Collision Scenario-based Cognitive Performance Assessment for Marine Officers

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ABSTRACT: The overall aim of this paper is to determine a fatigue factor that can be applied to human performance data as a part of a software program that calculates total cognitive performance. This program enables us to establish the levels of cognitive performance in a group of marine pilots in order to test a decision-making task based on radar information. This paper addresses one of the factors that may contribute to the determination of various fatigue factors: the effects of different work patterns on the cognitive performance of a marine pilot.

1 INTRODUCTIONS

A decrease in crew performance for maritime works can be caused by the complex causation related to physiological, psychological, and external sailing factors (Kim et al., 2004). A procedure in maritime accidents caused by the reduction of crew performance can be explained as follows. Physiological, psychological, and external sailing factors affect the working process of a marine pilot directly or indirectly. These factors decrease physical and psychological abilities and that ultimately affect decreases in the cognitive performance of crews as ultimate factors. The decrease in cognitive performance causes mistakes, such as negligence of lookout, and that lead to a direct cause of accidents.

As shown in Figure 1, human cognitive performance represents all abilities of the elements presented in an information processing model of human (Wickens, 1992). However, it may not be necessary to measure the all abilities of such cognitive elements in a project that investigates the cognitive performance of a worker who processes given works. In general, there exist cognitive elements to play a definitive role in the effective performance for given cognitive works. Because these elements are enough to perform such given works except for a decrease in cognitive performance caused by certain diseases, it is possible to estimate the cognitive performance of a worker in given works using such definitive elements in the cognitive works.

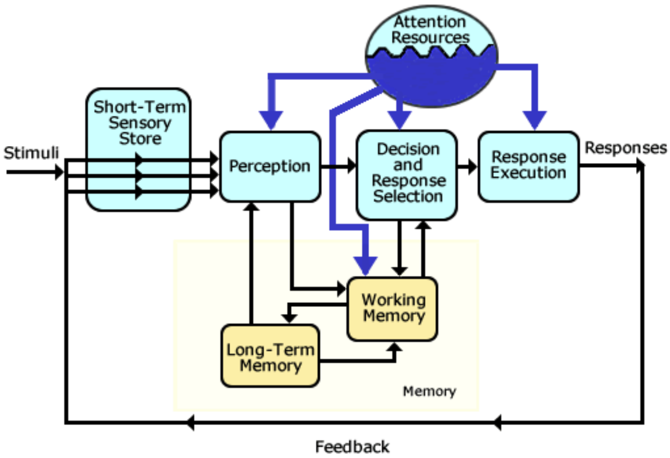


Figure 1. Model of human information processing

Subjective methods, physiological monitoring, and task loading methods are generally used to evaluate these cognitive performances. Also, these methods have been applied to some high risk industries, such as national defense, road transportation, railways, aerospace, process control, and power generation in which the selection of a method usually depends on specific requirements related to each industry.

A representative study in subjective methods is the Modified Cooper-Harper Scale (MCH) (Wierwille and Casalli, 1983) that complemented the Cooper-Harper Scale, which was developed to evaluate the performance of the handling characteristics of military aircrafts in the end of the 1960s. In addition, the NASA TLX (Hart and Staveland, 1988) is a biploar-rating scale-based study using self-report scores.

In the case of the physiological monitoring, there are some studies on the variation of human physiology responses, such as Electroencephalogram (EEG), Electrocardiogram (ECG), Electrodermal activity (EDA), and Electrooculogram (EOG), according to task demands (Andreassi, 2000).

The task loading methods represent an engineering approach that is to measure workloads based on the estimation of task demands. The Task Analysis Workload (TAWL) Methodology (Mitchell, 2000) that was developed by using the US Army Light Helicopter Experimental Program and the Operator Function Model-Cognitive Task Analysis (OFM-COG) (Lee and Sanquist, 2000) that was developed to evaluate workloads in ship-borne automation systems applied these methods.

Marine officers perform various cognitive works, such as signal detection, situation recognition, general judgment, and other related works, in their ship operation jobs. For instance, it can be considered as perceptual ability to recognize target ships approached to their own ship through radars and the naked eye, memory ability in a steersman who memories the commands from his captain, and judgment ability to determine the scale of the conversion (heading) of the bow to avoid the collision with approached target ships. It is difficult to guarantee that such cognitive works occur intermittently or sequentially. Requirements in excessive cognitive performance may cause some mistakes in marine officers and that lead to maritime accidents (Lee, 2005). However, there are still limited studies on the quantitative evaluation of the cognitive performance for maritime officers.

Thus this study developed a maritime collision scenario-based cognitive performance evaluation system for marine officers. The evaluation criteria was configured by applying practical experiments for a group of marine pilots and verified the system through practical applications for cadet marine pilots. Because this system is able to evaluate general cognitive performance of marine officers, it is able to play a role in the avoidance of accidents based on their own awareness on such accidents by transferring the results of the evaluation of physical and psychological conditions through applying a test for a short period of time before going on duty or boarding.

2 COLLISION SCENARIO-BASED COGNITIVE PERFORMANCE ASSESSMENT

In this study, we developed a computer program to evaluate the abilities of signal detection and decision-making task in cognitive performance for marine officers. The objective of this program is to measure the perceptual ability (signal detection) of marine officers for searching other ships through the information presented on radars and the judgment ability (situation recognition or decision-making) that determines the direction and speed of a ship to avoid the collision with other ships. The cognitive performance evaluation program for marine officers developed in this study reflects general cognitive abilities for operating a ship and measures the performance through a 10 minute simple test before going on duty or boarding.

Also, this system is a program that measures the cognitive performance of a marine pilot who controls the heading and speed of a ship using the information presented in a ship operation process. In general, the information given to marine officers is the data presented on radars and speed information of their own ship. The marine officers possibly observe a planned course and control the heading and speed of their own ship in order to avoid the collision with other ships. After avoiding possible collision, the marine officers should return its own course.

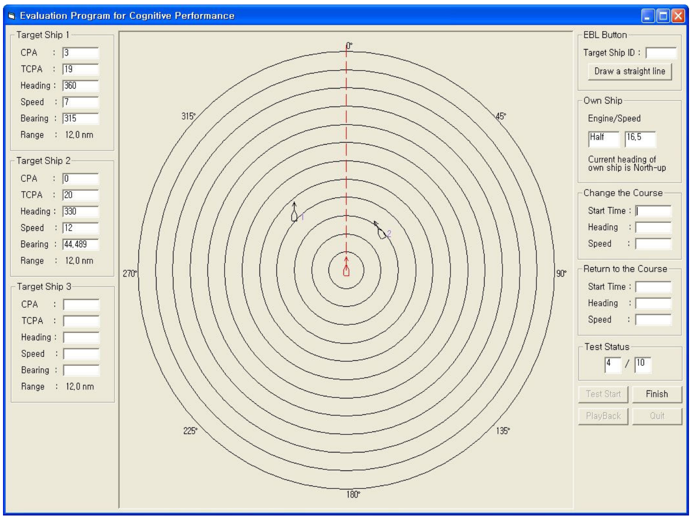


Figure 2. Screen of an evaluation of cognitive performance

Figure 2 illustrates a screen image of the cognitive performance evaluation. The left side of the screen represents the information of target ships (DCPA, TCPA, Heading, Speed, Bearing, and Range) and the right side shows the input menu of the information for changing a course. Whereas, the DCPA (Distance at Closest Point of Approach) shows the estimated distance to the recent closest point and the TCPA (Time to Closest Point of Approach) demonstrates the estimated time to the recent closest point. In order to attempt a proper action for collision avoidance, it is necessary to input the action time for collision avoidance, heading and speed at the starting point, termination time for collision avoidance, and heading and speed at the termination point.

This system configured 10 collision scenarios as noted in Table 1 by varying the number of target ships, heading and speed, and bearing based on the four rules presented in the International Regulations for Preventing Collisions at Sea (1972).

Although the Scenarios 1 and 3 show the same situation, "Head-on Situation", target ships represent different headings and speeds. The Scenarios 2 and 5 show the same situation, "Crossing Situation", but they represent different numbers of target ships, such as one and two ships. Also, the Scenarios 4 and 6 show the same situation, "Overtaking", but they demonstrate different headings and speeds.

Table 1. Types of scenarios

No.	Scenarios	Direction of Screen
1	Rule 14 : Head-on Situation	Normal
2	Rule 15 : Crossing Situation	Normal
3	Rule 14 : Head-on Situation	Normal
4	Rule 13 : Overtaking	Normal
5	Rule 15 : Crossing Situation	Normal
6	Rule 13 : Overtaking	Normal
7	Rule 10 : Traffic Separate Schemes	Normal
8	Rule 15 : Crossing Situation	Opposite
9	Rule 14 : Head-on Situation	Opposite
10	Rule 13 : Overtaking	Opposite

This system configured a scoring index to evaluate the cognitive performance of marine officers as follows.

(1) Collision avoidance ability
(2) Decision-making time
(3) Degree of deviation

The evaluation criteria were established for each scenario in order to measure the "Scoring Index". Table 2 shows the evaluation criteria for "Crossing Situation".

3 EXPERIMENTS & RESULTS

Three professional marine pilots and five cadet marine pilots were participated to verify the evaluation of the cognitive performance assessment system for marine officers developed in this study. Except for Scenario 1, which was applied as a pretest, experiments were applied to other nine Scenarios.

Figure 3 shows a screen image of the collision scenario of "Traffic Separate Schemes". An experiment based on this scenario represents the input and analysis data as shown in Figure 4.

Table 2. Evaluation criteria for "Rule 15 "

Criteria	Optimum answer (10 points)	Reasonable answer (5 points)	Unacceptable answer (0 point)
1 Decision	Starboard	Reduce Speed	Port or Stand-on
2 Time to Change of course (CT)	0-5 minutes	5-10 minutes	Over 10 minutes
3 New Heading (CH)	040 − 050	020 - 040 050 - 060	0 − 020 >060
4 New Speed (CS)	Same (18)	0 - 18	>18
5 Time to Return to course (RT)	10 − 15 minutes	5 - 10 minutes	< 5 minutes > 15 minutes
6 Final Heading (RH)	359 − 001	350 - 359	> 001 < 350
7 Final Speed (RS)	18	10 - 18	0 − 10 > 18
8 DCPA	1.0 − 2.0	2.0 − 3.0 0.7 − 1.0	< 0.7 > 3.0
9 Total Response Time (TRT)	< 1 mins	1−3 minutes	> 3 minutes
10 Distance of new track as a ratio of original track (RD)	< 1.05	< 1.25	> 1.25

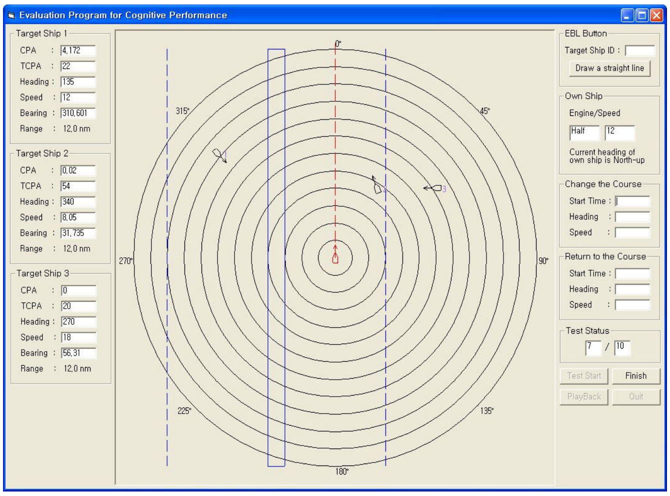
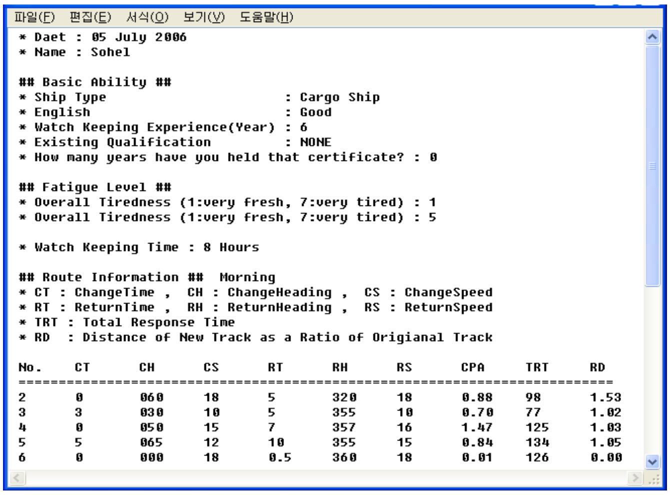


Figure 3. Screen of the scenario of "Rule 10 (TSC)"



파일(F) 편집(E) 서식(O) 보기(V) 도움말(H)

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* Daet : 05 July 2006
* Name : Sohel

## Basic Ability ##
* Ship Type                      : Cargo Ship
* English                        : Good
* Watch Keeping Experience(Year) : 6
* Existing Qualification         : NONE
* How many years have you held that certificate? : 0

## Fatigue Level ##
* Overall Tiredness (1:very fresh, 7:very tired) : 1
* Overall Tiredness (1:very fresh, 7:very tired) : 5

* Watch Keeping Time : 8 Hours

## Route Information ##  Morning
* CT : ChangeTime ,  CH : ChangeHeading ,  CS : ChangeSpeed
* RT : ReturnTime ,  RH : ReturnHeading ,  RS : ReturnSpeed
* TRT : Total Response Time
* RD  : Distance of New Track as a Ratio of Origianal Track
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No.	CT	CH	CS	RT	RH	RS	CPA	TRT	RD
2	0	060	18	5	320	18	0.88	98	1.53
3	3	030	10	5	355	10	0.70	77	1.02
4	0	050	15	7	357	16	1.47	125	1.03
5	5	065	12	10	355	15	0.84	134	1.05
6	0	000	18	0.5	360	18	0.01	126	0.00

Figure 4. Screen of the test results

In the results of these experiments, the professional pilots showed higher scores than cadet marine pilots, average 90.2 and 74.0.

Also, as shown in Figure 5, the total scores of the professional pilots for scenarios showed high levels more than 10 points compared to that of the cadet pilots.

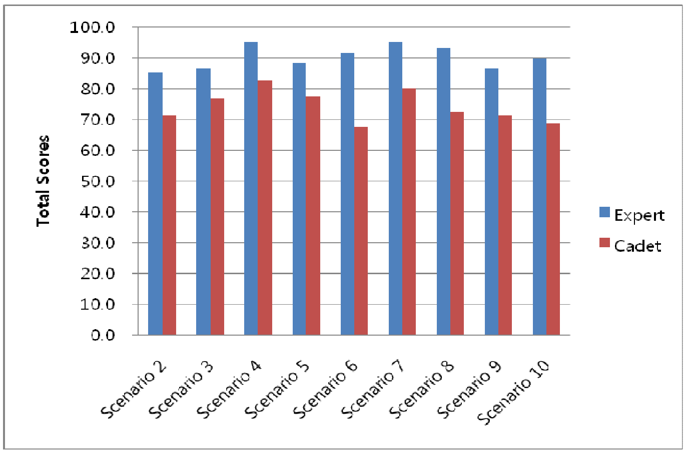

Figure 5. Comparison of the total scores by scenarios

For a comparison and analysis of this data, a 5% level of significance paired-wised t-test was conducted. According to the analysis result, there was a statistically significant difference in the total scores between the professional pilots and the cadet pilots for each experiment subject (p=0.015).

In addition, in the results of the comparisons of the Distance to the Closest Point of Approach (DCPA) that is the most important factor to achieve collision avoidance, the professional pilots showed higher scores than cadet pilots for all scenarios as illustrated in Figure 6 in the "Scoring Index".

For a comparison and analysis of this data, a 5% level of significance paired-wised t-test was conducted. According to the analysis result, there was a statistically significant difference in the DCPA scores between the professional pilots and the cadet pilots for each experiment subject (p=0.028).

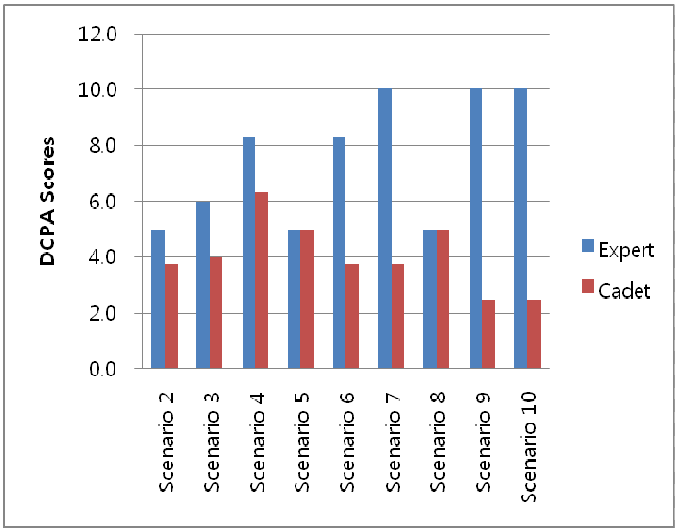

Figure 6. Comparison of the DCPA scores by scenarios

Regarding future studies, it will attempt to guarantee the evaluation data through additional experiments in order to complement the cognitive performance evaluation system for marine officers and that will increase the reliability of this system.

4 CONCLUSIONS

In recent years, various sailing equipments, such as GPS, ARPA, ECDIS, AIS, VDR, and hull monitoring system, have been introduced to ship operation and the development of such hardware still have been conducted.

However, the improvement and effort on the ship operator-based related software are still limited and in an elementary step.

The present circumstance is due to the lack of investment in this filed even though there are some words on the marine accidents that usually caused by human factors. It can be considered that there are still lack of studies on physical, psychological, and cognitive performance for marine officers who guarantee the safety of sailing using advanced equipments and consideration.

This study attempted to develop a cognitive performance assessment system for marine officers that evaluates the cognitive performance of marine officers through a simple way before going on duty or boarding and provides the results of the evaluation to the pilot as a warning message for avoiding marine accidents caused by the decrease in cognitive performance of marine officers.

In addition, there exist some problems for the reflection of the importance in detailed items that consist of the reflection issues of difficulties and evaluation criteria according to collision scenarios in the experiment and analysis processes in this study.

The result of the analysis in this study includes some problems of the limited subjects and quantitative evaluation criteria. Also, the cognitive performance assessment system developed in this study included the evaluation of the cognitive performance only, future studies will reflect an evaluation model for the fatigue of marine officers by considering their sleep conditions and workloads and establish a reasonable and reliable evaluation system by accumulating various collision scenarios and by complementing the existing evaluation criteria.

5 ACKNOWLEDGEMENTS

The authors would like to special thank Professor Mike Barnett and the instructors/cadets from Warsash Maritime Academy for their support with the research. The contents of this paper are the results of the research project of MOERI/KORDI (Analysis of Tug-Barge Accident and its Prevention)

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