An Analysis of Collision Avoidance Effectiveness by Using the Information Displayed in Driver’s Peripheral Vision

Makoto MOCHIZUKI *, Keisuke GOTO *, and Keisuke SUZUKI *

Abstract: A collision avoidance system has a potential to reduce traffic accidents and expected to become widely used. From the driver’s point of view, it is important to present a collision warning which does not disturb the driver’s concentration on driving. This paper describes the effectiveness of the collision avoidance system which uses the information displayed in the driver’s peripheral vision (peripheral vision information) in right turn at an intersection. In order to analyze the effectiveness of the peripheral vision information, the authors evaluated a response time to the information and an effect of over-trust behavior when the information was not presented. The analysis was conducted through a driving simulator experiment and the result showed that the peripheral vision information is effective to avoid a collision. Moreover, the over-trust behavior, the delay time of a response time when the information is not presented was reduced.

Key Words: collision avoidance system, peripheral vision, trust, dependence, response time.

1. Background

A collision avoidance system which detects obstacles around a vehicle and presents the information to avoid traffic accidents has been put into practical use. From now, various systems such as Forward Vehicle Collision Warning System, Lane Departure Warning System will be expected to become widely used. When multiple warning systems are installed in a vehicle, it is important to inform the driver of multiple information as the driver can understand appropriately. ISO/TS16951 describes a priority of information when the multiple ITS information is presented to a driver, and ITS/TR12204 describes a design guideline of warning systems when multiple warning information is presented to a driver simultaneously. In the previous study, Iwaki investigated that changing the size, sound and timing of information according to the priority of the information is effective to reduce a driver’s gaze time and response time [1].

The authors focus on a peripheral vision to utilize it as a new method of presenting multiple warning information when there are multiple risks around the vehicle. A peripheral vision is an outer area of a central vision and a basic characteristic has been reported until now. A maximum area of a peripheral vision is from 180 to 210 degree from a gaze point [2] and it is known that a peripheral vision is sensitive to temporal change in a visual field and it can grasp spatial information roughly. To utilize the peripheral vision as information presentation to a driver, Funakawa analyzed the characteristics of a peripheral vision, which is a spatial and temporal frequency of information that the driver can recognize in a peripheral vision [3]. Kato and Yasuda utilized the peripheral vision as a method to present driving support information [4],[5]. However, there are very few reports describing collision avoidance characteristics of the peripheral vision information.

On the other hand, as for a HMI design of collision avoidance system, it is important to consider a negative effect of the information to a driver’s behavior [6]. Especially over-trust to the system is one of the most important problems. The “concept of driving support” in ASV (Advanced Safety Vehicle project in Japan) describes that it is important to give a sufficient consideration not to trigger a driver’s over-trust or distrust to a system [7]. To evaluate a collision avoidance effectiveness of the information presentation, it is necessary to analyze collision reduction ability when the system operated normally. In addition, it is also necessary to analyze the negative impact of system when the information presentation is missed caused by a detection error of sensors or limitations of a collision prediction of the systems.

Based on the above-mentioned background, we analyze the collision avoidance effectiveness in right turn at an intersection using the information displayed in the driver’s peripheral vision (peripheral vision information). The objective of this paper is analyzing the effects of the peripheral vision information to the driver’s collision avoidance behavior in a driving simulator experiment. In order to analyze the effect of the over-trust to the information, the driver’s behavior is analyzed in case not only the information is presented normally but also the information is not presented.

2. Experimental Method

2.1 Experimental Scenario

An Experimental scenario constructed in a driving simulator (DS) is shown in Fig. 1. A subject vehicle was waiting at the center of intersection to turn right. An oncoming vehicle passed the intersection continuously at 40 km/h and a distance between oncoming vehicles was set from 20 m to 40 m randomly. As a large-sized vehicle stopping in front of subject vehicle made it difficult for the driver to recognize oncoming vehicles, the driver had to pay much attention to oncoming vehicles. The driver was instructed to turn right when the driver found it possible to turn right safely and a pedestrian started to run into a
crosswalk at 16 km/h when the driver started to turn right. At the same time, the information was presented to the driver to inform of an existence of the pedestrian. A driving scene of DS is shown in Fig. 2. Figure 2 shows a driving scene when a subject just started to turn right and a pedestrian also started to run into a crosswalk.

In this experiment, 1-back task was presented to let the driver pay more attention to the oncoming vehicle and overlook the pedestrian running from right side. A driver was instructed to memorize a color of oncoming vehicle and answer the color of previous oncoming vehicle which had just passed the intersection when a next oncoming vehicle was shown in a screen. The number of the subjects is 12 (male) and the average age is 22.4. Informed consent was obtained from all subjects before the experiment.

2.2 Information Presentation Method

2.2.1 Definition of the peripheral vision in this study

In this experiment, two different methods of information presentation are used to inform the existence of a pedestrian. One is an information presentation designed to be recognized by driver’s central vision field (central vision information). The other is a presentation designed to be recognized by driver’s peripheral vision (peripheral vision information).

The central region of a visual field is known as an effective visual field (8 degrees upside, 12 degrees downward, 15 degrees to the right and left), in which we can recognize the information only by an eye movement without a head movement [8]. Though there are several definitions of the peripheral visual field, the peripheral visual field in this study is defined as a region outside an effective visual field.

In this experiment, the central vision information is displayed in the effective visual field and the peripheral vision information is displayed in the peripheral visual field.

2.2.2 The collision avoidance information

The Experimental environment is shown in Fig. 3. A display for the central vision information was installed at the top of the dashboard at which a head up display is supposed to be installed in the actual vehicle and a driver was instructed to gaze information directly when information was presented. The notice alarm was presented at the same moment.

Two displays for the peripheral vision information were installed at right and left side of the instrument panel, which were in a peripheral visual field when a driver is looking ahead during a driving. The driver was instructed to recognize information without gazing at the information. The peripheral vision information is a yellow blurry circle of 3 degree view angle and blinking at 1 Hz. The edge of the circle is indistinct not to induce the subject gazing. These specifications were determined referring to a previous study about the visibility of peripheral vision information [3]. The information to right-side display indicates that something danger exists at the right side of driver and the meaning of information was instructed to the driver before the experiment. The notice alarm was not presented with peripheral vision information to compare the collision avoidance characteristics of the peripheral vision information to the typical warning information with alarms.

To confirm that the subjects recognize the peripheral vision information without gazing, the gazing point was analyzed through the eye tracker. Figure 4 (a) shows the analysis result of the gazing point when the central vision information was presented to the subject and Fig. 4 (b) shows the analysis result when the peripheral vision information was presented.

Figure 4 (a) indicates that the gazing point is on the central vision information and the subjects recognized the central vision information with gazing. On the other hand, Fig. 4 (b) indicates that the gazing point is not on the peripheral vision information. The authors think that the subject recognized the peripheral vision information without gazing and paid attention to the pedestrian directly.

2.3 Experimental Condition

Before the experiment, subjects experienced a preliminary driving to get used to driving simulator and each information presentation. An experimental condition is shown in Table 1.
The experiment was conducted under three conditions, which are no information, central vision information with alarms, and peripheral vision information, and 20 times experiments were conducted in each condition. Considering the driver’s expectation to the emergence of a pedestrian, a pedestrian run into crosswalk only 3 times randomly and no pedestrian emerged or oncoming bike emerged in the rest of the experiments. The information was presented only when a pedestrian emerged.

To analyze the effect of driver’s over-trust to the information presentation, the information was not presented only once during the experiment even if the pedestrian emerges. Once the driver experienced the missing information, the driver’s behavior is influenced by the experience. Therefore, the non-presented condition was conducted randomly after the three normal conditions were finished.

The subject drivers in this experiment were divided into two groups and the three experimental conditions were conducted in different order to cancel the learning effect of an experiment order.

### Table 1 Experimental condition.

<table>
<thead>
<tr>
<th>Experimental condition</th>
<th>Frequency of the Pedestrian appearance</th>
<th>Frequency of the Total experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>No information/Control</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Central vision</td>
<td>normal</td>
<td>3</td>
</tr>
<tr>
<td>Central vision with alarm</td>
<td>non-presented</td>
<td>1</td>
</tr>
<tr>
<td>Peripheral vision</td>
<td>normal</td>
<td>3</td>
</tr>
<tr>
<td>Peripheral vision with alarm</td>
<td>non-presented</td>
<td>1</td>
</tr>
</tbody>
</table>

The following indexes were analyzed based on the DS experiment.

(1) Dependence on the information presentation
To analyze a level of dependence on each information presentation, the level of dependence on the information in right turn was evaluated by the driver just after the DS experiment using a questionnaire. The dependence was evaluated in six levels from “not dependent at all” to “highly dependent”.

(2) Driver’s response time to the information
In this study, a response time was used as the index of a driver’s collision avoidance behavior. A time from the moment when the information presented to the driver until the driver took their foot off the acceleration pedal was calculated as a response time.

## 3. Experimental Result

In order to analyze the effect of the information presentation to the driver’s collision avoidance behavior, the driver’s behavior in terms of the above indexes were analyzed. The response time was analyzed in both conditions that the information was presented normally and the information was not presented.

### 3.1 Dependence on the Information Presentation

The result of the dependence on the information presentation is shown in Fig. 5. As for the central vision information with alarm, an average value of dependence is 4.5 and standard deviation is 1.1 and as for the peripheral vision information, an average value of dependence is 2.9 and a standard deviation is 1.7. This result shows that the dependence on the peripheral vision information is lower than that on the central vision information with alarm.

In the central vision information condition, subjects gazed at the pedestrian’s information displayed at HUD and understood that a pedestrian is crossing from the right side. As subjects could obtain the enough information around own vehicle from the central vision information, the subjects were thought to depend on the central vision information a lot.

However, the peripheral vision information only presents that some kind of obstacle is on the right. As subjects had to pay attention to the right to recognize the detailed situation around own vehicle, the subjects were thought not to depend on the peripheral vision information compared with the central vision information.

### 3.2 Driver’s Response Time to the Information

The result of a driver’s response time in condition that the information presented normally is shown in Fig. 6 and the result in condition that the information was not presented is shown in Fig. 7. The response time of all subjects from DS experiment is analyzed as an average response time (Fig. 6 (a)), (Fig. 7 (a)) and...
an accumulated frequency (Fig. 6 (b), Fig. 7 (b)). Each figure compares the response time under three conditions.

Figure 6 (a) shows that the average response time is reduced 0.48 seconds by the central vision information and 0.35 seconds by the peripheral vision information from the no information condition. The collision avoidance effect of the peripheral vision information is confirmed but it is a little less than that of the central vision information.

Figure 7 (a) shows the average response time to the central vision information with alarm is delayed 0.16 seconds from the no information condition when the information is not presented. The average response time to the peripheral vision information is not delayed and it is almost same with the response time of no information condition. Figure 7 (b) also shows the response time is delayed in the central vision information (indicated with a dot-circle).

4. Discussion

According to the experimental result shown in Fig. 7 (a) (b), the average response time was not delayed when the peripheral vision information was not presented. In this section, we discuss this result in terms of the driver's trust in a collision avoidance system.

A trust in a machine is same with a trust in human essentially [6], and the communication between human and machine is important to build a trust in the machine [9]. Okabe and Kamata reported that building a consensus about the risk between the human and machine is important for the coexistence of human and machine and the consensus is called as risk communication [10]. In this study, we think that there are two factors that made possible the risk communication between a system and a driver and reduced an over-trust behavior in the peripheral vision information condition.

Firstly, the peripheral vision information does not disturb a concentration to the main task of the driver and it can present the information with a low cognitive workload. By presenting the information as if it is an atmosphere of a risk around a vehicle, the subjects could understand the existence of some obstacle and also feel the uncertainty of the information. Secondly, the peripheral vision information was designed to be recognized by driver's peripheral vision and the amount of the information included in the peripheral vision information is less than that of the central vision information. As the subjects could not get the detailed information around the vehicle from the peripheral vision information, they had to pay attention to the right to recognize the detailed situation. Through the limited amount of the information, the subjects felt the uncertainty of the system.

Based on the discussion, it is effective to use the central vision information and peripheral vision information according to the reliability of the information. That is to say, it is preferable that the information with high reliability is presented by the central vision information and the information with low reliability is presented by the peripheral vision information when multiple information is presented to the driver.

5. Conclusion

We analyzed the effects of the peripheral vision information to the driver's collision avoidance behavior

1) When the information was presented normally, the average response time was reduced 0.48 seconds by the central vision information and 0.35 seconds by the peripheral vision information from the no information condition.

2) When the information was not presented, the average response time to the central vision information was delayed 0.16 seconds from the no information condition. The average response time to the peripheral vision information was not delayed.
was not delayed and it was almost same with the response time of no information condition.

3) The over-trust behavior was reduced in the peripheral vision condition because subjects did not depend on the information excessively.

References


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