Body sway affects visual attention while viewing a ship navigation simulation video

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Master's Thesis

BODY SWAY AFFECTS VISUAL ATTENTION WHILE VIEWING A SHIP NAVIGATION SIMULATION VIDEO

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CONTENTS

Abstract

Introduction 1

General Method 5

Participants 5

Stimuli and Apparatus 6

Procedure 9

Experiment 1 11

Results 11

RT. 11

RO. 13

Discussion 15

Experiment 2 16

Results 16

RT. 16

RO. 18

Discussion 19

General Discussion 21

References 25

Acknowledgements 28

Abstract

Objective: This study examined how two factors (vibration and multitasking) of ship navigation degrade visual attention.

Background: Twenty-one percent of maritime accidents that occurred from 2010 to 2014 were categorized as being due to oversight, which is the most common cause of ship accidents. We speculated that factors of ship navigation might affect visual attention, which might be a cause of this oversight.

Method: In Experiments 1 and 2, 11 and 20 participants, respectively, viewed a ship-navigation video for 1 minute and performed two tasks: one to detect a small target as quickly as possible, presented 0.3 seconds, in the video and the other to perform mental calculations while doing the same detection task. In Experiment 1, the chair was always stationary. In Experiment 2, the chair was animated to simulate the pitch and roll motion of the ship to induce body sway. Reaction time (RT) to the target, and rate of oversight (RO) were indexes of visual attention.

Results: In Experiment 1, the tasks affected RT, but not RO. In Experiment 2, the effect diminishes in RT; however, it appeared in RO. Furthermore, pitch and roll affected RT, but not RO.

Conclusion: The results suggest that visual attention can be degraded by the tasks and simulated ship motion (or body sway), and the degree of the degradation differs depending on its indexes.

Application: Research into the degradation of visual attention contributes to the construction of assistant systems to prevent the degradation and to the reduction of future shipping accidents.

Keywords: Cognitive psychology, vibration, visual attention, ship navigation, reaction time.

INTRODUCTION

Every year, the Japan Coast Guard reports the number of shipping accidents (Japan Coast Guard, 2014) and classifies causes that might have led to the accidents ("Present Situation," 2014). According to the Japan Coast Guard (2014), there were 7,783 small-ship accidents from 2010–2014 and the number accounted for 86 % of the total accidents (9,058), which were required to rescue. [The small ships in Japan are generally referred to as pleasure boats, sports fishing boats, and fishing boats that weigh less than 20 tons ("Expansion of The Scope of Small Ships," 2003).] Furthermore, according to the report *Present Situation* (2014), 76 % of the total shipping accidents (11,658) from 2010–2014 were thought to be caused by human error, where oversight (21 %, 2,479) was reported as the most common cause (see Figure 1). (The total number reported in *Present Situation* is larger than that reported in Japan Coast Guard because it includes ship accidents that were not requires to rescue.)

These statistics indicate that most shipping accidents occurred in small ships and oversight was the most common cause of the accidents. Accordingly, to effectively prevent these accidents from occurring again, it is necessary to study oversight, taking into account the properties of small ships. In this study, we focused on visual attention, which plays an important role in oversight (e.g., Chun & Marois, 2002; Simons, 2000). Visual attention is usually assumed an internal process that involves detecting objects and recognizing their features (e.g., Goldstein, 2002), and is modulated by conditions or tasks, which increase mental workload (e.g., Collet, Guillot & Petit, 2010; Ho & Spence, 2005). If visual attention declines during ship navigation due to some mental workload, the crew may overlook targets they should detect. Therefore, if we understand when or how the sensitivity of visual attention declines, it is possible to take effective action to reduce the risk of accidents.

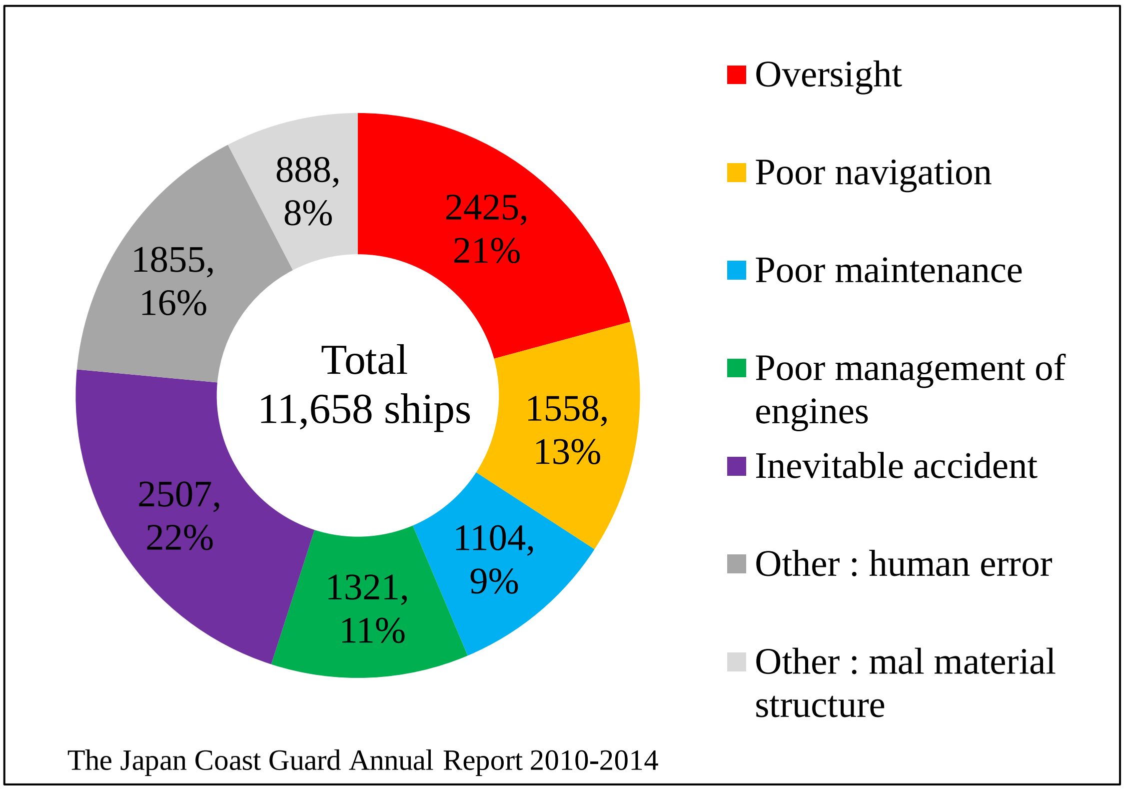

Figure 1. The accumulated number of ship accidents from 2010–2014 classified by determined cause (“Present Situation,” 2014)

In past literature, visual attention has been measured using two indexes: reaction time (RT) and error rate (rate of oversight (RO)). RT is defined as the time between presentation of a sensory stimulus and an associated motor response. It has often been used to examine the attention-allocation efficiency (e.g., in the spatial precueing task) (e.g., Posner, 1980) and in the visual search task (e.g., Eckstein, 2011). RT is thought to reflect a property of efficiency or speed of attention allocation: when the speed increases (decreases), RT is assumed to decrease (increase). RO is defined as the frequency of trials that participants do not respond. It has been used to examine the area properties where attention is directed (e.g., in the change blindness task) (e.g., Simons & Rensink, 2005) and in the inattentional blindness task (e.g., Mack & Rock, 1998). RO is thought to reflect the range of attention: when the range becomes smaller (larger), RO is assumed to increase (decrease). In past literature, visual attention was typically directed at a target in a serial manner, and the visual-field range, where visual attention can be directed, was limited (e.g., Carrasco, 2011). Therefore, to detect targets that appear at various positions in the visual field, which occurs in ship navigation, crews have to shift their visual attention in the whole visual field efficiently. Accordingly, if a task causes the speed of attention shift to be slower, or lowers its efficiency (e.g., Carrasco, 2011), RT will be delayed. Moreover, if a task causes the range of attention to be narrower, RO will increase.

Although the importance of a ship operator’s attention on ship safety has been determined (e.g., Grech, Horberry & Koester, 2008), only one empirical study has examined visual attention during ship navigation (Shimono & Takamine, 2009). Shimono and Takamine examined the RT and RO of a target presented in 2D still and motion pictures that were taken from a small boat moving towards or away from the shore at different speeds. They found that the RT was longer for the motion picture than for the still picture, and RO was higher in the condition where the picture was taken from the boat at a higher speed and going towards the shore. Although these results suggested that picture-image sway affected visual attention, it was not clear whether ship navigation could affect visual attention.

In this study, we selected two factors (vibration and multitasking) as prominent features of ship navigation that may affect visual attention. We examined the effect of these factors on visual attention using two indexes. In ship navigation, a ship operator experiences vibration through the motion of the ship (e.g., pitch, roll, and yaw) and sways his/her body, particularly for a small ship (Januma & Kawashima, 1981). Furthermore, the operator has to perform multitasking increasing mental workload (e.g., navigating ships, looking at a radar screen, and keeping watch). If the vibration and the multitasking degrade visual attention, this can cause an accident.

Although our primary interest was to examine the effect of vibration and multitasking on ship accidents, it would be dangerous and difficult to examine visual attention during “real” ship navigation. Therefore, we conducted two simulation experiments using simulation videos, which were used in the Ship Handling Simulator, and an oscillating device, which performed the roll and pitch motions. [We did not use the yaw motion as an experimental variable for ship motion because the frequency of yaw is much smaller than that of pitch/roll during ship navigation (Kayano, Okamura, Tomiji, Suzuki & Ohtsu, 2010)]. Furthermore, for multitasking, we employed a detection task and a mental calculation task. We expected that mental calculation increase participants’ mental workload (McKnight & McKnight, 1993), which could degrade their visual attention while viewing the simulation video. In Experiments 1 and 2, we examined the effect of multitasking and the effect of vibration, respectively.

GENERAL METHOD

Participants

In Experiments 1 and 2, eleven and twenty students from Tokyo University of Marine Science and Technology (mean age = 22, SD = 2 years; age range = 19–31 years; 25 men and 6 women) participated, respectively. Although one out of eleven students in Experiment 1 and twenty students in Experiment 2 had an experience of sea training for two months in total, at most, in their course of study, they had no experience in operating a ship. In Experiment 2, ten participants were assigned to each of the two ship-motion conditions. All participants had normal hearing and normal or corrected-to-normal vision. They were naive about the purpose of the experiment and provided informed consent prior to taking part in the experiments, which were conducted in accordance with the ethical principles embedded in the Declaration of Helsinki.

Stimuli and Apparatus

Visual stimuli consisted of simulation videos and targets, which were displayed on a screen (VPR-100PB, AURORA) using a projector (VPL-DXL10, Sony). Audio stimuli included two-digit numbers, which were played over a headphone (MDR-IF245R, Sony) and used for mental calculation. Presentation of the visual stimuli and the audio stimuli was controlled by SuperLab 4.5.3 (Cedrus Corporation, San Pedro, CA, USA) on a computer (Prime Galleria XG, Dospara). The screen was positioned 220 cm in front of the participants who sat in a chair. The height of the chair from the floor was 110 cm in Experiment 1 and 105 cm in Experiment 2 (see Figure 2). In Experiment 1, the chair was always stationary. In Experiment 2, the chair was fixed on the oscillation turning table (Horizontal Stabilizing Platform SS series, Cosmate Co., Ltd, Japan), and was stationary or animated sinusoidally with amplitudes of 5 or 10 arcdeg and frequencies of 0.07, 0.10, or 0.20 Hz in pitch and roll motion.

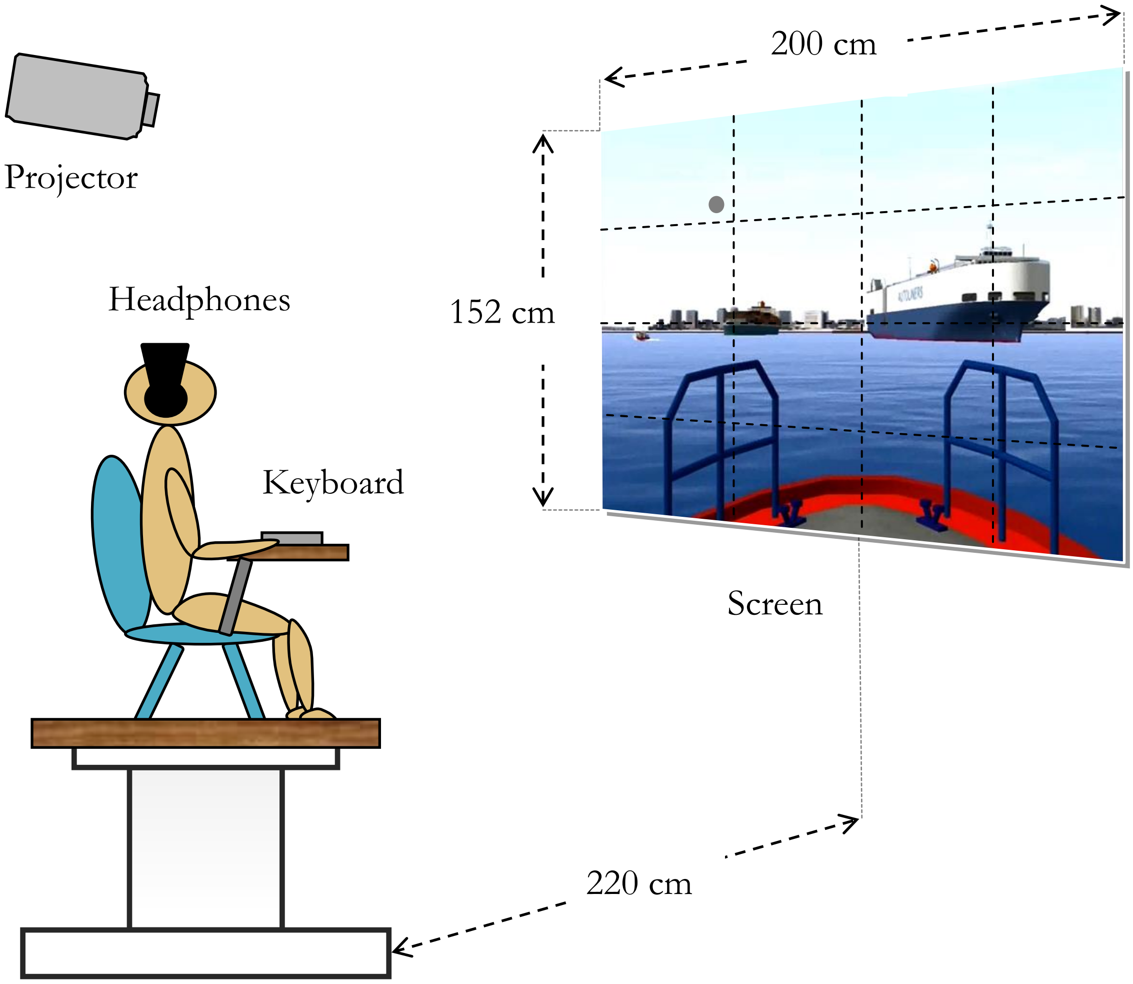

Figure 2. Schematic representation of the setup used in Experiments 1 and 2 (side view). Dotted lines in the screen were imaginary and were depicted to explain how we presented a target (gray small circle) (see text).

There were two different scenes for simulation videos taken from the Ship Handling Simulator (MARIX) using converter capture (DVI2USB Solo, Epiphan): “New York Port” and “Uraga Channel.” The scenes were taken from a rescue vessel of 12 m length that drove at 15 knots under calm and good weather. In each of the scenes in Experiment 1, there were two different traffic-congestion conditions: (1) an uncongested condition with no visible traffic and (2) a congested condition with three ships moving in front of the participants’ vessel. Figure 3 shows examples of still images of the uncongested condition for NY Port and of the congested condition for Uraga Channel. In Experiment 2, only the congested condition was used. In each traffic-congestion condition, the vessel was simulated to go straight to the opposite shore. Participants viewed each of the scenes for 60 seconds (s).

(a) (b)

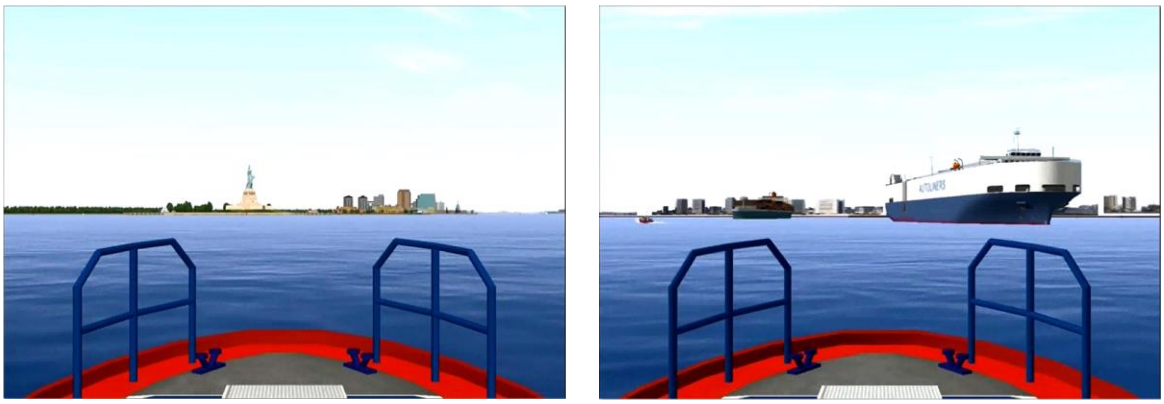

Figure 3. Example of the simulated scenes’ still image (a = NY Port, b = Uraga Channel).

A target consisting of a gray circle (diameter = 3 inches) was presented in each simulation video 16 times for 0.3 s in each presentation at different locations in the videos. The location was preset in an adequate place of one of 16 parts of the video image, which was equally divided as shown in Figure 2. Dotted lines depicted in the figure illustrate how we divided each part of the image, although the lines were imaginary and not seen in the images used in experiments. We inserted the target using a video editor (SEffect 1.53).

Procedure

There were two task conditions: (1) the single-task condition, named the detection task that involved detecting a target as quickly as possible and striking 'n' on the keyboard (Wireless Keyboard K270, Logicool), and (2) the dual-task condition that included an additional layer of difficulty. This entailed completing the detection task while performing mental calculations (i.e., subtracting 5 from a two-digit number and verbalizing the answer). The two-digit number was presented eight times; in six out of the eight presentations, the subtraction included a borrowing calculation, and the other two did not. The two-digit number was made by voice-read software (SoftTalk) and presented every 7.5 s, while the simulation video was presented for 60 s. The presented number was different for each participant and for each simulation video.

In Experiment 1, there were four simulation videos: two for the scene condition (NY and Uraga Channel) and two for the traffic-congestion condition (congested and uncongested conditions). Each simulation video had seven versions that differed in the target preset positions and the timing of the target insertion. We selected two arbitrary versions out of the seven possibilities and made five different pairs: four pairs were randomly used for two participants and the remaining one was determined randomly for three participants. In Experiment 2, there were two simulation videos: one for NY Port and the other for Uraga Channel; only the traffic-congested condition was utilized in Experiment 2. Each simulation video had 14 versions that differed in the target preset positions and the timing of the target insertion.

The experiment consisted of practice and experimental sessions. The participants performed a practice session that was randomly selected from the experimental sessions for each participant. They conducted eight experimental sessions (2 tasks × 2 scenes × 2 traffic-congestions) in Experiment 1 and 28 (2 tasks × 2 scenes × 7 motion combinations) experimental sessions either for the pitch- or roll-motion condition in Experiment 2. The seven motion combinations were the following: two amplitudes of ship motion (5 and 10 arcdeg) and three frequencies (0.07, 0.10, and 0.20 Hz) of motion and one zero motion. The order of the sessions was randomized for each participant. Participants were instructed to have a break at any time between the sessions when they felt tired or sick.

We assessed the participants' RT to the target together with the participants' RO of the target as an index of visual attention. A trial with an incorrect response or no response was regarded as an oversight trial and discarded. An incorrect response was determined as one not made between 0.2 and 1.5 s after the target presentation using an outlier criterion of ± 2 SD or greater. RTs were recorded by SuperLab 4.5.3.

EXPERIMENT 1

Results

RT. A logarithmic transformation was performed on each RT in each trial and condition to homogenize the variances, and the transformed value was used as a basic unit for analyses to follow. We performed a three-way repeated measures ANOVA (2 tasks × 2 scenes × 2 traffic-congestions) on the transformed value. Results of the analysis are shown in Table 1. The main effects of task and scene were statistically significant, while the main effect of traffic-congestion was not.

The significant main effects can be seen in Figure 4, which shows the mean RTs for single and dual tasks with the parameter of scene conditions, separately for congested (left panel) and uncongested conditions (right panel). As seen in each panel, RT was longer in the dual task than in the single task in each traffic-congestion condition. Furthermore, RT was longer in NY Port than in Uraga Channel, except for the uncongested/single-task condition.

As suggested by the exception, there were two-way and three-way significant interactions (see Table 1). These significant interactions can also be seen in Figure 4. The two-way interaction between task and traffic-congestion can be explained by noting that RT was longer in the congested condition than in the uncongested condition in the dual task, while no difference between the two traffic-congestions existed in the single task. The two-way interaction between scene and traffic-congestion can be explained by noting that RT was longer in NY Port than in Uraga Channel in the congested condition while no difference between the two scenes existed in the uncongested condition. The three-way interaction can be explained by noting that RT was longer in NY Port than in Uraga Channel in both the single and dual tasks for the congested condition (see the left panel in Figure 4). Moreover, there was a difference in RT between the two scenes in the single task, but not in the dual task condition for the uncongested condition (see the right panel in Figure 4).

TABLE 1: Main Effects and Interaction of the RTs for Experiment 1

Effect	*df*	*F*	*p*	η^2
Task (T)	1,10	22.028	.001	.266
Scene (S)	1,10	12.987	.005	.020
Traffic condition (TC)	1,10	1.537	.243	.004
T × S	1,10	0.221	.648	.001
T × TC	1,10	5.230	.045	.012
S × TC	1,10	13.031	.005	.045
T × S × TC	1,10	6.103	.033	.015

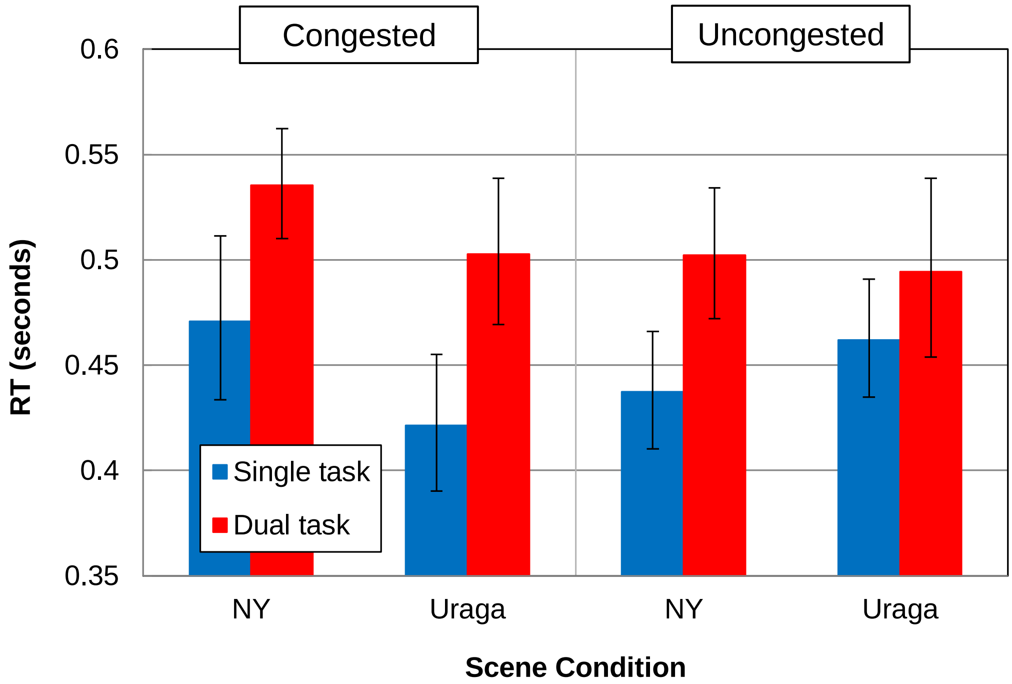

Figure 4. Mean RT as a function of scene and task in Experiment 1. The mean RT for each condition was calculated by averaging the basic unit over 11 participants and transforming the average back by using the equation mean = 10 ^ ($\sum_{n=1}^{11} \log_{10}$ (basic unit)$_n/11$). The vertical lines attached to the bars indicate 95% confidence intervals that were transformed back from those for the basic score.

RO. An arcsine transformation was performed on each RO in each condition to homogenize the variances, and the transformed value was used as a basic unit for analyses to follow. We performed a three-way repeated measures ANOVA (2 tasks × 2 scenes × 2 traffic-congestions) on the transformed value. Results of the analysis showed that the main effect of scene conditions, $F(1, 10) = 9.56$, $p < .05$, $\eta^2 = .06$, was statistically significant, while all other main effects and all interactions were not significant.

The significant main effect can be seen in Figure 5, which shows the mean RO for single and dual tasks with the parameter of scene conditions separately for congested condition (left panel) and uncongested condition (right panel). As seen in Figure 5, the RO was larger in NY Port than in Uraga Channel in each traffic condition.

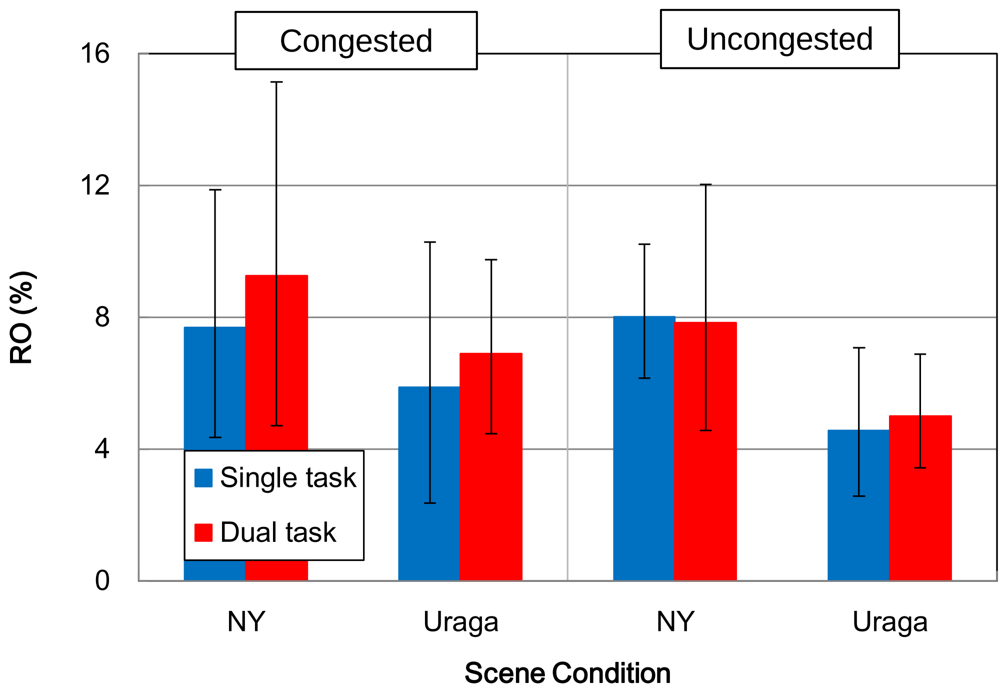

Figure 5. Mean RO as a function of scene and task in Experiment 1. The mean RO for each condition was calculated by averaging the basic unit over 11 participants and transforming the average back by using the equation mean = $(\sum_{n=1}^{11} sin\,(\text{basic unit})_n/11)$. The vertical lines attached to the bars indicate 95% confidence intervals that were transformed back from those for the basic score.

Discussion

Experiment 1 showed that the task condition significantly affected RT, but not RO. Participants reacted more rapidly to the targets in the single task (M = 0.45 s) than in the dual task (M = 0.51 s). The RT result can be explained by assuming that visual attention is allocated to targets more efficiently in the single task than in the dual task. The RO result can be explained by assuming that the spatial range over which attention can be allocated to detect a target was not affected by the task; to avoid overlooking targets the viewer needs to shift his/her visual attention over the whole screen. Taken together, the task condition affects the attention-allocation efficiency, but not the range of the allocation of attention in Experiment 1.

Additionally, Experiment 1 showed that the scene condition affected visual attention on both indexes. Participants reacted more rapidly to the targets in Uraga Channel (M = 0.47 s) than in NY Port (M = 0.49 s), and overlooked the targets more often in NY port (M = 8.2 %) than in Uraga Channel (M = 5.6 %). These differences can be explained in terms of attentional capture by a saliency, task-irrelevant object (Awh, Belopolsky & Theeuwes, 2012). In NY Port, the Statue of Liberty was always placed in the middle of the scene [see Figure 3(a)], where participants' attention might have been focused. On the other hand, in Uraga Channel, there were no conspicuous constructions [see Figure 3(b)]. If focusing the visual attention makes the attention-allocation efficiency increase and the attention-range decrease, the RT and RO should be larger in NY Port than in Uraga Channel.

EXPERIMENT 2

Results

RT. As in Experiment 1, a logarithmic transformation was performed on each RT in each trial and condition, and the transformed value was used as a basic unit for the analyses to follow. Results from the condition where the chair was moved with an amplitude of 10 arcdeg and a frequency of 0.20 Hz were omitted from further data analysis because after the experiment we found that the motion base occasionally did not produce the desired condition. We performed a four-way repeated measures ANOVA with task (2), scene (2), and motion combinations (6) as the within-subjects factors and ship motion (2) as the between-subjects factor on the transformed value. Results of the analysis showed that the main effects of ship motion (pitch and roll), $F(1, 18) = 6.48$, $p < .05$, $\eta^2 = .11$, and scene (NY Port and Uraga Channel), $F(1, 18) = 25.79$, $p < .01$, $\eta^2 = .03$, were statistically significant, while the main effects of task and motion combination were not. The analysis also showed that a two-way interaction between scene and motion combination, $F(5, 90) = 2.6$, $p < .05$, $\eta^2 = .02$, was statistically significant while all other interactions were not.

The significant main effects can be seen in Figure 6, which shows the mean RTs for single and dual tasks with the parameter of scene conditions separately for pitch condition (left panel) and roll condition (right panel). As seen in Figure 6, the mean RT was longer in NY Port than in Uraga Channel for each ship motion, and was larger in the roll condition than in the pitch condition in each scene. Although the two-way interaction between scene and motion combination cannot be seen in Figure 6, a simple main-effects analysis revealed that RT was longer in NY port than in Uraga Channel when the chair was moved with an amplitude of 5 arcdeg and frequencies of 0.10 and 0.20 Hz, $F(1, 108) = 23.97$, $\eta^2 = .03$, and $F(1, 108) = 4.60$, $p < .05$, $\eta^2 = .01$, respectively.

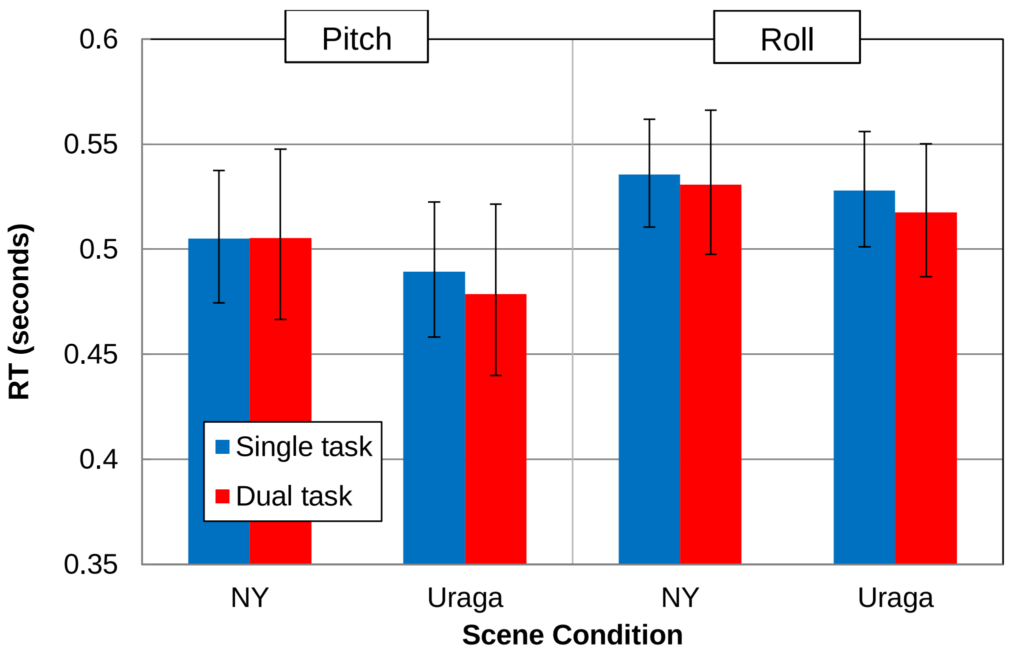

Figure 6. Mean RT as a function of scene and task in Experiment 2. The mean RT for each condition was calculated by averaging the basic unit over 10 participants and transforming the average back by using the equation mean = 10 ^ ($\sum_{n=1}^{10} \log_{10}$ (basic unit)$_n/10$). The vertical lines attached to the bars indicate 95% confidence intervals that were transformed back from those for the basic score.

RO. As in Experiment 1, an arcsine transformation was performed on each RO in each condition, and the transformed value was used as a basic unit for analyses to follow. We performed a four-way repeated measures ANOVA with task (2), scene (2), and motion combinations (6) as the within-subjects factors and ship motion (2) as the between-subjects factor on the transformed value. Results of the analysis showed that the main effect of task, $F(1, 18) = 10.11$, $p < .01$, $\eta^2 = .02$, was statistically significant, while all other main effects were not significant. The analysis also showed that a two-way interaction between task and scene, $F(1, 18) = 5.64$, $p < .05$, $\eta^2 = .01$, was statistically significant while all other interactions were not. The significant main effects can be seen in Figure 7, which shows the mean RO for single and dual tasks with the parameter of scene conditions, separately for pitch condition (left panel) and roll condition (right panel). Moreover, the mean RO was larger in the dual task than in the single task in every condition except for NY Port/pitch condition. The two-way interaction between task and scene can also be seen in Figure 7, in which the mean RO was larger in the dual task than in the single task in both ship-motion conditions for Uraga Channel, but not for NY Port. Furthermore, the single task was larger in NY Port than in Uraga Channel.

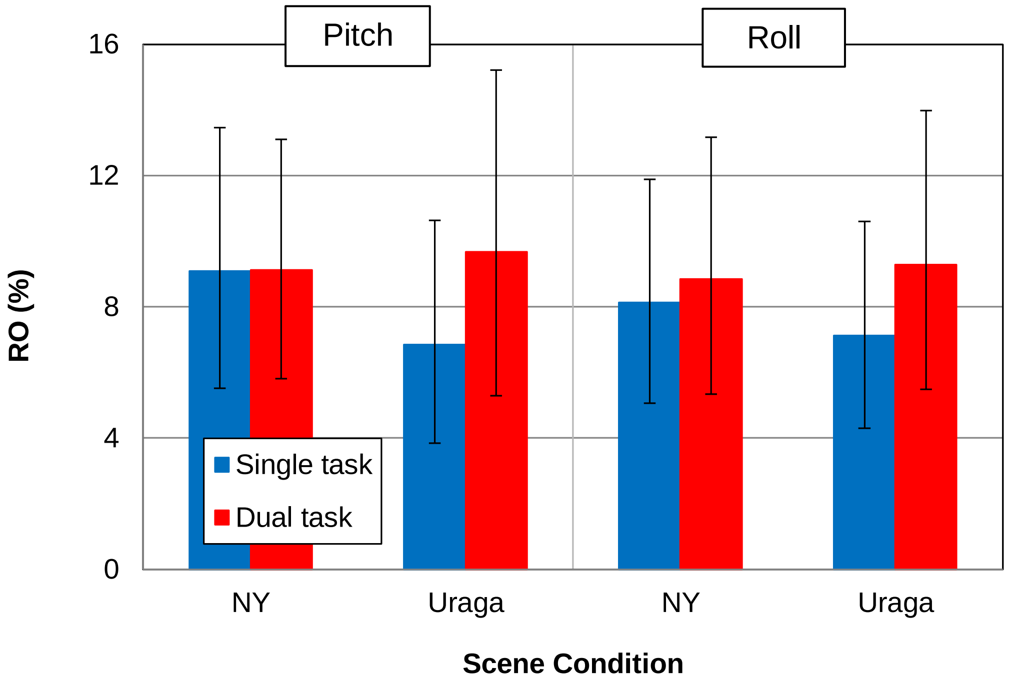

Figure 7. Mean RO as a function of scene and task in Experiment 2. The mean RO for each condition was calculated by averaging the basic unit over 10 participants and transforming the average back by using the equation mean = $(\sum_{n=1}^{10} sin\ (\text{basic unit})_n/10)$. The vertical lines attached to the bars indicate 95% confidence intervals that were transformed back from those for the basic score.

Discussion

Experiment 2 showed that the task significantly affected RO (except for NY Port in the pitch condition), but not RT. Participants overlooked the targets more often in the dual task (M = 9.2 %) than in the single task (M = 7.8 %). The RO result can be explained by assuming that the spatial range of attention is narrower in the dual task than in the single task, suggesting that the ship motion affected the range. The RT results can be explained by assuming that the attention-allocation efficiency is not affected by ship motion. The results of the tasks in Experiment 2 generally indicated that with simulated ship motion, the task affects the range of attention, but not the attention-allocation efficiency, regardless of direction of motion (pitch or roll).

Additionally, Experiment 2 showed that the ship motion conditions affected RT, but not RO. Participants responded more rapidly to the targets in the pitch condition (M = 0.49 s) than in the roll condition (M = 0.53 s). Although it is not clear what caused this difference, we speculate that the difference might be due to the difference of the muscles used for each ship motion, or the difference of stimulation to the vestibular system.

Furthermore, the scene condition affected the RT for two conditions while it did not affect RO. When the chair was moved with an amplitude of 5 arcdeg, the RT in Uraga Channel (M = 0.51 s) was faster than it was for NY Port (M = 0.53 s) for the 0.10 Hz frequency condition. In addition, the RT in Uraga Channel (M = 0.49 s) was faster than it was for NY Port (M = 0.53 s) for the 0.20 Hz frequency condition. We do not have a clear explanation for this effect.

GENERAL DISCUSSION

We examined how task and simulated ship motion affected visual attention using two indexes (RT and RO) while viewing a ship-navigation simulation video in two experiments. In each experiment, participants performed two tasks: the single task, involved detecting a target presented in the video as quickly as possible, and the dual-task, involved carrying out the detection task while performing mental calculations. In general, the results indicated that without ship motion (in Experiment 1), the task affected RT, but not RO (see Figures 4 and 5), while with ship motion (in Experiment 2), the effect of the task diminished in RT, but appeared in RO (see Figures 6 and 7). The results also indicated that while RT was longer in NY Port than in Uraga Channel regardless of ship motion (see Figures 4 and 6), RO depended on whether there was ship motion or not (see Figures 5 and 7). Moreover, without ship motion, RO was larger in NY Port than in Uraga Channel in both the single and dual tasks. Lastly, with ship motion, the scene affected RO only for the single task.

The first results can be understood by assuming that the task affected the attention-allocation efficiency, which is related with RT (e.g., Posner, 1980); however, not the range of attention, which is related with RO (e.g., Simons & Rensink, 2005). In other words, in Experiment 1 and conversely, it affects the range of attention, but not the attention-allocation efficiency in Experiment 2. The difference of the task effects between the two experiments can be due to body sway that may have been induced in Experiment 2, but very little, if any, in Experiment 1. When there is no or very little body sway as in Experiment 1, participants can easily locate themselves spatially and consequently, can shift their visual attention smoothly over the screen. In our dual task, where mental calculation task was added to the detection task, participants maintained their range of attention even when the attention-allocation efficiency was degraded. If this were the case, RT would be longer in the dual task than in the single task, while RO will be the same in both tasks. On the other hand, body sway may hinder participants from locating themselves spatially and from allocating visual attention accurately and precisely, affecting efficiency. When the task becomes difficult, as in the dual task, it would be difficult for participants to keep their range of attention constant, and may allocate their visual attention to a fixed range of the screen to maintain visual stability. If this is the case, RO will be larger in the dual task than in the single task while RT will be the same in both. This explanation is consistent with the fact that RT in the single task increased in Experiment 2 compared to Experiment 1 (see Figures 4 and 6).

The second result can be explained by assuming that induced body sway in Experiment 2 affected the range of attention more for Uraga Channel than for NY Port and did not effectively affect the attention-allocation efficiency. If body sway induced a narrow attention range, as discussed above, RO should increase in both NY Port and Uraga

Channel in Experiment 2. The increase might cause the disappearance of the RO effect if the narrowed range were similar for either scene. The fact that the scene affected RT similarly in Experiments 1 and 2 suggests that the attention-allocation efficiency worked similarly for NY Port and Uraga Channel.

Importantly, there was one condition where the task did not yield the same results. In the “zero” motion condition, the task had an effect on RT in Experiment 1, but not in Experiment 2. In Experiment 1, the mean RTs for the single and dual tasks were 0.45 and 0.51 s, respectively, and 0.51 and 0.50 s, respectively, for the zero-motion condition in Experiment 2. This result suggests that the effect of the task observed in Experiment 1 disappeared in one of the conditions in Experiment 2. This disappearance is referred to as “vestibular adaptation.” In Experiment 2, participants viewed the scenes successively for approximately 30 minutes; consequently, this might have caused the vestibular adaptation. If the adaptation did occur, participants may receive different vestibular information between the two experiments, even for the zero-motion condition.

This study clearly shows that mental workload caused by mental calculation and body sway and induced by simulated ship motion, degraded visual attention while viewing a simulating ship-navigation video. If the degradation is positively related to ship accidents caused by delay of reaction on time or oversight, examining visual attention is important to prevent future disasters. However, it is not clear yet what factors, other than mental workload and body sway, affected visual attention. One of the factors may be the fatigue of the ship's operator. In future studies, we should examine the time course of visual attention degradation for ship navigation scenes that were viewed relatively longer.

Furthermore, if the visual attention of a ship operation is degraded during ship navigation, we can take measures to warn the operator to gain his/her attention. We can find examples of this measure in the literature on car accidents: A number of studies have examined visual attention during driving and suggested that auditory (Ho, Gray & Spence, 2014) and tactile (e.g., Mohebbi, Gray & Tan, 2009) measures can reduce the number of accidents. We can examine the validity of these measures during ship navigation. In conclusion, research into the degradation of visual attention during ship navigation contributes to the construction of assistant systems that prevent this degradation and to the reduction of shipping accidents.

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