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IAMU 2016 Research Project
(No. 20160106)

Development of A New Evaluation System for Simulator Training utilizing Physiological Index

By

Kobe University, Graduate School of Maritime Sciences, Japan (KU-GSMS)

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Abstract *We aim the development of a new evaluation system for simulator training utilizing the physiological indices- Heart Rate Variability (HRV), Nasal Temperature (NT), and Saliva. According to the previous research results, physiological indices HRV and NT showed the changing tendency of mental workload. There is a difference at changing tendency of mental workload of captain and young mate during simulator training.*

In this research project, we focus to the difference of them, and we try to develop the mental workload evaluation/monitoring system to support the instructor. On the other hand, we confirm the index 'saliva' indicates stress level at an event of ship-handling. Moreover, we try to discuss on student perception about synergies in course sequencing using simulation as a tool for augmenting an officer-in-charge of a navigation watch (OICNW) watch-standing because the curriculum is the most important to step up the skill of navigators. In order to develop these systems, we need to compare the evaluation result of performance of simulator training. If we complete the systems, we are able to propose clearly how to simulate and how to make scenario.

The current scenario is just simulated for the real situation, and it is evaluated whether the subject finds/recognizes skill points into the scenario. If we could only check the skill points, it is enough.

Keyword: *Maritime education and training, Human element, Curriculum, Mental workload, Performance, Monitoring system, Simulator.*

Executive Summary

1. Research Title

Development of A New Evaluation System for Simulator Training utilizing Physiological Index

2. Research Objective

[Background] We, Kobe University (Kobe), Tokyo University of Marine Science and Technology (Tokyo), California Maritime Academy (CMA), challenged the "Evaluation of Bridge Teammates' Mental Workload for Simulator-based Training Using Physiological Indices" in International Association of Maritime Universities (IAMU) FY2014, and showed that the physiological index is useful to read the mental workload of bridge teammates (duty officer and helmsman). However, an evaluation/monitoring system using the indices did not develop yet, it was just confirmed the effect of the physiological index. We also got fine advises for the research report from IAMU researchers in AGA15 of IAMU. It is that we need more data for accurate evaluation, criteria of evaluation of the stress level, etc. We make a new research team adding World Maritime University (WMU) who gave fine suggestions in AGA15, and we set course to "Development of A New Evaluation System for Simulator Training utilizing Physiological Index" in FY2016.

[Aim] We aim the development of a new evaluation system for simulator training utilizing the physiological indices- Heart Rate Variability (HRV), Nasal Temperature (NT), and Saliva. According to the previous research results in FY2014, the physiological indices, HRV and NT, showed changing tendency of mental workload, and there is a difference at changing tendency of mental workload of specialist (master) and beginner (young mate) for simulator training. We focus to find the difference between them, and we try to develop the mental workload monitoring system to support the instructor. On the other hand, we confirm a new physiological index 'Saliva' indicates stress level at an event of ship-handling. Moreover, we try to discuss on student perception about synergies in course sequencing using simulation as a tool for augmenting an officer-in-charge of a navigation watch (OICNW) watch-standing because the curriculum is the most important to step up the skill of navigators.

3. Progress of the Research

We have been carried out the simulator and on-board experiments on from August, 2016 to January, 2017 (Aug., Sep., Oct., 2016, and Jan., 2017); we have confirmed the Heart Rate Variability response of professional (Captain) and beginner (Cadets and young officer), and are able to read the response to mental workload of navigators for a ship handling. The characteristic is clear for professionals, and it will be divided between the beginner and the professional for the respond time and the fluctuation. Then, we have tried to monitor the mental workload using plaster-type sensor and general used i-pad monitor by Bluetooth communication, and have confirmed the condition of the data transmission and the revaluation results on the real time. Moreover, we have considering to make more efficient (good time performance) scenario for the manoeuvring skill point. The research activities are follows.

1) 28-30 July, 2016: Meeting at CMA
   We discussed the experiment and how to educate by simulator.
2) 18-19 Aug., 2016: Simulator experiment
3) 13-16 Sept., 2016: On-board experiment at Hakata of Japan
   We confirmed the effectiveness of saliva index.
4) 1-2 Sept. and 6-7 Oct., 2016: Simulator experiments
5) 28 Oct., 2016: Report at AGA17 in Vietnam
6) 12- 15 Dec., 2016: extra-Meeting at China
   We discussed advanced simulator-based research.
7) 10-11 Jan., 2017: Simulator experiment
8) 2-8 April, 2017: Meeting at Kobe and Tokyo
   We discussed the measured data and this project.

4. Findings and Outcome of the research

This research project has found that the mental workload monitoring system using physiological index is fine to evaluate the simulator training. Moreover, its mental response has shown the difference between professionals and beginners. The monitoring system is useful educational system for the simulator training in the ship bridge simulator. It means the mental monitoring system is an educational support system for the instructor, and the shown data on the monitor is easy to understand their training results of trainee.

Regarding physiological indices, 1) HRV shows the changing of mental workload on the spot, 2) saliva and NT show the changing on the spot and its trend, 3) they are able to show the characteristics of professional and beginner. Moreover, this research project has discussed student perception about synergies in course sequencing using simulation as a tool for augmenting the OICNW watch-standing in case of CMA.

5. Research Deliverables

We deliver a part of this research project for annual conference of Japan Ergonomics Society, international conference IEEE SMC2017, and, we will submit to WMU journal. Also, we contributed a part of result of the 2016’s and 2014’s project to international conference WAC2016.

1. Introduction

1.1 Background

We, Kobe University (Kobe), Tokyo University of Marine Science and Technology (Tokyo), California Maritime Academy (CMA), challenged the "Evaluation of Bridge Teammates' Mental Workload for Simulator-based Training Using Physiological Indices" in International Association of Maritime Universities (IAMU) FY2014, and showed that the physiological index is useful to read the mental workload of bridge teammates (duty officer and helmsman). However, an evaluation/monitoring system using the indices did not develop yet, it was just confirmed the effect of the physiological index. We also got fine advises for the research report from IAMU researchers in AGA15 of IAMU. It is that we need more data for accurate evaluation, criteria of evaluation of the stress level, etc. We make a new research team adding World Maritime University (WMU) who gave fine suggestions in AGA15, and we set course to "Development of A New Evaluation System for Simulator Training utilizing Physiological Index" in FY2016.

1.2 Aim

We aim the development of a new evaluation system for simulator training utilizing the physiological indices- Heart Rate Variability (HRV), Nasal Temperature (NT), and Saliva. According to the previous research results in FY2014, the physiological indices, HRV and NT, showed changing tendency of mental workload, and there is a difference at changing tendency of mental workload of specialist (master) and beginner (young mate) for simulator training. We focus to find the difference between them, and we try to develop the mental workload monitoring system to support the instructor. On the other hand, we confirm a new physiological index 'Saliva' indicates stress level at an event of ship-handling. Moreover, we try to discuss on student perception about synergies in course sequencing using simulation as a tool for augmenting an officer-in-charge of a navigation watch (OICNW) watch-standing because the curriculum is the most important to step up the skill of navigators.

1.3 The Use of Simulator

The use of simulators has become indispensable for the training and assessment of competence in many high-risk industries. This is particularly true where training in the real context is deemed to be too risky - high probability of accidents and high consequence of those accidents. Contemporary maritime education and training is the epitome of this. At the top end, simulators can be used to train for and assess the performance of very complex tasks and the dynamics/interaction between humans and other humans as well as with technology and the external environment for example weather and sea state.

The most dominant use of simulators today is in the training for and assessment of competency related to the cognitive and psychomotor domains - what trainees and assesses know and how they behave (action and inaction). There is a dearth of research and application in using simulators to train for and assess cognitive load and acute stress and its contribution to competency and optimum behaviours.

In keeping with the requirements of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978 as amended, education and training of seafarers is for good reason targeted at the delivery of curriculum that helps to achieve the specific learning outcomes that are related to the competences indicated in the STCW Code, particularly in column 2 of the competence tables in the Code - "knowledge, understand and proficiency". Demonstration of the seafarer's competence and its evaluation are to be done per the contents of columns 3 and 4 - "Methods for demonstrating competence" and "Criteria for evaluating competence". One aspect of training and assessment is however not specifically covered in most training and

assessment. This aspect has to do with the cognitive load and stress levels on the watchkeeper in the real situation and how that influences decision-making and competence.
When using simulators, various scenarios can be set up which allows for the testing of competence under different levels of stress, pressure and resource limitation as well as situation awareness.

This report is made up of 5 chapters.
1. Introduction.
2. Student perception about synergies in course sequencing using simulation as a tool for augmenting OICNW watch-standing to consider the curriculum.
3. Evaluation of trainee's performance with physiological index.
4. Evaluation of mental workload using saliva to confirm as a new index.
5. The development of mental workload evaluation/monitoring system using plaster-type sensor.

2. Student Perception about Synergies in Course Sequencing Using Simulation as a Tool for Augmenting OICNW Watch-standing

2.1 Outline

Watch-standing is a basic activity for an officer-in-charge of a navigation watch (OICNW), and one in which he or she spends a considerable amount of time and energy during the workday. Historically, the training for OICNW was entirely experiential based and, an officer-in-training would spend hours on the bridge of a ship. Time and technology has changed that paradigm and today many officers-in-training are receiving a combination of practical training on ships and experiential training on full-mission bridge simulators.

The exact mix of classes, practical training on ships, and experiential training on simulators varies greatly between maritime training centers. Curriculum, which includes course sequencing, "is essentially a socially-constructed ordering of the knowledge-use in a social contest" [1] and each training center has its own philosophy. The common factor between maritime training institutions is that all have components of experiential learning.

Experiential, or active, learning is a student-centric pedagogy [2] that has proven itself to be effective on many different levels [3],[4],[5]. "Students become active learners through a hands-on approach to their discipline" [6]. A common assumption made by educators using experiential-learning techniques is that students will learn content independently. This is often not true and, in fact, students often "need structure, guidance, and direction" [6]. Although there are several different methods of experiential learning, different learners will have different perceptions of its value, effectiveness, and success [7]. For the purposes of this article, "success" will be defined, as it was in the study [5], in terms of student perceptions.

The CMA has adopted a short-frequency course-sequencing model combining elements of experiential simulation exercises that bridge a practical training requirement on the Academy's training ship. This paper presents that model and describes the students' perceptions regarding the model.

2.2 Literature Review

Aristotle (384-322 BC) may have been one of the first to verbalize the importance of experiential learning when he said, "That which we must learn to do, we learn by doing". While that statement makes sense intuitively, at least to those of us who train people to work on ships, it has not always been the practice in academia. In fact, traditionally the pedagogical paradigm that academic institutions have emphasized is the individual acquisition of knowledge through observation, which was separate from doing [8]. Currently the academic emphasis is shifting from teaching to learning, and it is the student, as a co-producer and beneficiary of learning, who must take responsibilities for his or her own learning [9]. In this new understanding of learning, students must become pro-active in their own learning. No longer is lecture alone, or even student research and paper presentation enough. Today, advocates of student learning describe the benefits of cooperative learning, or team-learning, as an effective pedagogy [5]. Maritime training institutions have long been advocates of team learning experiences in many different formats.

Advocates of the new learning techniques, often referred to as active learning techniques or experiential learning, have made many claims as to the virtues of this approach. Burbach, Martin, & Fritz (2004) [3] conducted a study of college students enrolled in a leadership course to determine if active learning techniques improved critical thinking skills. Their results suggest that active learning techniques do improve critical thinking skills. These results support earlier work in cognitive science that suggested that active learning, in environments that replicate real career situations, benefit the learner in many ways [4].

Kivinen and Ristelä (2002) [10] argue that learning is doing and experiencing in a social context. While there may be many reasons to support experiential learning, students will feel hesitant to participate if they do not have a clear sense of the purpose behind the activity. Even then, the success of the activity depends on the learner's perception of that activity as mediated by the instructor [7]. D'Aloisio (2006) [11] suggests that students will participate more actively in their education if a direct connection can be made between what they are learning in their classes and what they need to know in their career choice. In fact, Hickcox (2002) [6] takes the next step by saying that "students become active learners through a hands-on approach to their discipline". This is where the full-mission bridge simulator becomes an important tool for maritime educators. Using this sophisticated equipment, students have the opportunity, and the ability to create knowledge through experiences [12]. By living these experiences in simulation, they are developing memories that can subsequently be brought forth to deal with actual situation in which similar events occur [4]. We cannot recount the number of times we have heard students describe real-life experiences on watch as being "just like in the simulator".

Järvinen and Poikela (2001) [13] proposed a model that describes the process of learning in a work environment. This environment includes the organizational learning process that, by its nature, includes both group and individual learning. By itself, they argue, individual learning as a construct of formal knowledge is context free, and that is not a realistic approach to the practices in the work place. Experiential learning therefore should be a process "in which social, reflective, cognitive and operational processes" [13] are allowed to influence each other to produce an environment of continuous learning.

Experiential learning, in its simplest form, is a methodology that, through role playing, immerses a learner in an active learning environment that requires the use of a variety of mental capabilities to process information [4]. A faculty member in this experience is a facilitator and guide for the experience [2]. Simulation, which is a fine example of experiential learning, has the advantage of demonstrating very complex situations and it demonstrates to the learner quite dramatically the effects of their decisions [14]. The goal of experiential training at maritime academies and, in fact, the goal of the STCW is to reach some level of competence in the mariner. Competence consists of the relevant professional knowledge and skills along with the ability to perform skill-based tasks in any situations [15].

Performance is a function of knowledge, experience, and ability. Some of these variables we can control effectively and others not. Consider Figure 2.1. This Figure suggests that an individual, John, at time **o** is able to perform a given task at level a. At time **o** a training or experience opportunity is presented to John. As a result of the opportunity, at time T_1, his performance is improved to level **b**. Subsequently, John does not have an opportunity to practice what he has learned from the experience and so his performance will deteriorate over time. At time T_2, his performance has deteriorated to **d** and he effectively has lost performance equal to the distance **b-d**. This example is familiar and intuitive to most trainers.

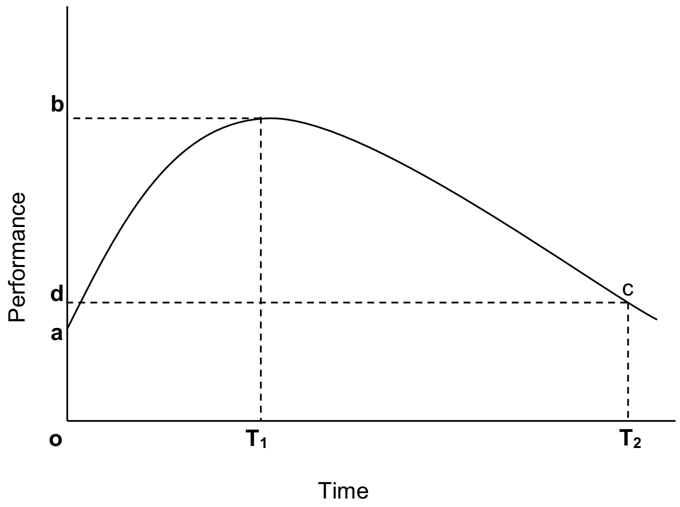


Fig.2.1 Performance with initial experience and no follow-up experiences

Let's now consider a situation where Mary not only receives training or experience initially, but has multiple opportunities to practice. This situation is depicted in Figure 2.2. Note that after the initial training or experience at time T_1, Mary's performance begins to deteriorate. At time T_2 she has an opportunity to practice what she has now learned and her performance goes up. A similar experience happens to Mary at time T_3. Note that with each opportunity to practice her performance improves. Again, this is intuitively evident and there is research to support the idea that repetition reinforces learning [16]. Deakin and Proteau (2000) [17] argue that practical experience, interspersed the knowledge acquisition, always leads to better performance.

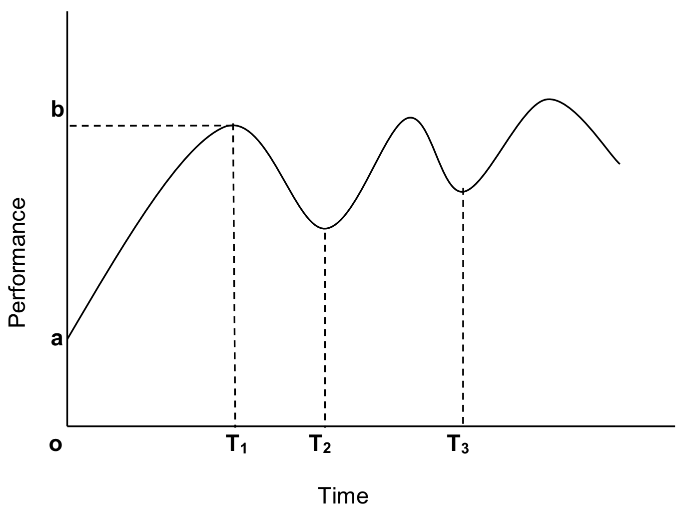


Fig.2.2 Performance with initial experience and follow-up experiences

2.3 CMA Model

Typically, learning is not seen as a replication of real-world practices that are being studied in school [8]. Working, or learning, in a more real-world setting of a full-mission bridge simulator provides added benefits by making it possible for a team to form, by providing real and accurate tools to use, by encouraging realistic dialogue, and all within appropriate context [8]. The California Maritime Academy has adopted a short-frequency course-sequencing model combining elements of experiential simulation exercises that bridge a practical training requirement on a commercial vessel and the Academy's training ship. Figure 2.3 depicts the courses and their sequencing along with the approximate time interval between courses.

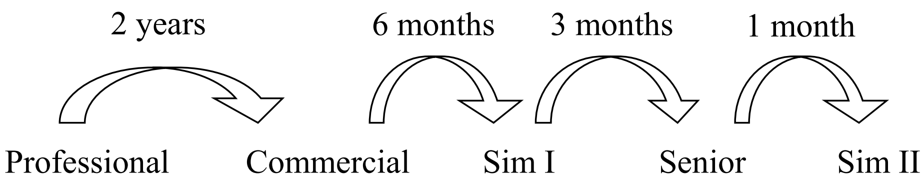


Fig.2.3 The CMA Model

2.3.1 Course Content

While course sequencing itself plays a major contributing role in the acquisition of strong professional watch-standing skills, the time-line frequency of that sequencing is crucial in preventing knowledge and experience decay as previously illustrated. In furtherance of the overall training objectives, while sequencing and timing have been discussed, it should be mentioned that course content plays a critical role in the learning reinforcement design of the overall program regime.

Carefully designed course content and specific subject-matter emphasis in each course of a program sequence has a fundamental impact on overall student skills retention within that program. This retention happens in two ways: through integration and through repetition.

Integration in this bridge watch-standing milieu is the logical and systematic assembling of previously learned knowledge and individual equipment operation elements into a coherent and complimentary skill-set that can be successfully adopted or adapted to other ship/route settings and circumstances. By bringing together many individual pieces of knowledge and information from prior course work and correctly ordering and aligning them in contextual real-world situations (simulated and actual), the integration process then places emphasis on overall situational analysis and correct task prioritization leading to correct decision making on the part of the bridge Officer. Well thought-out and designed course sequencing and course spacing within the curriculum greatly facilitates the learning integration process.

It is widely known among educators that repetition of previous knowledge exposures, particularly repetition of demonstrable skills, is the key to deep memory, long-term learning. By carefully designing course content utilizing complimentary building-block skills between those courses and then reinforcing those individual learning objectives by continually repeating them during the integration process of course sequencing, students amass and retain a solid background of bottom-to-top skills while permitting the periodic inclusion of new skills into the overall pool of accumulated experiences.

Thus, student perceptions of course sequencing include their underlying assumptions of well-designed course content. Effectiveness in course sequencing to reinforce and assess overall learning objectives depends not only on the careful design of what courses to sequence, but also on how close courses should follow each other, and an understanding of the underlying contributory factors within the course work that permits the accumulation of background knowledge and experience to be synergistic.

2.3.2 Multiple Simulator Experiences

The CMA program model of bridge skills training combines multiple exposures to part-task bridge skills coursework (e.g. radar & radio), real ship bridge experience (commercial and training vessels), and multiple bridge full-mission bridge courses. The part-task and actual hands-on experiences gained from real equipment and situations on actual operating ships are reinforced with two separate simulation courses, each with separate but closely complimentary objectives. This strategic mix of real and simulated bridge experiences are scheduled in such a way as one follows closely to the other in an alternating fashion. The time interval between learning exposures is decreased as the student moves through the program to inculcate proper watchkeeping skills more certainly.

There are several reasons for having two separate bridge simulation courses within CMA's overall bridge training program. Simulators can provide programming flexibility with respect to complexity of situations. This makes simulation training ideal to fit between at-sea courses because of the widely-separated student experience levels between actual ship cruise experiences. That same flexibility of programming operation can obviously be used to create training scenarios of varying complexity that might take years of actual experience to encounter but can be provided to each student for measurable assessment of performance.

Bridge resource management and bridge team management [18] skills constitute primary training objectives for junior entry-level Merchant Marine Officers within the STCW doctrine. Repetition is the key to deep learning and skills performance. Thus, multiple bridge exposures with varying group dynamics and situations that can be easily replicated in simulator as opposed to that observed in the actual at-sea experience. Students need to learn to adapt to working conditions in different bridge team dynamics in order to maximize their individual participation. That participation can potentially be suppressed either by operating within a team with other stronger members or within student-recruited groups where the learning "load" is divided between individual members instead of each learning about everything and then integrating everyone's overall skills into a more powerful dynamic. Forcing students into different bridge teams over multiple courses greatly enhances their ability to work in diverse work groups.

Perhaps the single most important reason for having multiple simulation courses is to increase student familiarity with the simulator nuances and the operation of the equipment. Simulation provides an incredibly powerful tool for trainers to recreate situations and scenarios almost impossible to experience in the real-world, especially with respect to emergency or extremis situation training. Because simulators can be programmed from simple to complex, they permit (by careful scenario design) instructors to continually challenge students' skills and experience levels. In order to get to this level of bridge skill "polish", students must have gained sufficient experience with the simulator operation and equipment manipulation to get to where they can extend their consciousness outside of their own vessel in order to become more "situationally aware". Experience has shown that students (as individuals or in teams) can never get to that level of understanding and training if they are still struggling with equipment operations or basic procedures within the simulator environment. The higher learning objectives never occur because the students simply do not recognize situations developing in real time because their heads are buried in the "cockpit". It has proven to be crucial that sufficient simulator time be included within a training program in order to provide the students with the requisite familiarity and then carefully increasing the complexity of scenarios so that the student is not overwhelmed and left behind the training objectives.

2.4 Methodology

With knowledge of the CMA model, and in light of the fact that it is not possible to establish a control group, our goal is to determine the success of this current model in terms of student perceptions. This methodology is similar to that used in a study by Rassuli & Manzer (2005) [5]. Therefore, the primary investigation will consider how the students perceive the sequencing of the program as providing value to their watch-standing learning experience. This will be considered from two different perspectives: overall sequencing of courses, and whether or not the students felt their skills had deteriorated between their most recent experience and the one immediately preceding to it. We also considered how they perceived the value of each of the courses to their watch-standing skill.

To measure the perceptions of the students with regard to the CMA model, only those students (n = 44) who had already taken their Commercial Cruise, Simulator 1, Senior Cruise, and Simulator II were eligible to participate. Two classroom visits were made and the purpose of the survey was explained to all eligible students. Of those eligible to participate, we received completed surveys from 93% (n = 41). The data was coded and entered in SPSS version 13.0 for analysis.

2.5 Result

Overall, just over 80% (n = 33) of the respondents indicated that they liked the current sequencing of the courses and 73% (n = 30) either agree or strongly agree that the short time period between Commercial Cruise, Simulator I , Senior Cruise, and Sim II provided for strong learning reinforcement and repetition of skills. The longest gap between experiences was between their Commercial Cruise experience and their Simulator I course. Only half (n = 21) of the students felt that their watch-standing skills had not decreased during this period of time. For the shorter time between Simulator I and Senior Cruise, about 70% (n = 27) felt that their skills had not deteriorated and for the time between Senior Cruise and Simulator II, again 70% (n = 28) felt that their skills had not deteriorated.

With regards to their perceptions of the value to their watch-standing experiences, overall, 83% (n = 34) of the students felt that their watch-standing experience on Commercial Cruise was a valuable experience, 78% (n = 32) felt that their watch-standing experience in Simulator I was a valuable experience, 61% (n = 25) felt that Senior Cruise was a valuable watch-standing experience, and 83% (n = 34) felt that Simulator II provided a valuable watch-standing experience for them.

Many written comments were provided by the students that indicated that they did not get as many bridge watches as they would have liked on their senior cruise. This probably accounted for the relatively lower degree of value to them for that experience. There appeared to be some differences in perceptions concerning the Commercial Cruise experience depending on the route of the ship (e.g., inland, coastal, ocean) and the vessel type. However, these differences were not statistically significant due to the small number of respondents in many of the categories.

As the literature suggests, reflection is an important part of experiential learning. In that regard, over 85% (n = 35) of the students either agreed or strongly agreed that the watch debriefs and assessments that are part of their experiential regime were valuable to their learning experience. When asked to provide written comments concerning possible changes to the sequences, all but one student thought that the current sequencing was the best. They also thought that there should be more time spent in the simulator.

2.6 Conclusion

Consistent with the literature, active learning for the purpose of knowledge and skill integration is a preferable learning methodology for our students. Careful use and integration of multiple simulation experiences closely sequenced with actual ship training experiences can add synergy to and deep learning to STCW bridge skills. Learning objective effectiveness is further strengthened by repetition

of skills and general principles exercising but applied to new situations and scenarios where critical thinking is required to integrate previous lessons learned to new situations.
The CMA model of bridge watch-standing training is a building-block approach of complimentary courses and experiences spaced close together to reinforce deep-rooted skills acquisition. The CMA program begins with stand-alone coursework to provide pre-requisite part-task skills and background knowledge necessary to understand basic communications, equipment operation, navigation, traffic rules and watch-standing procedures needed to manage a modern bridge environment.
Once the individual pieces of bridge watch-standing components are learned and important elements emphasized, students are placed in a closely coordinated series of courses sequenced in such a way as to repeat the application of integration principles to new situations while subjecting the student to scenarios of ever-increasing complexity and ambiguity. The program of course sequencing is carefully designed so that each course's learning content and objectives are consistent with and complimentary to the overall integration of bridge watch-standing skills. This sequence is comprised of:

- Multi-course background of professional subjects
- Commercial cruise
- 1st bridge simulation course
- Senior cruise
- 2nd capstone simulator course

Using this bridge watch-standing training model, the data from student perceptions of the success of the model were overall positive. The students recognized the value of using this model and felt that it should remain unchanged.
The overall objective in training modern-day mariners in a highly dynamic, complex, and technologically-intense environment is to insure that the bridge watch-standing officer is sufficiently trained and experienced. In addition to the requisite technical skills, this means that he or she is "situationally aware" of their vessel's surroundings and the current conditions. Faster and less maneuverable vessels require the competent bridge officer to extend their decision matrix well beyond the vessel in order to execute corrective action sufficiently in advance to diffuse potentially dangerous situations or to be able to quickly and correctly respond to an immediate action event. In order to be able to do that however, the bridge officer must first recognize potential dangers posed to ships in advance. Maritime educational pedagogies and training methodologies are designed to achieve this outcome to an acceptable level for newly training officers.
Obviously, there is no substitute for experience in honing the skill and judgment expected of a well-seasoned bridge officer. However, in training entry-level officers with a minimum level of competence necessary to stand a safe bridge watch, carefully designed training regimens and programs that maximize student participation in closely coordinated training experiences are crucial to the safety and viability of the international maritime industry.
Training time and resources are always limited in any maritime educational institution. Therefore, maximizing resources and student availability is paramount to meeting the expected training objectives. The advent of marine bridge simulation has permitted much higher levels of training. Some institutions have elected to substitute simulator time for the more expensive real ship cruising experience. Others have simply adopted a one-time International Maritime Organization (IMO) model simulator course and inserted it into a curriculum not designed to maximize its benefits nor necessarily coordinated it with other coursework in an effective way.
At the California Maritime Academy, a bridge watch-standing model has been adopted that we believe maximizes STCW training objectives while balancing overall training expense, student availability, and other resources while ensuring measurable and demonstrable assessment verification. That assertion was recently confirmed by a United States Coast Guard and Maritime Administration five-year STCW program audit where the findings of the team reaffirmed the necessity to retain both simulator courses within the overall bridge watch-standing training program.

3. Evaluation of trainee's performance with physiological index

This chapter shows two examination results about the relation between the evaluation of trainee's performance at the ship maneuvering simulator training and trainee's physiological index. As a method of evaluating trainee's performance, a subjective evaluation method which an instructor observes trainee's behaviour during the simulation run based on a checklist is general. Therefore, we had the experiment which presumed trainees' mental workload under the simulation run from trainees' hart rate interval [19], and examined the relationship with trainees' performance evaluation results. As a method of evaluating the trainee's performance of evading navigation, there is a technique for evaluating trainee's situation awareness [20]. Then, we executed evading navigation experiment using with ship maneuvering simulator, and measured subject's situation awareness. At the experiment, we measured subject's nasal temperature then estimated subject's mental workload [21]. These evaluation methods used by experiments and results of experiments are described in following section.

3.1 Subjective Evaluation Method

The subjective evaluation of the simulator training is executed by the instructor. Therefore, the evaluation criteria and the checklist are different according to the educational organization. However, the substance is common. Then, the example of the evaluation criteria is shown in Table 3.1.

Table 3.1 Example of Performance Evaluation List

Criteria		Trainee's Score
Fundamental	Understands and applies COLREGs & their application	
	Proper use of terminology	
	Sets adsusts radars correctly/knobology	
	Voyage planning - element understanding	
Technique	Conns vessel properly (order) & resists distractions	
	Uses appropriate scales to circumstances	
	Speed & accuracy of work generally	
	Ability to maintain course	
	Calls out headings during C/C & monitors PSC	
BRM	Bridge equipment function & layout familiarity	
	Generally applies solid BTM & BRM skills (inc. delegation)	
	Ensures accurate execution/monitor of voyage plan	
	Duplicatiotes plots/indexes on both radars	
	Maintains a proper lookout	
	Specific use of radio & VTS for situation awareness	
	Contributes well during debrief	
Integration	Has mentally oriented themselves to chart & roule	
	Oriented to traffic situation & reports	
	Cross checks (multiple systems, fathometer, etc)	
Leadership	Personally organized & adequately prepared	
	Conforms to standing & day orders	
	Display good subordinate behavior	
	Response during stress	
Score(Ave.)		

Using the performance evaluation list, the instructor fills in the score of each criteria with five grade such as, Very Good(4.0), Good(3.5), Satisfactory(3.0), Poor(2.5), Unsatisfactory(2.0).

3.2 Evaluation Method for Trainee's Situation Awareness

In order to evaluate the mariner's navigation skill, it was effective to use a method of measuring which ship a mariner had been recognizing in the simulation run. Situation awareness global assessment technique (SAGAT) is a typical technique for measuring subject's situation awareness under the simulation run. Therefore, we modified SAGAT to measure ships that the trainee was recognizing in the simulator training, and then we developed the application tool which identified the ship that the trainee had been recognizing. In this section, the modified SAGAT and the developed application tool were introduced

SAGAT was used to measure how the trainee had been recognizing other ships. In this technique, the simulation run was suddenly interrupted; the subject's situation awareness was measured by the questionnaire. While the subject answered the recognized situation; the simulation run was stopped temporarily and the screen of the simulator became all black. After the questionnaire, the simulation was restarted. If the simulation interruption time became too long, the continuity of the simulation run was decreased. Therefore, the interruption time was appropriate within two minutes [22]. However, there was a possibility that the reporting time interval exceeded two minutes if the subject answered in oral, because a lot of ships may appear in this scenario. Moreover, there was a possibility that the expression of the position of the ship became ambiguous in the oral report. To overcome these problems, we adopted the method that the subject filled in the recognized ship on a radar chart instead of the oral report. The example of the radar chart was shown in Fig.3.1. The coordinate system of the radar chart was same as the marine radar screen. The center of figure showed own ship, y axis indicated the direction of own ship course, and x axis indicated the direction of abeam of own ship. In the figure, the concentric circles were drawn every one mile from the own ship. Then, the subject filled in the ship's picture in this figure based on the recognized ship's information such as distance from own ship, the bearing from own ship, and the aspect of the ship.

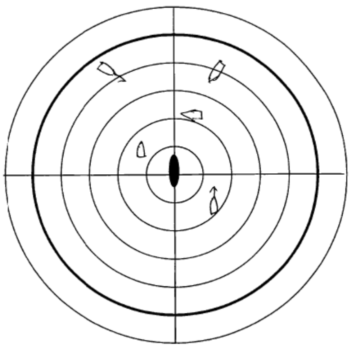


Fig.3.1 Example of RADAR Chart

Usually, ship maneuvering simulator could save simulation results as time series data of own ship and other ships movement. Using these time series data, simulator training result could be replayed by ship maneuvering simulator. However, it is inconvenient to use the replay function of ship maneuvering simulator for identifying the ship that the subject had been recognizing. Therefore, we developed an application tool that reproduce the simulation result on the radar chart for identifying the ship that reported by the subject. Fig.3.2 shows the example of display screen of the developed application tool. In the application, ship's position was displayed by the circle, ship's course was displayed by vector, and ship's ID number in the simulation scenario was also displayed by number. By comparing the application display such as Fig.3.2 and the radar chart which filled by subject such as Fig.3.1, the ship that subject was recognizing could be identified in ship's ID number of the simulation scenario. Then, the movement of the ship that subject had been recognizing could be analyzed from the time series data of the simulation result.

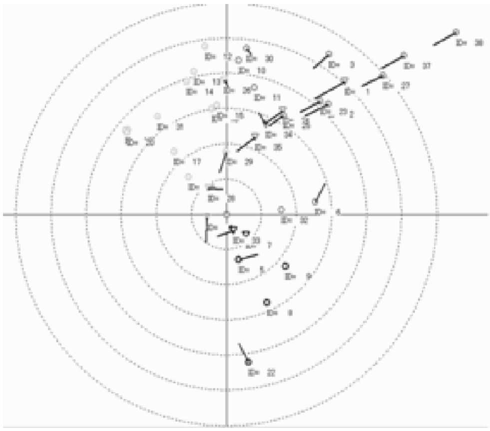


Fig.3.2 Example of display image of idintification tool

To evaluate the subject's situation awareness of the simulator training, significance of the recognized ship should be classified whether the recognized ship had risk of collision. Then, it is necessary to examine whether how many ships that had risk of collision was recognized by the subject. To define whether the ship had risk of collision, we use an index that focusing target ship's changing rate of bearing. In this study, the ship which corresponded to this index was called "caution ship".

The caution ship was the ship had possibility of the collision risk. If the ship had the possibility of the collision risk, the relative bearing seen from own ship did not change. Therefore, the caution ship was defined as the ship that the change rate of relative bearing satisfied the following constraint [23],

$$\dot{\omega} \leq \alpha \cdot R^{\beta} \qquad (1)$$

where, $\dot{\omega}$ denoted changing rate of relative bearing, R denoted relative distance, α and β denoted weight coefficient. The value of α and β was proposed from the experiment result data of 30,000 points as follows [23].

If the target ship will cross the own ship heading in the future,

$$\alpha = 4.5 \times 10^{5}, \quad \beta = -1.7. \qquad (2)$$

If the target ship already crossed the own ship heading,

$$\alpha = 3.0 \times 10^{5}, \quad \beta = -1.7. \qquad (3)$$

We added the function to calculate this caution ship from simulation data to the application tool which denoted in previous section. In the application tool, the caution ship was drawn as triangle mark on the radar chart display. Therefore, the caution ships could be listed at the stage of identifying the reported ship.

3.3 Method for Estimating Trainee's Mental Workload from his Nasal Temperature

In order to measure mental workload of navigator who is under ship maneuvering simulator training, method for measuring subject's nasal temperature is eligible method. Subject's nasal temperature is measured by thermal image video camera. Therefore, it is possible to measure subject's nasal temperature without mounting measurement equipment on the subject. In this section, outline of the method for measuring navigator's mental workload by his/her nasal temperature and example of measured data were introduced.

If a human feel strong stress, his/her skin's temperature decrease, because a blood flow volume decreases when a sympathetic nerve becomes dominant. Especially, this phenomenon appears remarkably in a nose, because peripheral blood vessel concentrates around the nose. Therefore, it is possible to obtain changing trend of subject's mental workload using with subject's nasal temperature that measured by thermal image video camera. Fig.3.3 shows an example of thermal image.

Fig.3.3 Example of thermal image in the bridge

In order to show effectiveness of method for measuring navigator's mental workload by his/her nasal temperature, we introduce some subjects' nasal temperature data during ship maneuvering simulator training. In the simulation, outline of the scenario was described in Fig.3.4. Therefore, it was predicted that subjects may get strong stress when they crossed from among the traffic stream of south going ships at around No.2 buoy. Subjects had license of 3rd grade marine officer and also they had onboard experience for a year.

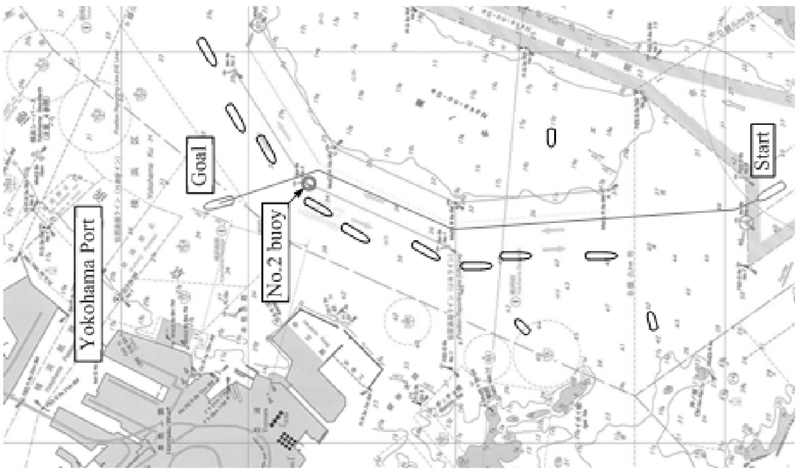


Fig.3.4 Outline of simulation scenario

Fig.3.5 and Fig.3.6 showed time series data of subject's nasal temperature. In the figures, break line indicated the start point for crossing from among the traffic stream. From Fig.3.5, it was read that subject's nasal temperature decreased around the point that own ship crossed the traffic stream. It means that subject A felt strong stress at that point. On the other hand, from Fig.3.6, it was read that subject B did not feel stress at the point that own ship crossed the traffic stream.

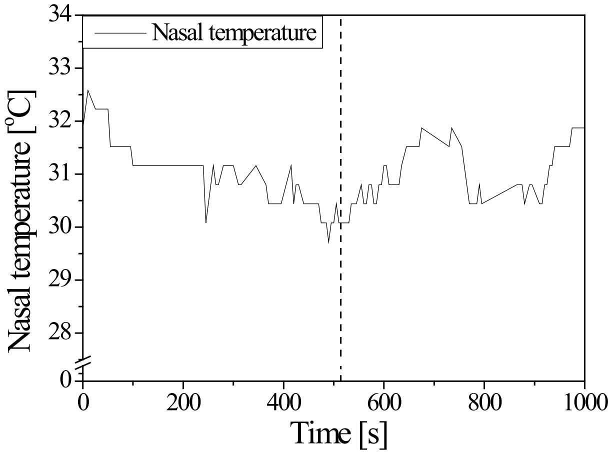


Fig.3.5 Time series of nasal temperature of subject A

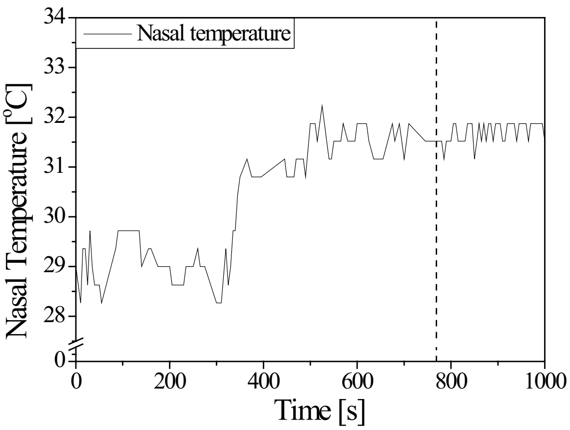


Fig.3.6 Time series of nasal temperature of subject A

Reason of this phenomenon was indicated by the ship's track which showed in Fig.3.7. He did not cross the traffic stream around No.2 buoy. He crossed the traffic route after all ships passed away, because this simulation scenario did not prepare enough ships for traffic stream. He found the end of traffic stream in 350 seconds, because his nasal temperature was low for 0 to 350 seconds, but after 350 seconds, his nasal temperature become higher. It means he was relaxed after 350 seconds.

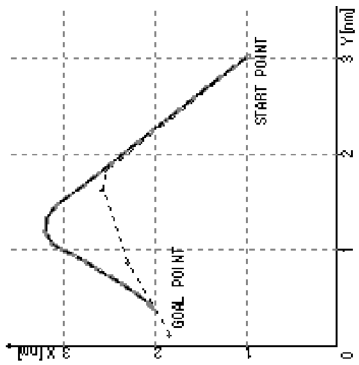


Fig.3.7 Track of subject B's simulation result

According to these results, it was clear that the method for measuring navigator's mental workload by subject's nasal temperature was effective method.

3.4 Method for Estimating Trainee's Mental Workload from his R-R Interval

The rhythm of pulsation is adjusted by the autonomous nervous system. It consists of the sympathetic nervous system and parasympathetic nervous system, which are closely related. The sympathetic nervous system predominates for stress. Therefore, it is possible to evaluate the mental workload that influences the autonomous nervous system by measuring the R-R interval which is a heart rate for a moment. Fig.3.8 shows example of electrocardiogram (ECG). The R-R interval means the time interval from a peak point R wave is one of waves consists of P, QRS and T of an ECG.

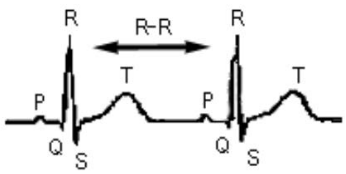


Fig.3.8 Example of electrocardiogram

To evaluate the mental workload, Sympathetic Nervous System values (SNS value) is calculated from the equation as follows,

$$SNS(i) = LF(i) / HF(i) \tag{4}$$

where LF is low frequency amplitude of R-R interval spectrum which frequency is from 0.04Hz to 0.15Hz and HF is high frequency amplitude of R-R interval spectrum which frequency is from 0.15Hz to 0.40Hz. The LF value is reflected by the sympathetic nervous system and parasympathetic nervous system, and the HF value is reflected by the parasympathetic nervous system. Therefore, increasing SNS value means increase of mental workload.

3.5 Experiment for Subjective Evaluation with Physiological Index

In order to examine the relation between the subjective evaluation of trainee's performance and trainee's mental workload estimated by physiological index, we had ship maneuvering simulator experiment. Setting of the experiment and results were described as follows.

(1) Setting of Experiment

In this experiment, a ship maneuvering simulator of California Maritime Academy was used. The simulator is full-mission type simulator and it has visual view of 360 degrees. We employed three subjects who had license of navigation officer and on-board experience. Three subjects trained respectively as mate, radar observer, and helmsman. Each role was changed and the simulator experiment was executed three times. Therefore, we prepared three scenarios. The outline of each scenario was described as follows.

- Scenario 1
  Area: San Francisco (SF) bay, Alcatraz to Oakland
  Own ship: Tanker (L: 261.21 m, B: 48.16 m, d: 8.99 m)
  Objective: Traffic management will be a part of this scenario. Experience heavy traffic in normal condition of SF Bay. To develop a passage plan. Use Bridge Team, and available tools.

- Scenario 2
  Area: The Brothers to Richmond Inner Harbor
  Own ship: Bulk Carrier (L: 199.95 m, B: 23.77 m, d: 6.64 m)
  Objective: To utilize Bridge Resource Management (BRM) procedures to raise situational awareness. To manage low speed maneuvers of vessel in mild wind. Decision making relative to environment.

- Scenario 3
  Area: Southampton Ch. To Richmond Long Wharf
  Own ship: Tanker (L: 242.93 m, B: 32.30 m, d: 7.01 m)
  Objective: To manage low speed maneuvers of light draft vessel. Decision making relative to traffic and environment. Utilization of conventional and tractor tugs. To work with radar, and Electronic Chart Display and Information System (ECDIS).

Subjects' behavior was recorded with the video camera and work sampling was done. And subjects' hart beat were measured with the following equipment (Fig.3.9).

Fig.3.9 Snap shot of heart rate monitor (POLAR Pro Trainer 5TM)

Before the experiment, we explained the informed consent form for human research to all subject, and they accepted and signed the informed consent.

(2) Result of Experiment

We executed ship maneuvering simulator experiment by using Scenario 1, Scenario 2, and Scenario 3 and measured subjects' hart rate. From the subject's hart rate, SNS value which indicates subject's mental workload was calculated. Also, each subject's behavior was listed to work sampling list every 20 seconds by using recoded video. Fig.3.10, Fig.3.11, and Table 3.2 showed subjects' SNS value, time series of ship state value, and work sampling list of experiment 1 which used Scenario 1. From the figure, it can be read that SNS value of three subjects at 17 minutes rises all together. This change shows that all subjects' mental workload increase in 16-17 minutes. When we looked work sampling list in Table 3.2, the mate is giving the order of astern for the main engine at 15.3 minuites. The deceleration control is an important phase for very large crude carrier. Therefore, the mate and radar observer's mental workload increased after the order of astern engine. Moreover, when the engine is set to astern, response of rudder becomes worth, then, helmsman has to prepare the change of the ship's maneuverability. Therefore, the helmsman's mental workload was increased. From this phenomenon, it was clear that all subjects worked cooperatively by an important phase of the scenario.

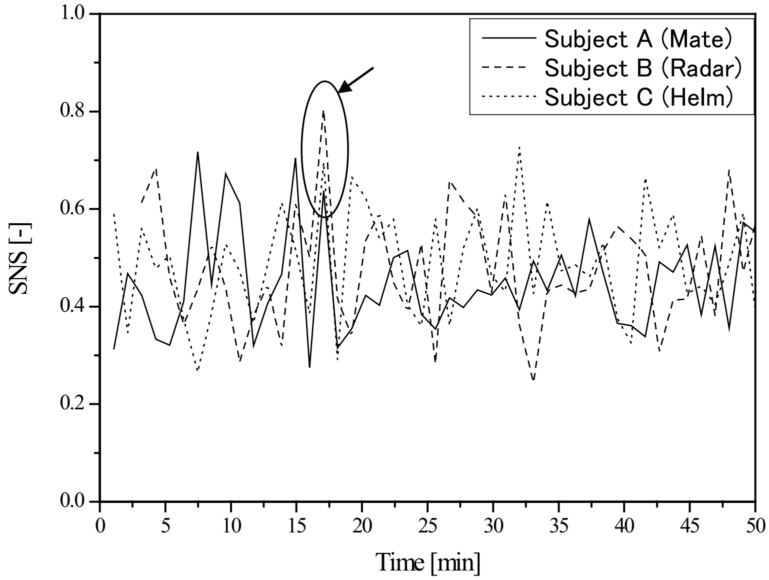


Fig.3.10 Time series of subjects' SNS value at experiment 1

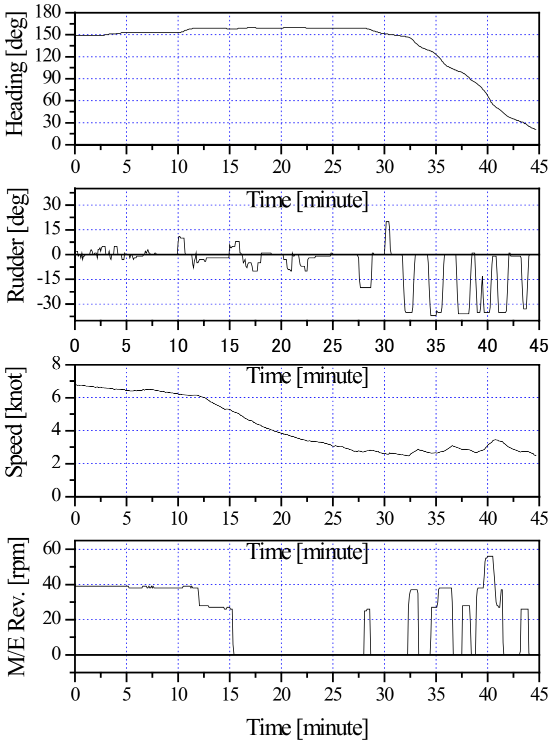


Fig.3.11 Time series of own ship's state value at experiment 1

Table 3.2 Work sampling list of experiment 1

Time (min)	Mate (Subject A)	RADAR Observer (Subject B)	Helm (Subject C)
0.3	Mate reported "147 steady"/ Mate ordered to checked it by RADAR at 8 and 10 behind ship	RADAR Observer operated RADAR	"147 midships" "Steady 147"
0.7	Mate pointed at forward of starboard and port side and ordered to checked it by RADAR while talking with RADAR Observer	RADAR Observer checked RADAR because Mate said that, and then RADAR Observer responded it/ RADAR Observer checked forward and received order	Helmsman was steering
1.0	Mate looked around forward of ship while checking RADAR	RADAR Observer checked RADAR, touched eyes, and went to ET	Helmsman checked wristwatch while steering
1.3	Mate looked around forward of ship while checking RADAR/ Mate	RADAR Observer checked forward starboard side/ RADAR Observer operated	Helmsman pointed at forward and talked/ Response from RADAR

	checked RADAR (B) after talking with Helmsman	ET because Mate said	Observer
1.7	Mate looked around forward of ship/ Mate responded to Helmsman	RADAR Observer checked forward, and RADAR Observer operated of ET/ Whistle blew	Helmsman talked something
2.0	Mate checked RADAR/ Mate ordered "right 147"	RADAR Observer checked RADAR	Helmsman was Steering which was ordered by Mate
2.3	Mate was ordered by Helmsman, and corrected to "right 151"	RADAR Observer smiled because Mate had order mistake/ RADAR Observer checked RADAR	Helmsman Asked "Left 147?"/ Helmsman was ordered as "right 151"
2.7	Mate responded to RADAR Observer	RADAR Observer checked RADAR, and RADAR Observer talked	Helmsman was Steering
3.0	Mate checked RADAR, and responded to RADAR Observer/ Mate checked ECDIS with RADAR Observer	RADAR Observer checked RADAR, found something, and RADAR Observer talked with Mate	
3.3	Mate checked ECDIS and RADAR	RADAR Observer checked RADAR with Mate/ found ECDIS and talked/ RADAR Observer operated ET	
3.7	Mate checked ECDIS with RADAR Observer	RADAR Observer was talking with Mate while checking ECDIS	Helmsman talked "steady 151"
4.0	Whistle blew and Mate ordered "right 153"/ 3 point	RADAR Observer checked RADAR	Helmsman ordered as "right 153"
4.3	Mate checked back and forward/ Mate checked RADAR	RADAR Observer checked RADAR and forward	Helmsman was steering
4.7	Mate ordered to RADAR Observer/ Mate checked chart	RADAR Observer checked chart because Mate ordered	
5.0	Mate checked back and forward/ Mate talked with RADAR Observer	RADAR Observer checked chart	Helmsman talked "steady 153"
5.3	Mate checked wristwatch because Helmsman said	RADAR Observer checked wristwatch because Helmsman talked	Helmsman checkeded wristwatch and talked with Mate
5.7	Mate operated RADAR/ Mate was considering while touching nose	RADAR Observer talked after checked RADAR, ET, and RADAR	Helmsman was steering
6.0	Whistle blew/ Mate looked at RADAR and thinking/ Mate hold transceiver	RADAR Observer checked RADAR, wind indicator, and so on	
6.3	Mate listened to transceiver, and looked at RADAR	RADAR Observer checked RADAR and ECDIS	

6.7	Mate listened to transceiver, and talked with Helmsman and RADAR Observer	RADAR Observer smiled because Mate talked/ RADAR Observer checked document on chart	Helmsman was talked from Mate
7.0	Mate responded to RADAR Observer/ Mate checked RADAR	RADAR Observer was talking while holding document/ RADAR Observer checked ECDIS	Helmsman was steering
7.3	Mate checked ET/ Mate talked with RADAR Observer	RADAR Observer was checking RADAR with Mate while pointing at RADAR	
7.7	Mate talked with RADAR Observer/ Mate checked ECDIS	RADAR Observer talked with Mate/ RADAR Observer checked ECDIS	
8.0	Mate checked chart with RADAR Observer and talked	RADAR Observer checked chart and talked with Mate	
8.3	Mate checked chart and ECDIS with RADAR Observer/ Mate talked	RADAR Observer checked chart and ECDIS and talked with Mate	
8.7	Mate looked around ship	RADAR Observer checked chart and ECDIS	
9.0	Mate checked forward	RADAR Observer checked transceiver	
9.3	Mate talked with RADAR Observer	RADAR Observer talked with Mate by transceiver	
9.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate by transceiver after checked chart	
10.0	Mate talked with RADAR Observer and Helmsman/ "right ten"	RADAR Observer talked with Mate by transceiver and checked chart	
10.3	Mate checked forward	RADAR Observer checked chart	
10.7	Mate checked forward/ "Midships"	RADAR Observer checked RADAR and ECDIS	
11.0	Mate passed transceiver and ordered	RADAR Observer received transceiver and talked "vessel traffic"	
11.3	"Steady course 159"	RADAR Observer talked by transceiver	
11.7	Mate checked and operated RADAR		
12.0	Mate checked and operated RADAR/ "going to dead slow"	RADAR Observer checked chart	
12.3	Mate checked and operated RADAR	RADAR Observer checked chart/ RADAR Observer talked by transceiver	
12.7		RADAR Observer checked chart	
13.0			

13.3	Mate checked and operated RADAR	RADAR Observer checked RADAR and ECDIS/ RADAR Observer got memo and went to chart table	
13.7	Mate checked chart with RADAR Observer	RADAR Observer checked chart	
14.0	Mate talked with RADAR Observer while checking RADAR		
14.3	Mate checked forward		
14.7	Mate checked RADAR/ Mate was called by RADAR Observer, and Mate checked chart together	RADAR Observer called Mate and RADAR Observer checked chart	
15.0			
15.3	Mate checked RADAR/ "astern"	RADAR Observer checked chart	
15.7	Mate checked RADAR		
16.0	Mate talked with RADAR Observer/ Mate checked RADAR	RADAR Observer talked with Mate	
16.3	Mate checked chart	RADAR Observer talked with Mate/ RADAR Observer checked and operated RADAR and ECDIS	
16.7	Mate checked RADAR and ECDIS with RADAR Observer	RADAR Observer checked RADAR and ECDIS with Mate	
17.0	Mate checked RADAR and forward	RADAR Observer checked and operated RADAR･ECDIS	
17.3		RADAR Observer checked and operated RADAR･ECDIS/ RADAR Observer checked chart	
17.7	Mate checked and operated RADAR and ECDIS	RADAR Observer talked with Mate while pointing at forward/ RADAR Observer checked chart	
18.0		RADAR Observer checked chart	
18.3	Mate checked and operated ECDIS		
18.7	Mate checked forward/ Mate talked with RADAR Observer	RADAR Observer checked chart with Mate	
19.0	Mate checked chart with RADAR Observer		
19.3	Mate checked forward/ Mate talked with RADAR	RADAR Observer checked forward/ RADAR Observer	

	Observer	talked with Mate	
19.7			
20.0	Mate checked wristwatch	RADAR Observer checked wristwatch	
20.3	Mate was reported from transceiver/ Mate pushed wristwatch	RADAR Observer checked chart/ RADAR Observer received something by transceiver/ RADAR Observer pushed wristwatch	
20.7	Mate checked and operated RADAR	RADAR Observer checked wristwatch/ RADAR Observer checked chart	
21.0		RADAR Observer checked chart	
21.3	Mate checked and operated ECDIS	RADAR Observer checked forward	
21.7	Mate pointed at forward port side while checking RADAR	RADAR Observer checked RADAR and ECDIS	
22.0		RADAR Observer checked and operated RADAR･ECDIS with Mate	
22.3	Mate talked with RADAR Observer/ Mate checked and operated RADAR	RADAR Observer talked with Mate/ RADAR Observer checked chart	
22.7			
23.0	Mate paid attention to forward port side/ Mate checked forward	RADAR Observer pointed at forward left side and pay attention to it	
23.3	Mate checked forward/ Mate checked RADAR	RADAR Observer checked RADAR and ECDIS	
23.7	Mate checked RADAR and ECDIS		
24.0	Mate was talking with B while looking at RADAR and ECDIS	RADAR Observer talked with Mate/ RADAR Observer checked and operated RADAR	
24.3	Mate checked RADAR	RADAR Observer checked chart	
24.7	Mate talked with Helmsman/ Mate checked and operated RADAR		
25.0	Mate checked and operated RADAR	RADAR Observer wrote down while checking RADAR and ECDIS, and RADAR Observer went to chart table	
25.3		RADAR Observer checked chart	
25.7			
26.0	Mate checked RADAR and		

	ECDIS		
26.3	Mate checked forward	RADAR Observer pointed at forward and checked chart	
26.7	Mate checked RADAR	RADAR Observer checked chart	
27.0			
27.3		RADAR Observer checked and operated ECDIS	
27.7	"left twenty"	RADAR Observer checked forward	
28.0	Mate checked RADAR	RADAR Observer checked ECDIS	
28.3		RADAR Observer checked forward	
28.7	Mate touched ET	RADAR Observer checked RADAR and ECDIS	
29.0	"midships"		
29.3	Mate checked forward/ Mate talked with RADAR Observer	RADAR Observer was noticing to Mate while pointing at forward right side	
29.7	Mate checked RADAR	RADAR Observer pointed at forward	
30.0		RADAR Observer checked wristwatch/ RADAR Observer checked RADAR and ECDIS	
30.3	"right twenty"/ Mate talked with RADAR Observer	RADAR Observer checked forward/ RADAR Observer talked with Mate	
30.7	"midships"	RADAR Observer checked RADAR and ECDIS	
31.0	Mate checked RADAR/ Mate talked with RADAR Observer, and Helmsman		
31.3	Mate checked and operated RADAR	RADAR Observer pointed at speed meter/ RADAR Observer checked and operated ECDIS	
31.7		RADAR Observer checked and operated ECDIS	
32.0	"hard left"	RADAR Observer touched ET	
32.3	Mate checked RADAR/ "slow ahead"	"slow ahead"	
32.7	Mate checked RADAR/ Mate ordered to RADAR Observer for checking ship speed	RADAR Observer checked chart and ECDIS	
33.0	"midships"	RADAR Observer checked chart	

33.3	"stop"	RADAR Observer checked Engine console/ "stop engine"	
33.7	Mate checked RADAR	RADAR Observer checked ECDIS	
34.0	Mate checked and operated RADAR		
34.3	Mate checked forward/ "hard left"	RADAR Observer pointed at forward left side, and talked with Helmsman	
34.7	"dead slow"	"dead slow"	
35.0	Mate checked forward/ Mate checked ECDIS	RADAR Observer checked RADAR	
35.3	"slow ahead"	"slow ahead"	
35.7	"midships"	RADAR Observer checked and operated ECDIS	
36.0	Mate checked RADAR	RADAR Observer checked forward	
36.3	Mate checked and operated RADAR/ Mate talked with RADAR Observer	RADAR Observer checked forward/ RADAR Observer talked with Helmsman	
36.7	Mate touched engine console	RADAR Observer checked ECDIS	
37.0	Mate checked and operated RADAR/ Mate talked with RADAR Observer and Helmsman	RADAR Observer talked with Mate and Helmsman while looking at forward left side	
37.3	"hand left"/ Mate talked while looking forward port side with RADAR Observer	RADAR Observer talked with Mate while looking at forward left side	
37.7	Mate checked forward port side/ "dead slow, please	Whistle blew five times/ "dead slow"	
38.0	Mate checked forward port side	Whistle blew one time	
38.3	Mate checked RADAR/ "midships"	RADAR Observer checked forward	
38.7	"all stop"	"engine all stop"	
39.0	"hard left"/ "slow ahead, please"	RADAR Observer pointed at forward left side/ "slow ahead"	
39.3	Mate checked RADAR/ "midships"	RADAR Observer checked forward	
39.7	Mate checked forward port side/ "half, ahead	RADAR Observer checked RADAR and ECDIS/ "half ahead"	
40.0	Mate checked forward	Whistle blew one time	
40.3	"midships"	RADAR Observer paid attention to forward left side	
40.7	"dead slow"	RADAR Observer checked ECDIS/ "dead slow"	
41.0	"hard left"/ Mate checked	RADAR Observer checked	

	ECDIS	ECDIS	
41.3	"slow ahead" by oneself	RADAR Observer checked forward	
41.7	"astern"	"astern"	
42.0	"midships"	RADAR Observer checked ECDIS	
42.3	Mate checked forward	RADAR Observer checked forward	
42.7	Mate ordered to RADAR Observer for checking forward port side	RADAR Observer talked by transceiver	
43.0	Mate checked and operated RADAR	RADAR Observer talked by transceiver	
43.3	"dead slow" by oneself/ "hand left"	RADAR Observer checked forward	
43.7	Mate checked ECDIS while pointing at forward left side/ Mate talked with Helmsman	RADAR Observer checked ECDIS	
44.0	Mate checked ECDIS/ "midships"	RADAR Observer checked RADAR and ECDIS	
44.3	"stop engine" by oneself		
44.7	Mate talked with RADAR Observer while checking ECDIS	RADAR Observer talked with Mate while checking ECDIS	

Fig.3.12, 3.13, and Table 3.3 showed subjects' SNS value, time series of ship state value, and work sampling list of experiment 2 which used Scenario 2. From Fig.3.12, it can be read that all subjects' SNS value at 8 minutes rises all together. From the work sampling list indicated at Table 3.3, it was read that the mate was giving the order of "left 10" for changing her heading. It was difficult situation to change bulk career's course under the wind while decelerating, because the bulk career's maneuvering performance was bad as written in the objective of scenario 2. Therefore, their mental workload was increased at that time. Also, SNS values of mate and radar observer were increased at 31 minutes. At this time, the ship turned slowly, then, there was a possibility to contact the pier. Then, the mate was giving the order for "Half ahead" to improve turn rate of heading. Therefore, the mate and radar observer felt stress at this moment. From these phenomena, it was clear that subjects worked together for difficult situation.

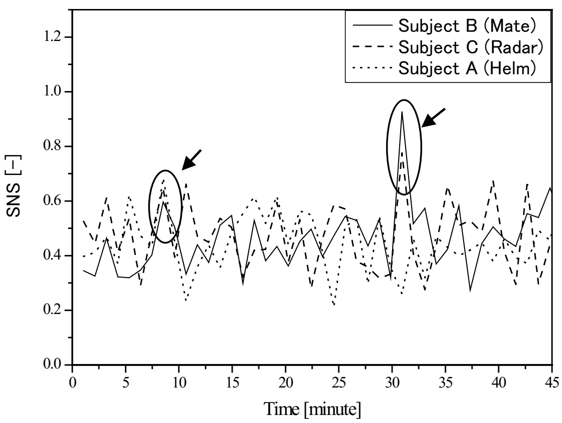


Fig.3.12 Time series of subjects' SNS value at experiment 2

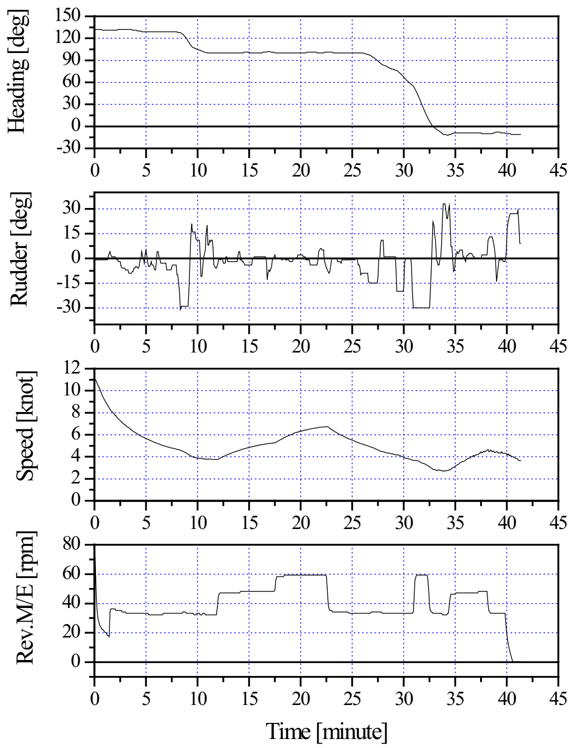


Fig.3.13 Time series of own ship's state value at experiment 2

Table 3.3 Work sampling list of experiment 2

Time (min)	Mate (Subject B)	RADAR Observer (Subject C)	Helm (Subject A)
0.0	Mate pushed wristwatch	RADAR Observer pushed wristwatch	start
0.3	Mate pushed ECDIS	RADAR Observer checked forward	
0.7			
1.0	"131"/ Mate operated ET		"131"
1.3	Mate checked forward/ Mate talked with RADAR Observer	"dead slow"/ RADAR Observer talked with Mate	"steady 131"
1.7		RADAR Observer talked with Mate	
2.0	Mate talked with RADAR Observer/ Mate operated RADAR	RADAR Observer talked with Mate/ RADAR Observer operated RADAR	
2.3	Mate talked with RADAR Observer		
2.7	Mate talked with Helmsman and RADAR Observer		
3.0	"left 129"	RADAR Observer checked RADAR	
3.3	Mate operated RADAR and ECDIS	RADAR Observer checked forward/ RADAR Observer checked RADAR	
3.7	Mate checked RADAR	RADAR Observer checked RADAR	
4.0	Mate checked forward/ Mate checked RADAR	RADAR Observer checked forward	
4.3			
4.7	Mate checked forward	RADAR Observer checked RADAR/ RADAR Observer talked with Mate	
5.0	Mate checked ET/ Mate talked with RADAR Observer	RADAR Observer checked ET/ RADAR Observer talked with Mate	
5.3	Mate checked ECDIS	RADAR Observer checked RADAR	
5.7	Mate checked RADAR and ECDIS		"steady 129"
6.0		RADAR Observer checked chart	
6.3	Mate talked with RADAR Observer / Mate pointed at forward	RADAR Observer talked with Mate/ RADAR Observer pointed at forward	
6.7			
7.0			
7.3	Mate talked with RADAR Observer	RADAR Observer checked chart/ RADAR Observer	

		talked with Mate	
7.7	"left 10"	RADAR Observer checked RADAR	
8.0	"left 15" -> "left 4"	RADAR Observer talked with Mate	
8.3	Mate talked with RADAR Observer/ Mate pointed at forward left side	RADAR Observer talked with Mate/ RADAR Observer pointed at forward left side	
8.7	Mate checked forward/ "midships"	RADAR Observer checked chart	
9.0	"right 10" -> "right 15"	RADAR Observer checked forward	
9.3	"decrease 10"	RADAR Observer talked with Mate	
9.7	"midships"/ Mate checked forward	RADAR Observer checked RADAR	"right 10"
10.0	"Steady course 098"	RADAR Observer checked and operated RADAR	
10.3	"Steady course 100"	RADAR Observer checked and operated RADAR/ RADAR Observer talked with Mate	
10.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
11.0	Mate talked with RADAR Observer / Mate operated ECDIS		
11.3	Mate checked and operated ECDIS	RADAR Observer checked and operated RADAR	
11.7	"slow ahead"		
12.0	Mate operated RADAR/ Mate talked with RADAR Observer	RADAR Observer checked and operated RADAR/ RADAR Observer talked with Mate	
12.3	Mate checked forward	RADAR Observer checked and operated RADAR/ RADAR Observer checked chart	"steady 100"
12.7	Mate checked RADAR	RADAR Observer checked chart	
13.0	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
13.3		RADAR Observer operated RADAR/ RADAR Observer talked with Mate	
13.7			
14.0	Mate checked RADAR	RADAR Observer checked chart	
14.3	Mate checked forward	RADAR Observer checked forward	
14.7	Mate talked with Helmsman	RADAR Observer checked chart	

15.0			
15.3			
15.7	Mate checked forward	RADAR Observer checked forward	
16.0	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
16.3	Mate checked forward	RADAR Observer walked around	
16.7	Mate talked with RADAR Observer	RADAR Observer operated RADAR/ RADAR Observer talked with Mate	
17.0	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
17.3			
17.7			
18.0			
18.3	Mate checked forward	RADAR Observer checked forward	
18.7		RADAR Observer checked chart	
19.0			
19.3	Mate checked ECDIS	RADAR Observer operated and checked RADAR	
19.7		RADAR Observer checked RADAR	
20.0	Mate talked with RADAR Observer	RADAR Observer operated ET/ RADAR Observer talked with Mate	
20.3	Mate checked ECDIS	RADAR Observer blew whistle	
20.7		RADAR Observer checked RADAR	
21.0	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
21.3	Mate talked with RADAR Observer/ Mate checked ECDIS	RADAR Observer checked ECDIS/ RADAR Observer talked with Mate	
21.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
22.0	Mate operated and Mate checked RADAR	RADAR Observer checked forward	
22.3	"dead slow"/ Mate talked with Helmsman		
22.7	Mate checked forward		
23.0	Mate pointed at forward with RADAR Observer and Mate talked with RADAR Observer	RADAR Observer pointed at forward and talked with Mate	
23.3	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
23.7	Mate checked forward	RADAR Observer checked RADAR/ RADAR Observer checked chart	

24.0	Mate checked ECDIS	RADAR Observer checked chart	
24.3	Mate checked forward	RADAR Observer checked forward	
24.7			
25.0			
25.3	"left 5" -> "left 10"		"left 5"
25.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate	"left 10"
26.0			
26.3	"left 15"	RADAR Observer checked forward	"left 15"
26.7	Mate checked forward		
27.0	Mate checked forward/ "midships"	RADAR Observer checked chart	"left 090"
27.3	"right 10"	RADAR Observer checked forward	"midships"
27.7	"midships"		"right 10"
28.0	Mate checked forward		"midship"
28.3			"pass left 080"
28.7			
29.0	"left 20"		"left 20"
29.3	Mate checked forward		
29.7	"midships"		"left 070"
30.0	Mate checked forward		"midship"
30.3	"left 4"		"left 060"
30.7	Mate checked forward		"left 4"
31.0	“Half ahead”	RADAR Observer checked RADAR	"left 050"
31.3		RADAR Observer checked forward	"left 040" "left 030"
31.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate	"left 020"
32.0	"dead slow ahead"	RADAR Observer checked chart	"left 010"
32.3	Mate talked with Helmsman	RADAR Observer hold transceiver	
32.7	Mate talked with RADAR Observer	RADAR Observer talked by transceiver	
33.0			
33.3	Mate talked with Helmsman	RADAR Observer checked forward	"351?"
33.7	Mate operated ECDIS	RADAR Observer operated RADAR	
34.0	"slow ahead"		
34.3	Mate operated ECDIS		
34.7			
35.0			
35.3	Mate operated forward	RADAR Observer checked forward	

35.7			
36.0			
36.3	Mate checked backward right side	RADAR Observer operated RADAR	
36.7	Mate checked forward	RADAR Observer checked forward	"steady 351"
37.0	Mate checked wristwatch	RADAR Observer checked wristwatch	
37.3	Mate checked forward		
37.7	"dead slow ahead"		
38.0	Mate operated RADAR		
38.3	Mate checked wristwatch with Helmsman		
38.7	Mate checked forward		
39.0	Mate checked ECDIS	RADAR Observer checked forward	
39.3	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
39.7	"stop"	RADAR Observer checked forward	
40.0	Mate checked forward		
40.3			
40.7	Mate talked with Helmsman		
41.0	Mate talked by transceiver/ Mate pushed wristwatch	RADAR Observer pushed wristwatch	Finish

Fig.3.14 and Table 3.4 showed SNS value and work sampling list of experiment 2 which used Scenario 2. Unfortunately, there was error to measurement for mate's hart rate as shown in Fig.3.14. It was difficult to find the synchronized point of subjects' mental workload.

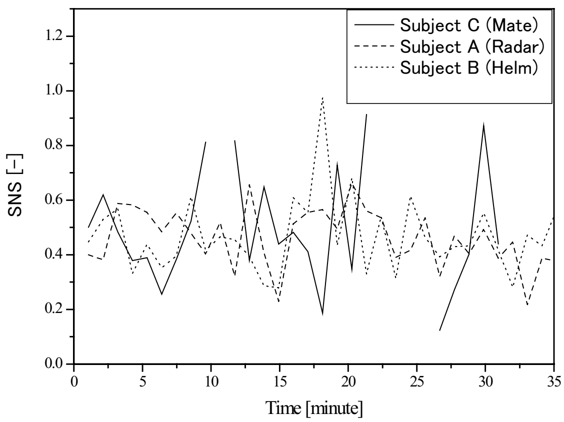


Fig.3.14 Time series of subjects' SNS value at experiment 3

Table 3.4 Work sampling list of experiment 3

Time (min)	Mate (Subject C)	RADAR Observer （Subject A）	Helmsman （Subject B)
0.0	"350"	RADAR Observer checked RADAR	start/"350"
0.3	Mate checked and operated RADAR	RADAR Observer talked by transceiver	
0.7		RADAR Observer checked and operated RADAR	
1.0	Mate operated ET/"slow forward"	RADAR Observer walked around/ RADAR Observer checked and operated ECDIS	
1.3	Mate talked by transceiver	RADAR Observer checked and operated ECDIS	
1.7	Mate checked and operated ET		
2.0	"350?"/ Mate talked with RADAR Observer	RADAR Observer talked with Mate	"yeah"
2.3	Mate checked RADAR / Mate talked with RADAR Observer	RADAR Observer checked and operated ECDIS / RADAR Observer talked with Mate	
2.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate while checking ECDIS	
3.0	Mate was pointing at front/ Talked with RADAR Observer	RADAR Observer talked with Mate	
3.3	Mate checked and operated RADAR	RADAR Observer checked and operated ECDIS	
3.7			
4.0		RADAR Observer checked and operated RADAR	
4.3			
4.7			
5.0			
5.3	"left 350"	RADAR Observer checked forward	
5.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
6.0	Mate checked forward	RADAR Observer checked and operated ECDIS	
6.3	Mate checked backward	RADAR Observer walked around	
6.7	Mate checked and operated RADAR	RADAR Observer checked and operated ECDIS	
7.0	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
7.3	Mate talked with RADAR Observer while looking ECDIS	RADAR Observer talked with Mate while checking ECDIS	

7.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
8.0	Mate talked by transceiver on port side	RADAR Observer checked forward	
8.3	"stop engine"	RADAR Observer checked and operated ECDIS	
8.7	Mate talked by transceiver	RADAR Observer checked forward	
9.0			
9.3	Mate checked forward	RADAR Observer talked with Mate	
9.7	Mate talked with all	RADAR Observer talked with all	
10.0	Mate checked and operated RADAR	RADAR Observer checked and operated RADAR	
10.3		RADAR Observer talked with Mate	
10.7	Mate checked forward	RADAR Observer checked and operated RADAR	
11.0	Mate talked by transceiver	RADAR Observer checked forward	
11.3	Mate checked forward		
11.7		RADAR Observer checked chart/ RADAR Observer checked and operated RADAR	
12.0	Mate talked by transceiver on starboard side	RADAR Observer checked forward	
12.3	Mate talked by transceiver (tag1, slow forward)		
12.7	"right 25"	RADAR Observer checked and operated RADAR	"right 25"
13.0	"hard right"	RADAR Observer checked and operated RADAR/ RADAR Observer told information to Mate	"hard right"
13.3	"dead slow forward"	RADAR Observer checked and operated RADAR/ RADAR Observer checked chart	
13.7	Mate checked and operated Rader	RADAR Observer checked chart/ RADAR Observer told information to Mate	
14.0	Mate blew short whistle 5 times	RADAR Observer checked and operated RADAR/ RADAR Observer told information to Mate	
14.3	Mate talked with RADAR Observer		
14.7	Mate talked by transceiver (tag1)		
15.0	Mate talked by transceiver (port side, please)	RADAR Observer checked forward	

15.3	Mate checked backward		
15.7	Mate checked forward	RADAR Observer checked and operated RADAR/ RADAR Observer told information to Mate	
16.0	Mate talked by transceiver (tag2)	RADAR Observer checked forward	
16.3	Mate checked forward		
16.7			
17.0		RADAR Observer checked and operated RADAR	
17.3	Mate talked by transceiver(tag1 starboard side, please)		
17.7		RADAR Observer checked forward	
18.0	Mate talked by transceiver(tag2 stop)/"left 10"	RADAR Observer talked with Helmsman	"left 10"
18.3	Mate talked with RADAR Observer / "hard left"		
18.7	Mate talked with RADAR Observer / "midships"	RADAR Observer checked and operated RADAR / RADAR Observer informed to Mate	
19.0	Mate talked with RADAR Observer	RADAR Observer checked forward	"midships"
19.3	Mate talked with RADAR Observer while looking RADAR	RADAR Observer talked with Mate while checking RADAR	
19.7	"dead slow forward"	RADAR Observer checked and operated RADAR	
20.0	Mate checked and operated RADAR		
20.3	"left 5"	RADAR Observer checked and operated ECDIS	
20.7	Mate checked forward	RADAR Observer checked forward	"left 5"
21.0			
21.3	Mate talked with RADAR Observer / "left 10"	RADAR Observer talked with Mate/ RADAR Observer checked and operated RADAR	"left 10"
21.7	Mate talked by transceiver(tag1, right push)	RADAR Observer checked forward	
22.0	Mate talked with RADAR Observer / "left 20"	RADAR Observer talked with Mate	
22.3	Mate checked and operated Rader	RADAR Observer checked forward	"left 20"
22.7	"left 10"	RADAR Observer checked and operated RADAR	
23.0	Mate checked backward	RADAR Observer checked	"left 10"

		forward	
23.3	Mate checked and operated RADAR	RADAR Observer checked and operated RADAR	
23.7	"right 20"	RADAR Observer checked and operated ECDIS	"right 20"
24.0	"midships"	RADAR Observer checked chart	
24.3	"stop"		"midships"
24.7	Mate talked by transceiver(tag2, right push)	RADAR Observer checked forward	
25.0	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
25.3	Mate talked by transceiver(tag1 push)		
25.7	Mate talked with Helmsman	RADAR Observer checked forward	
26.0	Mate talked by transceiver(tag2 stop)/ Mate talked with C	RADAR Observer talked with Mate	
26.3	Mate talked by transceiver(tag2 push)	RADAR Observer checked forward	
26.7	Mate talked by transceiver(tag2 push right)		
27.0	Mate talked by transceiver(tag2 push out)		
27.3	"stop engine"		
27.7	Mate checked forward		
28.0	Mate talked by transceiver(tag1 stop)	RADAR Observer checked around	
28.3	Mate talked by transceiver	RADAR Observer checked forward	
28.7	Mate talked with RADAR Observer	RADAR Observer talked with Mate	
29.0	Mate talked by transceiver	RADAR Observer checked chart	
29.3			
29.7	Mate talked by transceiver(tag2)	RADAR Observer checked and operated ECDIS	
30.0	Mate talked by transceiver/"slow astern"	RADAR Observer checked around	
30.3	Mate talked by transceiver(tag2 stop)		
30.7	Mate talked by transceiver(tag2 push)		
31.0	Mate talked with RADAR Observer		
31.3	Mate talked by transceiver	RADAR Observer checked ECDIS while talking with Mate	
31.7	Mate talked with RADAR Observer/ "midships?"	RADAR Observer talked with Mate	"yes"
32.0	Mate talked by	RADAR Observer checked	

	transceiver(tag2 stop)	around/ RADAR Observer talked by transceiver	
32.3	Mate talked by transceiver(tag2 stop, please)	RADAR Observer talked with Mate	
32.7	Mate talked with RADAR Observer		
33.0	Mate talked by transceiver(tag2)	RADAR Observer checked forward	
33.3	Mate talked by transceiver/ Mate talked with RADAR Observer	RADAR Observer talked with Mate	
33.7	Mate talked by transceiver(tag1 stand by)	RADAR Observer checked forward	
34.0	Mate talked by transceiver(tag1)		
34.3	Mate talked with RADAR Observer/ Mate talked by transceiver(tag2 stop)	RADAR Observer talked with Mate	
34.7	Mate talked by transceiver(tag2 stand by/ tag1 stop)	RADAR Observer checked and operated RADAR	
35.0	Mate talked by transceiver	RADAR Observer checked forward	
35.3	Mate talked by transceiver(tag2)		
35.7	Mate checked and operated RADAR	RADAR Observer checked around	
36.0	Mate talked by transceiver(tag1 stop)		
36.3	Mate talked by transceiver	RADAR Observer checked forward	
36.7		RADAR Observer checked and operated ECDIS	
37.0	Mate Checked left side for berthing		
37.3	Mate talked by transceiver(tag1)		
37.7	Mate talked by transceiver(tag1 stop)		
38.0	Mate talked by transceiver(tag2)		
38.3	Mate talked by transceiver(tag2 stop)	RADAR Observer checked forward	Finish

Subjective evaluation was filled by the instructor who is specialist of marine pilot. The results of evaluation were shown in Table 3.5, 3.6, and 3.7. From the score of each subject, there was tendency that subject B's score was lower than other subjects. However, it was difficult to find the relationship between subjects' mental workload and their score which indicated in Table 3.5, 3.6, and 3.7.

Table 3.5 Evaluation result of Experiment 1 by using Scenario 1

	Subject A	Subject B	Subject C
Criteria	Mate	Radar observer	Helm
Understands and applies COLREGs & their application	3.5	3.0	
Proper use of terminology	3.5		3.5
Sets adjusts radars correctly/knobology		3.0	
Voyage planning - element understanding			3.5
Conns vessel properly (order) & resists distractions	4.0		
Uses appropriate scales to circumstances		3.0	
Speed & accuracy of work generally		3.0	
Ability to maintain course			4.0
Calls out headings during C/C & monitors PSC			3.5
Bridge equipment function & layout familiarity			
Generally applies solid BTM & BRM skills	3.5		
Ensures accurate execution/monitor of voyage plan		3.0	
Duplicate plots/indexes on both radars			
Maintains a proper lookout			4.0
Specific use of radio & VTS for situation awareness	3.0		
Contributes well during debrief			3.5
Has mentally oriented themselves to chart & route	3.5		3.5
Oriented to traffic situation & reports	3.0	2.5	
Cross checks (multiple systems, fathometer, etc.)		2.5	
Personally organized & adequately prepared	3.5	3.0	
Conforms to standing & day orders			
Display good subordinate behaviour			3.5
Response during stress	3.5		
Score(Ave.)	3.4	2.9	3.6

Table 3.6 Evaluation result of Experiment 2 by using Scenario 2

	Subject B	Subject C	Subject A
Criteria	Mate	Radar observer	Helm
Understands and applies COLREGs & their application		3.5	
Proper use of terminology	3.0		3.5
Sets adjusts radars correctly/knobology		3.0	
Voyage planning - element understanding			3.5
Conns vessel properly (order) & resists distractions	2.5		
Uses appropriate scales to circumstances		3.0	
Speed & accuracy of work generally		2.5	
Ability to maintain course			3.5
Calls out headings during C/C & monitors PSC			3.5
Bridge equipment function & layout familiarity			3.0
Generally applies solid BTM & BRM skills	3.0		
Ensures accurate execution/monitor of voyage plan		3.5	
Duplicate plots/indexes on both radars		3.0	
Maintains a proper lookout			3.5
Specific use of radio & VTS for situation awareness	3.0		
Contributes well during debrief			
Has mentally oriented themselves to chart & route	2.5		3.5

Oriented to traffic situation & reports		3.0	
Cross checks (multiple systems, fathometer, etc.)			
Personally organized & adequately prepared			
Conforms to standing & day orders			
Display good subordinate behaviour			
Response during stress			
Score(Ave.)	2.8	3.1	3.4

Table 3.7 Evaluation result of Experiment 3 by using Scenario 3

	Subject C	Subject A	Subject B
Criteria	Mate	Radar observer	Helm
Understands and applies COLREGs & their application	3.5	3.5	
Proper use of terminology	3.0		3.5
Sets adjusts radars correctly/knobology		3.5	
Voyage planning - element understanding			3.5
Conns vessel properly (order) & resists distractions	3.5		
Uses appropriate scales to circumstances		3.5	
Speed & accuracy of work generally		3.5	
Ability to maintain course			3.5
Calls out headings during C/C & monitors PSC			3.5
Bridge equipment function & layout familiarity			3.5
Generally applies solid BTM & BRM skills	4.0		
Ensures accurate execution/monitor of voyage plan		3.5	
Duplicate plots/indexes on both radars			
Maintains a proper lookout			3.5
Specific use of radio & VTS for situation awareness	3.5		
Contributes well during debrief			3.5
Has mentally oriented themselves to chart & route	4.0		3.5
Oriented to traffic situation & reports	3.5	3.5	
Cross checks (multiple systems, fathometer, etc.)		3.5	
Personally organized & adequately prepared	4.0	3.5	3.5
Conforms to standing & day orders			
Display good subordinate behaviour			3.5
Response during stress			
Score(Ave.)	3.6	3.5	3.5

3.6 Experiment for Evaluating Trainee's Situation Awareness with Physiological Index

In order to examine the relation between the evaluation of trainee's situation awareness and trainee's mental workload estimated by physiological index, we had ship maneuvering simulator experiment. Setting of the experiment and results were described as follows.

(1) Setting of Experiment
We employed four subjects who had on board experience for captain. Their age was 46-62 years old. The experiment was executed at ship maneuvering simulator in Tokyo University of marine science and technology. The snapshot of the ship maneuvering simulator was showed in Fig.3.13. This ship maneuvering simulator consisted of a bridge system, a visual system, and a control system. The bridge system was installed all equipment necessary for navigation. The visual system produces a seascape of

360 degrees in horizontal view and 40 degrees in vertical view. The control system was for creating and editing of scenarios and for operation of simulation runs.

Fig.3.13 Snapshot of a ship maneuvering simulator

The scenario reproduced heavy marine traffic area. In the scenario, own ship keeps her heading course if there is no risk for collision. Total number of ship in the scenario is 24. Outline of the scenario is shown in Fig.3.14.

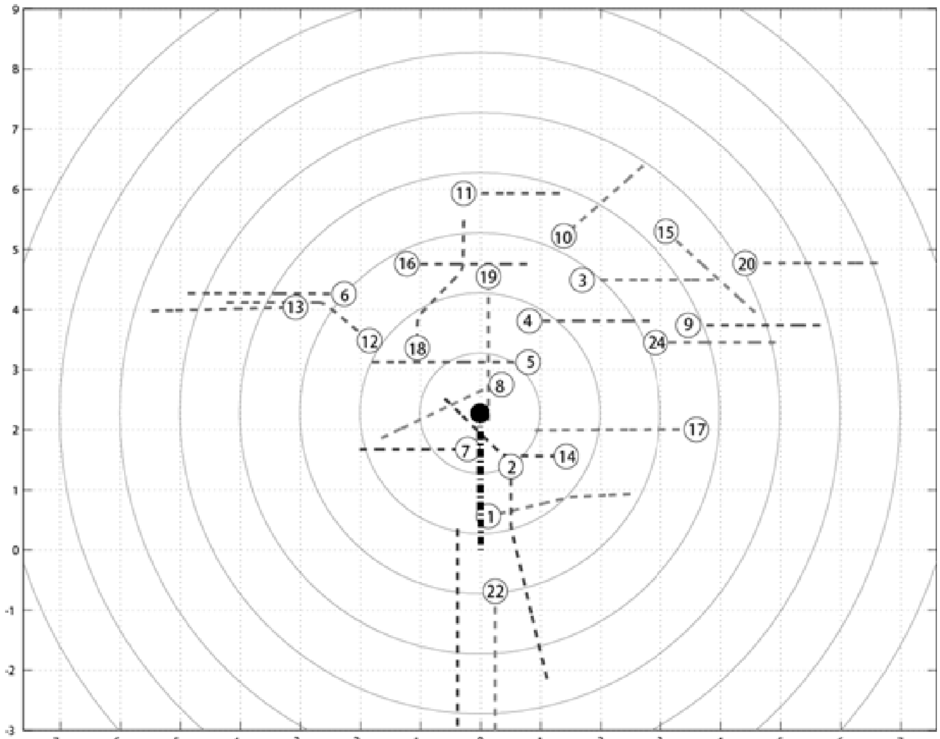


Fig.3.14 Outline of scenario

During the simulation run, subject's situation awareness was measured by modified SAGAT that described in section 3.2. Also, subject's nasal temperature was measured by thermal image video camera which shown in Fig.3.15.

Fig.3.15 Snap shot of thermal image camera (NEC AVIO TS91-726)

Before the experiment, we explained the informed consent form for human research to all subject, and they accepted and signed the informed consent.

(2) Result of Experiment

We executed ship maneuvering simulator experiment four times and we measured subject's situation awareness. First measurement was executed when seven minutes passed from the start, and afterwards, subject's situation awareness was measured every five minutes. The scenario took 22 minute, therefore four times of situation awareness were measured for each subject. Table 3.8 showed result of subject situation awareness. In Table 3.8, first row indicated ship ID which reproduced in the scenario and then from second row, which ship was recognized by subject was indicated. Total number of ship which recognized subject at each measuring time was indicated in 3rd column. In the experiment, we set the ship that subject have to recognize by priority level for recognizing ships in heavy marine traffic area as described in section 3.2. In the Table, the ship that subject should recognize during simulation was indicated by shaded part. From the result, it seemed that subjects recognize all most same ships. However, subject A was recognizing only two ships in each time.

Table 3.8 Ships recognized by subject

Exp. min	**1 (7min.)**				**2 (12min.)**				**3 (17min.)**				**4 (22min.)**			
Sub.	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Ship	***2***	***5***	***6***	***6***	***2***	***8***	***6***	***5***	***2***	***7***	***7***	***7***	***2***	***7***	***6***	***7***
1				O												
2				O				O	O	O		O		O	O	O
3		O			O	O	O	O	O	O	O	O	O	O	O	O
4						O	O			O	O					
5		O	O													
6										O		O				O
7				O												
8	O	O	O	O			O									
9			O	O		O	O	O			O	O				
10						O				O	O	O		O	O	O
11																
12								O								
13																

Exp. min	1 (7min.)				2 (12min.)				3 (17min.)				4 (22min.)			
Sub.	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Ship	*2*	*5*	*6*	*6*	*2*	*8*	*6*	*5*	*2*	*7*	*7*	*7*	*2*	*7*	*6*	*7*
14			O									O				
15														O		O
16						O										
17		O														
18						O										
19	O	O	O		O	O	O			O	O			O	O	
20														O	O	O
21																
22																
23										O	O		O	O	O	O
24			O	O		O	O	O			O	O				

During the simulation, we took a picture of subject by thermal image video camera then we obtained four subjects' nasal temperature data. Figs.3.16, 3.17, 3.18, and 3.19 indicated time series data of subject's nasal temperature during the simulation run. In the figures, shaded part indicated time for measuring subject situation awareness by SAGAT. Therefore, during the shaded part, simulation scenario was interrupted, then after the shaded part, simulation was restarted. From Figs.3.17, 3.18, and 3.19, it was read that during the SAGAT (shaded part) subject's nasal temperature became higher than when he navigated the own ship. It means that during the SAGAT, subject felt relax then after restarted the simulation run they felt stress for navigating own ship. On the other hand, from Fig.3.16, it was read that subject A's mental workload was high during the SAGAT and he felt relax during the simulation run.

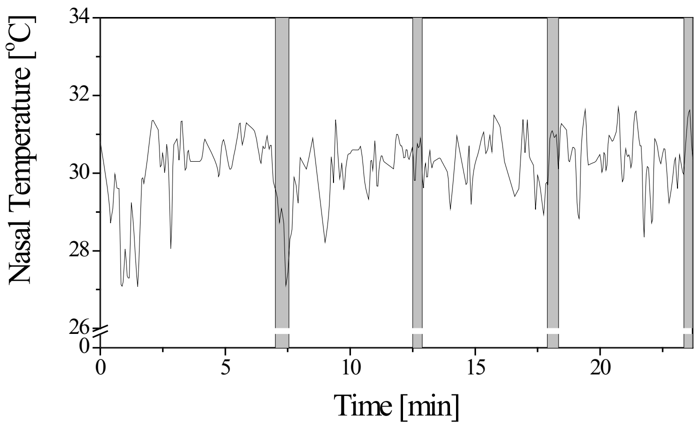


Fig.3.16 Time series of subject A's nasal temperature

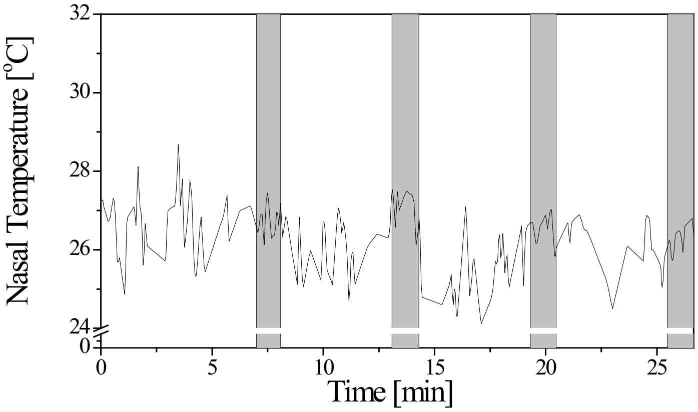


Fig.3.17 Time series of subject B's nasal temperature

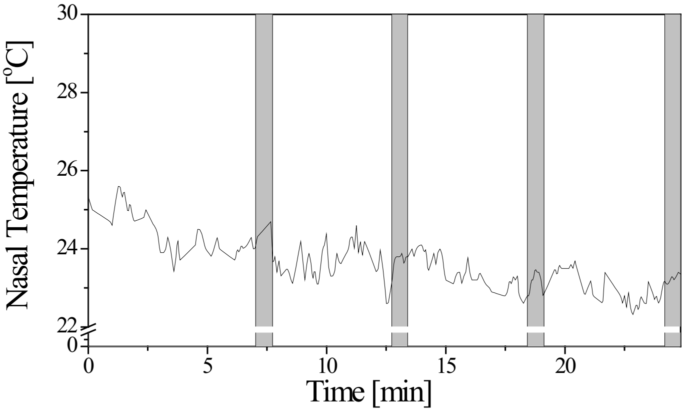


Fig.3.18 Time series of subject C's nasal temperature

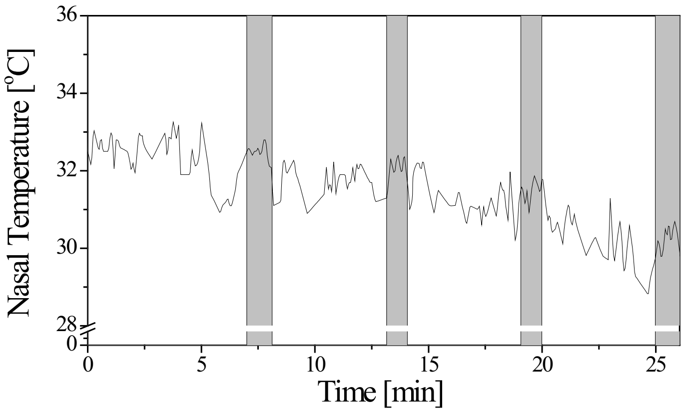


Fig.3.19 Time series of subject D's nasal temperature

When we focusing tendency of changing subject nasal temperature, it was understood that subjects C and D's mental workload became high in the latter half of simulation, because their nasal temperature was decreasing slowly. They executed evading navigation at the end of the simulation run. The other two subjects (subjects A and B) keep her course till end of simulation run. Therefore, there is relationship between subject's situation awareness and mental workload.

3.7 Consideration

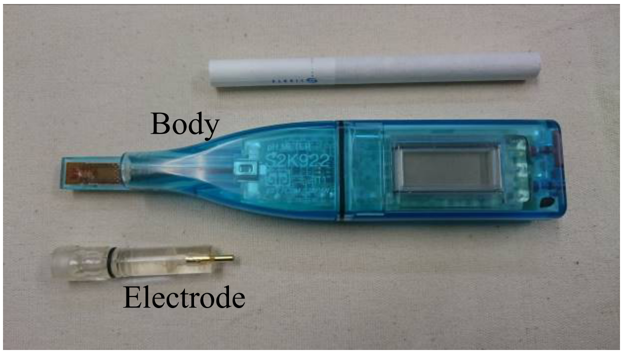
In order to examine the relation between the evaluation of trainee's performance at the ship maneuvering simulator training and trainee's physiological index, we had ship maneuvering simulator experiment. From the experiment result of situation awareness, we found the relationship between subject's situation awareness and mental workload. Therefore, it is thought that measuring trainee's mental workload is effective to evaluate subject's situation awareness for evaluating their navigation skill. On the other hand, it was difficult to find the relationship between subjective evaluation of trainee's performance and trainee's mental workload form the experimental result. However, it is thought that using the data of trainees' mental workload in the debriefing is effective for their education.

4. Evaluation of Mental Workload Using Saliva

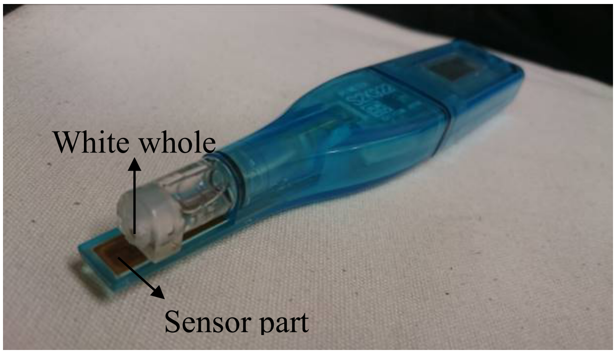
4.1 Salivary Nitrate Ion

In advance, we know a physiological response that Nitrate ion (NO_3^-) is emitted into blood vessel from vascular endothelial cells when a body feels mental workload and NO_3^- is gotten from blood-borne saliva [24]. We focus on, and treat salivary NO_3^- as a new/fine physiological index to evaluate mental workload.

The NO_3^- measurement device consists of a measurement body part and an electrode for liquid junction (Figure 4.1(a)). An electrode is filled with NO_3 solution and has a white hole connecting the NO_3 solution in the electrode to saliva (Figure 4.1 (b)).The NO_3^- device is originally a pH-checker to measure number of moles and needs to change a sensor part of the checker (Figure 4.1(a)). National Institute of Advanced Industrial Science and Technology (AIST) made liquid film to coat the sensor part. The liquid film changes pH value into NO_3^- concentration.



(a) The components of NO_3^- measurement device



(b) Saliva connecting part of NO_3^- measurement device

Fig.4.1 The NO_3^- measurement device

The size of the device' body is L: 143×H: 15×W: 28 [mm^3], and weight is 48 [g] (Figure 4.1(a)). The measured range is 0.0 to 14.0 [pH]. We mention to a relation between pH and NO_3^- value; 6.9 showed by the device is the standard for one point calibration, 10^{-3} [M] (moles/l) concentration of NO_3^-. If 7.9 is showed by the device, its value means 10^{-2} [M] concentration of NO_3^- the sampled solution has, the sensor part of the NO_3^- measurement device always immersed in NO_3 solution of 10^{-3} [M] before every experiment because of stabilize the condition of the sensor part in this experiment.

We use metal spoon in sampling and the spoon needs to clean saliva. Every sampling time including cleaning spoon time is 1 minute, owing to the NO_3^- measurement device enables us to get values from saliva soon. This device is proper to grasp instantaneous mental workload on the spot.

4.2 R-R Interval of HRV

The R-R interval is one of the good physiological indices to read the mental workload, and we utilize the index after we extract R wave from the heart rate variability. R-R Interval is literally an interval between R waves, and R wave is peak point of heart rate variability in Electrocardiogram (Figure 4.2).

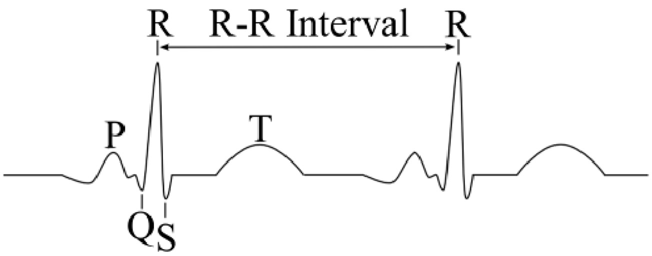


Fig.4.2 R-R Interval in Electrocardiogram

The R-R Interval is difficult to read the mental workload; needs analysis to get Low Frequency (LF) and High Frequency (HF) from heart rate variability, and to calculate LF/HF value [25]. The LF is an index of sympathetic nervous system, and the HF is parasympathetic nervous system. Mental workload has effect on heart rate variability, that is, LF and HF, we utilize LF and HF to grasp the balance of autonomic nervous system. The higher LF/HF value, more mental workload we know subjects felt.
Figure 4.3 shows heart rate monitor composed of a chest belt and a wrist watch. The heart rate sensor with back of the chest belt measures the R-R interval. Transmitter part on face of chest belt sends the data to the wrist watch, and we confirm subject's heart rate variability on the spot.

Fig.4.3 Components of heart rate monitor

4.3 Experiment

4.3.1 Outline

The experiment was carried out at *Hakata* bay, Japan. The weather and visibility was fine, and a tidal condition was calm. The experimental time was four times. We were carried out experiments for three leaving and one entering *Hakata* port (Table 4.1). Total four times. In Table 4.1, 'Ship' means an experimental vessel, the order means experimental order, 'GT' is gross tonnage, 'L.O.A.' is length over all, and 'Event' is the typical event for the experimental situation. The 2nd and 4th ship is the same. The 2nd is entering port, and 4th is leaving port. Figure 4.4 shows the real situation that a ship on sea traffic route leaves *Hakata* port. This ship is γ in Table 4.1. Bullets show in Figure 4.4 is the ship's route, and the both edge of bullets show start and end point of the experiment. This paper shows the experimental result of γ for a candidate of 4 times experiments. The measurement time on γ started all three subjects wear the heart rate monitor, and stopped.

Table 4.1 The experimental vessel

Ship	Experiment	GT (t)	L.O.A. (m)	Scenario
α	1st	5,070	119.23	Leaving port
β	2nd 4th	27,437 27,437	221.62 221.62	Entering port Leaving port
γ	3rd	9,568	141.00	Leaving port

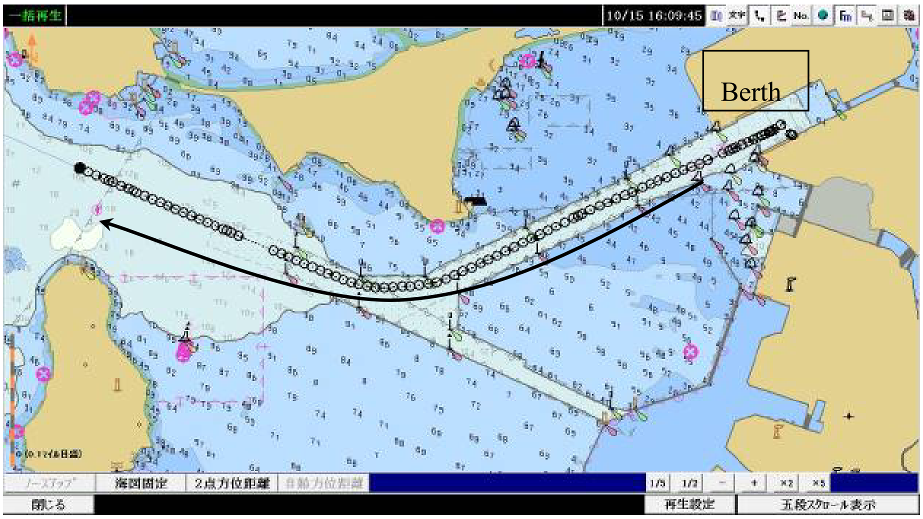


Fig.4.4 The experimental ship's route of *Hakata* port (Leaving port)

4.3.2 Subject

Table 4.2 shows subjects' information. Table 4.2(a) is two Pilots (A, B) and a Captain (C), and Table 4.2(b) is two Port-coordinators (D, E).
Subject A is a first-grade pilot belonging to *Hakata* Pilot Associations [26]. He has engaged pilot duties for 6 years and 7 months and had been a navigator of ocean going vessels for 35 years (as a

captain for 10 years). Subject B is an apprentice of first-grade pilot. He was also a captain of a shipping company. Subject C is a captain of a experimental vessel for a leaving port. He has on-board experiences for 36 years. These three subjects were on duties on the same vessel, and we measured salivary NO_3^- for subjects A and B. We also measured heart rate variability for three subjects.
Subjects D and E are port coordinators of *Hakata* port radio, who are looking at *Hakata* bay and prevent sea traffic accidents from occurring there. Two port coordinators keep watch all the time and take two parts, main- and sub-part. The main-part usual conducts the business of a port coordinator to the letter and the sub-part supports main-part.

Table 4.2(a) Subject (Pilot and Captain)

Subject	Age [year]	Gender	Experience of Pilot [year and month]
A	67	Male	6 years and 7 months
B	56	Male	None
C	63	Male	None

Table 4.2(b) Subject (Port coordinator)

Subject	Age [year]	Gender	Experience [year and month]
D	33	Male	8years and 6 months
E	26	Female	5 years and 10months

In the experiment, we especially evaluate of mental workload for Subjects A, B, and C compared with subjects D and E because we have been carried out several experiments for port-coordinators but few experiments for a pilot and a captain. We notice the fact that subject B, an apprentice of pilot, had been handling ships for captains every four times, and subject A, had watched calmly the subject B as an adviser to subject B; moreover, we notice the fact that subject C gave his captain part to subject B, and he did not have much duties but he had responsibility for ship's accidents.

4.3.3 Informed Consent Form

We inform the consent for human research. The Kobe permits the consent form under the human research ethical standards of the Kobe. We explain the experiment by 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 the next page.

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

“Development of A New Evaluation System for Simulator Training utilizing Physiological Index”

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, facial temperature, and saliva 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 develop of the new evaluation system for simulator training utilizing physiological index. 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 analysed 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 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.

Confidentiality and Privacy of Data

- The records of this study will be kept strictly private. The date 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 analyse 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.

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: ______________________

4.3.4 Evaluation List

The evaluation list is composed by 3 main duties, and the main duty has 9 tools (Table 4.3). The evaluation of events is carried out by the traffic management content base of Table 4.3. Three duties are “Communication”, “Watch”, and “Information service”, and these duties are divided to tools. The communication is “VHF Radio” and “On-Board Cell Phone”. The watch is “Observation”, “Radar”, “AIS”, and “Phone”. The information is “Port Administrator computer terminal”, “FAX/E-mail”, and “Tel Phone” (VHF radio, Radar and AIS are general tools in maritime societies). The events mean that events can become stressor to occur the mental workload.

Table 4.3 Outline of evaluation list

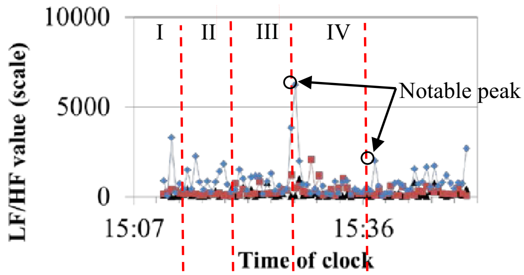
Duty	Tool
Communication	VHF Radio On-board cell phone
Watch	Observation Radar AIS Phone
Information	Port administrator computer terminal FAX and e-mail Tel phone

4.3.5 Result

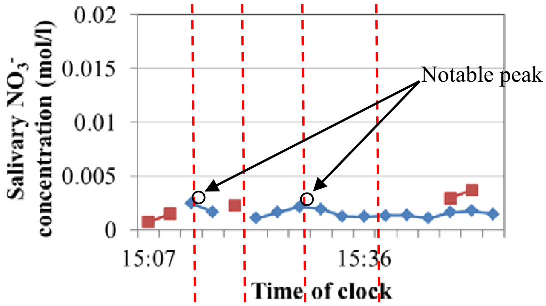
Figure 4.5 shows the typical result of experiments. In Figure 4.5, four vertical dot lines are experimental event points. The events I to IV add a number for each line. Table 4.4 shows the detail of events for each vertical line. The content of event II is none; however, we focus on that point because LF/HF value of subject A increased. The ‘Yes’ of evaluation list in Table 4.4 means we read the event using the evaluation list. In this study, we got only one event. Much more experimental event data we get, we can easily grasp the trend of situations where subject feels mental workload.

Table 4.4 Detail of experimental events

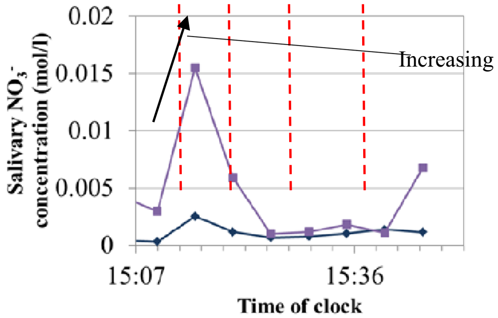
Event no.	Event	Evaluation list
I	Pilot's communication to port coordinator (ask entering port information)	Yes
II	-	-
III	Order from Sub.B to Sub.C “stand-by engine and let go lines”	-
IV	ship's perpendicular to quay	-



(a) The result of LF/HF value for subjects A, B, and C



(b) The result of salivary NO_3^- for subjects A and B



(c)The result of salivary NO_3^- for subjects D and E

Fig.4.5 Two indices' result for each subject

In Figure 4.5(a), vertical axis shows LF/HF value and horizontal axis shows time of clock. The evaluation of mental workload was that higher LF/HF value, more mental workload subject felt.

In Figures 4.5(b) and 4.5(c), vertical axis shows salivary NO_3^- concentration, and horizontal axis shows time of clock. The method to evaluate mental workload was also that higher salivary NO_3^- concentration value, more mental workload subject felt.

In Figure 4.5(a), diamond, square, and triangle lines correspond to subject A, B, and C. the LF/HF value's trend of subject C is totally lower, and is buried under other two lines because he was not handling a ship. While we focus on subject B, he was handling a ship for subject A, and several peak points of LF/HF value were higher, especially, in events III and IV. We understand his mental workload corresponds to experimental events. The LF/HF value of subject B is higher events II and III.

In Figure 4.5(b), diamond and square lines correspond to subjects A and B. We cannot grasp subject B feels mental workload in event II in Figure 4.5(a); however, compared with Figure 4.5(b), two physiological indices reveal that subject B felt mental workload undoubtedly. The square line in Figure 4.5(b) is not made line. Subject B got passionate about handling a ship in this time. That's why there is a lot of lacks of sampling saliva. We must consider another method to get the saliva. The value of the peak of experimental event III in Figure 4.5(a) corresponds to the salivary concentration's in Figure 4.5(b). The contents of event III are stand-by engine and let go lines, and all of subjects A, B and C feel the mental workload. On the other hand, salivary NO_3^- concentration values are lower here from Figure 4.5(c) because the event III is unconcerned by port coordinators. Subjects D and E felt mental workload after event I. The event I is a communication with subject B. Here, we understand from Figure 4.5(b) that Subject B also felt the mental workload. We confirm that LF/HF value corresponds to the salivary NO_3^- value. Other situations for other ships are the same.

4.3.6 Conclusion

In the experiment, we fail to sampling for subject B. In other three ships, the same accidents are occurred. We must consider other sampling saliva method.
We confirmed the below items from the experiments;

- Salivary NO_3^- corresponds to the result of R-R Interval index.
- R-R Interval is not much possible to fail to sample, while salivary NO_3^- sampling is easy to fail, depending on a subject and a measurer.
- Evaluation list is difficult to exploit for evaluation mental workload in the present circumstances.

We find out the future works to be solved as below;
- To improve the evaluation list
- To make a new sampling method of saliva

In future works, we get a lot of saliva, and we will create another new sampling method, not to use the metal spoon. We also confirm the effectiveness of R-R Interval (LF/HF value).

5. The Monitoring System Using Adhesive Plaster-type Sensor.

5.1 Outline

We used to measure the heart rate using the heart rate monitor which consists of chest belt with a sensor and wrist watch with a memory. This type is a simple and convenience more than a medical devise; however, a subject must wear two items- chest belt and wrist watch, and the data is off-line for measuring the data. Moreover, the port coordinators take a nap for a night shift, and the chest belt sometimes disturb the good one.

The Micro Electro Mechanical Systems (MEMS) technology is developing, and we are able to get reasonable and enough specific sensors. In other word, we can make a familiar sensor for the onboard, port radio, and etc. in the maritime world. Regarding the experiment at port radio, it is fine that the measured data are displayed as a real time system. In this study, we choose an adhesive plaster-type sensor (sensor) because it is soft and easy to fit the body to measure the heart rate and 3 axis body accelerations at the same time [27]. Figure 5.1 shows the outline of sensor the subject wears, and Figure 5.2 shows the image of put it on the body.

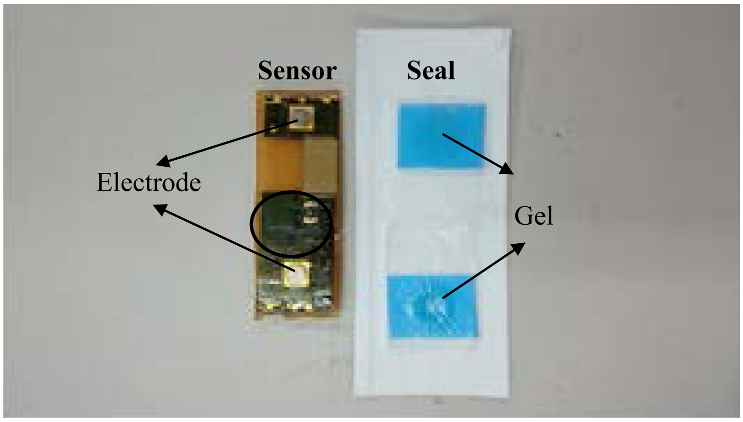
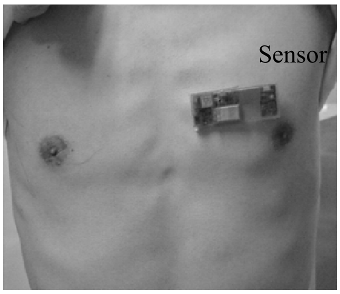
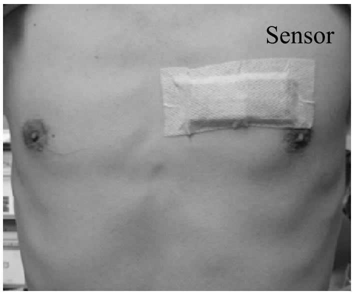


Fig.5.1 The outline of adhesive plaster-type sensor



(a) Just use the gel (square part in Fig. 5.1) for putting the sensor

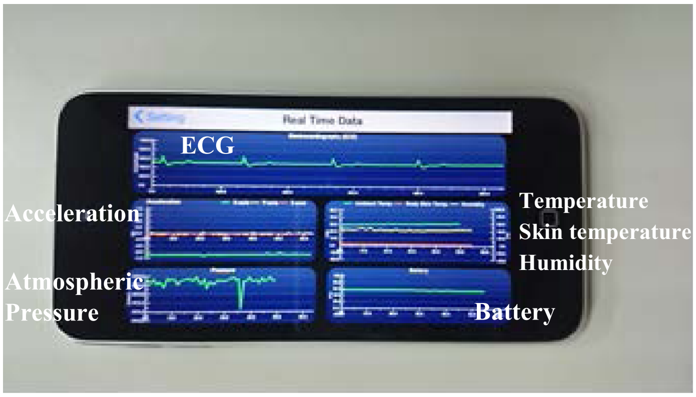


(b) Actual condition for putting the sensor using covered seal

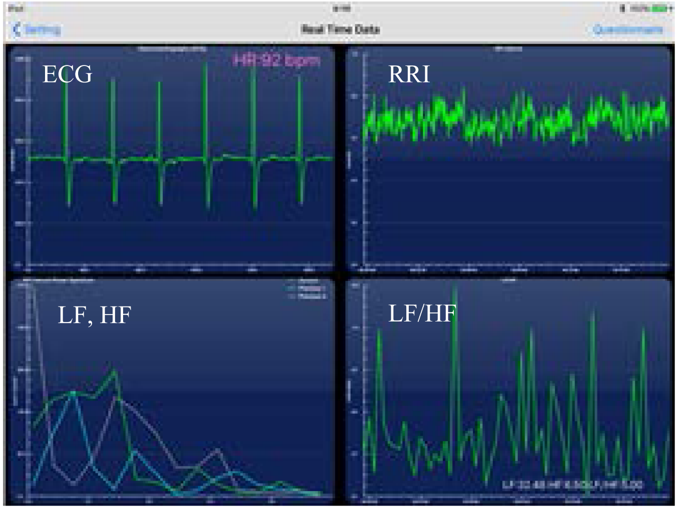
Fig.5.2 Image of the adhesive plaster-type sensor on the body

The size of sensor is W: 22*L: 90*D: 4.5 [mm3], weight: 10 [g], Battery 3.0 [v] (type: CR2032). The measured data is electrocardiogram (ECG), 3 axis accelerations, skin temperature, humidity, and atmospheric pressure and temperature. All sensors set up on the sensor part (circle of Figure 5.1), and just put on the body (chest) like Figure 5.2. We are able to be smaller for the sensor. The subject never take off the wear when they put on the sensor on the body.

Figure 5.3 shows the on-line real time monitored data: ECG, body acceleration, and etc. The data monitors by iPod touch (iOS terminal), and send them by Bluetooth 4.0. We, of course, record other data: air/skin temperature, humidity, atmospheric pressure. The size of measured data is 30 MB/hour by sampling of ECG: 125 Hz, accelerations: 25 Hz, and others: 0.33 Hz. The real time monitoring system is important to understand their mental and physical conditons; morover, they help to understand the conditions of bay and hourbor.



(a) Display 5 kinds of data: body accelerations, skin temp., atm. pressure, temperature, battery



(b) Display 4 kinds of data: ECG, RRI, LF and HF, LF/HF

Fig.5.3 The monitor of sensor (iPod touch, iPad mini)

The ECG and three kinds of body acceleration (up-down, right-left, fore-back of the body) is measured by 125 Hz, 10 bits, and 25 Hz, 8 bits sampling respectively.
We pick up heart rate (HR) from ECG data. The heart beat consists of P, QRS, T wave (Figure 4.2), and the R wave is remarkable of all waves, and easy to catch up. We pick up a peak of R wave, and its interval time means R-R interval. We calcurate HR using the R-R interval.

In this study, we challenge to make an evaluation/monitoring system using HR for the mental and physical performance and body accelerations for physical performance because the user is easy to understand on the knowledge of indices- HR and body accelerations.

5.2. Simulator-based Experiment

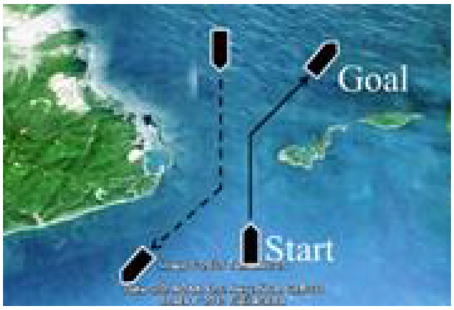
5.2.1 Outline

The simulator-based experiment was carried out in Kobe University on August and September, 2016. The subject was 8 (2 captains, 1 officer, and 5 students). The bridge team consists of a duty officer (navigator) and a helmsman, and we made professional team and student team. The captain is specialist who has on-board experience of captain of ocean-going vessel, and officer and some students has license of deck officer. Fig.5.4(a) is the experimental image of the bridge house. The simulator has 360 degree horizontal view and flat view; 360 degrees view needs to keep safe navigation for lookout for both scenarios, the flat view needs to understand approach speed and distance to the berth for the entering port. Fig.5.4(b) is outline of the simulator system. The scenario is a narrow route and an entering port in where the navigator needs a lot of judgment for short time (Fig.5.5). The scenario time is 30-40 minutes. Professional and student team have the experiment more than 3 times.

(a) Bridge house

(b) Outline of simulator system

Fig.5.4 Ship maneuvering simulator.



(a) Narrow channel

(b) Entering port

Fig.5.5 Image of scenario

5.2.2 Subject and Bridge Team

In this study, we propose a new evaluation system for simulator training using the mental workload, and we choose 2 professionals and 2 students. Table 5.1 shows a detail of subjects. Before the experiment, we explained the purpose of research and content of experiment for subjects with informed consent form which we submitted to Graduate School of Maritime Sciences, Kobe University on July 7, 2016.

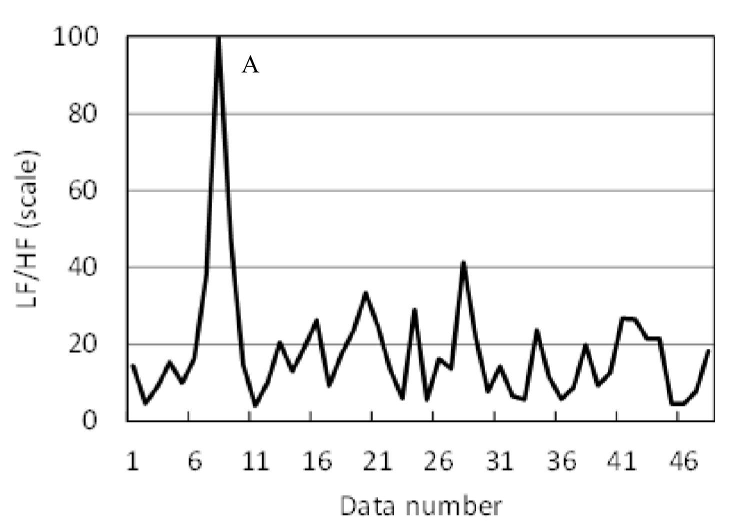
Table 5.1 Subject

Subject	Gender	Age of year	On-board experience [year]	Nationality
A	M	62	10	Japan
B	M	54	10	Japan
C	M	25	1	Japan
D	M	24	0.5	Japan

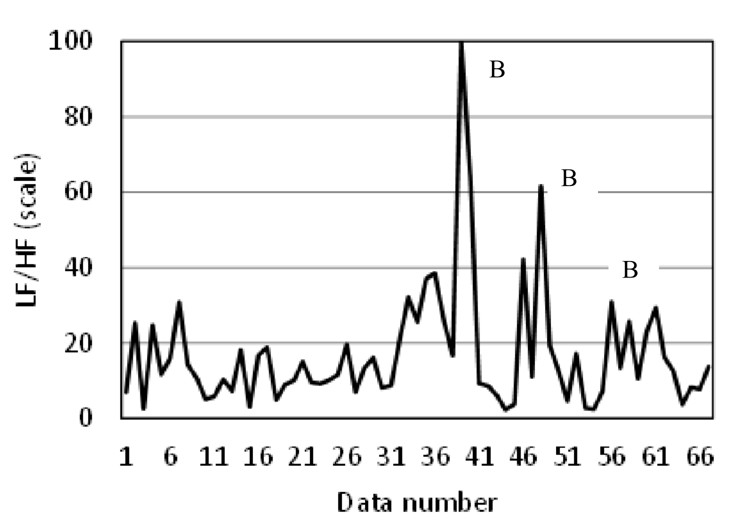
Subjects A and B are professionals who are master of ocean-going vessel. Subjects C and D are students of graduate school of maritime sciences of Kobe University, and Subject C has the license of deck officer of ocean-going vessel. The subject makes the bridge team of Captain (navigator) and helmsman (helm). In this study, the bridge team is just 2 members for all scenarios. We just measure the response of main navigator, and we restricted the team member.
We were carried out 6 time experiments for the entering port, and 12 times for the narrow channel. 1 subject tried 3 times, but the students cannot for the entering port because there is not any experience. A bridge teammate uses English in communication.

5.2.3 Result

We got the LF/HF every 30 seconds [28] which is an index of mental workload using the frequency components of RRI. The Low Frequency (LF) is 0.04-0.15 Hz, and High Frequency (HF) is 0.15-0.40 Hz. The increasing of LF/HF shows high mental workload.
Fig. 5.6 is the results of LF/HF of the navigator for professional and student team for the narrow route. From Fig. 5.6, the mental workload is read by the response of LF/HF when they need the judgment for avoiding the collisions (‘A’ and ‘B’ in Fig. 5.6). The professional made decision at early time (a); however, students are not able to do; he made it then and there (b), and need more time to arrive the goal. The professional needed 23.5 minutes (47 data numbers), and the student did 33.0 minutes (66 data numbers).
From the results, if the instructor get the data on real time, they give students useful advises at point of ‘A’ in Fig. 5.6.



(a) Professional



(b) student

Fig.5.6 The results of LF/HF

5.2.4 Conclusion

In this study, we proposed a new evaluation system for simulator-based exercise using heart rate variability as the plaster-type sensor monitoring system. We confirmed that we are able to read bridge teammates' mental workload using HRV on the real time, and the monitoring system is useful for evaluating the simulator-based exercise.

In future works, we need 1) to measure a lot of data for accurate evaluation; 2) to develop more easy method to wear the sensor, 3) to consider the effectiveness of skin temperature.

Acknowledgment

This research project was supported by a large number of people; the staff of Kobe University, Cariforna Maritime Academy, Tokyo University of Maritne Science and Technology, World Maritime University, and IAMU. We, especialy, would like to thank Director Veronica Boe of Calironia Maritme Academy who managed this project. Also, we appriciate excellent discussion at AGA17 in Viet Nam.

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