Research Note

Emergency Vehicle Alarm System for Deaf Drivers by Using LEDs and Vibration Devices

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ABSTRACT

We are developing the emergency vehicle alarm system for deaf drivers by using LEDs and vibration devices. In order to design the alarm for deaf drivers, we have conducted basic experiment in order to evaluate perceptual characteristic on visibility of LED.

KEYWORDS: hearing-impaired, multi-modal, alarm system, LED

1. Introduction

There are more than 360 thousands hearing impaired people in Japan, and about 10% of those have a driver license. Due to abolishing the disqualification clause of a driver license for the hearing disabled, the number of hearing impaired drivers is expected to increase rapidly. However, they have a difficulty to recognize their driving situations from sounds around them when the emergency vehicle is approaching or they are honked at by the other car. They should always pay attention to vehicles outside their peripheral visions while they are driving. The purpose of our emergency vehicle alarm system for deaf drivers is to relieve their stress for driving a car by letting them know such information by using LEDs and vibration devices as the type of the emergency vehicle approaching and the direction that it is coming from just after the system automatically calculates those information based on a wave analysis of sounds around the deaf drivers.

In order to develop such alarm system, it is important to utilize the knowledge on a characteristic of visual perception to LED blinking light. However, there is no report on such visual perception as response accuracy or response time to LED blinking patterns. Therefore, we examined these characteristics of visual perception by presenting various blinking pattern of LED.

In this paper, at first, we briefly outline related works with our approach for developing the emergency vehicle alarm system for deaf drivers. Then, we introduce the overview of our system architecture. Next, we present our basic experiments on LED visibility and these results. Finally we conclude.

2. Related Works

There is a report on the emergency vehicle alarm

system for deaf drivers¹⁾. Compared with proposed system in this report, our system has such features as using the microphone array that consists of four microphones in order to determine the direction of the sound source correctly, and also presenting the information on the emergency vehicle by using the combination of visual and vibrotactile sensation. In the driving situation, driver's visual attention is usually used for confirming the safety in the direction of driving. Therefore, the alternative channel except vision for alerting drivers is required. For this purpose, there are many researches on using vibrotactile stimulus for alerting drivers in order to avoid the danger (for example²⁾). In this report, authors defined the danger in a driving situation as near-miss with the car running in front and that with the car coming from behind, and examined whether drivers could recognize which danger was alerted by using vibrotactile stimulus. It said that it was difficult for drivers to determine the direction of the danger only by using vibrotactile stimulus. Therefore, in addition to vibrotactile stimulus, other cues are necessary for drivers to identifying the danger correctly.

3. System Overview

3.1 Overview

Figure 1 shows the illustrative example of our system overview. At first, this system identifies the types of the emergency vehicle approaching by using a frequency analysis of sounds that microphones pick up. Next, it detects the direction where the emergency vehicle is coming from by analyzing a phase difference between these sounds. The alarm generator generates the stimulus in order to let the driver know approaching the emergency vehicle.

3.2 Identifying Type

The frequency characteristic of an ambulance siren has two peaks at 770Hz and 960Hz. On the other hand, that of a fire engine and a patrol car has a peak at 850 ± 50 Hz. Therefore, this module analyzes the wave form of the sound picked up by microphones, and calculates the power of each frequency component. Then, it identifies the type of emergency vehicle based on the number of samples whose power of frequency components of 770Hz, 960Hz, and 850Hz exceed certain threshold in a unit time.

3.3 Detecting Direction

By comparing each wave form of sounds pick up by microphones M1, M2, M3 placed at equilateral-triangular vertexes with that of the sound picked up by M0 placed at the median point of the equilateral triangle, this module detects the direction where the emergency vehicle is approaching.

Because the sound source is assumed to be sufficiently far, the sound wave picked up by each microphone is considered as a plane wave. Therefore, for example, if M1 catches the sound earlier than M0, this module judges that the sound source is on the side of M1 as shown in Figure 2.

The same is true of M2, and M3. We used mutual correlation function to calculate the phase difference between sounds caught by microphones. Then, the direction of the sound source is determined by using Table 1.

3.4 Generating Alarm

The vibration device attached on the antebrachial region let the deaf driver know that the emergency vehicle is approaching by using the vibration pattern that is mostly recognizable without a feeling of discomfort for the driver. Furthermore, by using the LEDs set up on the dashboard, the system conveys the information on the type of the emergency vehicle and the direction that the emergency vehicle is approaching from.

4. Experiment

4.1 Purpose

In order to develop the system for letting the driver to know the information on the type of the emergency vehicle and the direction that the emergency vehicle is approaching from, it is important to utilize the knowledge on a characteristic of visual perception to LED blinking light. However, there is no report on such visual perception as response accuracy or response time to LED blinking patterns. Therefore, in this experiment, we examined above-mentioned characteristics of visual perception of subjects by presenting various blinking pattern of LED while subjects were concentrating the experimental task.

Figure 1 Illustrative example of our proposed Emergency Vehicle Alarm System for Deaf Drivers

Figure 2 Calculation of phase difference between sounds

Table 1 Values of K in non-linear colour spaces NC-II

Direction	Sign of Phase Difference		
	M1, M0	M2, M0	M3, M0
Front	+	—	—
Right Front	+	+	—
Left Front	+	—	+
Right Back	—	+	—
Left Back	—	—	+
Back	—	+	+

4.2 Method

Parameters of this experiment were blinking frequency and LED position while duty (the rate of lighting period during one blinking cycle of emission) was fixed to 50%. Four blinking frequencies (5, 10, 15, 20 Hz) and eight LED positions (A – H as shown Figure 3) were tested in this

experiment. Height of the LED position was set to 117cm. The model number of the LED used in this experiment was TLR114A (made by Toshiba). The color of the lens and the light was red. The diameter of LED was 5mm.

The experimental task used the monitor (W 40.5cm × H 37cm). The monitor was set up at a distance of 75cm from the eye position of the subject. LEDs were set up at a distance of 150cm from the eye position of the subject. The background of LEDs was blackout curtain.

This experiment was conducted in the dark room with the artificial illumination. The average illumination intensity at around the eye position of the subject was 672 lx (measured five times, $\sigma=7.2$), and that of at around the monitor for the experimental task was 435 lx (measured five times, $\sigma=8.2$).

In this experiment, 96 trials (four frequencies × eight LED positions × three times) were conducted for each subject. The combination of the frequency and the LED position was randomized. The subject clicked the mouse when they noticed the blinking while s/he was performing the experimental task.

The purpose of the experimental task was to make subject's eye gaze point concentrate to the center of the monitor in order to catch the blinking of LEDs in his/her peripheral vision. For this purpose, one digit number from 0 to 9 was displayed at the center of the monitor with 1400ms interval, and the subject answered which number was displayed. In case where the subject answered wrong number, we considered that the gaze point was away from the center of the monitor, and eliminated such trials from calculating the average response time.

The subject was sat in front of the monitor, and his/her chin was fixed on the chin support. After the explanation on the experiment and three minutes practice, the subject conducted trials. In consideration with subject's fatigues, the experiment was divided with four sessions. The interval between sessions was about four minutes.

Figure 3 LED position of our experiment

Figure 4 Accuracy rate of the task according to LED positions

Figure 5 Average response time to LED blinks of each LED position according to blink frequencies

4.3 Results

Figure 4 shows the result of the accuracy rate of the experimental task according to the LED position. As the LED position became peripheral, the accuracy rate decreased. The accuracy rate severely worsened at positions of A and H.

Fig. 5 shows that the average response time to the blink of LED according to the blinking frequency. As the LED position became peripheral, the average response time tended to be longer. However, average response times of 15Hz at C and that of 20 Hz at C were shorter than those at inner positions of C and F. Furthermore, response times at B and G severely worsened.

5 Conclusions and Future Works

5.1 Conclusions

In order to develop the emergency vehicle alarm system for deaf drivers, we examined a characteristic of visual perception to LED blinking light by conducting the experiments where we measured response accuracy and response time to LED blinking patterns.

The result of this experiment shows such a tendency that the accuracy rate decreased and the response time became longer as the LED position became peripheral. Specifically, the accuracy rate kept relatively high to 70 degrees from center of the monitor, but the response time severely worsened at 70 degrees.

On the other hand, as for the blinking frequency, the experimental result shows such a tendency that, as the frequency became larger, the response time became longer. As for the reason of this tendency, we think that the blinking of very high frequency perceived as a stationary light and as a consequent, it became difficult for subjects to recognize the change of the luminance.

5.2 Future Works

In this paper, we presented the experimental results on characteristics of visual perception to LED light from the viewpoint of calling driver's attention. In addition to that, our system intends to present information on the type of the emergency vehicle and the direction that it is coming from. Also, our system stimulates the driver by using both LEDs and vibration devices. Therefore, we are planning the experiment from such viewpoints in order to implement the alarm system that does not disturb the driver.

We are also designing the experiment that is more realistic situation of driving car, in which we will utilize the gaze point measurement as objective indicator for the disturbance in the driving situation.

References

- (1) Otsuka, S., Hara, H., and Ozawa, S: The Detection System for Existence and Direction of Emergency Vehicle using Microphone on-Vehicle, IEEJ Transactions on Industrial Applications Vol.124-D, pp.388-395 (2004).
- (2) Ho, C., Tan, H.Z., and Spence, C.: Using spatial vibrotactile cues to direct visual attention in driving scene, Transportation Research Part F, 8, pp.397-412 (2005).

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