Visual information processing characteristics of drivers in prediction of dangerous situation
- Comparison among novice, expert and non-licensed person -

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Abstract— **The aim of this study was to examine the difference of visual information processing in KYT (Kiken Yochi Training) among novice, expert and non-licensed persons. In KYT tasks, participants were required to search for a potentially dangerous part using a static image under driving situations. The location of fixation point and the time series change of eye gaze were measured using an eye camera. In order to detect the difference of visual information processing among three groups above, an important area that the participants must pay attention to with the highest priority was set for each static image. The time until the eye gaze fixates to the important area, and the ratio of the fixation time to the total search time were detected. Using these measures, the difference of visual information processing among three groups was clarified. Moreover, for novice and non-licensed participants, it was also explored whether a lecture related to KYT would improve the efficiency of visual information processing. The time until the eye gaze fixates to the important area was longer for the non-licensed participants than for the experienced participants. The learning effect by means of a KYT lecture was also observed.**

1. Introduction

With the growth of intelligent transportation systems (ITS), such as car navigation systems or hands-free cellular phones, driving is becoming more and more complex[1]. As much of the information provided contains texts and images, drivers are apt to become distracted and inattentive. Driving a car places a characteristically heavy workload on visual perception and cognitive information processing[2]. Drivers often simultaneously perform two or more tasks; for example, they adjust the volume of a radio or CD player and control the air conditioner to adjust the temperature while driving. Such sharing of attention may lead to dangerous situations. It is pointed out that such a driving skill to avoid dangerous driving situations differs between expert and novice drivers[3]. However, there are few studies that tried to clarify the difference of perceptual and cognitive skill[4]-[8] in potentially dangerous driving situations and made an attempt to apply the results to the enhancement of safety driving.

Ceder[9] considered the relationship between eye movement characteristics and attentional level during driving under different traffic conditions. Mourant et al.[10] analyzed how the visual scanning pattern of drivers changed as the drivers got used to the traffic situation of the same route. Underwood et al.[11], Underwood[12] and Cohen[13] paid attention to the driving skill, and compared the eye movement pattern during driving a real-world route between expert and novice drivers. Underwood et al.[11] investigate the visual scanning pattern of novice and expert drivers when driving three kinds of routes (rural, suburb, and urban routes). They concluded that novice drivers cannot carry out the scanning of the scene effectively like expert drivers. Although these studies[9]-[13] identified the difference of scanning characteristics between expert and novice drivers for a variety of routes, they have not carried out an experiment how the eye movement characteristics differ between expert and novice drivers under dangerous situations where the predictions of danger plays an important role. .

In this study, the situation where the prediction of danger must be carried out correctly and quickly was taken up to clarify the difference of eye movement characteristics between expert, novice, and non-licensed participants. The aim of this study was to examine the difference of visual information processing in KYT (Kiken Yochi Training) among novice, expert and non-licensed persons.

2. Method

2.1 Participants

Twenty seven participants took part in the experiment. All were from 19 to 25 years old. The driving skill of participants was divided into the following three categories.

(1) Novice driver: It is less than four years since the acquisition of driver's license. The participant in this category drives less than 10 times per year.

(2) Skilled driver: It is more than two years since the acquisition of driver's license. The participant in this category drives more than three times per week.

(3) Non-licensed participant

2.2. Apparatus

An eye-tracking device (EMR-VOXER, Nac Image Technology) was used to measure eye movements characteristics during the search task. This apparatus enables us to determine eye movements and fixation by measuring the reflection of low-level infrared light (800 nm), and also admits the head movements within a predetermined range.

The eye-tracker was connected with a personal computer (HP, DX5150MT) with a 15-inch (303mm x 231mm) CRT. The resolution was 1024 x 768 pixels. Another personal computer was also connected to the eye-tracker via a RS232C port to develop an eye-gaze input system. The line of gaze, via a Rs232C port, is output to this computer with a sampling frequency of 60Hz. The illumination on the keyboard of a personal was about 200lx, and the mean brightness of 5 points (four edges and a center) on CRT was about 100cd/m^2.
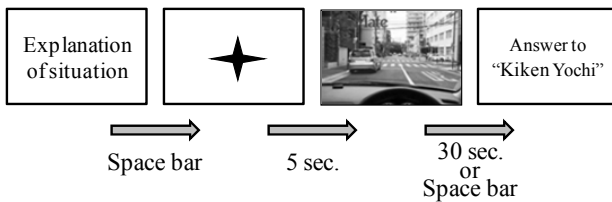
Fig.1 Flow the "Kiken Yochi" task.

The viewing distance was about 70 cm.

2.3 Task

The participant was required to look at the static image and predict dangerous situations in the image. Thirty images were used in the experiment. The images were selected from the article "Kiken Yochi Training" of monthly magazine "JAF Mate" issued by JAF (Japan Automobile Federation). The thirty images were selected from 142 images issued from June, 1994 to October, 2008. The answer to each "Kiken Yochi" task was made on the basis of the model answer of each issue. The flow chart of experiment is shown in Fig.1.

2.4 Design and procedure

Before entering the experiment, the calibration of eye-tracking device was conducted. First, the sentence which described the traffic situations was presented to the participant. The participant was required to read this sentence and understand the traffic situation. The participant pressed a space key when he or she judged that he or she could understand the situation. After that, a cross appears on the center of the display. The participant was required to gaze at the cross for 5 s. The image was presented at most for 30 s. After 30 s passed or the participant pressed the space key, the answer display appeared. The participant was required to answer orally. The procedure was repeated 30 times. The participant was required to imagine his or her driving situation and move their eyes according to it.

The following subjects were incorporated into the "Kiken Yochi" task.
(1) Always paying attention to pedestrian and bicycle
(2) Paying attention to traffic signs or road displays
(3) Confirmation of the behavior of oncoming cars
(4) Paying attention to the behavior of cars running on the same direction (lane)
(5) Identifying potential dangers which are hidden by obstacles and so on.

The experimental factors were skill level (expert, novice, and non-licensed).

2.5 Evaluation measures

The following seven evaluation measures were used to compare the ability to predict dangers in traffic environment among three groups (expert, novice, and non-licensed).
(1)Task completion time (time until the prediction of danger had been completed)
(2)Percentage correct (Percentage of correct answer to total number of problems)
(3) Percentage of eye fixation duration (=fixation duration/ total task completion time)
(4) Percentage of eye fixation duration to an important area (=fixation duration to an important area / total task completion time)
(5) Duration per one eye fixation to an important area
(6) Number of eye fixations to an important area
(7) Time until an important area was fixated

The eye fixation data were obtained as follows. The eye-tracking device output the x and y coordinates of eye mark every 1/60 s. The fixation was judged as follows. When the x or y coordinates at the next is moved more
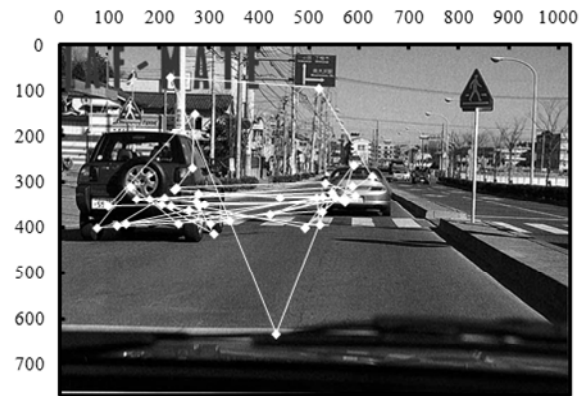

Fig.2 An example of eye movement.

Fig.3 An example of important area.

than 50 pixels, this was regarded as the eye movement. If the movement was within 50 pixels, this was regarded as the eye fixation. Groups of eye fixations are produced in such a way. The fixation coordinate is defined as mean values of x and y coordinates within the group. The difference of duration between the first and the last coordinates is defined as the fixation duration of the group. The fixation duration less than 0.13 s was exclude from the further analysis. An example of eye movement is depicted in Fig.2.

An important area to which the participant should pay attention with first priority was set to each static image. An example of important area is demonstrated in Fig.3. In Fig.3, the area where a man was about to cross the road corresponds to an important area.

In order to analyze the eye movement characteristics in more detail, the traffic situations were classified into the following five categories. The analysis was carried out not only among Drivers' skill levels but also among traffic situations.
(A) Intersection
(B) Straight path (heavy traffic)
(C) Straight path (light traffic)
(D) Highway
(E) Curve

3. Results

3.1 Task completion time (time until the prediction of danger had been completed)

In Fig.4, the mean task completion time is plotted as a function of skill level. A one-way (skill level) ANOVA carried out on the task completion time detected no significant main effect.
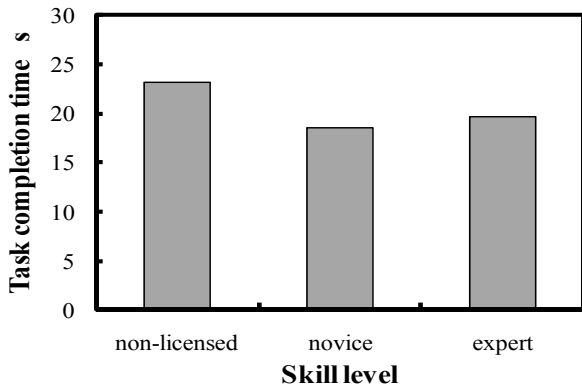
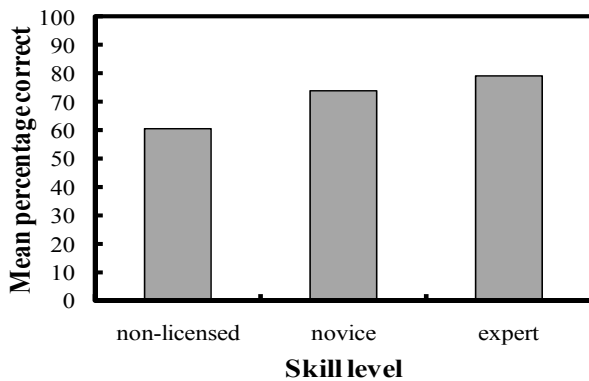Fig.4 Mean task completion time as a function of skill level.

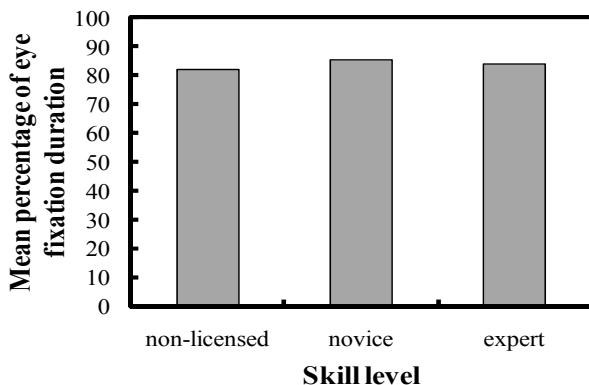Fig.5 Mean percentage correct as a function of skill level.

Fig.6 Mean percentage of eye fixation duration as a function of skill level.

3.2 Percentage correct (Percentage of correct answer to total number of problems)

In Fig.5, the mean percentage correct is plotted as a function of skill level. A one-way (skill level) ANOVA carried out on the percentage correct revealed a significant main effect of skill level ($F(2,32)=6.513$, $p<0.01$).

3.3 Percentage of eye fixation duration

In Fig.6, the percentage of eye fixation duration is plotted as a function of skill level. A one-way (skill level) ANOVA carried out on the percentage of eye fixation detected no significant main effect of skill level.

3.4 Percentage of eye fixation duration to an important area

A two-way (skill level by traffic situation) ANOVA carried out on the percentage of eye fixation duration to an important area detected only a significant main effect
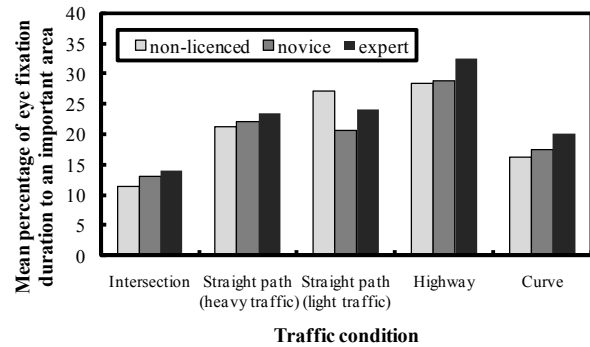

Fig.7 Mean percentage of eye fixation duration to an important area as a function of skill level and traffic situation.
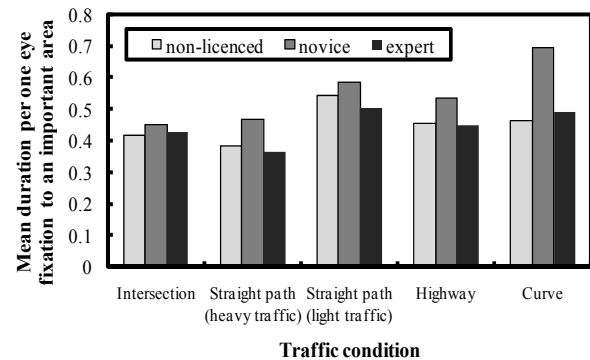

Fig.8 Mean duration per one eye fixation to an important area as a function of skill level and traffic situation.

of traffic situation ($F(4,64)=4.874$, $p<0.01$). In Fig.7, the .percentage of eye fixation duration to an important area is plotted as a function of skill level and traffic situation.

3.5 Duration per one eye fixation to an important area

A two-way (skill level by traffic situation) ANOVA carried out on the duration per one eye fixation to an important area detected significant main effects of traffic situation ($F(4,64)=3.974$, $p<0.01$) and skill level ($F(2,32)=3.564$, $p<0.05$). In Fig.8, the mean duration per one eye fixation to an important area is plotted as a function of skill level and traffic situation.

3.6 Number of eye fixations to an important area

A two-way (skill level by traffic situation) ANOVA carried out on the number of eye fixation to an important area detected only a significant main effect of traffic situation ($F(4,64)=5.236$, $p<0.01$). In Fig.9, the mean number of eye fixation to an important area is plotted as a function of skill level and traffic situation.

3.7 Time until an important area was fixated

A two-way (skill level by traffic situation) ANOVA carried out on the time until an important area is fixated revealed only a significant main effect of traffic situation ($F(4,64)=4.563$, $p<0.01$). In Fig.8, the time until an important area was fixated is plotted as a function of skill level and traffic situation. The time until an important area is fixated tended to decrease with the increase of skill level. The skilled driver tended to take less time until an important area is fixated.

4. Discussion

The task completion time did not differ significantly among skill levels (Fig.4). The percentage correct also
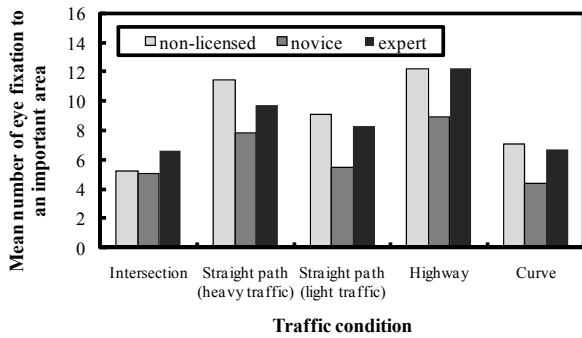
Fig.9 Mean number of eye fixation to an important area as a function of skill level and traffic situation.
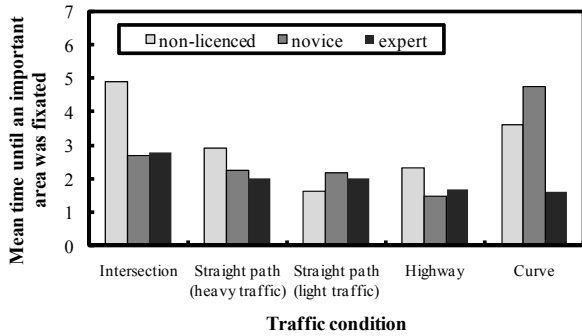

Fig.10 Mean time until an important area was fixated as a function of skill level and traffic situation.

did not differ significantly among skill levels (Fig.5). These results must be due to the self-paced task. Because the time limitation was not set, all participants might carry out the task without stress, and even skilled participants could take much time to reach to an answer. As shown in Fig.6, the percentage of eye fixation duration did not differ among skill levels. The reason might be the same with the discussion above. This experiment imposed no strict time limitation on the participant. Therefore, even the skilled participant must be very careful to reach the answer to the "Kiken Yochi" task.

As shown in Fig.7, the mean percentage of eye fixation duration to an important area for (A) Intersection, (B) Straight path (heavy traffic), (D) Highway, and (E) Curve tended to be higher for the skilled participant than for the novice and the non-licensed participants. This tendency was not observed for (C) Straight path (light traffic), which is relatively easier to treat than other traffic situations (A), (B), (D), and (E). In relatively complicated traffic situations, it seems that skilled participant pay more importance on an important area. In other words, the skill might be reflected in this measure.

As shown in Fig.8, the mean duration per one eye fixation to an important area of novice participants tended to be longer than other skill groups. In particular, with regard to (E) curve, the novice participant takes more time on an important area than other groups. As the reason cannot be identified in the range of this experiment, it must be pursued in future work.

As shown in Fig.9, the mean number of eye fixation to an important area of novice participants tended to be few than other groups. Contrasting this result with that in Fig.8, as for the novice participant, the longer the mean duration per one eye fixation to an important area is, the few the mean number of eye fixation to an important area is. While the novice participant fixates an important

area fewer than other groups, he or she seems to take more time to fixate an important area.

As shown in Fig.10, the time until an important area was fixated was for the skilled participant tended to be shorter than that for other two groups (non-licensed and novice participants). This might reflect the quick processing of potentially dangerous information by the skilled participant. The safety driving skill includes such an ability to notice the potential danger as soon as possible. The skill of expert might be reflected more remarkably than other measures. Especially, the expert participant was fast to notice the potential danger in (C) curve. As Murata et al.[14] have pointed out that the skilled expert are superior in the predictive property of behavior to novices. The result that the expert moves their eye more quickly to an important area might mean that the superior predictive ability of expert might be reflected in the quick movement time to an important area.

Although the static images were used to predict potentially dangerous situations, a real-world situation should be used to compare the skill level among groups with different skills, and be verified whether the similar result to this experiment is acquired. From the viewpoints of accuracy of eye movement measurement using an eye-tracking system, a static image is more ideal because head movement can be controlled to a minimum. In order to verify the results in this study in a real-world situation, the improvement of eye-tracking system would be necessary so that the eye movement can be measured accurately even if frequent head movement occurs.

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