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Comparisons of Seafarers' Perception of Maritime and Onshore Traffic Conditions

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Abstract : *The purpose of this paper is to compare seafarers' behavior according to traffic conditions of a road and an onshore locations. Behaviors are classified into three categories: Skill-, Rule- and knowledge-based mode. Experimental data were collected using the questionnaires for navigators, working in a merchant ship. To compare the behaviors, we used the four analysis method; the degree of frequency, reliability test, correlation and linear regression. As a result of the study, it was found that Skill-based behavior shows more higher in the road traffic than the maritime traffic, and rule-based behavior shows more higher in the maritime traffic than the road traffic. Also, the behavior in the navigation situation showed statistical significance. Especially, in the case of Rule-based behavior, a high correlation between road and maritime was found. This study can be expected to apply to complementary system utilization between error management system of onshore and maritime traffic.*

Key Words : *Human error, Human behavior, Navigator, Correlation analysis, Linear regression*

1. Introduction

About 80 % of marine accidents are reported to be due to human error (KMST, 2018). Research has identified the causes of human errors in terms of social science (Norman, 2013; Reason, 2016). In maritime particularly, human error identification of marine accidents is important (Yim et al., 2014), since identified errors can be corrected through education and training (Yim, 2017a). In addition, it is reported that it is possible to establish a countermeasure for the prevention of human error of seafarers (Park et al., 2019).

Currently, research is underway to prevent, reduce or inhibit human error in various research fields both at home and abroad (Reason, 2016; Chauvin et al., 2008). In particular, research by Norman (1983), which breaks down human errors, has been widely applied (Reason, 1990). In particular, the SRKBB Skill-, rule-, knowledge-based behavior) model proposed by Rasmussen (1983) is widely applied in social science as well as engineering. Widely applied categories in the field of industry are transportation and aviation (Stanton and Salmon 2009; Imbert et al., 2015). These two industries are most actively studied for human error (Embrey, 2005; Stanton and Salmon, 2009). At the same time, research on human error reduction is conducted in the nuclear power plant (Lin et al., 2014), the electric industry (Drivalou and Marmaras, 2009), and the maritime fields (Youn et al., 2019; Yim et al., 2018). The common feature of these research areas is that when an accident occurs, there is a huge economic or casualty damage.

In the field of road traffic, a driver's error management method for improving safety was proposed (Salmon et al., 2010; Petridou and Moustaki, 2000). In recent years, questionnaire-based driver evaluation studies have also identified driver habits and operational skill errors (Shirmohammadi et al., 2019; Banks et al., 2019).

In particular, studies on human error can be divided into human errors and behavioral errors of behavior. Norman (1983) classified the human error into SLMV (Slip, lapse, mistake, and violation), Rasmussen distinguishes errors by behavior using the SRKBB model (Reason, 1990).

In this study, we classified human error caused by the behavior of the navigator into three types. The behavioral errors of the navigator are based on a study of human errors in drivers in road traffic (Reason et al., 1990) and are based on a previous study in maritime traffic (Park et al., 2018). Then, we analyzed two cases where the navigator is in a road environment and a navigation environment.

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The composition of this paper is as follows. In Section 2, we describe how to create a questionnaire and analyze the questionnaire behavior using the research method. In addition, the questionnaire participants were selected. In Section 3, we analysed the frequency of the questionnaire results and verified the reliability of the variables. After that, we analyzed the correlation between the human errors in the road traffic and the human errors in navigation and tested the hypotheses through linear regression analysis. In the last section, the results of the study are summarized.

2. Material and Method

2.1 Development of Questionnaire

The questionnaire for the behavior of the navigator was written in two ways. It included questions related to the error of the behavior that the navigator may cause while driving in road traffic and the error of the behavior that can occur in ship handling. Here, the human error is classified by the SRKBB theory proposed by Rasmussen (1983) and segmented by the SLMV as classified by Reason. In this study, only human errors were excluded from the last stage of violations in SLMV.

The classification of human errors proposed by Reason (1990) is shown in Fig. 1. Human error is divided into slip, lapses, and mistake, slip is divided into skill-based mode, mistake is divided into rule-based mode and knowledge-based mode. At this time, slip includes modes for the maximum of automated actions. A mistake is divided into two parts. The rule is a mode in which conscious and automated behaviors are combined. knowledge is classified into modes that include conscious or perceived behavior in an unfamiliar environment (Reason, 1990).

Skill (S), rule (R), and knowledge (K) modes of human error can be defined according to procedures or decision-making methods (Park et al., 2018), summarized as follows.

S-based behaviors represent sensory behaviors among intentional or unconscious behaviors or activities (Rasmussen, 1983). It is reported that about 70 % of S-based behaviors are the most frequent errors in various studies (Reason et al., 1990). R-based behaviors appear in familiar work situations (Rasmussen, 1982), and represent behaviors controlled by stored rules or procedures by previous experience or by other people's know-how (Rasmussen, 1983). The last K-based behavior appears in unfamiliar situations that have never been experienced or know-how or controllable rules cannot be used (Rasmussen, 1983).

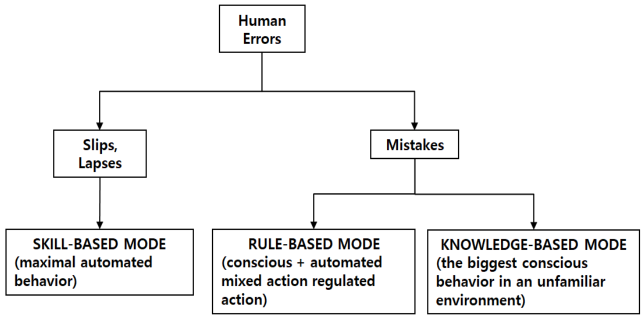

Fig. 1. Classification of Human Errors (Adapted from Reason, 1990).

First in the study of Reason et al. (1990), behaviors that may occur while driving in road traffic were developed by questionnaire to identify driver's errors. In the questionnaire, questions for road traffic were prepared by selecting the applicable questions for domestic roads.

Second, questions about the maritime situation were written using the results of a prior study (Park et al., 2018; Yim, 2017b). For example briefly, S is an action that a sailor who was aboard a ship maneuvers the ship proficiently with manual steering in ordinary situations, or does not need to pay attention, such as manipulating various interfaces. "R" shall include a "port-to-port" in accordance with Convention on the International Regulations for the purposes of collision avoiding at sea when the ship is in a collision encounter with an opponent ship. The final K is an error that is caused by the behavior of the attitude to encounter the unexpected situation, the field reasoning about the unfamiliar situation, and the action to cope with the emergency situation.

As Table 1 shows, the questionnaire was composed of 28 questions. Questions 1 to 17 are questions about improper behavior in road traffic, which is the question used in Reason's study. In this case, the questionnaire should be very simple and should be written in a simple way (Reason et al., 1990). Questions 18 through 24-2 relate to behavioral errors that can occur in navigation situations. The navigation situation is also simplified in the same way as road traffic. The questions were similar to those based on aviation and road traffic. Here, questions 23 and 24 are questions about K. As an adjunctive question, I have written 23-1 and 24-1 to R on K, and the implementation of S on R is 23-2, 24-2 respectively.

Table 1. Questionnaire of navigator behaviors

No.	Based behavior	Questionnaire
1	Skill	Do you often make minor slip?
2	Skill	Have you ever found a key of car even if you own a key of car
3	Skill	Have you forgotten the location of your car in the parking lot?
4	Skill	Have you ever turned on a light instead of wiper?
5	Skill	Have you missed the exit on the highway?
6	Skill	Have you noticed that the driver of the other car flickers after turning on the headlights?
7	Skill	When you turn right, are there any enemies that you have put on your bike or walker?
8	Rule	Have you ever rubbed or bumped your car when you walked through a park or a narrow area in the wrong way?
9	Rule	Have you ever driven a wild animal during a ride?
10	Rule	Have you ever misread your navigation instructions while driving a vehicle and have gone the wrong way?
11	Rule	When raining or snowing, have you ever slipped on your brakes?
12	Rule	When you turn left, is there any possibility of colliding with walker or bicycles?
13	Rule	Have you ever traveled one way (opposite) on the alleyway while driving?
14	Rule	When backing up, have you ever hit something?
15	Knowledge	Do you plan your route incorrectly and have you gone to heavy traffic?
16	Knowledge	When you passed a slow car, did the overtaking lane ever get underway?
17	Knowledge	Have you ever been in the wrong lane or near the road junction at the intersection?
18	Skill	Do you occasionally misidentify the scales on the radar screen as actual scales?
19	Skill	When using Rudder on a regular basis, have you often turned more than the designated heading?
20	Skill	I have experience on when I used Rudder, I like to turn to starboard but I was turned to Port.
21	Rule	In the event of a ship collision, do you follow the procedures that apply to situations you encounter and take actions often?
22	Rule	Did you always navigate in the traffic separate scheme or coastal route along the coast of the ship?
23	Knowledge	If the weather changes to sudden terrors, have you set up a sudden plan?
23-1	Rule	If so, did those plans contain rules or procedures?
23-2	Skill	Did the operation of the radar or the expedition work properly when reflecting the procedure?
24	Knowledge	Have you ever set a sudden plan when you meet a number of fishing boats?
24-1	Rule	If so, did those plans contain rules or procedures?
24-2	Skill	Did the operation of the radar or the expedition work properly when reflecting the procedure?

2.2 Result Analysis of Method

Since the answers to the questionnaire were 'Yes' and 'No', the frequency analysis was performed first and the consistency of the variables was tested through the reliability test. After the test, we analyzed the correlation between variables using correlation analysis, and linear regression analysis to test hypotheses (Lee, 2012).

Frequency analysis can easily grasp the distribution of the basic data in order to understand the characteristics of the collected data. However, since we can not confirm the inference or the relationship between the variables, we use correlation analysis. Reliability analysis is called reliability verification or Cronbach alpha verification to see if it is possible to obtain the same measurement value and if the measurement is repeated for the same variable. In a normal paper, reliability is judged at 0.6 or more.

Correlation analysis is a method of analyzing the linear relationship between two variables. The Pearson correlation coefficient was used for the correlation analysis and the calculation was as shown in equation (1).

$$r = \frac{\sum(x-\overline{x})(y-\overline{y})}{\sqrt{\sum(x-\overline{x})^2 \times \sum(y-\overline{y})^2}} \quad (1)$$

Where, x and y mean the variables. $\overline{x}$ and $\overline{y}$ mean average of the variables. The variables include SRKBB of maritime and onshore traffic.

The general meaning of the correlation coefficient is that when the absolute value of the correlation coefficient is 1.0, it has a perfect linear relationship.

Finally, we conducted a linear regression analysis to check whether the skill, rule, and knowledge of the road have a causal relationship with the behavior of skill, rule, and knowledge of the navigation.

2.3 Participants

Participants in the questionnaire were limited to participants who had sailing experience. The purpose of this study was to analyze the relationship between the behavior of navigators in maritime traffic conditions and human errors onshore. In order to select the target, the ship was boarded in the past or selected those who have been on board so far. Questionnaires participants were selected as having both an officer's license and driver's license. A total of 104 respondents responded to the navigator questionnaire.

The details of participants is shown in Table 2 and were classified into five categories: gender, age, position, seafarer license, and boarding experience.

Table 2. Details of participants

Categories	Details (number)			
Gender	Male (92)		Female (12)	
Age	Mean (36.80)		Standard Deviation (7.80)	
Position	Captain (4)	C/O (36)	2/O (50)	3/O (14)
Seafarer License (degree)	first (8)	second (54)	Third (42)	
Boarding Experience(years)	Less 1 (4)	1-4 (22)	4-8 (56)	More 8 (22)

3. Result and Discussion

3.1 Frequency Calculation Result

The frequency of the questions for the 104 participants is shown in Table 3, and illustrated in Fig. 2, which is classified into the driver and the navigator. The result of frequency was converted to a percentage.

In Fig. 2, the correct behavior of skill- mode showed that the driver is 8 % higher than the driver. Particularly, the correct behavior of rule- mode showed that navigator is 54 % higher than the driver. Also, the correct behavior of knowledge- mode showed that the navigator is 23 % higher than the driver.

Table 3. Results of frequency calculation for the questionnaire of navigator behaviors

#	Cg.	Fr.		#	Cg.	Fr.	
		Yes	No			Yes	No
1	S	29	75	15	K	82	22
2	S	23	81	16	K	31	73
3	S	56	48	17	K	47	57
4	S	19	85	18	S	41	63
5	S	54	50	19	S	25	79
6	S	23	81	20	S	18	86
7	S	36	68	21	R	95	9
8	R	35	71	22	R	89	15
9	R	7	97	23	K	74	30
10	R	82	22	23-1	R	72	32
11	R	34	70	23-2	S	72	32
12	R	28	76	24	K	76	28
13	R	41	63	24-1	R	66	38
14	R	29	75	24-2	S	64	40

#, Serial number of questionaries; CG, Category; Fr., Frequency; S, Skill-based mode; R, Rule-based mode; K, Knowledge-based mode.

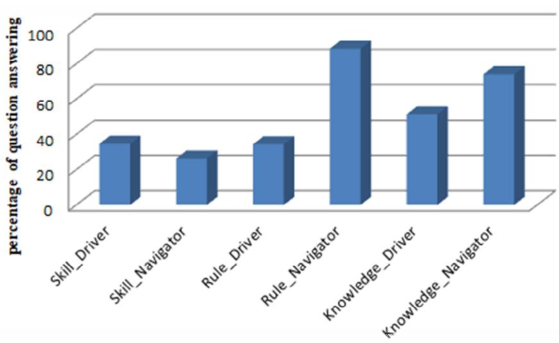

Fig. 2. Results of percentage of questions answered for the driver and navigator with skill, rule- and knowledge -mode.

Fig. 3, 4, and 5 show the frequency of question-answering based on the age, the certificate rank and the year of career, respectively.

In Fig. 3, Skill-mode showed higher differences between the correct behaviors of the driver and the navigator. In Fig. 4, the captain is higher the correct behavior in all cases knowledge-mode, but, the chief officer and the second officer are similar to each other. In Fig. 5, the year of career less than one year showed higher differences than the other factors.

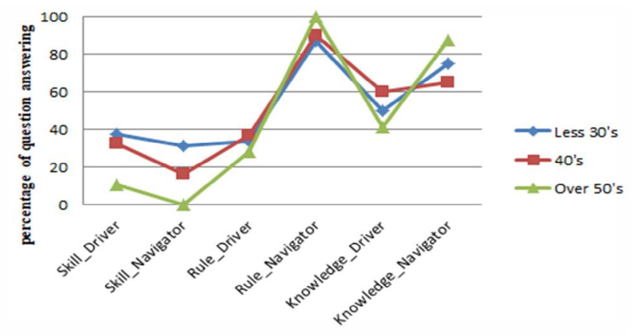

Fig. 3. Percentage of question-answering based on Age.

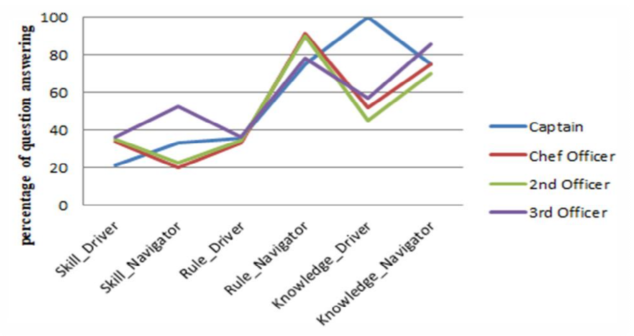

Fig. 4. Percentage of question-answering based on Rank.

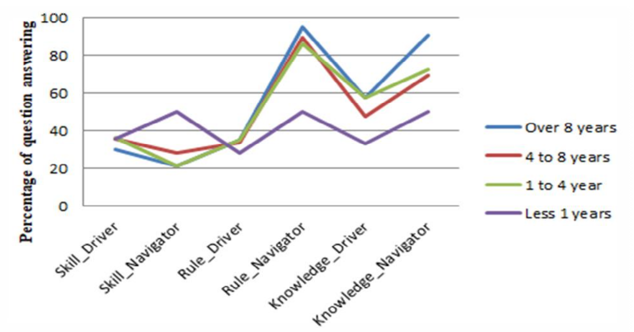

Fig. 5. Percentage of question-answering based on Career.

3.2 Result of Reliability Test

The results of the reliability test are shown in Table 4. First, when looking at the skill behavior of the road, the reliability value is low as 0.670. Next, the rule of the road shows reliability of 0.730, and the knowledge of the road has reliability of 0.689. In the following, the skill of the direction shows the reliability of 0.741 and the reliability of the rule toward 0.747. Finally, the knowledge of navigation is very reliable with a reliability value of 0.977. As a result, there was a difference in reliability in the six variables but it was used as a variable because reliability was recognized.

Table 4. Result of reliability test

Variables	Number of Questions	Cronbach`s Alpha
Skill_ Driver	7	.670
Rule_ Driver	7	.730
K_Driver	3	.689
Skill_Navigator	5	.741
Rule_Navigator	4	.747
K_Navigator	2	.977

K, Knowledge

3.3 Result of Correlation Analysis

Pearson correlation analysis was performed to analyze the correlation of the results. We distinguished onshore traffic and maritime traffic conditions for each of the three behaviors.

Table 5 shows the results of correlation analysis between SRK-based behavior at road and navigation situation. When we look at the road skill and road rules, the correlation coefficient is 0.545, showing a statistically significant positive correlation. When we look at the road rules and road knowledge, the correlation coefficient is 0.482, showing a statistically significant positive correlation.

The correlation coefficient is 0.653, which shows a statistically significant positive correlation in the skill of the navigation and rule of the navigation. The correlation coefficient was 0.539, indicating a statistically significant positive correlation in the skill and the knowledge of the navigation. A correlation coefficient is 0.810 in the knowledge and rule of navigation, showing a statistically strong significant positive correlation.

Table 5. Result of correlation analysis between driver and navigators of skill, rule and knowledge based error

	Skill_ Driver	Rule_ Driver	K_ Driver	Skill_ Navigator	Rule_ Navigator	K_ Navigator
Skill_ Driver	1					
Rule_ Driver	.545**	1				
K_Driver	.287*	.482**	1			
Skill_ Navigator	.235	.236	.139	1		
Rule_ Navigator	.327*	.352*	.163	.653**	1	
K_ Navigator	.289*	.249	.188	.539**	.810**	1

K, Knowledge, *p<0.05, **p<0.01

3.4 Result of Linear Regression Analysis

Linear regression analysis was performed to verify three hypotheses. First, it was to check whether the road skill affects navigation skill. Second, to see whether the road rules affect the rule of the navigation. And finally, whether road knowledge affects navigation knowledge. The results of the three analyzes are close to Durbin-Watson's result to 2. Therefore, there is no abnormality in the variable. In regression analysis, this means the total rate of change of dependent variables can be explained by variable factors such as the coefficient of determination. Explanatory power appeared to be normal. The significance level is 0.05 (95 %). If the value is higher than 0.05, it is not significant. If it is lower, it is meaningful.

First, Table 6 shows the results of the linear regression analysis to see whether the road skill affects navigation skill. Road skill showed a the value of the non-standardized beta of 0.283. The test statistic shows that the t-value is 1.708 and the significance probability is 0.094, which is not statistically significant.

Table 6. Result of linear regression analysis of road skill and navigation

	Skill_Navigator						
IV	B	Std. Err	Beta	t	p	DW	R^2
(constants)	.699	.063		11.014	.000		
Skill_Road	.283	.166	.235	1.708	.094	1.953	.055

*p<0.05, **p<0.01, DW: Durbin-Watson, IV: Independent Variables

Second, the results of the linear regression analysis are shown in Table 7 to see whether road rules affect the rule of navigation. Road rules showed 0.485 as the value of the non-standardized beta. The test statistic shows that the t-value is 2.662 and the significance probability is 0.010, which is statistically significant. Since the value of the non-standardized beta (B) is 0.485, the rule increased by 0.485 when the road rule is increased by 1 unit.

Table 7. Result of linear regression analysis of road rules and navigation

	Rule_Navigator						
IV	B	Std. Err	Beta	t	p	DW	R^2
(constants)	.364	.072		5.079	.000		
Rule_Road	.485	.182	.352	2.662	.010**	2.012	.124

*p<0.05, **p<0.01, DW: Durbin-Watson, IV: Independent Variables

Third, the results of linear regression analysis are shown in Table 8 to see whether road knowledge affects navigation knowledge. In road knowledge, the value of the non-standardized beta was 0.275. The test statistic shows that the t-value is 1.354 and the significance probability is 0.182, which is not statistically significant.

Table 8. Result of linear regression analysis of road knowledge and navigation

	Knowledge_Navigator						
IV	B	Std. Err	Beta	t	p	DW	R^2
(constants)	.616	.089		6.880	.000		
K_Road	.275	.203	.188	1.354	.182	2.080	.035

*p<0.05, **p<0.01, DW: Durbin-Watson, K: Knowledge, IV: Independent Variables

3.5 Discussion

The outlier in the results of the frequency analysis shows that 54 % of the rule 's behaviors are more correct than those of road traffic in the navigation situation. We interpret that the rules and procedures of ships are different from those of road traffic because they are acquired by education and training at professional institutions compared to the traffic environment. Knowledge is 23 % different, which is the same reason. However, skill means minor mistakes in everyday life, so it is interpreted that the equipment to operate offers a few more mistakes in navigation situations due to environmental problems.

As the reliability test results verified the reliability of the variables, they were used as variables. The results of the correlation analysis showed a statistically significant correlation in the behavior on the road, but a weak correlation except for road rules However all of SRKBB showed a strong correlation in navigation situations. In the linear regression analysis, independence condition was satisfied in all variables, and rule found significance in causality. The results of this analysis show that the behavior of the road rules correlates with the behavior of the navigation rules and also influences causal relationships. However, although road behavior is related to all behaviors, no significant causal relationship was found for navigation behavior.

As a result, the correlation between the onshore traffic and the maritime traffic conditions correlated significantly with the human errors caused by behaviors. However, the causal relationship had only an effect on the rule in linear regression analysis. In order to apply the system developed in road traffic and ship navigation, it is necessary to consider the rule of navigation situation to road traffic systems. In other words, consideration of the rule should take into account further behaviors related to various maritime traffic laws, procedures, and rules.

4. Conclusion

This study analyzed the correlation of human errors that navigators might encounter in road traffic and navigation situation. We have developed questions related to errors caused by behavior that can occur while a navigator is driving in road traffic, and errors caused by behavior that can occur in a ship. The questionnaires were selected and the frequency of the questionnaire responses was analyzed and the consistency of the variables was verified through the reliability test. After the test, the correlation between variables was analyzed using correlation analysis, and linear regression analysis was used to confirm the causal relationship between the two behaviors. The results of the study are summarized as follows.

First, the behavior questionnaire of the navigator was made by a total of 104 persons who had experience of having an officer license and a driving license. The frequency of the question was divided into two situations, onshore traffic, and maritime traffic. Each question was classified as SRKBB.

Second, the results of the frequency analysis of the questionnaire results showed that the skill had more correct behavior than the navigation situation. Rule showed the frequency of more correct behavior due to many differences in navigation conditions. Knowledge also showed the frequency of behaviors that are more correct in navigational situations. The difference of the rule is interpreted as reflecting the characteristics of the navigation environment and that the rules and procedures of the ship were acquired through education and training at the specialized institutes compared to the onshore traffic environment. However, skill is interpreted as making a little more mistakes due to maritime environmental problems.

Third, the reliability test verified the variables, and the correlation analysis results showed statistical significance in the behavior in the navigation situation. The behavior of the road rules correlates with the behavior of the navigation rules, and its analysis affects the result of the linear regression analysis. However, the other behavior on the road correlated with the navigation behavior, but no significant causal relationship was found.

As a result, the navigator behavior confirmed to be related to the rule of the navigation situation and to affect the rule in the road traffic. Therefore, in order to apply the system to the ship navigation in road traffic, further consideration of rules and procedures is required for the rule of navigation conditions. The results of this study suggest that the system that manages the errors of road traffic should be considered when applying the system to ship navigation. When studying human error of the maritime fields it is expected that various systems can be utilized in ship navigation as well.

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