Proposal of Alleviation Method of Car Sickness Caused by Working on a PC in a Driving Car

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In recent years, research on automated driving has been actively conducted. It is expected that the automatic driving of cars will eliminate the need for drivers and drastically change the environment inside the cars. The driver who was needed until now will be an occupant and will be able to spend more free time in the car. In such a situation, it is expected that there will be more opportunities to work on a PC in the car and car sickness will increase. When a parson gaze at the screen in a driving car, there is a discrepancy between the signal sent from the inner ear to the brain and the signal sent from the eyeball to the brain, and the brain judges that it is "abnormal", and the autonomic nerves become unstable. And, as a result of the instability of the autonomic nerves, symptoms of car sickness such as nausea and headache appear. This study proposes a method for alleviating car sickness caused by PC work in a driving car. This is a method in which the PC user is notified in advance of the direction in which the car will turn left or right at the next intersection by voice, and the head is tilted in the turning direction. Previous studies have shown that the driver's head movement in the turning direction leads to relief of car sickness, and it can be expected that car sickness will be alleviated by PC work. In this study, in order to verify the alleviation of car sickness by prior notification of the proposed method, the following three patterns of prior notification timing are used in the verification experiment. There are three patterns: "twice notifications = before stepping on the brake for turning left or right, and before turning the steering wheel", "once notification = before turning the steering wheel", and "0 times notifications". Participants in the experiment are asked to perform PC work in a driving car in each pattern of twice notifications, once notification, and 0 times notifications. The superiority of the proposed method is shown from the evaluation results of the questionnaire, heart rate, salivary amylase activity value, and typing task.

Key words : automated driving, car sickness, voice notification

1. Introduction

In recent years, research on automated driving of cars has been actively conducted. The advantages of automated driving include reduction of traffic congestion and reduction of traffic accidents. In addition, by automating the driving of the car, it is expected that the driver will be freed from driving work and the environment inside the car will change drastically[1]. The driver who was needed until now becomes an occupant, and he will be able to spend more free time in the car. In such a situation, it is expected to have more opportunities to work on a PC in a driving car and increase car sickness[2]. When you gaze at the screen in the car, there is a discrepancy between the signal sent from the inner ear to the brain and the signal sent from the eyeball to the brain, and the brain judges that it is "abnormal", and the autonomic nerves become unstable. And, as a result of the instability of the autonomic nerves, symptoms of car sickness such as nausea and headache[3] appear. In the

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future, working on the PC in a driving car will easily induce car sickness, so it will not be able to make effective use of free time in a car and will not be able to enjoy the benefits of being freed from automated driving. In the future, in order to maximize the benefits of automated driving, it will be necessary to provide an environment that is less likely to cause car sickness while working in a driving car.

In this study, we propose a method for alleviating car sickness caused by PC work in a driving car. In recent years, since TV has been installed in the back seats of cars, measures against car sickness for watching TV[4] have been taken. However, in the future, it is expected that the number of operations while looking at the screens of smartphones and PC in automated driving car will increase[5]. Unlike watching TV, it needs to see small letters for tasks such as PC operation for typing, and it has a high degree of concentration on the screen. In addition, from the results of the previous study[6], "Low position of monitor in a driving car induces car sickness", when PC operation such as typing is performed in a driving car, the line of sight is low, the peripheral vision is narrow, and the degree of concentration on the screen is high. Therefore, it can be assumed that the car sickness symptom becomes severe. Therefore, we propose a method to notify the PC user in advance of the direction in which the car will turn left or right at the next intersection by voice. In the verification experiment, with reference to previous research[6-9], the alleviation of car sickness caused by PC work by this method is evaluated. It is hoped that this method will alleviate car sickness that occurs during typing work on the PC in a driving car and enjoy the benefits of automated driving.

2. Related Research

2.1 *Car sickness*

Much research on motion sickness, including car sickness and sea sickness, have been conducted[3], but the principle has not yet been clarified[10]. However, at present, there is a sensory contradiction theory[3] as the most influential theory about the principle of the occurrence of motion sickness. In the case of car sickness, the vestibular sensation is stimulated by the stimulation of intermittent acceleration and lateral shaking, the contradiction between the visual information and the somatosensory that the body is stationary causes a disagreement in the senses due to the rapid transition of the scenery. Then, the brain senses the deviation of the signal, judges that it is "abnormal", and the autonomic nerve becomes unstable. As a result of the disturbance of the autonomic nerves, symptoms of car sickness such as nausea and headache appear.

2.2 *Research aimed at car sickness*

A research by Morimoto et al.[11] and Nakanishi et al.[12] investigated whether watching TV screen in a driving car affects car sickness symptoms. From the experimental results, they have obtained data that car sickness increases about twice as much when viewing the screen in a driving car compared to the state where nothing is performed.

The research by Kuiper et al.[6] investigated whether differences in monitor position in a driving car affect car sickness symptoms. The car sickness symptom was evaluated by the pattern in which the height of the monitor was the line of sight and the height of the monitor was in the low position above the knee. As a result, the car sickness symptom was alleviated when the height of the monitor was the position of the line of sight. It is considered that when the height of the monitor is at the line of sight, the peripheral vision is widened, the view of the window becomes visible, and the behavior of the car can be grasped. On the other hand, when the height of the monitor is low above the knee, the peripheral vision is narrow and car sickness is likely to occur.

A research by Wada et al.[13] examined whether the difference in head movement between the driver and the passenger was related to car sickness. A person in a driving car receives acceleration stimuli and rotational stimuli when driving on a curve, but the driver tilts his

head in the turning direction and the passenger tilts his head in the opposite direction. Then, they conducted an actual vehicle experiment, measured the head data of the driver and passengers during driving, and evaluated the relationship between head movement and car sickness by a mathematical model by simulation. As a result, when comparing the driver and the passenger, the driver had a lower rate of car sickness. In other words, it was shown that the driver's head movement in the turning direction has the effect of alleviating car sickness.

3. Proposed Method

From the result of the previous research[6] "The low position of the monitor in a driving car induces car sickness", when a person operates the PC such as typing in a driving car, the line of sight is low, the peripheral vision is narrow, and the concentration will be higher. Then, it can be assumed that car sickness symptom becomes severe. Therefore, in this study, we hypothesize that it would be possible for PC users to prepare for sudden shaking by grasping the direction of turning left or right in advance, which would lead to alleviation of car sickness. We propose a method to notify the left or right turn direction by voice in advance. In addition, from the results of previous research[10], by tilting the head in the turning direction after the notification, the PC user can predict the movement of the car like a driver while working on the PC. And it can be expected to alleviate car sickness. The notification time of the proposed method is shown in Fig. 1. The notification time 1 in the verification experiment is "1 second before stepping on the brake for turning left or right", and the notification time 2 is "1 second before turning the steering wheel". When the notification time comes, the passenger (experiment participant) is notified by voice of the direction of turning left or right. If the notification time is 1, there is a t1 time grace before the car turns, and if the notification time is 2, there is a t2 time grace. By notifying at the notification time 1,

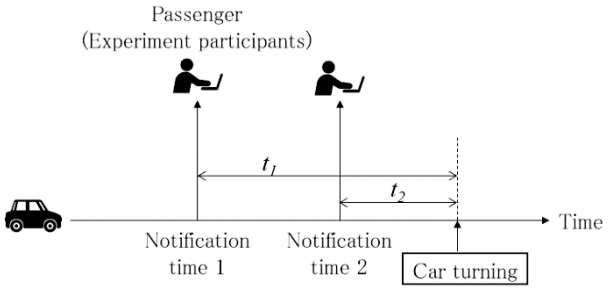

Fig. 1. Notification time of proposed method.

compared to the notification at the notification time 2, there is a margin of time to tilt the head by the difference between the times of t1 and t2. In this study, in order to verify the alleviation of car sickness by prior notification of the proposed method, the following three patterns of prior notification timing is used in the verification experiment. There are three patterns: "twice notifications = 1 second before stepping on the brake for turning left or right, 1 second before turning the steering wheel", "once notification = 1 second before turning the steering wheel", and "0 times notifications". There is a difference in the time grace until the head movement in the turning direction is performed between the twice notifications and the once notification. In addition, we also prepare an experimental pattern of "0 times notifications" without the proposed method. We investigate whether there is a difference in car sickness symptoms in a total of 3 patterns in a verification experiment.

4. Verification Experiment

4.1 *Overview*

In the verification experiment, participants are asked to work on typing tasks on a PC in a driving car. Fig. 2 shows the state during the verification experiment. The content of the daily experiment is to work on the typing task for 2 minutes, then take a 1-minute break as one set. And 5 sets are performed in succession for a total of 15 minutes. The number of left or right turns per set is 8 to 10 times. Participants are asked to experience 3 patterns of notifications on another day for 3 days. In the

verification experiment of this study, in order to simplify the implementation, the driver's voice is used to notify the PC user of the direction of turning left or right. The verification location is on a general road. As shown in Fig. 3, the road has many intersections and no traffic lights. The speed limit is 30km / h. The participants in this study are five men aged 22 to 24 years. The experimental car used is a Toyota / AQUA hybrid car.

4.2 *Experimental conditions*

The conditions of the verification experiment are shown below. One driver is selected. Participants can offer to suspend during the experiment. Verification experiments are conducted only in fine weather. The experimental car drives in consideration of traffic safety.

4.3 *Participation conditions*

The participation conditions for the participants in the verification experiment are shown below. Experiment participant has experienced car sickness in the past and feel that they are prone to car sickness. Experiment participant signs informed consent. Experiment participant has no difference in physical condition within 3 days of the experiment.

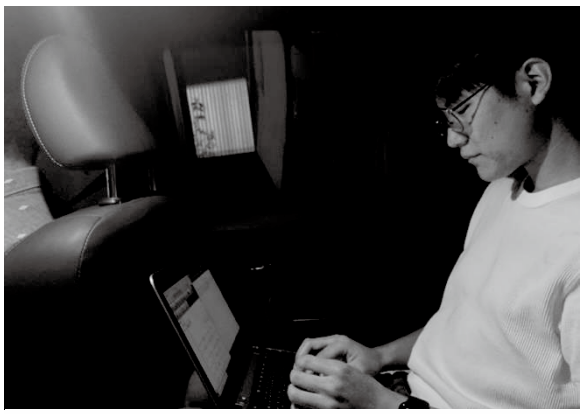

Fig. 2. State during verification experiment.

Fig. 3. General road used in the experiment.

5. Evaluation

5.1 *Questionnaire*

We created a questionnaire to fill in car sickness symptoms with 11 levels of discomfort. Table. 1 shows the contents of the questionnaire. We ask them to fill out a questionnaire after each set and investigate the tendency of car sickness.

5.2 *Heart rate*

Experiment participants are asked to wear an evaluation device on their arm to investigate changes in heart rate during the verification experiment. Heart rate is said to increase with the onset of motion sickness[14]. We measure a total of 6 times at the beginning of the experiment and at the end of each set. The equipment used is Apple's "Apple Watch Series 6". This device

Table 1. Questionnaire.

Symptoms	Degree	Scale
No problems		0
No typical symptoms		1
No nausea, but dizziness, cold / warm, headache, stomach / throat consciousness, sweating, blurred vision, yawning, belching, Tired, saliva secretion	Vague	2
	Slight	3
	Fairly	4
	Severe	5
Nausea	Slight	6
	Fairly	7
	Severe	8
	Very Severe	9
Vomiting		10

Fig. 4. Dry clinical chemistry analyzer Saliva amylase monitor.

measures the heart rate using photoelectric volumetric pulse wave recording (photopretismography), and it is possible to measure without burdening the participants in the experiment.

5.3 *Salivary Amylase Activity value*

We ingest saliva from participants in the experiment and measure saliva amylase activity value. Salivary amylase activity is characterized by an increase in salivary amylase activity in response to unpleasant stimuli and a decrease in comfortable stimuli[15]. The salivary amylase activity is associated with the symptoms of agitation[16]. We ingest saliva three times in total, before the experiment, after the third set, and after the experiment, and investigate the amount of change in amylase activity value. The evaluation formula for salivary amylase is shown in Eq. (1). S_0 is the amylase activity value at the start of the experiment, which is a normal state without mental stress. In addition, the difference is taken between S_{max}, which is the maximum amylase activity value measured during and after the experiment, and S_0, which is measured at the start of the experiment. Then, it is divided by S_0 to calculate the normalized value and compared in each experiment. The equipment used is shown in Fig. 4. Nepro's "Dry clinical chemistry analyzer Saliva amylase monitor". By attaching saliva to a special chip for 30 seconds, it is possible to measure the saliva amylase activity value.

$$S = \frac{S_{max} - S_0}{S_0} \quad (1)$$

Fig. 5. Task screen during experiment.

5.4 *Typing task*

We ask the participants to work on the task of typing "Rashomon" by Ryunosuke Akutagawa during the experiment. Fig. 5 shows the PC screen during the experiment. We ask the participants to copy the text displayed on the left side of the screen to the text editor on the right side of the screen. The evaluation items are "the number of characters typed correctly" and "typing error rate". When typing, there is no conversion to kanji, and the task is to type only hiragana.

6. Result

6.1 *Questionnaire*

Fig. 6 shows a comparison of the average questionnaires of the participants. Since there are individual differences in the response method in the

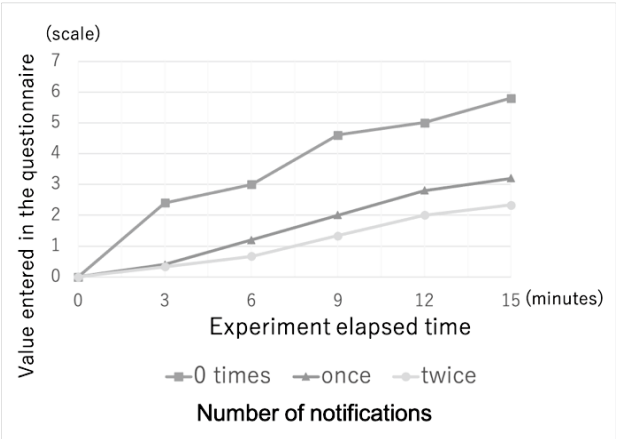

Fig. 6. Comparison of questionnaire average.

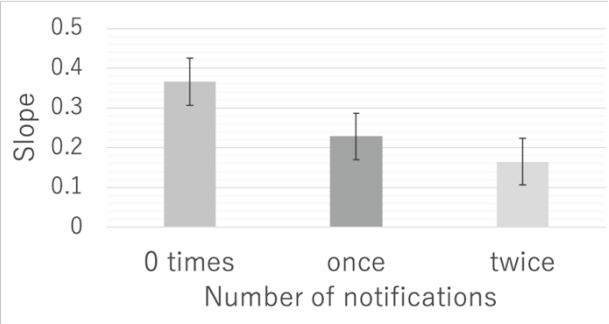

Fig. 7. Comparison of increasing tendency of car sickness by questionnaire.

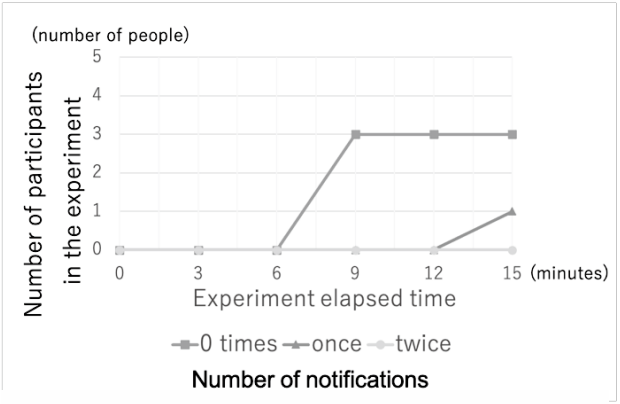

Fig. 8. Comparison of severe motion sickness symptoms.

questionnaire, we focus on the amount of increase in the degree of car sickness of each experiment participant as another survey. For each of the results of the questionnaire of the experiment participants, the regression line is calculated, and the slope is calculated. Here, the larger the slope of the regression line, the greater the degree of increase in car sickness. Fig. 7 shows the average slope of the obtained regression line. The vertical axis is the slope value. The result is that the slope is smaller in the order of twice, once, and 0 times notifications. The degree of increase is about twice as different between the number of twice and 0 times notifications, and it can be seen that the head movement in the turning direction by the twice notifications lead to the relief of car sickness symptoms. In addition, Fig. 8 shows the results of summarizing the number of people who entered scale of 6 or more in the questionnaire in order to compare whether there is a difference in severe car sickness symptoms due to the difference in the number of notifications. From the results of the verification experiment questionnaire, it is found that the greater the number of notifications, the less the symptoms of car sickness.

6.2 *Heart rate*

Fig. 9 shows a comparison of the average heart rates of the participants. In the evaluation of heart rate, we focus on the amount of increase in heart rate. Similar to the questionnaire, the regression line is calculated, and the slope is calculated for each heart rate result of the experiment participants. The greater the slope of the regression line, the greater the degree of increase in car sickness. Fig. 10 shows the average slope of the obtained regression line. The vertical axis is the slope value. Twice notifications are the smallest inclination value. And it is indicating that the increase in heart rate is gradual and car sickness is alleviated.

6.3 *Salivary Amylase Activity*

Fig. 11 shows the results of measuring the salivary amylase activity value, calculating with the evaluation formula, and calculating the average. The highest number is obtained when the number of notifications 0 time. From this result, it can be seen that when the

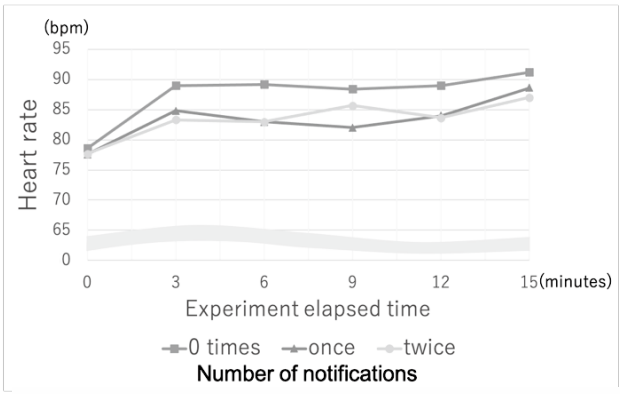

Fig. 9. Comparison of heat rate average.

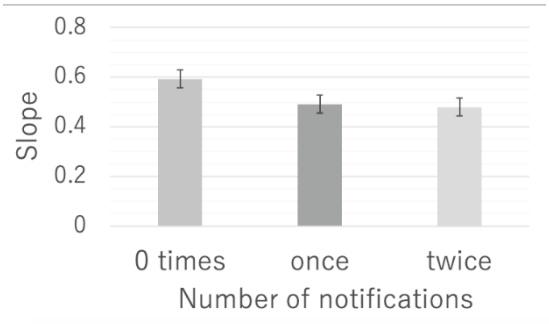

Fig. 10. Comparison of increasing heart rate.

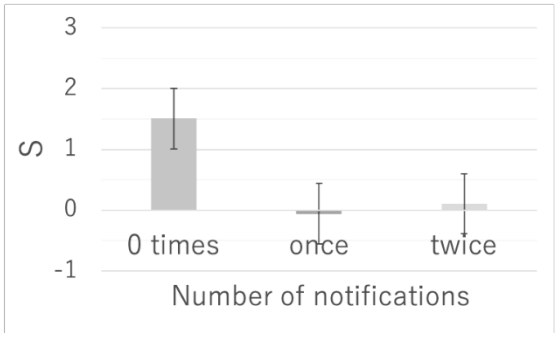

Fig. 11. Comparison of aggregated data of salivary amylase activity value.

number of notifications is 0, stress is strongly felt from the car sickness caused by the shaking of the car from the normal state before the experiment, and the measured value became large. There is no difference between the number of once and twice notifications.

6.4 *Typing task*

Fig. 12 shows a comparison of the average number of correctly entered types of experimental participants. Twice and once notifications result in a larger number of inputs than 0 times notifications. From this result, car sickness can be alleviated, and work efficiency is improved. Fig. 13 shows a comparison of the average typing error rates. The maximum difference in typing error rate is 0.004% between 0 times and once notifications.

7. Consideration

From the evaluation results, it can be seen that the notification of the proposed method enabled the PC user to reproduce the head movement in the turning direction like a driver, and alleviated car sickness. In this study, we hypothesized that if there is a grace period before turning left or right, the stress caused by sudden shaking will be reduced, leading to alleviation of car sickness. Throughout the overall results, with once notification and twice notifications, twice notifications are the result of alleviating car sickness. As a result, it is demonstrated that the notification one second before stepping on the brake for turning left or right creates a mental margin

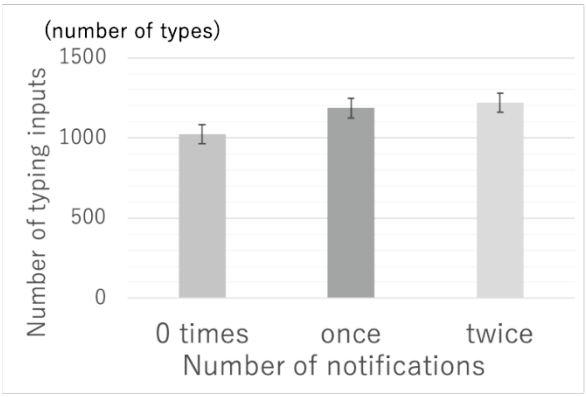

Fig. 12. Comparison of average typing numbers.

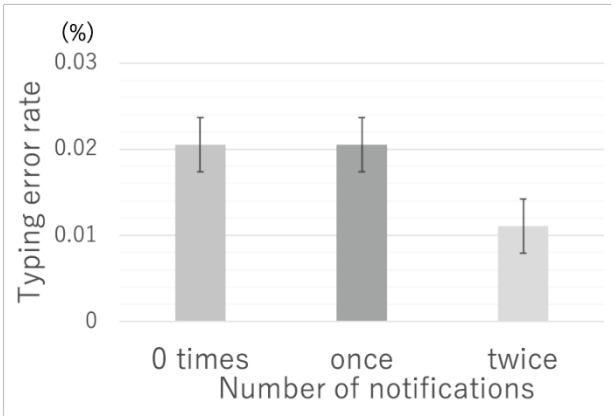

Fig. 13. Comparison of average typing error rates.

while doing the task, which leads to alleviation of car sickness. In the case of once notification, an experiment participant stated that he was concentrating on the task and could not hear the notification. In addition, by giving a notification one second before stepping on the brake for turning left or right at the intersection, the participants in the experiment will soon know that the car will slow down and can prepare for vertical shaking due to the deceleration. As a result, it is assumed that it led to alleviation of car sickness. From the evaluation results of the typing task, the work efficiency changed depending on the number of notifications. From this result, it is found that alleviating car sickness leads to improvement of work efficiency in the driving car. However, one of the participants in the experiment felt annoyed that there were twice notifications and stated that there was no change in the symptoms of car sickness between once and twice. In other words, assuming actual use, it is necessary to provide the number of notifications according to the

user's preference in order to alleviate the symptoms of car sickness and increase the amount of personal work.

8. Conclusion

With the spread of automated driving in the future, it is expected that the work in free time in the car will increase and the car sickness will increase accordingly, so we propose a method for alleviating car sickness caused by PC work in the driving car. This is a method in which the PC user makes a head movement in the turning direction like a driver by notifying the PC user of the left or right turn direction by voice in advance. Previous research has shown that the driver's head movement in the turning direction leads to alleviation of car sickness, and we hoped that advance notice would alleviate car sickness. In this study, in order to verify the alleviation of car sickness by prior notification of the proposed method, the following three patterns of prior notification timing are used in the verification experiment. There are three patterns: "twice notifications = 1 second before stepping on the brake for turning left or right, 1 second before turning the steering wheel", "once notification = 1 second before turning the steering wheel", and "0 times notifications". A verification experiment was conducted to investigate the difference in car sickness symptoms depending on the number of notifications. As a result of the verification experiment, the twice notifications were the most alleviated. In the case of once notification, if the direction of travel is suddenly communicated while concentrating on the task, there is little time from the reaction to tilting the head, and the car starts to turn before tilting the head. It may not be prepared for the shaking. As a result, it is assumed that the result shows a difference from twice notifications. However, one of the participants in the experiment felt annoyed that there were twice notifications and stated that there was no change in the symptoms of car sickness between twice and once. Assuming future use, it is necessary to provide the number of notifications according to the user's preference in order to alleviate the symptoms of car sickness and increase the amount of personal work.

In this study, we proposed a method to alleviate car sickness by shaking only in the left or right direction of the driving car, but we have not been able to take measures against car sickness caused by vertical shaking caused by the accelerator or brake of the car. Therefore, in the future, it will be necessary to devise a proposal for a car sickness method that also takes into account the fluctuations in acceleration and deceleration. In addition, it is possible to notify the direction of travel by sight or touch in addition to voice, and it is necessary to investigate a method that makes passengers feel less stressed. For the coming automatic driving era, research on the construction of an in-vehicle environment that does not induce car sickness is required.

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