Behavior of Driver on Visual Warning on Car Driving

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In this work, we proposed the visual warning method by flashing LED (Light Emitting Diode) to make a driver notice dangerous information quickly and precisely. We simulated sudden traffic danger on our driving simulator and operated some warning systems. Then we observed the behavior of subjects and discussed what the most effective warning method was. In the case of the LED warning, the gaze tracks of the subjects did not contain useless behavior and moved to the dangerous area quickly. Therefore under the LED warning, the rate of noticing danger and the Recognition Time were the best in the other warning systems.

1. INTRODUCTION

In these late years, the number of accidents in the traffic is increasing. The traffic conditions are extremely severe. Technology to quickly inform a driver about dangerous information has been developed to reduce cognitive mistakes that are occupied 64% of the causes of traffic accident. Recently a car navigation system is mainly used in warning method, however it is expected that the method cannot receive the information of some sudden traffic danger because drivers have to move their eyes to the display. In this work we proposed the visual warning method by a LED flashing to make the driver notice dangerous information quickly and precisely. In the experiment about warning methods, we replicated sudden traffic danger on the driving simulator. And four warning methods: using only alarm sound, using the car navigation, the LED flashing and without warning were compared. Then we evaluated warning methods with the gaze track of the subjects and the driving behavior of the subjects. Therefore the easiest method to notice the traffic accidents was discussed.

2. EXPERIMENT OF WARNING METHOD

Under the experiment of warning method, the driving simulator (DS) was used. As shown in Fig. 1, we put objects of human mocking on the sidewalk along the road where a subject drives. We made a car run ahead of the subject’s driving car in the DS. All subjects were instructed to drive after the leading car that sometimes accelerated and braked with a stop-lamp. We raised the subjects' load of driving by the following task. As shown in Fig. 2, when a subject operated the DS, the human object sprang out suddenly from the sidewalk.

The distance from the driving car to the position of the springing human object was 15m, 17m or 19m on either the right or the left side of the road (we call 15R, 15L, 17R, 17L, 19R or 19L below). And a car sometimes overtakes the driving car on either the right or the left side (we call O-R or O-L below). The warning system was operated when the human object sprang out from the sidewalk or the overtaking car passed the driving car on the right or left traffic line. The number of subjects was five in the experiment.

Fig. 1 The driving simulator image on the screen

Fig. 2 Conditions of danger


3. EVALUATION POINTS

We evaluated warning methods with the next three points mainly. First, we obtained the rate that a subject could not notice when the danger appeared in all trials. Second, when a subject could notice the human object or the overtaking car and step on the brake pedal, we measured the "Reaction Time", which was the time between the danger appearance and the subject's stepping on the brake pedal. In addition, we introduced the "Transmission Time", which was the time between a subject noticing a springing out the human object and the subject's stepping on the brake pedal. The Transmission Time contains the personal margin of error. We supposed that the Reaction Time in the case of showing a big object suddenly in front of the subject's nose is the personal Transmission Time. And we measured the Transmission Time of all subjects. Then, we introduced the "Recognition Time", which is the time that is subtracted the Transmission Time from the Reaction Time. The Recognition Time reduces the personal margin of error. Third, we measured gaze track of the subjects as shown in Fig. 3. In addition, we introduced the "Gaze Points Arrival Time", which is the time between the danger appearance and arrival of the subject's gaze points to the dangerous area at first time.

4. SYSTEMS

4.1 The Driving Simulator (DS)

The subject operates a steering wheel, an accelerator pedal and a brake pedal. The program collects the data of the angle of the steering and the displacements of two pedals on PC2 through an AD board as shown in Fig. 4. The system calculates the position and the angle of a driving car, and represents the DS image on the screen. The image is projected on the rear side of a screen by a projector, and a subject drives the DS while watching the image. The screen is set at the distance of 1050mm from the subject. The size is 2000mm in width and 1000mm in height. And the system controls LED flashing, the car navigation display the alarm sound at the same time when the danger occurs.

4.2 Warning System

The layout of the LEDs and the car navigation display are shown in Fig. 5 and 6. The warning system was operated when the danger appear. The warning methods were how to indicate some sudden danger by the car navigation display, the LED flashing, the sound warning or without warning. The car navigation system indicates the direction of a danger appearance on the display with alarm sound. The LED system flashes the LED on the direction of a danger with alarm sound. The system can guide the subject's eyes to the direction of a danger by the LED flashing. Therefore a subject is expected to quickly detect the danger by the system. In addition, the warning system was made to operate occasionally even when the danger did not appear. Then the subject is instructed to step on the brake pedal only when the subject recognized the danger. Thus the subject did not step on the brake pedal by detecting the alarm sound only.

4.3 Gaze analysis

The face of the subject was recorded by the video camera put in front of the subject. We used our gaze analysis system applying the image processing as shown in Fig. 7. The system can calculate the posture of the face and the direction of the gaze of the subject.
5. RESULT OF EXPERIMENT WITH WARNING METHOD

5.1 The rate of noticing danger

We show the rate of noticing the danger in the six conditions in Fig. 8. Under the experiment conditions of 15R, 19L and 19R with the LED warning, all of the subjects were able to notice the dangers in all trials. In addition, under the experiment condition of 17R, a subject was not able to notice the danger once. The LED warning was better than the other warnings under the experiment conditions except 17L.

Under the experiment conditions except 17L, the rates of noticing the danger with the car navigation warning were lower than or equal to the rates by the sound warning.

5.2 Recognition Time

We show the results of the averaged Recognition Time in Fig. 9 when the subjects had noticed the danger under the eight conditions of danger. There were differences in the number of samples among the eight conditions in the results of the averaged Recognition Time, because there were many cases that subjects were not able to notice the danger. The each number of samples is shown in Fig. 9. Under the experiment conditions of 17L, 17R, 19L, 19R, O-L and O-R, the Recognition Time with the LED warning was the shortest in all warnings. On the other hand under the experiment conditions of 15L and 15R, the Recognition Time without warning was the shortest in all the warning methods.

The reason is why almost subjects were not able to notice the danger under the experiment condition of 15L and 15R. So there was few data in these conditions. In Figure 9 we show the number of times that subjects were able to notice the danger by chance. Therefore the Recognition Times without warning tend to shorten.

Under the experiment condition of 17R and 19L, the Recognition Time with the car navigation warning was the longest in all the warnings. And under the experiment condition of 15L, 19R and O-L, the Recognition Time with the car navigation warning was longer than that with the sound warning.

The reason is why the subjects sometime turned their gaze on dangerous area after they had watched the car navigation display and understood the direction of danger. Therefore in the case of the car navigation warning, the subjects caused wasteful behavior of gaze points. So there were the cases that watching the car navigation display interfered with the behavior that the subjects searched for danger.

5.3 Gaze tracks

5.3.1 Car navigation warning

We show an example of gaze tracks of the subject from the danger appearance to the subject stepping on the break pedal in case of the car navigation warning under the condition of O-R.

At first in Figure 10 we show the gaze track of the subject between the danger appearances starting to move his gaze point to the car navigation display. He stayed his gaze point at the center of the screen until the 21st frame as shown in Fig. 10.

Secondly in Figure 11 we show the gaze track of the subject between his starting to move his gaze point to the car navigation display and his gaze point's arriving to the preliminary stayed area. The subject began to move his gaze point to the car navigation display after 0.733 seconds since the danger appeared. And he moved his gaze point to the right side quickly after he watched the car navigation display and understood the direction of danger as shown in Fig. 11. It took 1.033 seconds from the danger appearance to his gaze point's arriving on the vicinity of horizontal position 250mm.

Thirdly in Figure 12 we show the gaze track of the subject between his gaze point arriving to the preliminary stayed area and his gaze point arriving to the dangerous area. He stayed his gaze point on the
vicinity of horizontal position 250mm until
1.800 seconds since the danger appeared as shown in Fig.
12. It took 1.867 seconds between the danger

Fig. 10 The gaze track of subject for 0.733 seconds after
the danger appeared with the car navigation warning

Fig. 11 The gaze track of subject for 1.033 seconds after
the danger appeared with the car navigation warning

Fig. 12 The gaze track of subject for 1.867 seconds after
the danger appeared with the car navigation warning

appearance and his gaze point’s arriving on the
dangerous area.

Finally in Figure 13 we show the gaze track of the
subject between his gaze point’s arriving to the
dangerous area and stepping on the brake pedal. It took
2.000 seconds between the danger appearance and his
releasing the accelerator and it took 2.407 seconds
between the danger appearance and his stepping on the
brake pedal as shown in Fig.13.

We discuss the reason why the subjects stayed their
gaze points at the area of horizontal position 250mm.
In this time the vicinity of horizontal position 250mm
was not dangerous area, because the position of the
overtaking car appeared at the horizontal position
850mm as shown in Fig.12. Under the experiment
conditions of 15L and 15R the human objects started to
spring out from the horizontal position 320mm on the
screen. Thus we think subjects learned that the danger
appeared from the vicinity of the horizontal position
300mm on the screen. So even if the danger appeared
on the horizontal position 850mm like the overtaking
car, they searched on the vicinity of the horizontal
position 300mm at first. Here we introduced the “the
Preliminary Stayed Area”, where the subjects stayed
their gaze points on the way to arrive their gaze points
at the dangerous area. Some subjects moved their gaze
points to the dangerous area after they stayed their gaze
points on the Preliminary Stayed Area.

In Figure 14 we show the gaze track of a subject
from the position that the danger appeared to the
position that the subject stepped on the break pedal
under the experiment condition of 15L with the car
navigation warning. In Fig. 15, we show the time
history of the horizontal position of gaze points shown

Fig. 13 The gaze track of subject for 2.047 seconds after
the danger appeared with the car navigation warning

Fig. 14 The gaze track of the subject under the 15L
with the car navigation warning

Fig. 15 The time history of the horizontal position
of gaze points what shown in Fig. 14
in Fig. 14. After a danger appeared, the subject watched a car navigation display, stayed his/her gaze on the vicinity of horizontal position 400-500mm and released the accelerator. They proceeded to watch the car navigation display even though his gaze point passed the dangerous area as shown in Fig. 14. We think that they did not notice the danger because he did not focus on the screen while he moved their gaze points to the car navigation display. Thus they could not notice the danger while moving gaze points and it is necessary to stay their gaze point on the screen to notice the danger.

5.3.2 The sound warning

In Figure 16 we show the gaze track of a subject under the experiment condition of O-L with the sound warning. In Fig. 17, we show the time history of the horizontal position of gaze points shown in Fig. 16. After the sound warning alarmed, subjects searched the danger on both right and left side on the DS screen. It is thought that they could only understand a danger's appearance with the sound warning, but they could not get the information of the direction of the danger. Therefore the subjects had to search for the dangers themselves. They assumed that the dangers appear only from the sidewalk on the right or left side. As a result, they were not able to notice the danger in many cases.

In Figure 18 we show the gaze track of subject under the experiment condition of O-R with the sound warning. In Figure 19 we show the time history of the horizontal position of gaze points in Fig. 18. On the other hand, there were the subjects who stayed their gaze on the central position on the screen without searching both right and left sides after the sound warning alarmed as shown in Fig. 18.

After the danger remarkably approached, they turned their gaze on the dangerous area and stepped on the brake pedal. In the case of the sound warning only they could not get information of the direction of the danger. So we think that the subjects set their central vision on the center of the screen and searched for the danger with their peripheral vision. In this case it was hard for the subject to notice a slight movement of danger in the peripheral vision. Therefore noticing the danger of the subjects was delayed.

5.3.3 LED warning

In Figure 20 we show the gaze track of subject under the experiment condition of 19R with the LED warning. In Figure 21 we show the time history of the horizontal position of gaze points shown in Fig. 20. There were many subjects who turned quickly their gaze on the dangerous area directly as shown in Fig. 20. It is understood that the LED warning system can guide subject's gaze to the dangerous area quickly and precisely. As the result, with the LED warning the subjects could begin to search for the danger earlier than with the other warnings. And the Recognition Time with the LED warning tended to be short.

In Figure 22 we show the gaze track of subject under the experiment condition of 15L with the LED warning. In Figure 23 we show the time history of the horizontal position of gaze points shown in Fig. 22.

As shown in Fig. 20, in the case of the LED warning, the subject turned their gaze on the danger area directly. On the other hands there were many subjects who stayed the their gaze points on the vicinity of
horizontal position 300-400mm at first. Afterwards subjects moved their gaze points following the movement of the dangerous area as shown in Fig. 22. In this case the subject did not notice the danger even though he stayed his gaze points on the dangerous area where his gaze point arrived. Under the conditions of human object’s springing out, we think the subjects cannot notice the danger unless they search for the danger carefully because the human object’s speed is much slower than the driving car’s speed. Moreover under the experiment condition of 15L, the human object disappears from the screen at 0.8 seconds after the human object starts to spring out. Therefore it is so hard for the subjects to notice the danger. But as shown in Figure 23 the subject moved his central vision to the dangerous area due to the LED warning at only 0.367 seconds after danger appeared. Thus under the LED warning, the subjects could notice a slight movement of human object and he let his gaze follow the human object. Then he could judge the whether it was the danger or not.

6. CONCLUSION

Under the car navigation warning, the subjects sometimes turned their gaze on the car navigation display. Therefore the subjects tend to notice the danger lately.

The LED warning system was the most effective warning method in both the Recognition Time and the rate of noticing danger in all the warnings. In addition the LED warning was remarkably effective for noticing the overtaking cars. In the case of the LED system the subjects could judge the directing of the danger is in the right or the left side when the human object had sprung out or the overtaking car had passed quickly. Therefore, they could easily detect the danger because they search only on the right side or the left side. Thus it is possible to hope that this LED warning system on a car reduces the detection mistakes of the driver. If the dangerous area is ramified by increasing the number of LED, the LED warning system is expected more effective to make driver recognize traffic dangers.

REFERENCES