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Availability of Wave Transducer in Car Onboard System Interface

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ABSTRACT

The accident caused by a pedal mis-application of a passenger car becomes the social problem in Japan. The spread of advanced safety vehicles (ASV) is hurried as a passive safety in late years to reduce and prevent the damage of the accident. However, requiring a certain period of time for the spread of ASV and the valid situations are limited. The problem such as not necessarily working appropriately is pointed out. On the other hand, it is thought that an information presentation system to let a driver recognize danger as the active safety is effective. To effectively operate such an onboard system, a relevant interface is required. The cognitive of the wave transducer interface implemented on the seat is confirmed by an experiment for developing the interface. The difference of the performance between a visual and a transducer, which embedded in both sides of the seat back, interface was investigated. As a result, the difference was not seen between the visual and the vibration. In addition, by the subjective evaluation, the experiment participant felt that both stimulations were recognizable, and the difference was not seen. The experiment was suggested by a laboratory test as one of multi-modal interface by the transducer stimulation to be possible.

Keywords: Car onboard system, Interface design, Wave transducer, Prototyping

INTRODUCTION

In this research, we focus on the interface of Advanced Safety Vehicle, which has been popularized in recent years to prevent traffic accidents. Ministry of Land, Infrastructure, Transport and Tourism Japan has incorporated ASV promotion plan since 1991. It has formulated the concept of driving assistance that considers the practical application of ASV technology and drivers. In addition, technological development of ASV is being carried out with the spread of autonomous driving vehicle. Some of ASV vehicles are those equipped with collision safety brakes that detect obstacles and automatically stop or sensors that automatically keep the following distance from the leading vehicle. Although the on-board AI is highly reliable, it cannot completely prevent accidents. For example, it is difficult to distinguish between intended and unintended acceleration.

There are about 3,800 accidents by the pedal misapplication and nearly 10,000 in the last three years (ITARDA, 2022). Accidents caused by pedal misapplication do not account for a large percentage of all accidents, but in

Japan where the population is aging, they cannot be ignored. In such cases, if the problem of AI imperfection can be compensated for by the user interface, it is thought that the risk of accidents by unintended acceleration can be reduced. So, it is important to give appropriate feedback to the driver through the interface (Schmidt, 1989). We consider the use of vibration stimulation by a wave transducer device in addition to the visual and the sound stimulation used in conventional on-board systems. In this research, the characteristics of stimulation by the wave transducer are clarified by experiments. The experiments used stop-signal task including inhibitory function (Eagle, 2008). The experiment indicated the difference between visual and vibration stimulations.

METHOD OF EXPERIMENT BY STOP-SIGNAL TASK

Accidents involving misapplication of the accelerator and the brake pedal in automobile driving often occur when the driver suddenly accelerates and crashes into a building when starting from a parking lot or when the vehicle moves backward. It should be possible to release the accelerator immediately and depress the brake pedal again, but the driver who cannot perform this simple operation panics and further depresses the accelerator. However, it is difficult to analyse the causes of pedal misapplication and the circumstances in which the pedal misapplication occurs because they are ambiguous.

Therefore, stop-signal task is used in the experiment. The task is used to analyze the situation and behavioral characteristics of stepping errors. The purpose of the task is to inhibit the behavior regulation function that initiates and terminates behavior, and to cause a pseudo stepping mistake (Tsuchida, 2007). In this situation, subjects are given visual and vibration stimuli to measure the driver's discriminating ability. In addition, subjective assessments are used to assess stimuli after the experiment. We investigated the degree of recognition of the stimulus by having the experiment participants fill out a questionnaire about the perception during pedal operation.

Equipment of Experiment

The purpose of this experiment is to investigate the discrimination of visual and vibration stimulation and the drivers' performance to pedal operations (Nakano, 2021). The experiment uses facilities as the driving environment. PC displays images of stimulus and the other PC for a driving simulator (Tsuchiya, 2022). The participants were given a task of driving a car as the main task. The participants are also shown a task of distinguishing left and right presented with images at random intervals. For that purpose, a steering wheel, driver's seat, and pedals are installed to construct a pseudo-driving space. The operation uses two USB foot pedal switches for accelerator and brake. A highway simulator is projected on the screen. The participants were given the main task of driving according to the lane. As a subtask, the red and blue circles are presented as visual stimuli for 3000 milliseconds (ms) illustrated in Figure 1. The participants were instructed to press the right pedal for blue and the left pedal for red. As a vibration stimulus, transducers (Vibro-transducer Vp416 16Ω, Acouve Laboratory) were placed on the left and right sides of the back at positions spaced apart by 23 cm (Okuwa, 2019). A sine wave sound source is transmitted to the transducer from PC through an amplifier for 3000ms. The participants were instructed to press the right pedal when the right transducer vibrated and the left pedal when the left transducer vibrated. As an inhibition, the participants were instructed to press the opposite pedal (left pedal for blue or right transducer, right pedal for red or left transducer) when both color and vibration stimuli were presented with flash on and of every 300ms. Twenty stimuli (ten visual stimuli, five red and five blue, ten vibration stimuli, five right and five left, with one of each five being an inhibition stimulus) are presented per trial. This trial is performed four times per person, so total 80 operations were performed by the participants. The interval between stimuli was random and was set to 8 to 18 second intervals. The participants were given sufficient practice after instructions to become familiar with the equipment before proceeding to the actual trials. After completing the trials, the participants responded to a questionnaire regarding their subjective evaluation of the stimuli used (Table 1). The survey aimed to assess the ease of recognition and the difficulty experienced during driving under the influence of these two types of stimuli.

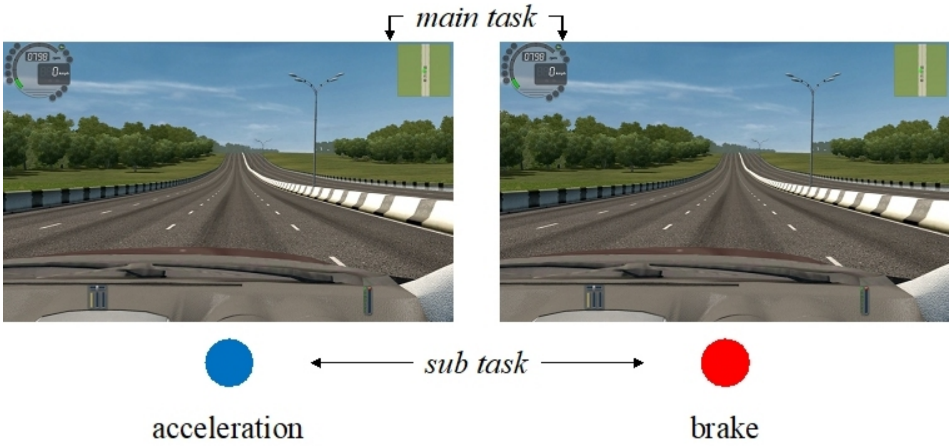

Figure 1: Pattern diagram of main and sub task in experiment.

Table 1. Questionnaires of subjective evaluation to stimulus.

Visual	1	2	3	4	5
1. Did you recognize the visual information sufficiently?					
2. Did you notice the difference in colour between red and blue?					
3. Did you notice the flashing of visual information?					
Vibration	**1**	**2**	**3**	**4**	**5**
4. Could you recognize the vibration information sufficiently?					
5. Could you distinguish between the vibrations on the left and right?					
6. Could you perceive the repetition of the vibrations?					

Research Method

Table 2 shows the stimulus types and the number of occurrences used in the stop-signal task. Based on these conditions, the participants' reaction times and errors were measured. The reaction time was prescribed as from the presentation of visual or vibration stimuli to the pressing of the pedal. From this data, the average value of reaction time was calculated. Subjective evaluations from the participants were also collected and used for the analysis. The participants consisted of 8 university students in their 20s. The possession of a driver's license was not a requirement.

Table 2. Stimulus type and number of occurrence for stop-signal task.

Label of stimulus	Type of stimulus	Inhibition	Pedal	Number of occurrence in one trial
A1	Right vibration	No	Acceleration	4
A2	Blue Circle	No	Acceleration	4
A3	Right vibration	Flash	Brake	1
A4	Blue Circle	Flash	Brake	1
B1	Left vibration	No	Brake	4
B2	Red Circle	No	Brake	4
B3	Left vibration	Flash	Acceleration	1
B4	Red Circle	Flash	Acceleration	1

RESULTS OF STOP-SIGNAL PEDAL DISCRIMINATION TASK

Table 3 shows the average reaction time along with the standard deviation (SD) for the eight patterns of stimulus labels, measured in milliseconds. The number of the occurrence was 640 times (8 participants, 4 trials, 20 stimuli). Among them, the number of correct pedal operation was 631. The number of mis pedaling was 9.

Table 3. Stimulus type and number of occurrence for stop-signal task.

Label of stimulus	Average reaction time (ms)	Standard Deviation	Count of successful operation	Error trial (%)
A1	787	293	126	2 (1.6)
A2	783	312	128	0 (0.0)
A3	812	238	31	1 (3.1)
A4	796	269	32	0 (0.0)
B1	744	252	127	1 (0.8)
B2	716	211	125	3 (2.3)
B3	1014	646	31	1 (3.1)
B4	859	309	31	1 (3.1)
Total	780	307	631	9 (1.4)

We examined the statistical significance of the differences in average reaction time for each attribute. The average reaction times for the visual stimuli and the vibration stimuli were 765ms and 795ms, respectively, and the difference was not statistically significant at the probability level $p < 0.05$

($p = 0.232$) by Welch's t-test. Therefore, we cannot conclude that there is a significant difference in reaction time between the visual stimulus and the vibration stimulus. The differences in reaction time for the involvement of inhibition or not and the pedal positions (accelerator or brake) were 758ms, 870ms and 815ms, 745ms, respectively. Both of differences were statistically significant ($p = 0.004$, $p = 0.004$). The results of the average reaction time did not indicate an advantage of vibration stimuli. However, it was statistically suggested that it is at least an effective means comparable to the visual stimuli. On the other hand, the error rate was 1.4 % over all pedal operations. Since it was very low, we were not unable to make many consideration. There was no significant difference in the error rates in the all attributes (type of the stimulus, the inhibition or the pedal) by Fisher's exact probability test.

Table 4 shows the summary of the subjective evaluations. The ratings for the stimuli were high across the questionnaires. There was not observed between visual and vibration stimuli in these evaluations. Due to the small number of participants, further investigation is required.

Table 4. Results of subjective evaluation, count of responses, in difference of stimulus.

Visual	**1**	**2**	**3**	**4**	**5**	**Average**
Question 1.	0	0	0	1	7	4.9
Question 2.	0	0	0	2	6	4.8
Question 3.	0	0	0	0	8	5.0
Vibration	**1**	**2**	**3**	**4**	**5**	
Question 4.	0	0	0	0	8	5.0
Question 5.	0	0	0	3	5	4.6
Question 6.	0	0	0	0	8	5.0

CONCLUSION

This study focused on the method of information presentation for onboard system to let a driver recognize driving situation. The cognitive of the wave transducer interface was confirmed by the experiment using stop-signal task. The difference of the performance between the visual and the transducer interface was investigated. The stop-signal task was composed with the driving task and the task of pressing the pedal in response to the stimulus. The measures of evaluation for the task were the response time, the number of pedal errors and the subjective evaluations.

From this experiment, there was no statistically significant difference in response time between the visual and the vibration stimuli. As there was a significant difference in response speed due to the variation in the inhibition and the pedal position, it cannot be concluded that the vibration stimuli are inferior to the visual stimuli. There was no significant difference observed between the two stimuli in terms of the error rate. Based on the results of subjective ratings, though the number of participants was limited, the vibration stimuli exhibited performance comparable to the visual stimuli especially in the recognition and the inhibition by the questionnaires. However, there were some responses indicating that it is a little harder to discriminate between left and right by the vibration stimulus.

As a result, the appreciable difference was not seen between the visual and the vibration. In addition, by the subjective evaluation, the experiment participant felt that both stimulations were recognizable. The experiment was indicated by the laboratory test as one of multi-modal interface by the transducer to be possible. Further investigation is necessary to consider its effectiveness in real driving situations, the wave transducer interface can be considered a positive option.

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