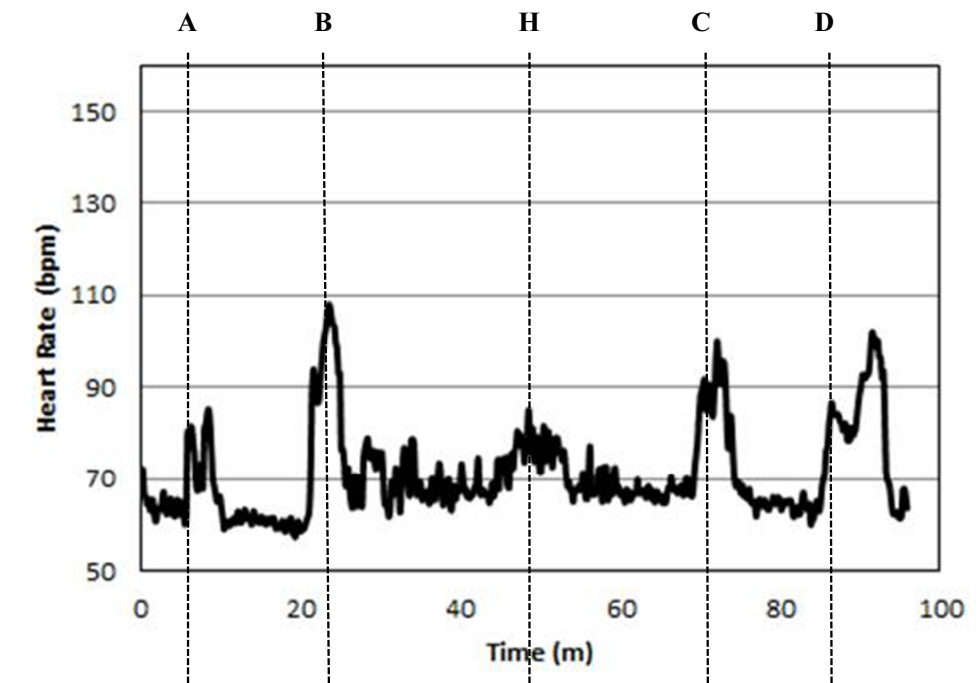
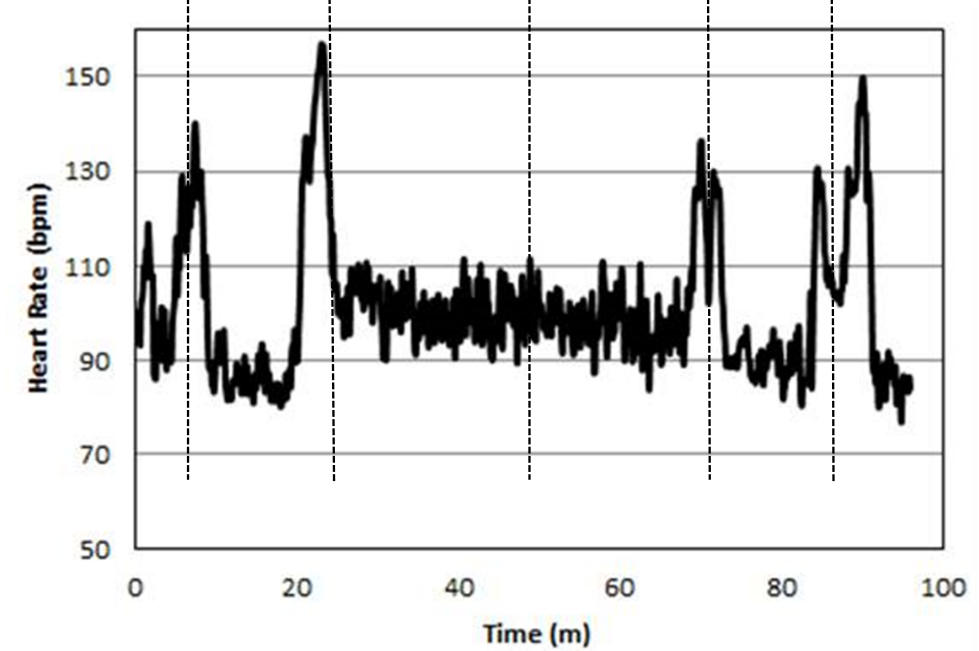


Fig. 33. The results of atmospheric pressure



(a) Pilot



(b) Cadet

Fig. 34. The results of measured heart rate

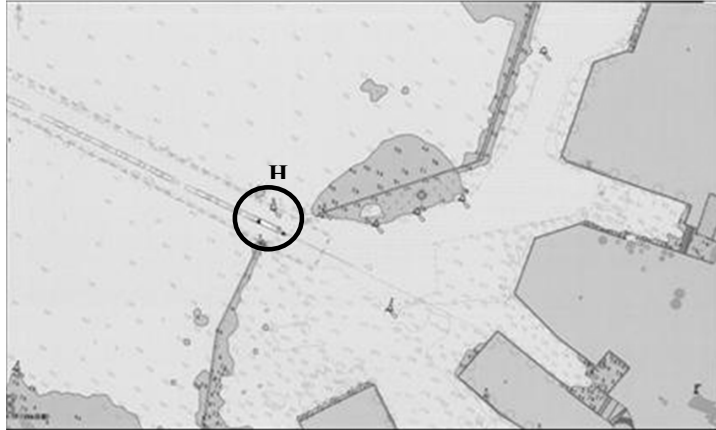


Fig. 35. AIS data

10.3 Consideration

We obtained that the body acceleration is about 1.5-2.0 G during transfer from the vessel to the pilot boat, and it is similar to the values of going downstairs in the daily life (Figure 32, event A). The measured values of heart rate are able to detect the mental workload for ship handling, it doesn't take the high in a moment like body activity (Figure 32, events B to D).

From the results, we estimate that fall accidents occur as instantaneous high accelerations, for example, due to a sudden wind, or a sudden wave affecting the pilot (body). In other word, a consideration to reduce the high body acceleration during the transfer prevents the fall accident, and we will research the relation between the body acceleration and how to transfer in future works. We can consider a new method for reducing accidents to parry these sudden high accelerations. The method differs among pilot associations, and there are two typical methods, one is ladder, the other is man-ropes [26]. Regarding the man-ropes, they slide down to hold it under their arms, and it might be a better solution to avoid any sudden acceleration of the body. We think the man-ropes are better for strong wind and waves at sea.

We would measure pilot body and mental conditions using sensors, and it is possible to read the fatigue and mental workload. It leads to develop a system of navigator-centered automation interaction for safe harbor. If the measured value catch the over workload for body/mentality, it communicates to port traffic center, and they control the safe harbor as Harbor Resource Management (HRM), and it is automation interaction in harbor.

11. Conclusion

This research project has found that the physiological index is fine to evaluate the simulator-based ship handling education and training [46],[47]. It utilizes the simulator room is a compact. It means the measured data of physiological index is not noisy for physical performance of the body. Regarding our indices; The Heart rate variability, heart rate and the frequency components, showed the changing on the spot; The nasal temperature did the changing on the spot and its tendency; The saliva did the level on the spot for reading the performance and the mental workload for the judgment of the ship handling. We also found the weak and good points for how to measure and read the mental workload.

This research project has found the new aspect of how to evaluate the training and education of simulator-based and on-board ship handling using heart rate variability, facial temperature, and saliva. The results read a characteristic of a navigator's mental workload for ship handling, the specialist has a similar/common response, and the response differs between a beginner and a specialist. It supports there is a possibility of reading an individual character.

Moreover, this research project has found our index is useful to evaluate the mental communication, we could say one aspect of team work reads using the data. Also the instructor and student is easy to understand the results of the education and training each other.

We got a lot of useful comments and questions in AGA15, and in the consideration, we got a future work- more subject, more education and training conditions, development of smart sensor to measure the indices. We are considering the next challenge based on this project.

Acknowledgment

This research was supported by staffs of Kobe University, California Maritime Academy, and Tokyo University of Marine Science and Technology. We thank Director Veronica Boe of California Maritime Academy.

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Attachment

2014 Research Project [Human Element] Evaluation of Bridge Teammates' Mental Workload for simulator-based training Using Physiological Indices - AGA15 research report -

OKoji Murai
(Kobe University, JPN)
Tadatsugi Okazaki
(Tokyo University of Marine Science and Technology, JPN)
Victor J. Schisler
(California Maritime Academy, USA)

Outline

1. Background
2. Goal
3. Experiment
Scenario, Subject
How to get data (Index)
4. Evaluation
Index: HRV, Facial temp., Saliva
5. Result
HRV
Progressed research
6. our Research
Future work

Background

- Simulator training is a popular worldwide.
- ↓
- Master / Senior evaluate them.
- ↓
- It is a subjective, only performance (outside).
- ↓
- Mental (inside) response is Important.

Goal

The purpose is;

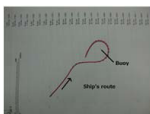
- To develop a evaluation method (index) of simulator-based training **using physiological index.**
- To read **a characteristics of a navigator's common / individual skills.**
- To evaluate a **team work** and their mental workload for ship handling.

Experiment: Scenario

Scenario:

3 Kinds- Basic, Advance, Berthing

	Kind	Contents of scenario
A	Basic maneuvering	go ahead and aback, emergency stop, turning, treatment of tug boat
B	A advanced maneuvering	scenarios required to avoid other ships
C	Maneuvering at berth	scenarios contain entering or leaving port



Experiment: Subject

- **Subject:**
Senior student
Pilot candidate
- **Team:**
Mate (Navigator), Helmsman
*Pilot, Captain *real ship

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Experiment: How to get data

Heart Rate Variability (HRV)
Facial Temperature (FT)
Saliva Nitrate (NO_3^-)

HRV: CMA, Kobe, Tokyo
HR and LF/HF

Chest belt (sensor)

Wrist watch (memory)

[1] Get R-R data (HR) by HR monitor
[2] Interpolate R-R data by Spline
[3] Calculate LF and HF by MEM

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Evaluation: LF and HF

◆ Frequency component

LF: 0.04 ~ 0.15, SNS and PNS
HF: 0.15 ~ 0.40, PNS

Index: LF/ HF

Increase: MW is high
Decrease: MW is low

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Experiment: How to get data

Heart Rate Variability (HRV)
Facial Temperature (FT)
Saliva Nitrate (NO_3^-)

FT: Tokyo, Kobe
N-F: Nasal Temperature

[1] Get Facial temperature by Thermo
[2] Pick up the Nasal and Forehead temperature

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Evaluation: NT

Index: N-F

≥ 0 , increase : MW is low
 < 0 , decrease: MW is high

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Experiment: How to get data

Heart Rate Variability (HRV)
Facial Temperature (FT)
Saliva Nitrate (NO_3^-)

NO_3^- : Kobe
 NO_3^-

[1] Get Saliva by metallic spoon
[2] Measure nitrate ion

Index: NO_3^-

increase, large : MW is high
decrease, small: MW is low

11/13

Result: LF/HF, 3 Scenarios

A: Basic

In Turning

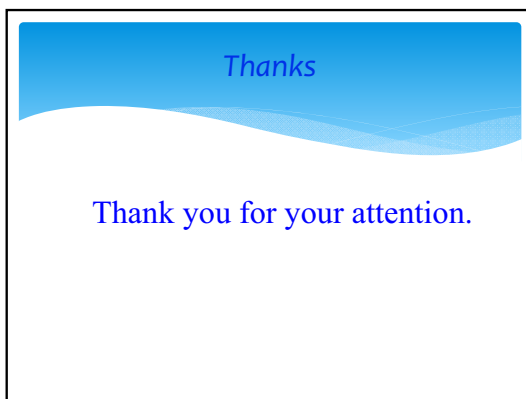
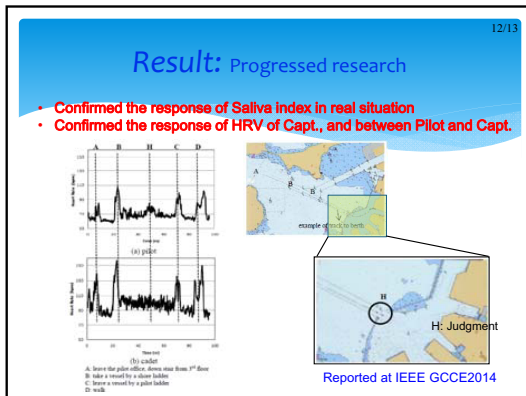
B: Advance

In Manoeuvring near Other ships

C: Berthing

In Reaching the Berth

Reported at IEEE SMC2014



JSPS SAN FRANCISCO NEWSLETTER

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PAST EVENTS

JUNBA 2015 - Symposium and Summit on University Governance



The Japanese University Network in the Bay Area (JUNBA) held the JUNBA 2015 Symposium and Summit on the theme of "Governance as a Major Leverage Tool for Improving Quality in Higher Education" on January 8 and 9, 2015 at the Hilton San Francisco Airport Bayfront (Burlingame, CA). This 9th annual JUNBA conference brought together Japanese and U.S. university leaders to exchange views on the governance systems in higher education institutions. Approximately 120 participants attended the JUNBA 2015, which included representatives of 20 Japanese universities and governmental organizations as well as those affiliated with U.S. universities.

The symposium held on the first day began with opening remarks by Masato Matsuo, President of JUNBA, followed by 2 lectures on the governance of the University of California (UC) system. The first lecture titled "Higher Education Leadership and the Role of Provosts at the University of California" was given by Aimée Dorr, Provost and Executive Vice President, University of California Office of the President (UCOP). Provost Dorr engaged the audience with her

(Continued on page 2)

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NEWS FROM JAPANESE UNIVERSITIES



Evaluation of Seamanship

Simulator-based education and on-board ship training are major components of the curriculum in maritime education. Designed for students wishing to gain a navigator's license, the curriculum also stresses the development of leadership and seamanship skills. Much like the keel of a ship, this will prove the foundation on which students are able to achieve success.

Along with its friendship-schools, Tokyo University of Marine Science and Technology (TUMSAT) and the California Maritime Academy (CMA), part of the California State University system, and supported by International Association of Maritime Universities (IAMU), the Faculty of Maritime Sciences at Kobe University is aiming for a new educational evaluation system that stresses physiological responses. The basis for this research originated in collaboration between Kobe University and the Maine Maritime Academy (U.S.) between 2008-09.

The research project titled "Evaluation of Bridge Teammates' Mental Workload for Simulator-based Training Using Physiological Indices" found that keys to successful training were: simulator training, common/individual skills, team work and monitoring the mental workload of students. This project stressed the evalua-

tion of the mental workload of bridge teammates, which stands in contrast to previous evaluation methods that depend on the subjective value of physical performance. The assessment of both physical and mental performance is the best way of evaluating performance.

The goal of this project is to develop a method of simulator-based education and training using a physiological index able to read characteristics of a navigator's common and individual skills (sense) and to evaluate teamwork and the role mental well-being plays in a team's handling of a ship. Kobe University evaluates a seafarer's mental workload by monitoring his heart rate variability, saliva flow, and facial temperature. TUMSAT evaluates a seafarer's performance index by using a thermograph able to measure facial temperature. CMA conducts performance evaluations on the basis of simulator-based education and training. Research collaboration will lead to continued success in advancing these methods of evaluation.

This research project involved both undergraduate and graduate students. Team members from Kobe University, TUMSAT, and CMA will continue their collaboration in the coming years.



Meeting and Simulator-based Experiment at CMA



Ship Bridge Simulator of CMA

Koji-Victor-Tadatsugi Research Team

MINUTES

16-18 July 2014
Kobe

Present: Dr. K. Murai, Capt. S. Victor, Dr. T. Okazaki.

1. The purpose and goals of the research were confirmed by Dr. Murai.

PURPOSE: To try to improve maritime transportation education on a simulator by determining the mental workload (stress) of navigators

GOALS:

- Measure the heart rate variability, the facial temperature, and saliva of a student (seniors only) and professional mariners.
 - Compare heart rate variability, facial temperature, saliva data.
 - The goal is to eventually develop a comprehensive analysis of physiological indices to aid in the improvement of education on a simulator. These tests have already been done on car drivers.
 - Present the results.
2. Dr. Murai explained the methods he will use to conduct the experiment and received several valuable suggestions.
 - ◆ Revise the Questionnaire - Kobe and Tokyo is the same. CMA will be revised a little.
 - ◆ Check the outline of the scenario.
 - ◆ Discuss the assessment sheet for the performance.
 - ◆ Check to see if we can get some information about the performance of other fields during their simulator training.
 - ◆ Review the Fatigue Management research if there is any useful information.
 3. Questions were generally associated with needing more clarification about the goals and methods.
 4. Capt. Victor took the special lecture on the Pilot in the Kobe University.

国際海事研究センター

講演会の案内

2014 年 7 月 17 日 (木)

15:50 ~ 16:30 神戸大学 海事科学研究科

総合学術交流棟 1 階 梅木 Y ホール

Capt. Victor J. Schisler

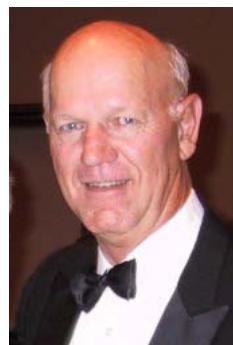
Director of Professional Simulation Programs Sponsored Projects and Extended Learning
CALIFORNIA MARITIME ACADEMY

An Overview of the Maritime Pilot Systems in the USA

- From A Pilot's Perspective of 50 Years in the Industry -

Victor J. Schisler is currently the Director of Professional Simulation Programs at California Maritime Academy. He has forty three (43) years piloting experience in San Pedro and San Francisco Bays and tributaries utilizing tugs and their services successfully while maneuvering over 16,000 vessels in and out of these harbors. He has served as a consultant and simulator facilitator to various groups in the Maritime Industry for over twenty years. During the three (3) years prior to becoming a pilot he was employed as a Mate and Captain of seagoing tugs

by Crowley Maritime performing many tows throughout the Pacific Ocean. He received a Bachelor of Science Degree in Marine Transportation from the United States Merchant Marine Academy at Kings Point in 1964. He is a Fellow of The Nautical Institute. He received the 2008 Professional Mariner's **Plimsoll Award** for contributions to the safety of mariners through training.



問合せ先 : 海事科学研究科 村井康二 murai@maritime.kobe-u.ac.jp, 078-431-6242

主催 : 神戸大学 海事科学研究科 国際海事研究センター IMaRC

協力 : IEEE SMCS TC on Human Centered Transportation Systems

日本人間工学会 海事人間工学研究部会 JES TC on MaE

Koji-Victor-Tadatsugi Research Team

MINUTES

29 September - 3 October 2014
California

Present: Dr. K. Murai, Capt. S. Victor, Dr. T. Okazaki.

1. The assessment sheet and the scenario were confirmed by Capt. Victor.
 - ◆ Assessment sheet is to evaluate the performance of Fundamentals, Technique, BRM, Integration, Leadership
 - ◆ Performance is scored
 - ◆ Bridge teammates are evaluated
 - ◆ Scenario requests their judgments
 - ◆ Check and try the scenario
2. The simulator equipment was checked by Capt. Victor.
 - ◆ Check the Video camera to record the performance
 - ◆ Confirm relation between the Video image and the Assessment sheet
3. Director B. Veronica (CMA research project team) supported the research projects.
 - ◆ Discuss the next meeting
 - ◆ Review the other aspects

Koji-Victor-Tadatsugi Research Team

MINUTES

6-10 January 2015
Tokyo and Kobe

Present: Dr. K. Murai, Capt. S. Victor, Dr. T. Okazaki, Dir. Veronica.

1. The measured data in CMA were checked by Capt. Victor.
 - ◆ Performance
 - ◆ Heart rate variability
 - ◆ Discuss the results
2. The simulator experiment of Tokyo - equipment, scenario was confirmed by Dr. Okazaki.
3. Director B. Veronica (CMA research project team) supported the research projects.
 - ◆ Discuss the next meeting
 - ◆ Confirm the simulator equipment

Koji-Victor-Tadatsugi Research Team

MINUTES

21 May 2015
California

Present: Dr. K. Murai, Capt. S. Victor, Dr. T. Okazaki, Dir. Veronica.

1. The research project was concluded by all members.
 - ◆ Measured data of physiological indices
 - ◆ Evaluated assessment performance sheet
 - ◆ Attended subjects
2. The final report was discussed by all members.
3. The future research was discussed on the next IAMU research project.



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