Effects of motion sickness on driving tasks

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ABSTRACT

With the introduction of self-driving vehicles, it is assumed that the succession of the driving tasks of the car is carried out between the driver and the automatic operating system. Under such conditions, the driver was induced motion sickness because the driver cannot predict the direction of vehicle travels when the driver does not operate the vehicle. Moreover, previous studies indicated that the cognitive function of the driver is lowered by motion sickness. Therefore, we investigated how the effect of motion sickness on the succession of the driving tasks of the car by conducting two experiments. Our aim in Experiment 1 was to investigate how the strength of motion sickness is affected by combinations of conditions involving two driving operations and two predicting the direction of vehicle travels. In Experiment 2, we investigate how the effect of motion sickness on the succession of the driving tasks of the car. The results of experiment 1 suggested that the seriousness of motion sickness in no driving tasks condition was higher than that in driving tasks condition.

1. INTRODUCTION

Recently, self-driving cars have been developed in various countries in the world, and in Japan, the commercialization of the fully automatic driving car which can run by the automatic driving system in the expressway regardless of the situation is made to be a goal by 2025. As a social expectation by the popularization of the automatic driving car, the following are mentioned: Reduction of the traffic accident and relaxation and resolution of the traffic jam, improvement of the quality of life by the high degree of freedom of action in the car. However, there are some problems in contrast to the expectation by the popularization of the automatic driving car.

First, when a driver who does not need to operate an automatic driving system operates a terminal or reads a book while driving, the direction of travel cannot be predicted and motion sickness may easily occur. Rolnick and Lubow (1991) showed that when 2 persons, a driver and a passenger, got on a rotating chair, the passenger got motion sickness more seriously than the driver. This result suggests that the susceptibility to motion sickness is related to the presence or absence of driving operations during riding.

Griffin and Newman (2004) found that the severity of motion sickness in the rear seat of an automobile is higher in the absence of vision information than in the presence of vision information in the front. And, Feenstra, Bos, and van Gent (2010) clarified that the seriousness of motion sickness lowers by adding prediction information corresponding to the physical motion as a visual clue. These results suggest that the susceptibility to motion sickness is related to the prediction of the direction of travel.

Second, a decrease in the cognitive function of the driver who developed motion sickness may cause traffic accidents due to improper driving and lack of safety confirmation. Matsangas, McCauley, and Becker (2014) found that even mild motion sickness resulted in poor performance in memory search tasks and arithmetic task.

Gresty et al. (2008) also revealed that motion sickness causes a decrease in performance and an increase in reaction time in visual reaction tasks. As de Winter et al. (2014) reported, driving operations in the front-rear, left-right directions and visual recognition of situations performed by vehicle drivers are also cognitive tasks for drivers, so these tasks may also be affected by motion sickness.

Self-driving technology is being implemented in a stepwise fashion to enable level 3 self-driving vehicles, defined by SAE International (2018), to travel on public roads in the near future, passing on driving operations between the driver and the system. Therefore, it is considered that a traffic accident occurs when a driver whose cognitive function is lowered by the onset of motion sickness takes over driving from the automatic driving system. However, this risk has not been discussed at all. Therefore, in this study, we clarify the effect of cognitive decline caused by motion sickness on driving.

The characteristic of the level 3 automatic driving car is that the automatic driving system operates only in the limited area (Roads, Geography, Environment, etc.) and the driver operates in other areas. Therefore, if the situation deviates from the limited area and it becomes impossible to continue the operation by the system (system limit), the automatic operation system takes over the operation to the driver (Takeover). After the takeover, the driver must immediately take charge of all driving tasks. Therefore, the response of the driver to the takeover at the system limit, that is, the time from the start of the takeover request to the system limit (TORlt: Take Over Request Lead Time) has been studied.

Eriksson and Stanton (2017) concluded that TORlt should be more than 7 (sec) from the viewpoint of safe vehicle control. Indeed, in situations where both steering and pedal operations are required at system limits, Gold et al. (2013) suggested that vehicle control by driver's operation approaches the condition of manual operation without takeover when TORlt is 7 (sec). Although the details of the experimental conditions were different, Damböck et al. (2012) suggested that when TORlt is 8 (sec), the vehicle control is equivalent to the condition of manual driving.

Based on the results of the above studies, we measure the driver's response to vehicle control and takeover at the system limit when the driver takes over the operation of the level 3 self-driving vehicle and the system, and clarify the effect of cognitive decline caused by motion sickness on driving.

In this study, we investigate the influence of driving operation and prediction of vehicle behavior on motion sickness in experiment 1. In addition, the effect of motion sickness on the driver's response to takeover at the system limit is examined in the case in which motion sickness develops and in the case in which it does not follow the past research on takeover as experiment 2. However, it is not possible to evaluate only the effect of motion sickness on vehicle control because of the task for the driver of the limit of the system. Therefore, the situation in which the limit of the system does not exist is also set, and the effect of motion sickness on the vehicle control is also examined.

2. METHODS

2.1 Apparatus

We used a driving simulator which was constructed using a head-mounted display (HMD) (HTC VIVE, HTC & Valve Co.) and steering wheel and pedal (LPRC-15000, Logicool) (Figure 1). Kaptein, Theeuwes, and van der Horst (1996) indicated that there was no difference in driving behavior such as route control and speed control, when the driving simulator was compared with the actual road. Therefore, we though that it was possible to examine driving behavior using a VR driving simulator without using an actual car. We installed a chair in front of the steering wheel so that an observer sitting upright had her/his feed touching the pedal.

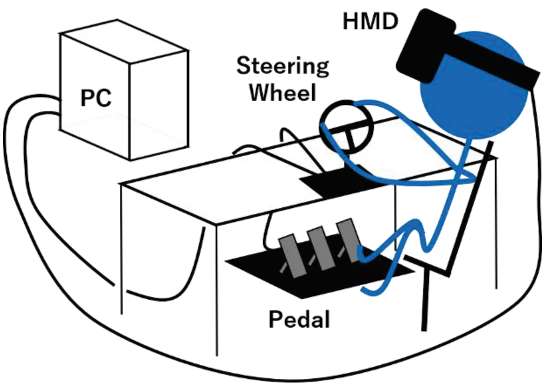

Figure 1. Apparatus

2.2 Stimulus

A visual stimulus that simulated was the trafficway which passenger cars run rendered in real time as a computer-generated image on a Windows-based PC (LITTLEGEAR i330SA4, GTUNE) with Unity (Figure 2). The frafficway was constructed by straight lines, left and right turns, and intersections. In addition, the sign which showed the traveling direction of the automobile was installed in the intersection of the road. The value of the speed of the automobile was presented in the position of the tachometer of the general automobile.

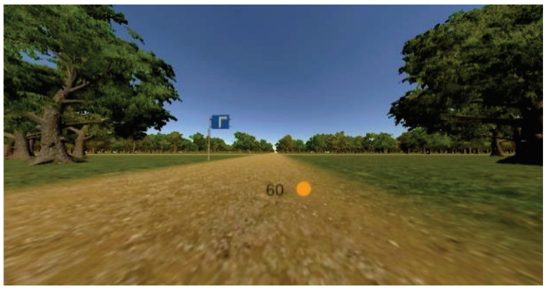

Figure 2. Visual stimulus

2.3 Observers

Five adults (five male; 23.2 ± 0.4years), who had a driver’s license of a standard motor vehicle or more, participated in the study after providing informed written consent, in accordance with the provisions of the Ergonomics Experiment Policy of the Niigata University. The observers were naïve to the purpose of the experiments and had normal or corrected-to-normal visual acuity.

2.4 Experimental Conditions

One trial was conducted with each of the four combinations of two driving operations-Active and Passive-and two predicting behavior of automobile-Predictable and Unpredictable. In Active condition (Ac condition), the visual stimulus was changed when the observer manipulated the steering wheel and pedals. In Passive condition (Pa condition), the visual stimulus was change without the observers manipulating the steering wheel and pedals. In Predictable condition (P condition), the observers can predict the behavior of automobile at intersections by the sign. In Unpredictable condition (U condition), the observers could not predict the behavior of automobile at intersections, because the automobile did not run by the sign.

In experiment 1, the visual stimulus included 21 intersections of the road. In AcU and PaU conditions, the number of times that the automobile run at the intersection of the road as expected by the observers was seven. Moreover, the number of times that the automobile did not run at the intersection of the road as expected by the observers was fourteen,

The route on which the car runs was made to be the same for each condition, and there was no difference between observers.

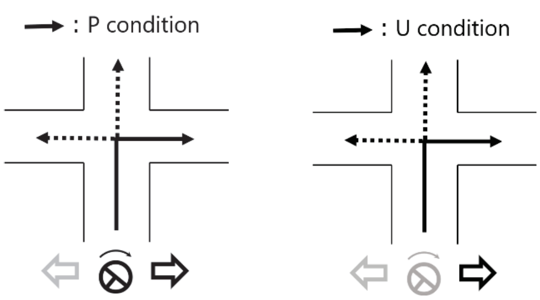

Figure 3. The difference between Predictable and Unpredictable conditions
(a) P condition, (b) U condition

2.5 Procedures

Before starting the experiment, observers are given an explanation of the tasks in the experiment. The observer then viewed the visual stimulus for about 10 minutes. Each trial began by presenting as gray scale image for 30 s, followed by a trafficway image for 10 minutes.

To measure the VIMS strength, we adopted two different subjective measurements: continuous measurements during a trial and a questionnaire before and after a trial. During a trial, whenever the observers experienced VIMS, they continuously indicated the change in VIMS strength using a subjective response box to evaluate it on a five-point scale. On that scale, “0” represented “did not feel anything strange”, “1” represented “feel a slight discomfort”, “2” represented “especially, feel a discomfort for head or sense of existence of stomach”, “3” represented “feel like disgusting”, and “4” represented “feel like disgusting and vomiting”.

Moreover, the observers were asked to complete a SSQ before and after viewing the 20-minute as one of the psychological evaluations. The SSQ questionnaire consisted of 16 questions which were adjusted Japanese translation of previous study [13] and four choices of answers (none, slight, moderate, severe) on VIMS.

Upon completion of these tasks, each observer rested for 30-minute in the quasi-dark room. All the observers participated on five different days, with a trial per day.

3. RESULTS

We conducted a two-way ANOVA for the average of VIMS strength and found that the main effect of each factor was not significant (driving operation: F (1, 16) = 0.72, p = .41; predicting behavior of automobile: F (1, 16) = 0.39, p = .54), while the interaction between two factors was not significant (driving operation × predicting behavior of automobile: F (1, 16) = 0.14, p = .72).

The nausea score of SSQ was affected by the effect of driving operation. However, we conducted a two-way ANOVA for the value of each index of SSQ and found that the main effect of each factor was not significant (Total Score driving operation: F (1, 16) = 1.66, p = .22; Total Score predicting behavior of automobile: F (1, 16) = 0.60, p = .45; Nausea driving operation: F (1, 16) = 3.69, p = .073; Nausea predicting behavior of automobile: F (1, 16) = 0.45, p = .51; Oculomotor driving operation: F (1, 16) = 0.33, p = .58; Oculomotor predicting behavior of automobile: F (1, 16) = 0.57, p = .46; Disorientation driving operation: F (1, 16) = 1.50, p = .24; Disorientation predicting behavior of automobile: F (1, 16) = 0.69, p = .42), while the interaction between two factors was not significant (Total Score driving operation × predicting behavior of automobile: F (1, 16) = 0.27, p = .61; Nausea driving operation × predicting behavior of automobile: F (1, 16) = 0.45, p = .51; Oculomotor driving operation × predicting behavior of automobile: F (1, 16) = 0.11, p = .75; Disorientation driving operation × predicting behavior of automobile: F (1, 16) = 0.25, p = .63).

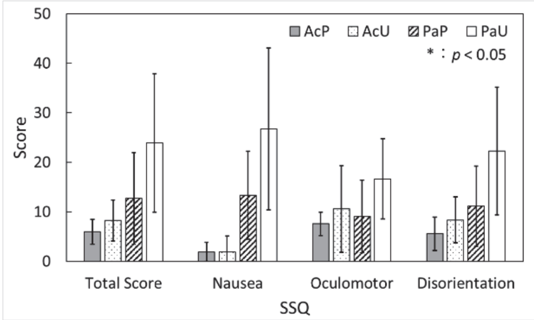

Figure 4. The each index of SSQ score for each condition

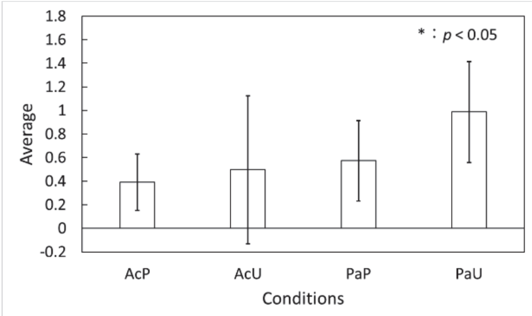

Figure 5. The average of VIMS strength for each condition

4. DISCUSSION

Similar to the results of Rolnick and Lubow (1991), the VIMS strength of Pa condition was higher than that of Ac condition in Experiment 1. On the other hand, the VIMS strength was not affected by predicting behavior of automobile. This result suggested that it is important to provide the observers with information to predict the behavior of the vehicle in order to reduce the VIMS strength. Feenstra, Bos, and van Gent (2010) indicated that the VIMS strength was decreased by contiguous predictive information. However, the observers was only given to the direction of travel at intersection of the road in AcP and PaP conditions. Therefore, there was no difference between P condition and U condition because the observers was not provide the prediction information necessary for reducing the VIMS strength.

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