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Effects of Overlaid Navigational Information on Seascape on Ship Crew Performance

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***Abstract*—Many of marine accidents cause by the perception error during navigation watch. We developed a new navigation support system which expected to decrease cognitive workload of officer of the Watch. The support system can project marine radar information onto head up display combiner which is placed on a compass. An experiment was carried out in order to evaluate the effectiveness of the support system. Seventeen subjects participated in the experiment who is asked to navigate vessel at PC-based ship bridge simulator. Eye fixation duration for under navigation task was measured as index for efficiency of the support system. As a result of this experiment, the statistical significance could not be found. However, there has been shown to be tendency towards extend the fixation duration for navigation watch with the support system as increase collision risk.**

***Keywords*—human factors, mental workload, navigation support system**

I. Introduction

According to Japan Marine Accident Inquiry Agency's Report, the collision of the vessel accounts for 52% of all marine accident. Inappropriate watch by officer of the watch is a cause on 56% of the collision. The major causes of inappropriate watch are "Careless navigation", and "Distracted by a third vessel" [1]. In accordance with these statistics mentioned above, the following explanation can be made: Many collisions are caused by errors on perception and decision of the officer on the cause of the collision in marine accident. The error of these perception and decision must be decreased in order to prevent marine accident.

A. Navigation watch on bridge

Main task of the officer is to navigate the vessel by following to a planed route in consideration of the condition such as arrival time, meteorological phenomena, oceanographic phenomena, and movement of other vessels. The officers use various navigational aids such as marine radar, binoculars, and compass are used in the watch on the bridge, in order to find targets which should be paid attention to, and to decide the course. The properties of these equipments are as follows: Marine radar is best way to find the target. And, the binocular is effective, when the officer finds the target of about 30km or less, and when the officer knows course and ships by type of the target. The compass is utilized in knowing the position of the own vessel, and confirming the bearing of the target. At first, the existence and course of the targets are observed by the binoculars. Next, range and direction from the own vessel to the target are checked by radar information so that the officer may recognize the movement of target. Finally, the changes of the bearing of own vessel and target is confirmed by the compass. Much information can obtain from radar such as target range and direction, of both moving and fixed objects. Automatic radar Plotting Aids (ARPA) is effective in order to get the information of target which is one of the functions of radar. ARPA calculate Distance to Closest Point of Approach (DCPA) and Time to Closest Point of Approach (TCPA). These information are useful for estimate collision risk. Navigation watch by the visual observation using navigation radar, binoculars and compass is essential task for the officer. Since the optimum equipment varies according to target information, it is rare to use these equipments independently; two or more equipments are used simultaneously. Therefore, the navigation task to obtain information by visual observation and radar operation must be carried out continuously while navigation watch. However, the utilization of ARPA is limited, because of its complicated operation and oversensitive collision alarm. In addition, target information of radar may be misunderstood by the officer, even if the radar function was utilized, especially, when the ship encountered many targets at the same time. As the result, the perception and the decision error probability will be increase. The support system which decreases the officer's cognitive workload is desired in order to prevent such mistake.

B. Precedence research

Integrated Navigational Information System on Seascape Image (INT-NAV) developed as the equipment which supports the officer's perception is the system which can be easy to check visually observed target with its information on the radar. And, INT-NAV offers the information, such as predicted course and collision risk area of the target, which gives hints to know effective collision avoidance path. The collision risk area is calculated by an algorithm of Obstacle Zone by Target (OZT). The operational display of INT-NAV is shown in Fig. 1. The display of INT-NAV supports perception of the collision risk and finding of the collision avoidance path. With the result of evaluation experiment, the perception efficiency of target was improved by the utilization of INT-NAV. And, it was confirmed to be effective in order to know the movement of the vessel of which collision risk is high in the congestion sea area.

In addition, the mental workload while ship handling was decreased. Since the display coordination is different, between INT-NAV and conventional navigation equipment, the enough mastery is required. The conclusion that the design and the interface of the system had to be improved was issued [2].

C. Aim

In order to remove these defects, we developed a new navigation support system which supported the perception by the visual observation of the officer. The navigation support system is able to project the target information from marine radar onto head up display (HUD). The support system set up behind the compass. Fig. 2 shows that external appearance of the support system. The officer will be able to keep watch on outside as usual while the radar information is obtained. In addition, the support system project radar information just onto the target position, so that it is easy to be understood, it doesn't need further practice to use. And also, it is expected that coordinate error will be decrease. In this study, the experiment which evaluated the effects of the navigation support system on performance by imposing navigation task with PC-based ship bridge simulator to subjects was carried out.

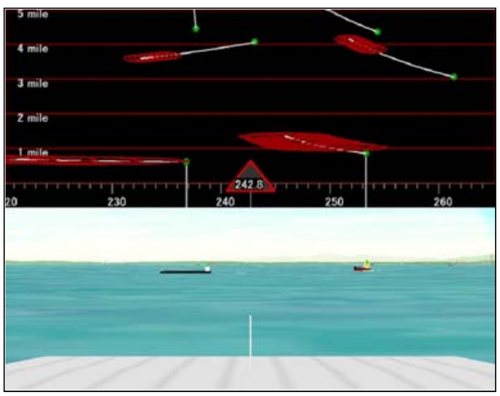

Figure 1. An example display image of INT-NAV. Target range, bearing, radar echo, and OZT are shown in the upper part. Seascape view is shon the lower part.

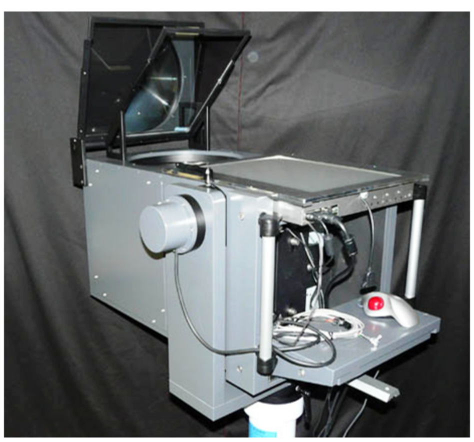

Figure 2. The external appearance of the new navigation support system.

II. EXPERIMENT

A. Subject

Seventeen subjects participated in the experiment. Subject age ranged from 27-63 years, and all subject had experience of navigating ship for overseas service as officer.

B. Navigation scenario

The experiment conditions and layout of target are shown in Table I and Fig. 3. Navigation scenario consists of "number of vessel" and "crossing angle". One of the constituents of navigation scenario is "number of vessel" that was defined by not only "total number of vessels", but "number of vessels which are high collision risk". The calculated DCPA is one of information, is useful for estimate collision risk. So that, the officer judge that the vessels which short DCPA is high risk of collision. In the experiment, it defined the vessel which DCPA of 1.852km (one nautical mile) or less as "high risk of collision vessel". On the other hand, "crossing angle" is classify into "port side" and "starboard side" which from "high risk of collision vessel" approached. The reason is that; convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) has internationally determined the traffic rule of the vessel. In Japan, it has determined that "When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel." by the Law for Preventing Collisions at Sea, Crossing Situation Article 15. The cognitive demands of collision avoidance will be increase for the ship handling under the condition in which the vessel which must avoid the course [3].

C. Method

The subject was asked to keep watch for 120 seconds for each trial. Eye fixation duration in "Outside view display" (Display A) and "Radar display" (Display B) was measured from the eye movement. There were two conditions on display A with or without projected the target information. Projected information by the support system were DCPA (nautical mile), TCPA (second), True Course (degree), True Speed (knot), and ship name. The example image is shown in Fig. 4. The own vessel maintained fixed speed and course. The experiment condition prohibited the subject from handling vessel such as steering operation and control of the engine. A picture of the experiment and schematic figure of PC-based simulator are shown in Fig. 5 and Fig. 6.

D. Measurement

Since the support system aim to integrate the radar information with outside view, it shall be assumed that shorten the radar operation time. Therefore, the support system efficiency can evaluate from fixation duration for Display B. In this paper, we mention about the fixation duration for what equipments were used. The eye movement was recorded using TalkEye II (Takei Scientific Instruments Co.,Ltd.). The sampling rate of the record is 1/30sec. The fixation duration was totaled by the classification of the area in the fixation point in Display A, Display B, and Others. In this report, the time which totaled the fixation duration to each area every scenario was compared.

TABLE I. CONDITION OF NAVIGATION SCENARIO

Scenario	***No.1***	***No.2***	***No.3***	***No.4***
Target approach from	Port		Starboard	
Total number of Vessels	12	24	12	24
Number of vessels which collision risk are high	1	4	1	4

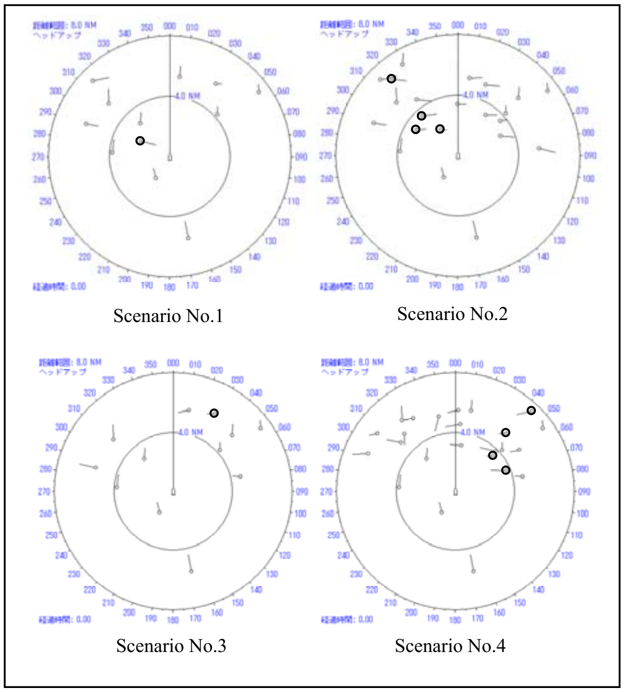

Figure 3. These image are the layout of targets. Bold circle indicates where the high collision risk targets (Actually the bold circles are not displayed).

Figure 4. The example image of diplay information inscribed in green lettering. Information about DCPA, TCPA, speed, bearing, and ship name are shown above the target.

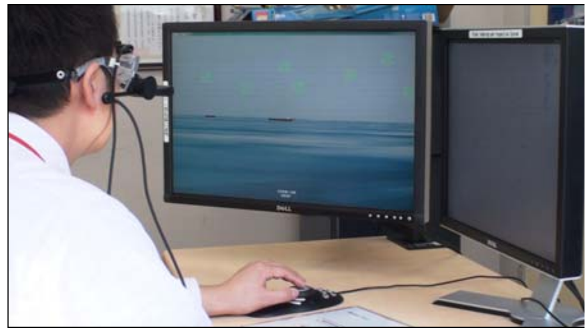

Figure 5. This picture shows the experiment. Subject wear eye movement recorder system, and manipulate the jog dial with the left hand.

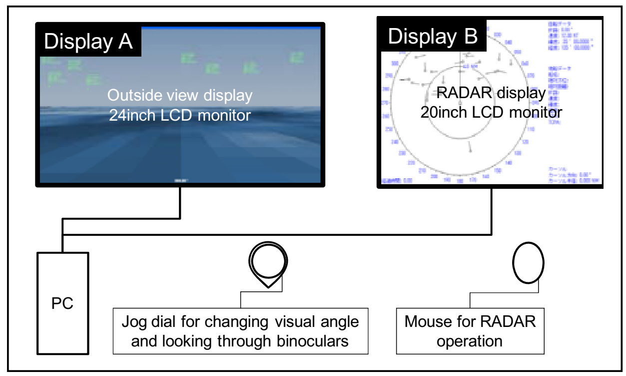

Figure 6. The PC-based ship bridge simulator is shown schematically. The simulator consists of two LCD displays and two input devices which are, jog dial for look around and mouse for radar operation.

III. RESULTS AND DISCUSSION

The independent variable was made to be task demand of the scenario and existence of overlaid information. And, the dependent variable was made to be the fixation duration to each area. The experimental results are shown in Table II. Analysis of variance shows that, the statistical significance was not obtained between the fixation duration and the existence of overlaid information. However, in the scenario No.4 which highest risk of collision, with overlaid information, the fixation duration in Display A was extended at 35%, and the fixation duration in Display B shortened 12%. And, the fixation duration in Display A was extended even in the scenario No.2, and the fixation duration in Display B was shortened. In addition, the extension width in the starboard side scenario Display A is wider than that in the port side scenario. As the above experiment results show, it was proven that it shortened the fixation duration in Display B and extends the fixation duration in Display A in high collision risk scenario. The extension of visual observation time in the congestion sea area is the result indicating the effectiveness of the support system.

TABLE II. RESULTS OF EXPERIMENT

	Scenario	No.1	No.2	No.3	No.4
		Mean fixation duration (S.D.)	***Mean fixation duration (S.D.)***	***Mean fixation duration (S.D.)***	***Mean fixation duration (S.D.)***
Display A	Without support	38.33 (13.38)	32.62 (14.84)	41.14 (20.35)	29.93 (15.50)
	With support	35.28 (18.58)	35.65 (16.26)	39.95 (21.45)	40.66 (21.01)
Display B	Without support	78.59 (12.89)	85.50 (14.68)	75.54 (19.24)	87.73 (14.93)
	With support	81.80 (16.88)	82.13 (16.33)	78.22 (21.41)	77.13 (20.97)
Others	Without support	2.84 (1.93)	1.80 (1.16)	3.02 (2.21)	2.34 (1.94)
	With support	2.71 (1.76)	2.23 (0.97)	1.83 (1.05)	2.24 (1.45)

(sec.)

IV. CONCLUSION

We developed the system which integrated the radar information with outside view in order to reduce the perception error of the officer. The experimental result could not show the statistical significance. However, in the scenario of which collision risk is high, the radar operation time decreased in the navigation of which the perception load is high and tended to extend the visual observation time. This is a result of indicating the effectiveness of the support system.

ACKNOWLEDGMENT

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