SUB-COMMITTEE ON HUMAN ELEMENT, TRAINING AND WATCHKEEPING
4th session
Agenda item 8

HTW 4/INF.5
24 November 2016
ENGLISH ONLY

REVISION OF THE GUIDELINES ON FATIGUE

Report on the seafarer's workload assessment

Submitted by the Republic of Korea

SUMMARY

Executive summary:	This document provides information on the result of a research project on seafarer's workload, which may be expected to contribute to the discussions on the revision of the *Guidelines on fatigue mitigations and management*
Strategic direction:	5.4
High-level action:	5.4.1
Output:	5.4.1.2
Action to be taken:	Paragraph 8
Related documents:	MSC 94/18/7, MSC 94/21; MSC 95/9/3, MSC 95/9, MSC 95/22; MSC/Circ.1014; HTW 2/8, HTW 2/8/2, HTW 2/19 and HTW 3/8

Background

1 MSC 94 considered document MSC 94/18/7 (Australia, Dominica, the Marshall Islands, Norway, IFSMA and The Nautical Institute), proposing to revise and update the *Guidelines on fatigue mitigations and management* as set out in the annex to MSC/Circ.1014, to reflect current fatigue and sleep research and ensure inclusion of science-based approaches to fatigue risk management at sea.

2 The Committee included in its post-biennial agenda, a new output on "Revision of the guidelines on fatigue", assigning the HTW Sub-Committee as the coordinating organ (MSC 94/21, paragraph 18.8).

3 At HTW 2, Australia, Dominica, the Marshall Islands, IFSMA and The Nautical Institute (document HTW 2/8) provided information on a proposed approach for the revision and updating of the guidelines, for preliminary consideration by the Sub-Committee.

4 At HTW 3, Australia (document HTW 3/8) provided a proposal for the revision of the guidelines on fatigue in the annex to MSC/Circ.1014, which took into account the outcome of discussions during HTW 2 and MSC 95, and was based on contemporary fatigue and sleep research that included a risk-based approach managing fatigue at sea.

Introduction

5 It is generally known that seafarer's operational negligence is caused by excessive workload and fatigue. It is, therefore, important to accurately assess the seafarer's workload in order to efficiently manage fatigue at sea. For the assessment, a comparative experiment has been carried out on both simulator and real ship prior to measuring various types of mental workload that can occur while working in the marine environment.

6 The experiment was carried out on a training ship of the Korea Maritime and Ocean University (KMOU) and at the Full Mission Simulator of the Korea Research Institute of Ships and Ocean Engineering (KRISO). The subjects in this study were the captain and the officer. The seafarers' mental workload/performances were measured based on Electrocardiogram (ECG) and NASA-TLX, while the scenarios selected were during arrival and departure at the port of Busan in the Republic of Korea.

7 The results from ECG and NASA-TLX analysis, as set out in the annex, showed a similar tendency between the simulator and the training ship which, in other words, means that it is necessary to engage in a continual accumulation of data to analyse the mental workload of the seafarers. Further experiments were also performed with a variety of subjects. Based on the results of this study, it will be possible to evaluate the workload under various conditions using a simulator.

Action requested of the Sub-Committee

8 The Sub-Committee is invited to note the information provided.

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ANNEX

REPORT ON THE SEAFARER'S WORKLOAD ASSESSMENT

1. Introduction

1 Long-term navigation is likely to be fatiguing and requires long periods of alertness and attention, which make considerable demands on a seafarer. According to statistics collected by the Korean Maritime Safety Tribunal from 2010 to 2014, 82.8% of marine accidents were caused by operational negligence. Operational negligence was caused by excessive workload and cumulative fatigue.

2 Mental workload is intrinsically complex and multifaceted (Jex, 1988). The attribute person-task loop, and the effects of workload on human performance, have been studied (Gopher, D., and Donchin, E., 1986). Research is still in progress to clearly define the factors that affect mental workload.

3 The measurement of mental workload is an important consideration in human factors research because workload measures have the potential to prevent marine accidents and improve the marine environment. Excessively high levels of mental workload can lead to human error and accidents. Also, underload can lead to human error because of operator inattention (Braby et al., 1993).

4 There are three broad categories of workload measurement techniques:

.1 performance-based measures;

.2 physiological measures; and

.3 subjective techniques (Williges and Wierwille, 1979).

5 There are four broad categories of physiological measurement techniques:

.1 the cardiovascular system;

.2 the respiratory system;

.3 the nervous system; and

.4 Biochemistry (Reproduced from Meister, 1986).

6 Heart Rate Variability (HRV) is one of the most well-known methods to measure workload (Mulder, 1988). Electrocardiography (ECG) is used to record the electrical activity of the heart over a period of time. HRV analysis can also be performed. HRV is sensitive to physical, mental, and emotional factors, and to stress. The more tension there is, the greater the increase in the heart rate. Therefore, HRV is used to quantify the measurement of the mental workload and can be used as an indicator of:

.1 R-R interval;

.2 LF;

.3 HF; and

.4 LF/HF (The Road Traffic Authority, 2011).

7 There are a variety of subjective assessment techniques: Overall Workload (OW), the Modified Cooper-Harper Scale (MCH), the Subjective Workload Assessment Technique (SWAT), and the National Aeronautic and Space Administration Task Load Index (NASA-TLX) (Hill et al., 1992).

8 Hill et al., (1992) attempted to analyse and compare the characteristics of four measures of subjective mental workload: SWAT, NASA TLX, OW, and MCH. NASA TLX is superior in its evaluation when considering validity. NASA TLX and OW are superior in their evaluation when considering availability. Also, Hart et al. (1988) showed that NASA-TLX is one of the best known methods to measure workload.

9 In this study, mental workload is compared on a simulator and on a real ship. This study was conducted as a basic study for measurement and evaluation of the mental workload in the simulator. HRV and NASA-TLX were used to analyse the change of mental workload.

Table 1 – Physiological measures of workload

System	Measure
Cardiovascular system	Heart rate
	Heart rate variability
	Blood pressure
	Peripheral blood flow
	Electrical change in skin
Respiratory system	Respiration rate
	Ventilation
	Oxygen consumption
	Carbon dioxide estimation
Nervous system	Brain activity
	Muscle tension
	Pupil size
	Finger tremor
	Voice changes
	Blink rate
Biochemistry	Catecholamine

2. Method

10 A total of two participants took part in the experiments. Participants were chosen so as to all have experience on board ships. A set of two participants (captain, officer) was used. The same subjects participated in the two experiments. The characteristics of the participants in this study are shown in table 2.

Table 2 – Characteristics of participants

	Age	On-board experience
Captain	44	8.7 years
Officer	28	2 years

11 The experiment were carried out on the Korea Maritime and Ocean University training ship HANBADA and at the Full Mission Simulator of the Korea Research Institute of Ship and Ocean Engineering. Two experiments were conducted in the same environment. The simulator experiment was conducted using a 5,000-tonne passenger ship similar to the HANBADA.

12 The HRV data was measured using Bodypro100 (Dusung Technology, Korea), which is a chest belt type device f (Fig. 1). Bodypro100 can perform measurements by connecting a computer to a sensor via Bluetooth. The participants were fitted with this device throughout the experiment. The method is able to detect R waves and R-R interval calculation in the ECG. Heart rate variability (HRV) was investigated for the time domain to determine the changes in the seafarer's conditions. The following four categories are recommended for time–domain HRV assessment: SDNN (Standard deviation of all NN intervals.); HRV triangular index (Total number of all NN intervals divided by the height of the histogram of all NN intervals measured on a discrete scale with bins of 7·8125 ms (1/128 s)); SDANN (Standard deviation of the averages of NN intervals in all 5 min segments of the entire recording.), and RMSSD (The square root of the mean of the sum of the squares of differences between adjacent NN intervals.).

Figure 1: Equipment for measurement of the ECG

13 Subjective evaluation was performed using a NASA TLX questionnaire (Fig. 2). Ratings for each of the six subscales were obtained from the participants following the completion of the experiment. A numerical rating, ranging from 0 to 100, was assigned to each scale. Weights were determined by the participants' selections from a pair of choices of the subscale most relevant to their workload. The weights were calculated from the tally of these choices from 15 combinatorial pairs created from the six subscales. The weights ranged

from 0 to 5. The ratings and weights were then combined to calculate a weighted average, which was used as the overall workload score.

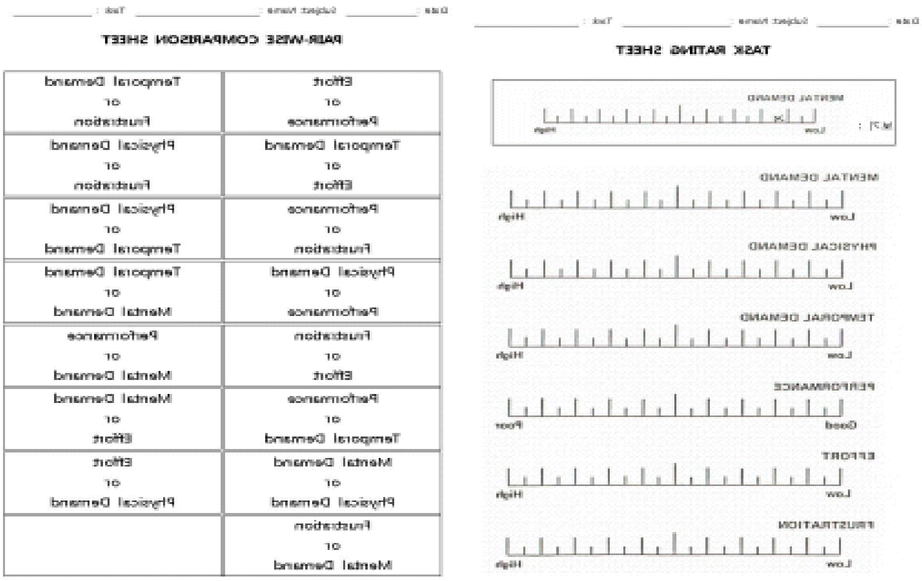
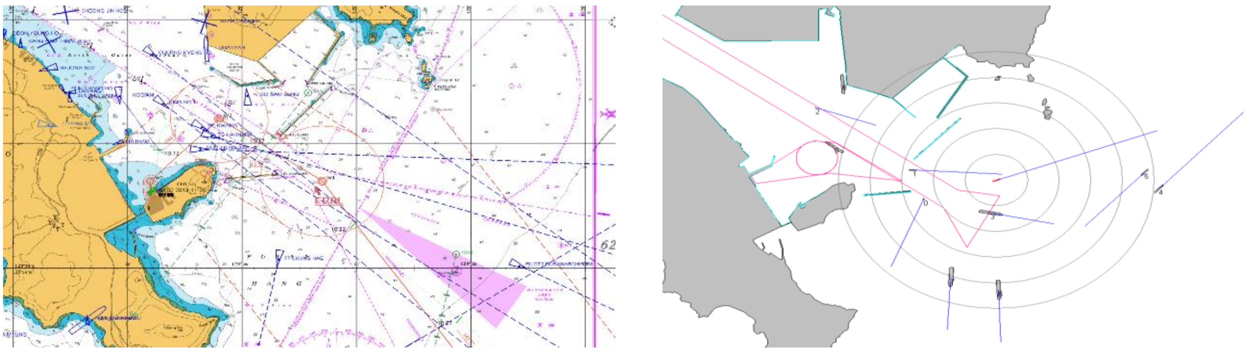


Figure 2: NASA-TLX questionnaire

14 There were two selected scenarios. The first scenario was departing from Busan port; the second scenario was arriving at Busan port. Figure 3 provides an outline of the scenarios. The scenarios can be seen to include "departing from a port" and "arriving at a port"; for both of these, the seafarer needs to make a lot of judgments in a short time and needs to make various decisions.



(a) Real ship experiment (b) Simulator experiment

Figure 3: Voyage scenario

15 Subjects were provided with verbal and written descriptions of the study procedures and rules before the experiment. Both participants rested for 10 minutes before the experiment. The participants were measured for HRV and filled out the questionnaire before and after the voyage.

3. Results

16 The results of the study are given below:

.1 *Electrocardiogram (ECG)*

This study analysed the heart rate (HR) and the SDNN using the averages of the measured values. HR is the average heart rate per minute. SDNN is the standard deviation of the RR interval. Increased HR means the workload has increased and, an increased SDNN means that the workload has decreased.

A normalized HR was used.

Normalization sensitivity (NS (%)) = (stimulus-normal)/normal × 100 (1)

The HR that was obtained on the real ship had a value that was higher than the value that was obtained on the simulator (Fig. 4). In the case of the departure from Busan port, the captain's value was found to increase by 9.82% and the officer's value was found to increase by 1.86%. In the case of arrival at Busan port, the captain's value increased by 18.62% and officer's value increased by 10.94%.

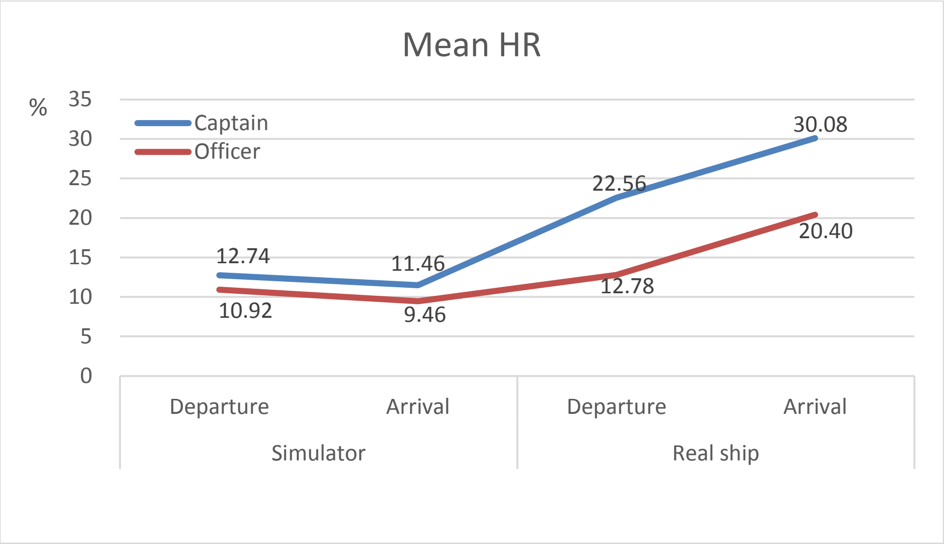


Figure 4 - Results for HR

Also, the SDNN was such that on the real ship the value was lower than it was on the simulator. In the case of departure from Busan port, the captain's value decreased by 60.31ms and the officer's value decreased by 3.32ms. In the case of arrival at Busan port, the captain's value decreased by 86.08ms and the officer's value decreased by 9.49ms (Fig. 5).

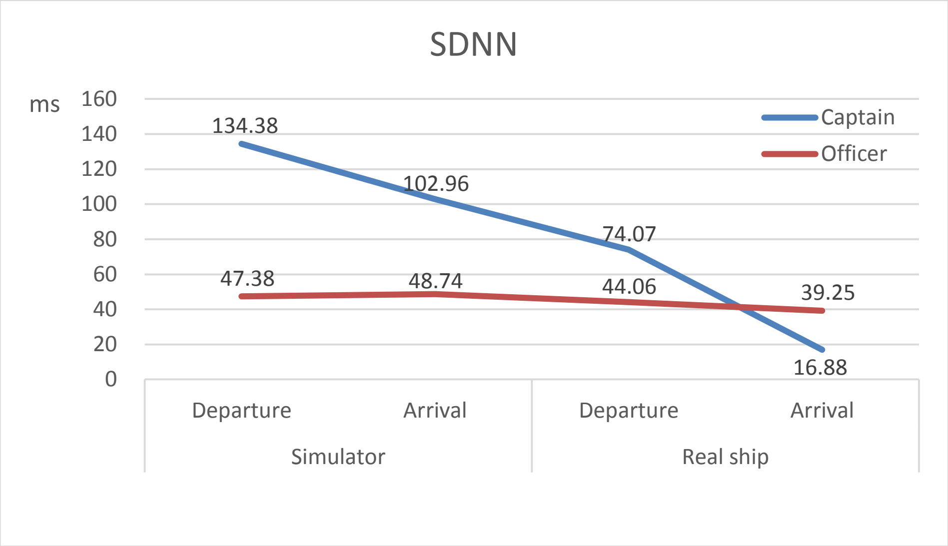


Figure 5 – Results for SDNN

.2 *NASA-TLX*

This study performed an analysis in order to obtain a total score using NASA-TLX data measured after the experiment. An increased total score indicates that the mental workload has increased.

The total score was such that on the real ship the value was higher than it was on simulator. In the case of the departure from Busan port, the captain's value increased by 31.21% and the officer's value increased by 61.04%. In the case of arrival at Busan port, the captain's value increased by 36.59% and the officer's value increased by 81.02% (Fig. 6).

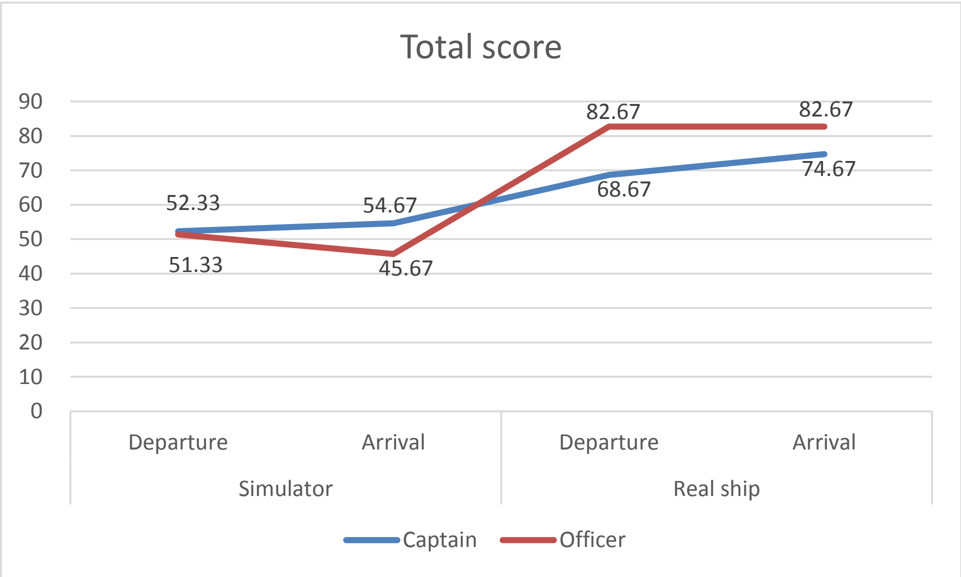


Figure 6 – Results for total score

4. Conclusion

17 This study analysed HR and the R-R interval and performed a subjective assessment using ECG equipment and a questionnaire. The results of the analysis show a similar tendency for all of the following: HR, SDNN, and total score. The results of this study showed greater differences between the real ship and the simulator.

18 The mental workload was found to have increased on the real ship compared to that on the simulator. Also, there was a high variation of values for the arrival compared to the departure. There were also variations according to the voyage time, with departure during the day and arrival at night.

19 Longitudinal follow-up studies based on measurement are needed to collect the data. And, more studies about various participant groups will be needed. The future work indicated by this study will include further analysis of various ports and pilot status (present or not). Based on the results of this study, the sponsor would like to suggest that there is the possibility for various situational types of research and assessment using simulators.

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