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Basic Evaluation of Performance of Bridge Resource Teams Involved in On-Board Smart Education: Lookout Pattern

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Abstract

This paper describes some patterns of a ship's bridge resource team's performance using a work-sampling method in on-board smart education. If we can find out performance patterns for attempting safe navigation, excepting knowledge-based shiphandling methods which we can get from textbooks, it is possible to give an outline of the navigators' and quartermasters' art and skill on a ship. This pattern also guides the practical implementation of on-board smart education. We aimed to find the lookout pattern which is the basic and most important work in navigational watch keeping. The observation of the navigational watch keeping was carried out during twenty navigational situations: three entering/leaving ports; two anchorages; five passage routes including three straits; and five open sea areas. We identified two lookout patterns among bridge teammates from this observation.

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1. INTRODUCTION

In Japan, education for a merchant ship's navigator is controlled by a university or a maritime technology college, not a navy or a coast guard. Practical on-board education is conducted on a training ship, such as a power vessel or tall ship. Specialists who have a lot of experience educate students on the ship. However, the contents of the practical on-board education are not always clear to the students, because real situations include all things, not just simple linear knowledge. Real life, complex situations are difficult for them to understand it. We need some patterns of navigational art which can form the basis of the shiphandling in on-board smart education. The research on ship's bridge teammate behavior/action (performance) is not clear yet. Only research for a duty officer is clear[1], [2]. We started research on this subject a few years ago[2]-[4]. In earlier, completed research, we find the results for the performance of airline pilots regarding human error[5], [6], but each vessel differs. In particular, the ship's navigator and the quartermaster usually walk around on the bridge. They never sit continuously in a seat the way an airline pilot does. We observe the bridge teammates and analyze the lookout method of the navigator and the quartermaster in order to make a framework for on-board smart education, with the aim to discover the lookout pattern of the bridge teammates.

The experiment is conducted in twenty navigational situations: three entering/leaving ports; two anchorages; five passage routes including three straits; and five open sea areas. We analyze the performance of the bridge teammates using a work-sampling method. The subjects are crews of the training ship of the Faculty of Maritime Sciences at Kobe University.

The results show that the lookout pattern for the navigator and the quartermaster differs whether the sea area is open or not. Moreover, the stream of the lookout method among bridge teammates has some rules which require nonverbal teamwork in order to achieve safe navigation.

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2. EXPERIMENT

In the experiment, we observed the performance of the ship's bridge teammates as conducted in twenty navigational situations to determine the lookout patterns of the navigator and the quartermaster using a work-sampling method[7]. The subjects are five crews consisting of Captain (Capt), two Duty Officers (DO) and two Quartermasters (QM) (see Table 1) aboard the training ship Fukae Maru belonging to Kobe University. Her length is 49.95 meters; breadth 10.00 meters; and gross tonnage 449.00 tons (see Figure 1).

Table 1 Five subjects, crews of training ship Fukae Maru

	Subject	Gender	Experience [year]
S_1	Captain	M	19
S_2	Chief Officer	M	30
S_3	Officer	M	8
S_4	Quartermaster A	M	22
S_5	Quartermaster B	M	3

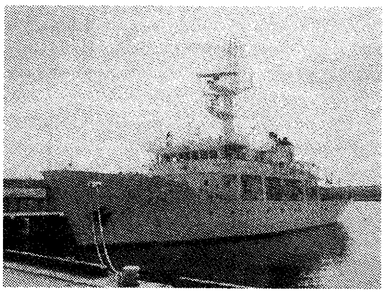

Fig. 1 Training ship Fukae Maru of Kobe University, Faculty of Maritime Sciences

We observed the bridge teammates' performance every second, and specialists totaled up each event after the experiment. Moreover, we recorded the bridge teammates' voices, the weather and sea conditions, etc. The relationship between the observer and the subject is 1 vs.1, where the observer never observes multiple subjects at the same time. We show the information from the five subjects designated 'S_1' to 'S_5' in Table 1. The outline of the experimental sea areas is shown from '1' to '13' in Figure 2. Table 2 shows the relationship between the sea areas '1' to '13' and the twenty navigational situations.

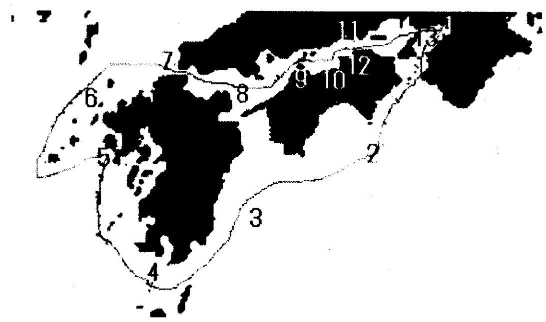

Fig. 2 Outline of the experimental sea areas for twenty navigational situations (west side of Japan)

In Figure 2, a number from '1' to '13' and a line show the sea area number and an outline of the ship's route. The weather and sea conditions were fine during all navigational situations.

Table 2 Relationship between experimental sea areas and twenty navigational situations

Sea area No.	Navigational situation	Sea area No.	Navigational situation
1	EP, LP, A, WA	8	O
2	O	9	PS
3	O	10	A, WA
4	O	11	P, P
5	EP, LP	12	EP, LP
6	O	13	PS
7	PS	-	-

In Table 2, 'EP', 'LP', 'A', 'WA', 'P', 'PS' and 'O' mean "Entering Port", "Leaving Port", "Anchoring", "Weighing Anchor", "Passage rout", "Passage route at Strait", and "Open sea" respectively. In this study, we define two sea areas, 'L_{sea}' and 'S_{sea}', to analyze the observed data for geographical features, not traffic density. We show the relationship between L_{sea}, S_{sea} and sea area number in Figure 2 below.

1) Large sea area (L_{sea}): L_{sea} is the open sea. Sea area numbers are 2, 3, 4, 6, and 8.
2) Small sea area (S_{sea}): S_{sea} is every area except the open sea. Sea area numbers are 1, 5, 7, and 9 to 13.

3. ANALYSIS

We code the bridge teammates' performance by using the event table which consists of fifteen categories 'A' to 'O' including eighty-nine events[8], [9] (see Table 3). We also show a detail of the lookout events including radar in Table 4. The specialists, who have a lot of on-board experience, made this table. In Table 3, a code for the event is '1' to '89', and in Table 4, '-Eye' and '-B' of the "A) lookout" event means observation using the naked eye and binoculars respectively. In this study, we define three types of lookout methods by "Naked eye (Eye)", "Binoculars (B)", "Radar", and divide the eight lookout sea areas by the naked eye and binoculars: whole (bow), right side ahead, right, left side ahead, left, right side behind, left side behind, and stern.

We describe the analysis process of the bridge teammates' performance below.

1. The observer records the subject's performance every one second.
2. The observer records the navigational information, such as ship's speed and course, wind speed and direction, weather and sea conditions, target information using radar and other important information, which we need to analyze the bridge teammates' performance.
3. We count the time for each category and calculate the ratio of each category to all.
4. We count frequency of the code numbers '1' to '17' to ascertain the lookout method.
5. We check the stream of the lookout to ascertain the lookout pattern.
6. This process is carried out for twenty navigational situations. The bridge teammates are Capt, DO and QM for eleven situations and DO and QM for nine situations.

Table 3 Event table, 15 categories

Category	Event (code number)
A) Lookout	1-16
B) Instrument	17-23
C) Steering order	24-32
D) Steering	33-42
E) Maneuvering order	43-47
F) Engine order	48-58
G) Telegraph	59-69
H) Thruster order	70
I) Chart/Catalog	71-73
J) VHF	74, 75
K) Verbal communication	76-84
L) Bell book	85
M) Watch memo	86, 87
N) Taking over duty	88
O) Others	89

Table 4 Event table of lookout

Code	Event
1, 9	Whole (bow) -Eye, -B
2, 10	Right side ahead -Eye, -B
3, 11	Right -Eye, -B
4, 12	Left side ahead -Eye, -B
5, 13	Left -Eye, -B
6, 14	Right side behind -Eye, -B
7, 15	Left side behind -Eye, -B
8, 16	Stern -Eye, -B
17	Radar

4. RESULTS

We show three results: 1) the event ratio of the navigator and the quartermaster using Table 3 for investigating the bridge teammates' performance; 2) the frequency of the lookout code including the radar '1' to '17' of the navigator and the quartermaster for determining the lookout method; and 3) the pattern of the lookout observation of the navigator and the quartermaster for ascertaining the framework of the lookout. As the typical results of L_{sea} and S_{sea}, we select sea area number 6 from L_{sea} and 13 from S_{sea}.

4.1 Performance of Bridge Teammates

We show the event ratio of the bridge teammates in Figures 3 (L_{sea}) and 4 (S_{sea}). In Figure 3, about 80% (A+B), the event ratio of DO and QM, is based on the lookout including radar observation (B), DO 79.2%, QM 78.0%, and 4 to 6% fixed position (I). This tendency also shows in Figure 4, DO 82.3% (A+B+C), QM 76.6% (A+B). We think the steering order (C) includes the lookout, because what the navigator judges as a ship's course and speed for safe navigation under the navigational information, which he gets from the lookout, is a matter of course. Moreover, the fixed position of DO and QM is 4.4% and 7.1%.

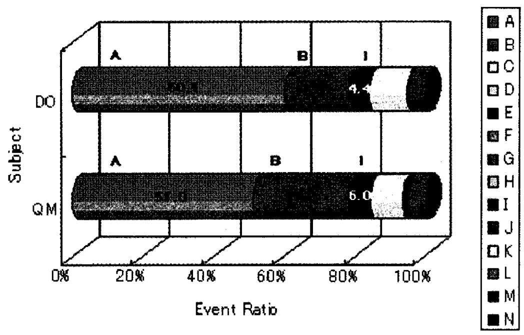

Fig. 3 Event ratio of the bridge teammates (L_{sea})

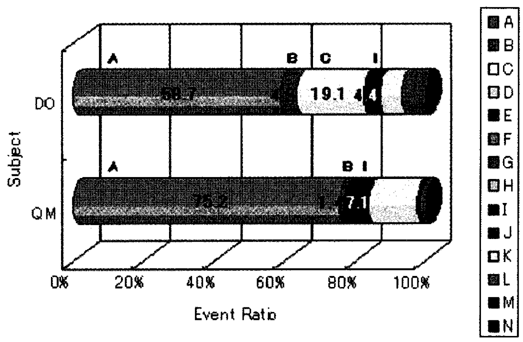

Fig. 4 Event ratio of the bridge teammates (S_{sea})

The event ratios of the bridge teammates for all sea areas were about 80% lookout and 4 to 7% fixed position. This result shows one of the guidelines of the ship's bridge teammates' performance when performing navigational watch keeping. We also guess that the importance of the lookout, based on the ratio of 80%, is the same for those of other transport systems such as an airline pilot, a train operator and a car driver. Perhaps, we again realize the importance of human ability, even if a lot of navigational systems have been developing toward non-human systems. Additionally, we can confirm the bridge teammates do the lookout under the assumption that targets are always around their own ship based on the result of 80% from the lookout patterns.

4.2 Lookout Method

We counted the frequency of codes '1' to '17' by dividing three lookout methods: Radar (3), Binoculars (2), Naked eye (1), Other (0); and show the relationship between the time [second] and the incidence of the lookout methods '0' to '3' in Figures 5 and 6. In Figures 5 and 6, a square represents the results of DO and a diamond represents the results of QM.

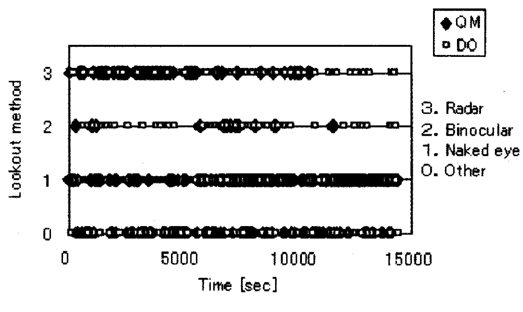

Fig. 5 Frequency of the lookout method (L_{sea})

We can determine the lookout method. In the L_{sea}, DO and QM sometimes use radar and sometimes use binoculars for detecting targets. The frequency is more than the situations of the S_{sea}. The navigators detect targets by moving eye points to a wide range in the direction of the ship's movement. Their observation area becomes smaller when they find targets.

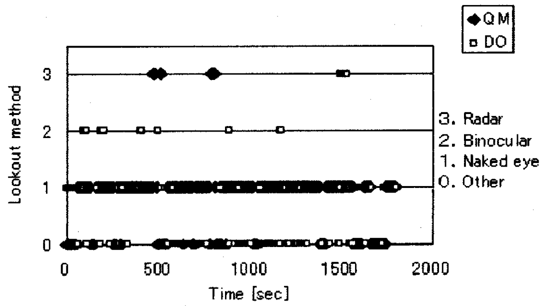

Fig. 6 Frequency of the lookout method (S_{sea})

4.3 Lookout Pattern

We show the lookout patterns in Figures 7 and 8 that are part of Figures 5 and 6. 'D1' to 'D3' and 'Q1' to 'Q3' of Figures 7 and 8 are typical streams of the lookout of DO and QM. Also, 'D1' to 'D3' is an order of the lookout performance for the DO and 'Q1' to 'Q3' for QM.

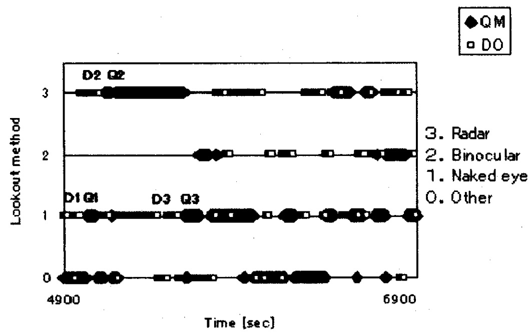

Fig. 7 Lookout pattern (L_{sea})

In Figure 7, 'D1' to 'D3' which is the stream of DO is "1-3-1", and QM have the same stream "1-3-1". Its timing is DO first and QM second. This tendency shows that QM confirms the performance of DO, and constitutes a double check of the bridge teamwork. On the other hand, in Figure 8, the stream is different between DO and QM. The pattern of DO is "1-2-1" and QM "1-3-0". However, the timing shows the same tendency: DO first and QM second. QM assists DO to fix the position and to get accurate information about the targets from the radar in the small sea area. We show the relationship between the sea area number, including the navigational situations of Table 2, and the main patterns which we found in this study, in Table 5. The parts with an underline show the results of L_{sea} and others are S_{sea}.

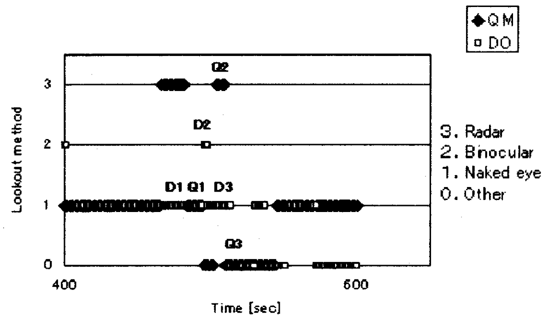

Fig. 8 Lookout pattern (S_{sea})

Table 5 Lookout Pattern

Sea area No.	Capt	DO	QM
1-L	1-2-1	1	1
<u>2</u>	-	<u>1-3-1</u>	<u>1-3-1</u>
<u>3</u>	-	<u>1-3-1</u>	<u>1-3-1</u>
<u>4</u>	-	<u>1-3-1</u>	<u>1-3-1</u>
5-E	1-2-1	1-2-1	1
5-L	1-2-1	1-2-1	1
<u>6</u>	-	<u>1-2-1, 1-3-1</u>	<u>1-3-1</u>
7-PS	1-2-1	1-2-1	1
<u>8</u>	-	<u>1-3-1</u>	<u>1-3-1</u>
9-PS	-	1-2-1	1
10-A	1-2-1	1-2-1	1-2-1
10-WA	1-2-1	1-3-1	1
11-S, 11-S	-	1-2-1	1-2-1
12-E	1-2-1	1-2-1	1
12-L	1-2-1	1-2-1	1
13-PS	-	1-2-1	1
1-A	1-3-1	1-3-1	1-3-1
1-WA, 1-E	1-2-1	1-2-1	1

In Table 5, there are two kinds of lookout pattern for the geographical conditions (L_{sea} and S_{sea}): 1) L_{sea} is "1-3-1" for DO and QM; 2) S_{sea} is "1-2-1" for Capt and DO. Moreover, radar observation time is different between L_{sea} (see Figure 7) and S_{sea} (see Figure 8). We show the relationship between the sea area number, including the navigational situations and the radar observation time, in Table 6. The parts which are underlined show the results of L_{sea} like Table 5.

In Table 6, the radar observation time of L_{sea} is more than S_{sea} for DO and QM. This tendency shows the difference in how to use the radar on navigational information, because the targets are close in S_{sea} for the navigator who just gets the aimed target's information. However, he searches whether the target is or is not in L_{sea}.

Table 6 Radar observation time [sec]

Sea area No.	Capt	DO	QM
1-L	0.0	61.0	0.0
2	**0.0**	**58.6**	**75.0**
3	**0.0**	**76.1**	**73.6**
4	**0.0**	**48.6**	**103.4**
5-E	0.0	16.5	27.0
5-L	43.0	50.0	8.8
6	**0.0**	**60.5**	**84.1**
7-PS	0.0	38.5	14.0
8	**0.0**	**63.6**	**70.1**
9-PS	0.0	20.0	19.3
10-A	52.0	36.0	14.0
10-WA	35.0	42.2	21.0
11-S, 11-S	0.0	27.0	32.0
12-E	0.0	0.0	33.0
12-L	29.5	0.0	24.7
13-PS	0.0	34.0	14.3
1-A	22.9	36.9	54.2
1-WA, 1-E	15.0	12.7	6.5

5. CONCLUSIONS

We observed ship's bridge teams composed of a captain, a duty officer and a quartermaster in order to find out their performance patterns; and specifically aimed at the lookout pattern in two kinds of geographical conditions divided by the sea area size. The experiment is carried out for thirteen kinds of sea area and twenty navigational situations in Japan.

According to the results, we confirmed the importance of the lookout for safe navigation, and identified two types of the lookout pattern.

1) In large sea area: the duty officer and the quartermaster have the lookout pattern: "Naked eye - Radar - Naked eye". The quartermaster confirms the performance of the duty officer.

2) In the small sea area, the duty officer and the captain have the lookout pattern: "Naked eye - Binoculars - Naked eye". The quartermaster supports the performance of the duty officer and the captain.

Our future aims are 1) to find the performance patterns of everyone except the lookout; 2) to develop a framework of the ship's navigator performance; and 3) to find a hybrid evaluation method using physiological indices.

Acknowledgments

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