Study on Educational Methods to Enhance Non-technical Skills required for The Officers in charge of a Navigational Watch

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ABSTRACT

In the airline industry, which handles the transportation as the maritime shipping industry does, the importance of non-technical skills as a required competency for airline pilots is recognized, and the education and training to enhance the ability such as situation awareness, decision making, and communication has begun. In the maritime shipping industry as well, Bridge Resource Management (referred to as BRM) competency was included in STCW from the Manila Amendments in 2010 for maintain a safe navigational watch, and it began to be required to educate and train the ability of situation awareness. It is necessary to enhance the ability of situation awareness of the officers in charge of a navigational watch (hereinafter, referred to as OICNW) to avoid collision with other ships.

However, the current education and training for seafarers focused mainly on the requirements for obtaining a mariners license (STCW requirements such as basic knowledge for navigational skills, principles of navigational equipment, specific factors that affect ship maneuvering and so on.), which classified technical skills.

In this study, in order to analyze the correlation between the situation awareness elements of OICNW's non-technical skills and the causes of ship collisions, authors created a situation awareness elements classification sheet on the navigational watch and analyzed which component is correlated to the collisions.

In this paper, authors considered what kind of the education and training should be introduced to enhance the ability of situation awareness required for the OICNW in order to prevent the situation awareness category from leading to the collisions.

Keywords: Collision accidents, Non-technical skills, Situational awareness, Education and Training

1. Introduction

According to the Japan Coast Guard's "Kainan no Genkyo to Taisaku" (2010~2019) (1), the number of the ship collision accidents in the roughly 30 years from 1991 to 2019 has almost halved from 1,214 to 574. Furthermore, the number of collisions (including the number of single-collisions) which remained at the 800 level from 2006 to 2010, has decreased to the 600 level since 2011 as shown in Fig 1. On the other hand, the trend in the number of single-collisions over the 10 years from 2009 to 2019 is almost no change. In other words, it can be seen that the number of collisions with other ships is on the decline.

In addition, more than 90% of the cause of collisions were human error such as inappropriate lookout and non-compliance with COLREGs (Convention on the

International Regulations for Preventing Collisions at Sea, 1972) rules [(2)]. We considered the decreasing trend of collisions was caused by a variety of complex factors, including hardware aspects such as navigation equipments and software aspects such as education and training for the OICNW. The 1978 STCW Convention (The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978) 2010 Manila Amendment was completed enforcement on January 1, 2017, it is necessary to continue to observe the effect of the newly stipulated the competence of BRM (Bridge Resource Management) knowledge and skills, but we believed that further measures to prevent the collisions are to educate and train the OICNW on the software side in the near future.

In this study, we focused on "non-technical skills", which are already being emphasized in the aviation industry (especially airline pilots education and training), and considered a new educational method for the OICNW to avoid collisions.

In 2008, IMO adopted resolution MSC.255(84) on International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code) [(3)], it mentioned important to enhance situational awareness skills, which constitutes non-technical skills in addition to existing crew competence requirements and training (mainly technical skills such as familiarize to the navigational equipment).

For this purpose, we created a sheet to classify the non-technical skills of the OICNW (RADAR range setting based on the situation, maintain the bridge watch level, etc.) based on the collisions, and we analyzed whether or not there is a correlation between collisions and the non-technical skills of the OICNW by using Hayashi’s quantification method-III which is a method of multivariate analysis.

2. Relationship between collisions and non-technical skills

The relationship between the collisions and non-technical skills was indicated from the rules that the OICNW did not comply with COLREGs.

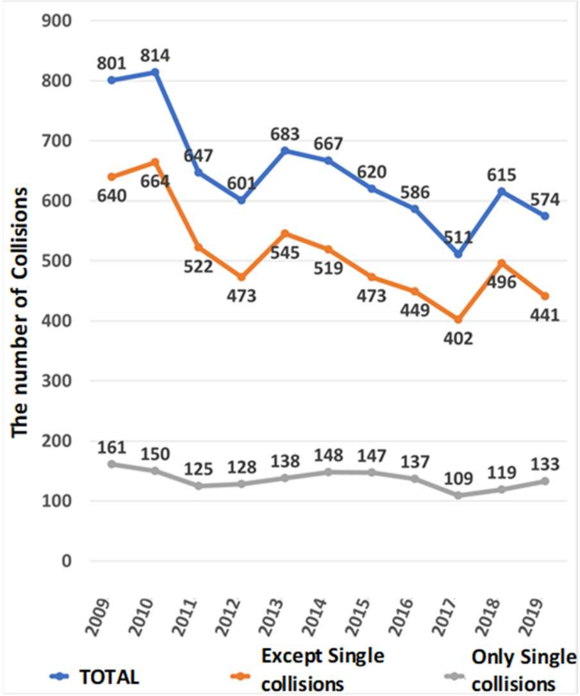

Fig.1 Changes in the Number of Collisions

2.1 Non-technical skills

Non-technical skills is consisted of situational awareness, decision-making, communication, teamwork, leadership, stress management, and control the fatigue [(4)].

According to a precedence study [(5)], situational awareness skills and decision-making skills accounted for more than 60% of the errors in collision avoidance maneuvering by the OICNW.

2.2 Relationship between situational awareness skills and decision-making skills

Minamikawa [(6)] stated that "situational awareness skills" is the most important of the seven categories that is consisted of non-technical skills. Fig. 2 [(6)] shows a flow chart of non-technical skills when ordinary workers act. After workers are aware of the situation and communicating with other workers, the worker makes a decision to act [(6)]. Depend on the situation, there are cases in which the worker makes a decision to act after be aware of the situation without communication [8]. In any case, the worker must be aware of the situation appropriately to act something.

Therefore in this research, we focused on the situation awareness skills of the OICNW as the worker.

2.3 OICNW's situational awareness skills and should follow the rules of COLREGs

As shown in Fig. 3, in a breakdown of non-compliance with the rules of COLREGs applied to collisions [7], rule2(A) "the ordinary practice of seaman's management " accounted for about half of the cases over the past nine years. When a collision cannot be avoided by the general rules of COLREGs, it is left to the OICNW's proper decision making (good seamanship)[8].

Fig. 2 Non-technical skills flow in worker behavior

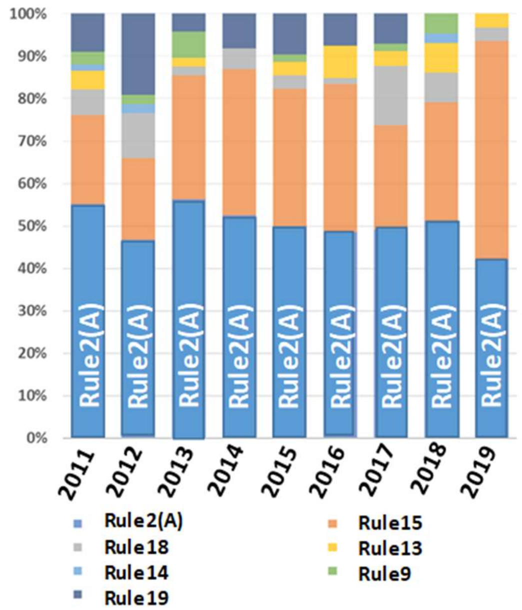

Fig. 3 Rules of COLREGs applied to collisions

3. Analysis of OICNW's situational awareness skills from collision cases

We analyzed the correlation between collisions and the situational awareness skills of the OICNW, using the investigation reports of ship collision cases.

3.1 Create a classification sheet of OICNW's situation awareness skills on navigational watch

Regarding the non-technical skills required for the OICNW on navigational watch, a classification sheet was created by using the marine accident investigation report [9] of the Japan Transport Safety Board. The classification sheet is shown in Table 1.

In this research, we considered "detect other ships" is the most important situational awareness skills, because the OICNW cannot avoid collisions unless detect other ships at first.

Table 1 Classification sheet

Detection of the other ships

Distance to ships		RADAR range	
DA1	<1NM	RA1	S/B<1NM
DA2	1NM<3NM	RA2	1NM<3NM
DA3	3NM<6NM	RA3	3NM<6NM
DA4	6NM<12NM	RA4	6NM<12NM
DA5	12NM<	RA5	12NM<
DA6	Never detected	RA6	Unknown

Way of the detection

EA1	by AIS data
EA2	by RADAR
EA3	by naked eyes including binoculars
EA4	by light signals from the other ships
EA5	by the blast from the other ships
EA6	by VHF calling from the other ships

Watch Level

WA1	Single OICNW
WA2	OICNW and helmsman
WA3	Captainm, watch officer and helmsman
WA4	PILOT, watch officer and helmsman
WA5	PILOT, captain, watch officer and helmsman
WA6	Unknown

Gross tonnage(M/T)

G01	0～19
G02	20～499
G03	500～999
G04	1000～2999
G05	3000～9999
G06	10000～19999
G07	20000～

3.2 Analysis method

Using the created classification sheet, 85 ships (except jet ski bikes) were analyzed from collision cases classified as serious marine accidents in the Marine Accident Investigation Report [9] of the Japan Transport Safety Board. For the analysis, we first investigated the number of hits in each category on the classification sheet, and then examined the correlation of each category using Hayashi's quantification method-III, which is a method of multivariate analysis. The reason for using Hayashi's quantification method-III is suitable for deriving strong correlation category groups [10] [11] by rearranging samples and categories so that the correlation is maximized correlation as shown in Fig. 4.

	DA1	DA2	DA3	DA4
A	0	1	0	1
B	1	0	1	0
C	0	0	1	1

	DA1	DA3	DA4	DA2
B	1	1	0	0
C	0	1	1	0
A	0	0	1	1

Fig. 4 Basic concept of Hayashi's quantification method-III

3.3 Number of categories

As a result of the analysis, Fig. 5 shows the number of applicable cases of each category of the classification sheet in a bar graph. If could not be clarified due to the sunk a ship, the category other than the "G" was not classified. Also, the number of total for each category and the number of analyzed ships are different because the number of total for each category is not included cases that can be clearly classified. The features of each category are as follows.

(1) Distance of detected the other ships

The maximum of 28 ships in which other ships were detected less than 1NM (nautical miles). After that, there are 15 cases for 1~3NM, and 14cases for 3~6NM continues. Therefore, the distance of detected other ships in collisions was overwhelmingly less than 6NM in 57 cases.

(2) RADAR range

The RADAR range when the other ships were detected, was the maximum of 19 ships used in 3~6NM. On the other hand, 6~12NM are 17 cases and less than 1NM are 15 ships, that are almost the same cases. It was often in collisions when the other ships were detected while using the RADAR range with 0 to 12 NM, but there were relatively few cases where collision marine accidents occurred during use in a long range of 12NM or more.

(3) Way of detected the other ships

The maximum of 43 ships by visually including the use of binoculars, were counted for the way of detected the other ships. In addition, there are 18 ships by detected on the RADAR. In collisions, there were many cases of detected other ships by visually.

(4) Watch Level

When the other ships were detected in collisions, there are 36 ships in which a single person (double as a lookout and a helmsman) on navigational watch.

(5) Gross tonnage of own ship

27 ships are small ships under 20 tons, but it was distributed as follow 3000-9999 tons (17 ships), 20-499 tons (15 ships), and 1000-2999 tons (12 ships). It covered less than 10,000 tons which is the size of a typical Japanese coastal ship.

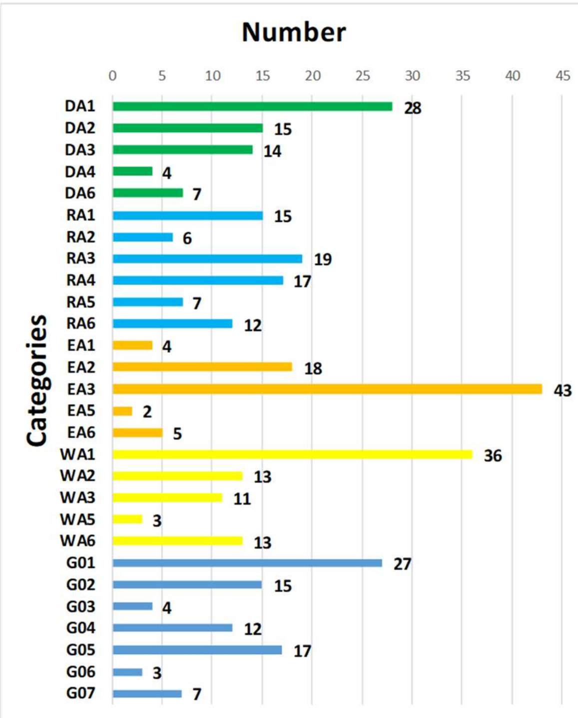

Fig. 5 Number of cases in each category of the ship OICNW's situational awareness classification sheet

3.4 Results

Each category on the classification sheet was analyzed by Hayashi's quantification method-III, and the results of the category plots shown on the X and Y axles are shown in Fig. 6-8. Categories not in the plot had no applicable cases. Analysis by quantification type III is an analysis method that creates a relational expression that give the weights the categories to be analyzed and calculates the score of the sample (sample score) using this relational expression [10]. The weight of a category is called a category score, and the correlation between categories can be grasped by using the category score [10]. Category scores can be interpreted by axles, the number of axles is the total number of categories minus the number of items. Generally, 2-3 axles are selected for analysis when there are many axles [10]. By showing categories with strong correlation for each axis in close proximity on the category plot, it is possible to visually grasp groups of categories with strong correlation.

(1) Correlation group A（DA1・RA1・WA1・EA5・G01）

The correlation between DA1, RA1, and WA1, which are overlapped on all of A to A'' in Fig. 6 to 8, is strong. EA5 and G01, which are overlapped on A and A', are also considered to be correlated. Details of each category are as follows.

DA1：Detected distance, less than 1NM.
RA1：RADAR range, S/B state to less than 1NM.
WA1：Watch Level, a single OICNW.
EA5：Way of detected, hearing(blast from the other ships)
G01：Gross tonnage of own ship, 0～19 tons.

(2) Correlation group B(DA3・EA2・WA2・G05)

There is a strong correlation between DA3, EA2, and G05, which are overlapped on all of B to B'' in Fig. 6 to 8. In addition, WA2 is overlapped on B and B", and it is considered that there is a correlation. Details of each category are as follows.

DA3：Detected distance、more than 3NM less than 6NM.
EA2：Way of detected, visually by using RADAR.
WA2: Watch Level, OICNW and helmsman.
G05：Gross tonnage of own ship, 3000～9999 tons.

(3) Correlation group C(DA6・RA5)

Although there are no overlap categories on all of C to C'' in Fig. 6 to 8, it is considered that there is a correlation between DA6 and RA5 which are overlapped on C and C''. Details of each category are as follows.

DA6：Never detected until collisions.
RA5：RADAR range setting distance, more than 12NM.

(4) Correlation group D(DA4・G07・WA5)

In addition to WA5 which is overlapped on all of D to D″ in Fig. 6 to 8, DA4, G07, and WA5 are overlapped between D and D″ and we considered to have a correlation. Details of each category are as follows.

DA4：Detected distance、more than 6~ 12NM.
G07：Gross tonnage of own ship, more than 20000 tons.
WA5：Watch Level, PILOT, Captain, Watch officer and helmsman.

(5) Correlation group E(RA2・RA4・EA3・G02・G03)

There are no overlap categories in E to E" in Fig. 6 to 8, but RA2, EA3, and G03 on E and E', RA4 on E' and E", and G02 on E and E" overlap and It is thought that there is a correlation. Details of each category are as follows.

RA2：RADAR range, more than 1~3NM.
RA4：RADAR range, more than 6~12NM.
EA3：Way of detected, visually including the use of binoculars.
G02：Gross tonnage of own ship, 20～499 tons.
G03：Gross tonnage of own ship, 500～999tons.

4. Discussion

Based on the analysis results obtained in Chapter 3, we considered the correlation between each category of situational awareness, and examined educational method to enhance the situational awareness skills of the OICNW.

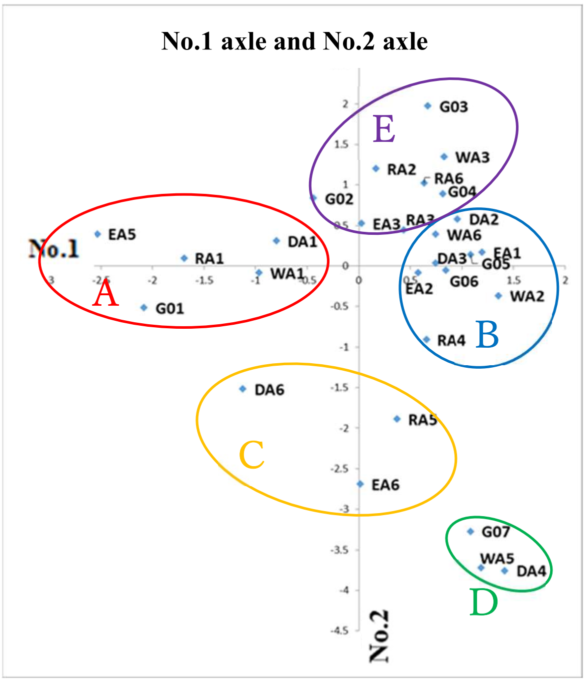

Fig. 6 Category plotting (No.1 axle and No.2 axle)

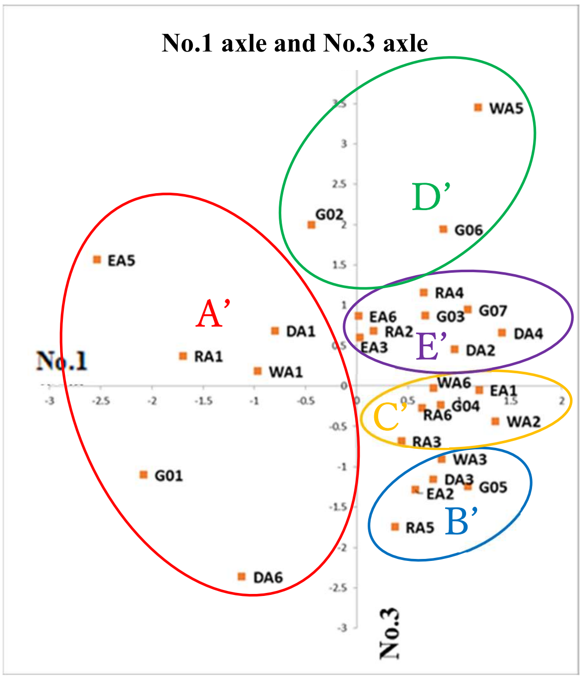

Fig. 7 Category plotting (No.1 axle and No.3 axle)

4.1 Correlation between Situational Awareness Categories

Based on the close category results, the correlation between the categories is considered below.

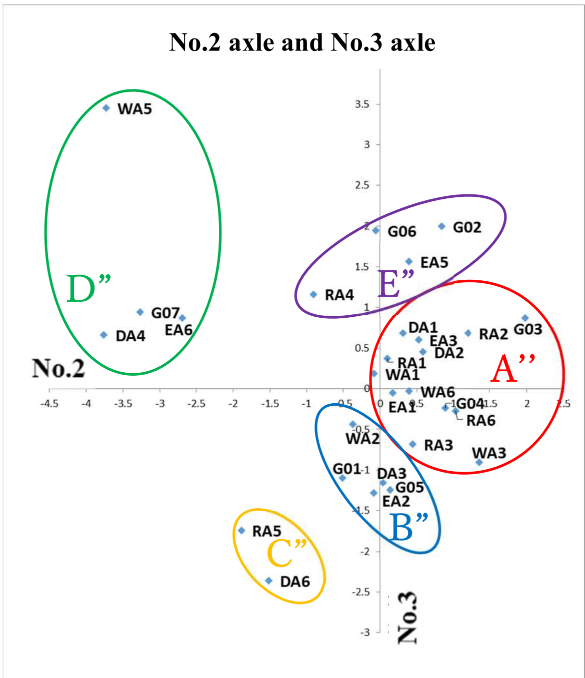

Fig. 8 Category plotting (No.2 axle and No.3 axle)

(1) DA1・RA1・WA1・EA5・G01

Small ships with a gross tonnage of less than 20 tons and operated by a single OICNW are strongly correlated with extremely short-range RADAR settings of less than 1NM in collisions, the detected distance of the other ships is also strongly correlated with the extremely close state of less than 1NM.

(2) DA3・EA2・WA2・G05

Ships with gross tonnage of 3,000 to 9,999 tons that were maneuvered by an OICNW and a helmsman had a strong correlation with detected the other ships by RADAR 3~6 miles in collisions. In other words, the OICNW was in a state of detected the other ships by RADAR even at a short distance of 3~6NM. In addition, when the other ships had been detected, even if a collision was unavoidable, the ship was maneuvered by the OICNW without a master until the collisions. It is possible that the OICNW did not make an appropriate call the master.

(3)DA6・RA5

Ships with a RADAR range of 12NM or more are strongly correlated with never detected the other ships until the collisions. It is possible that the small ship was overlooked on the RADAR because it was fixed at a long range.

(4) DA4・G07・WA5

Ships with a gross tonnage of more than 20,000 tons put a bridge team of pilot, captain watch officer, helmsman in collisions, and the detected distance of the other ships was a strong correlation with 6~12NM. Although other ships have been detected at long distances, they have resulted in collisions. It is thought that the BRM including the pilot, was working well until the other ships were detected.

(5) RA2・RA4・EA3・G02・G03

For general small coastal ships with a gross tonnage from 20 to 999 tons, there were a strong correlation with the RADAR range of 1~3NM or 6~12NM, and detected the other ships by visually in collisions. The detected distance of the other ships was also close to each other with less than 3 miles for DA1 and DA2 as a correlation. In other words, there is a wide range of RADAR range settings, and detected way of the other ships were overemphasized by visually, which means that lookout by RADAR is neglected. In addition, the visually detected distance was less than 3 miles, which is a short distance, so it is possible that binoculars were not used to lookout the collision situations.

4.2 Situational Awareness skills of the OICNW to be Enhanced

The situational awareness skills of the OICNW to be enhanced was considered from the correlation between the situational awareness categories in collisions.

(1)Lookout the situation by proper long range setting of RADAR

If the RADAR range is set to a short range during ocean going or coastal navigations, the detection of the other ships will be delayed. Ships of less than 20 tons are in a state of detected the other ships by the whistle from the other ships, and there is a possibility that proper lookout of the situations using RADAR is neglected. There was also a strong correlation between RADAR range of 1~3NM or 6~12NM and general small coastal class ships from 20 to 999 tons. If the RADAR range is set 1~3NM, it is biased to be aware of the short range and it is necessary to use the long range as well. Even if RADAR range is set to 6~12NM, the detected way of the other ships have a strong correlation with visually, so there is a possibility that lookout the situation using RADAR is neglected. Additional training will be required to use RADAR.

(2) Adaptive change of RADAR range and RADAR settings

Regarding the RADAR range, ships that continue to use the long range of 12NM or more have a strong correlation with the category that never detected the other ships, and when the long RADAR range is fixed, small ships may be overlooked. On the other hand, ships under 20 tons have a strong correlation with the RADAR ranges of less than 1NM, it is unable to detect the other ships earlier due to did not use the long range RADAR range. Ships with a gross tonnage from 3,000 to 9,999 tons also have a strong correlation with detected short distances such as 3~6NM, despite the strong correlation with detected way of the other ships by RADAR. It should try to switch RADAR range settings to long range so that it can be detected them from a longer distance. In any case, it is important to have the skills to change the range appropriately and be aware of the situation. The detection of the other ships by RADAR is not almighty, there is a high possibility that small ships and fishing gear will be overlooked unless the set values of GAIN, SEA, RAIN, range, etc. are appropriately changed according to the navigation environment,

(3) Visual lookout for the other ships not too much relying on RADAR

The skills to detect the other ships visually (including the use of binoculars) are as important as changing the RADAR range accordingly. For general small coastal ships from 20 to 999 tons, the way of detected the other ships in collisions were highly correlated with visually, while the distance of detected the other ships were highly correlated 3 NM. It is possible that they did not lookout their situation with binoculars. Ships with gross tonnage from 3,000 to 9,999 tons, the way of detected the other ships is strongly correlated with RADAR, but the detected distance is correlated with 3~6NM, so it cannot be said that early detection at a long distance. In unrestricted visibility situations, even small ships such as fishing boats can be visually seen from more than 6 miles away. It is thought that more education and training will be needed to lookout the situations using not only the naked eye but also binoculars.

(4) Make earlier call the master

In the case of a collisions, when a bridge team is put, it can be detected earlier the other ships than when there is only one OICNW, by comparison the correlation between (1) WA1 and DA1, and (4) WA5 and DA4, in Chapter 3 3.4. Of the WA1 total 36 ships with only one OICNW who also serves as lookout and steering, 23 were operated by the master and 13 were operated by watch officers other than the master. In addition, 13 ships were involved in collisions during maneuvering by the OICNW and a helmsman. Of the 85 collisions analyzed, 26 were clearly identifiable when the master was not in command in collisions. Of the 26 ships, the situations where the master should command are a total of 16 ships, the maneuvering are 7 ships navigated in narrow waters, 5 ships navigated in congested waters, and 4 ships were in restricted visibility condition. It is conceivable that the collision could have been avoided for the other 10 ships if the master had a command. Therefore, situational awareness skills such as OICNW request the master to command at the bridge (call the master) according to the navigation environment, are also required.

4.3 Educational methods to enhance situational awareness skills for the OICNW

As an educational method for enhance the situational awareness skills of the OICNW based on the previous section, we considered ship maneuvering simulator training using a scenario that adopts the situation in collisions. The outline of the scenario to be implemented in the ship maneuvering simulator was considered as follows.

＜Objects＞

The main aim is to enhance individual situational awareness skills of the OICNW on single navigation watch to appropriately avoid the other ships by recognizing changes in the situations such as navigation environment and detect the other ships at an early stage.

＜Mainly targets＞

Suppose the OICNW of domestic and ocean-going ships.

＜Initial settings of the scenario＞

①Excise area

Coastal navigation is supposed for the excise area of the scenario in order to reproduce the ships traffic congestion.

②Particular of own ship

In principle, the ship should be as close as possible to the gross tonnage and type of ship that the OICNW on board as usual.

③Settings of navigational instruments

Especially for RADAR, the GAIN, SEA, and RAIN adjustment values are set to 0, and the AIS function and TRAIL function are set to OFF.

④Watch level

The scenarios suppose the daytime voyages, the OICNW will be the single navigation watch who also serves as a helmsman. The helmsman is engaged in deck work and is not on the bridge. If the scenarios suppose night voyages, it will be a helmsman on the bridge. Make call the master possible if necessary.

⑤Excise duration

The training duration for one scenario is about 60 minutes.

⑥Visibility

Good visibility of 10 miles or more at the start of the scenario.

⑦Whether and sea condition

At the start of the scenario, the weather is fine and the wind and currents are in a calm state that does not affect the ship maneuverability.

⑧Traffic congestion

About 10 to 15 minutes after the start of the scenarios, do not deploy any ships at risk of collisions.

＜Changes the environment during excises＞

In order to enhance the situational awareness skills of the OICNW, the following situations are changed during the scenario execution.

①Visibility

In order to make the OICNW aware of the importance of always checking the visibility on the voyages, the visibility of 3 miles or less, which is less than the legal luminous range of the side light and hinders the visual judgment of other vessels' movements.

②Whether and sea condition

In order for the OICNW to be aware of the importance of constantly checking for changes in weather and sea conditions, it will be set up situations in which RADAR RAIN adjustment is required due to rainfall settings, and situations in which the ship maneuverability is changed by strong tidal currents.

③Traffic congestion

In order for the OICNW to be aware of the importance of applying appropriate the COLREGs rules, set the traffic situation such as impossible to avoid other ships by general rules of COLREGs. In addition, in order for the OICNW to be aware of the importance of lookout by visually, small fishing boats and fishing gear that are not equipped with AIS and are difficult to detect by RADAR will be placed on the course. Furthermore, in order to be aware of the danger of concentration on a single point, large ships with a risk of collision are placed in the group of fishing boats on the route.

＜Evaluation point＞

Appropriately be aware of changes in the navigation environment, detect other ships as early as possible by suitable way to the navigation environment (detection of targets that cannot detect on the RADAR by visual observation, RADAR settings in restricted visibility, etc.), and be able to monitor the movement of the detected vessel and aware the risk of collisions and necessity of collision avoidance and the ability to make call the master and recall a helmsman to the bridge if necessary.

＜Debriefing＞

A debriefing will be given by the lecturer after the scenario implementation. In the debriefing, in order to reflect on the maneuvering of the ship by the OICNW, the changes in the surrounding navigation environment are reviewed using a third person’s view function. In addition, by playing back video recordings of the actions of the OICNW on the bridge, the OICNW can confirm enhancements in situational awareness skills.

5. Conclusion

In this study, we were able to clarify the situational awareness skills (It is one of the component of non-technical skills) for the OICNW that should be enhanced by analyzing the correlation between the situational awareness skills and the ship collisions.

What is important for maintaining appropriate non-technical skills in navigational watch is to maintain an appropriate navigational watch environment (proper setting navigation instruments, etc.) based on the ship traffic situation. And also, the OICNW should be aware of if the ship traffic situation exceeds the limit of the OICNW's ability. (call the master, etc. if OICNW is not a master). These were widely known as necessary skills for OICNW, but we were able to show them again using collisions data.

We will consider continuously how to enhance non-technical skills based on the results obtained in this analysis.

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