Measurement of Depth Attention of Driver in Frontal Scene

Mamiko Fukuoka[1], Shun'ichi Doi[1], Takahiko Kimura[3], and Toshiaki Miura[2]

[1] Department of Intelligent Mechanical Systems Engineering, Kagawa University
2217-20 Hayashi-Cho
Takamatsu, Kagawa, 761-0396 Japan
s09g523@stmail.eng.kagawa-u.ac.jp, sdoi@eng.kagawa-u.ac.jp
[2] Department of Applied Cognitive Psychology, Osaka University
1-2 Yamadaoka, Suita, Osaka, 565-0871 Japan
toshi@hus.osaka-u.ac.jp
[3] Kansai University of Welfare Sciences
3-11-1 Asahigaoka, Kashiwara, Osaka, 582-0026 Japan
takimura@fuksi-kagk-u.ac.jp

Abstract. Safety driving has been maintained by suitable watching for frontal scene. The delay of reaction has been found to be the major cause of vehicle accidents. It is the purpose of this paper to investigate depth attention characteristic of drivers when drivers are in the traffic environment by the use of a semi-realistic setting a three-dimension (3-D) attention measurement system. The experiments were conducted in order to clarify the effect of the individual characteristic of driver and traffic environment on the characteristic of depth attention by studying various aspects of the effect of aging, illuminance and display color on characteristic of driver's depth attention from three elements of traffic.

Keywords: display color, three-dimensional space, shift of attention, depth, allocation of attention, driver.

1 Introduction

Recently, the number of heavy traffic accidents is on a declining trend. However, the ratio of the traffic accident related to the senior citizen is increasing, and the number of accidents at twilight stands out, too. A visual system of drivers receives massive amounts of information and prioritizes from frontal road signs and markings in traffic environment, so drivers have to switch continually their visual attention between the objects presented in front of drivers. The in-car devices including car navigation system and speedometer become widespread in recent years, thus drivers get information from various in-car devices while driving. The display colors, brightness, and the contrast, etc. of in-car devices were investigated from the viewpoint such as visibility. However, there are few researches that examine the influence that relation between in-car device and traffic environment exerts on characteristic of driver's depth attention.

D. Harris (Ed.): Engin. Psychol. and Cog. Ergonomics, HCII 2009, LNAI 5639, pp. 376–385, 2009.

In preceding study for the characteristic of depth attention, using cue to present the appearance position, it was shown that Reaction Time (RT) was earlier when the appearance position presented like the cue than the cue was not presented, and RT was slower when the appearance position was not presented like the cue than the cue was not presented. In addition, in transfer efficiency of depth attention, it was shown that RT was slower when subjects' attention was shifted "near to far" than "far to near" as asymmetry, and RT was slower when the moving distance was long than short. Furthermore, it was shown that these characteristics appeared more remarkably at the dynamic condition than static condition.

In the present study, we clarify the effect of the individual characteristic of driver and traffic environment on the characteristic of depth attention by studying various aspects of the effect of aging, illuminance and display color on characteristic of driver's depth attention from three elements of traffic.

2 Influence of Aging Given to the Characteristic of Depth Attention

2.1 Method

According to results of experiment, analyze characteristic of depth attention of young subjects and elder subjects.

Subjects: There were two group subjects. First group was 17 volunteers participated at Kagawa University. All the participants have normal vision or corrected to normal vision. Second group was 17 elder subjects from 59 to 68 years old. One subject's data was excluded, because of cull rate of error was over 20%.

Apparatus and stimuli: The overall size of the device is 8m length. Scale the model to be 1/25 of actual size in the inner of this device, it looks like a tunnel in which there were four targets. The subjects observed the scene by an eyepiece (1/2 multiple), so the apparent scenery was 1/50 scale. The fixation point was a yellow LED with approximately 4.3cd/m^2 in brightness. A fixation point was presented at a distance of 120cm from the subject. The targets were red LED with approximately 7.6cd/m^2 in brightness, and were located at 30cm, 81cm, 158cm and 231cm from the subject, separately. The subject sat on the chair of a cart moving forward in tunnel alleyway. The stimuli were digital LED located in the front of sight line of the subject. There were two targets separately in front and behind of the fixation, 30cm and 81cm (in front) as well as 158cm and 231cm (in behind) from observer. It is equated distance of 15m, 40.5m, 79m and 115m respectively in real space by means of eyepiece. Luminance of the environment was daylight condition (480-680 lx).

Design: Three independent variables were examined: cue validity (Valid, Neutral, and Invalid), asymmetry (“far to near” or “near to far”) and subjects group (elder subjects and young subjects).

Procedure: The observing condition was in moving condition (0.44m/s). Three within-observe variables were used: cue validity (valid, neutral and invalid). 65% of

all trials were valid, 15% were invalid and 20% were neutral. The entire experiment consisted of a unique session of 320 trials. Subjects have a short rest every 160 trials. The fixation point was presented after 1000ms from the beginning of each trial and the information of target location were presented in the fixation position by digital LED (1 to 4). And then, the targets were presented until subjects made response. In order to judge accurately targets which appeared timely, shape of targets were used in "E" or "3". Task of the subject was to judge whether the target presented nearer than fixation point or further than it, then the subjects must make a quick response according to the information presented beforehand at the targets location: "E" or "3", and then push the button as soon as possible. Subjects have to exercise before the formal experiment. The procedure and task in exercise are almost the same as the formal experiment. When subject can accomplish the task by achieving the criteria of accuracy, the exercises stop. Reaction time (RT), for correct trials only, was calculated for every subject. Besides, it were not adopted that reaction time were beyond 1000 ms and within 100 ms because response of the subjects to the targets was too fast or too slow.

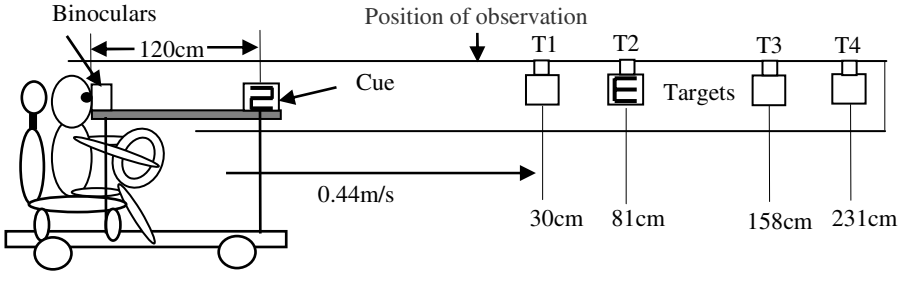

Fig. 1. A three-dimensional depth attention measurement system

2.2 Results and Discussion

Fig.2 showed RT and standard deviation in three kinds of cue cases (valid, neutral and invalid). There were significant differences in RT of each cue[$F(2,62)=25.02$ $p=.000$], subjects group[$F(1,31)=56.36$ $p=.000$] and asymmetry[$F(1,31)=9.65$ $p=.004$]. In additional analyses, RT was slower in invalid than valid ($p=.000$) and neutral ($p=.000$), and RT was faster in valid than neutral ($p=.002$).

From the above result, it was indicated that RT of elder subjects were delayed approximately 200ms behind young subjects, and RT was slower when subjects' attention was shifted "near to far" than "far to near". In addition, it was indicated that RT when the subjects was turned one's mind was faster than when the cue was not presented, and RT was slower when the subjects was turned one's mind to the place that was not appearance position than when the cue was not presented. These results are consistent with the preceding study.

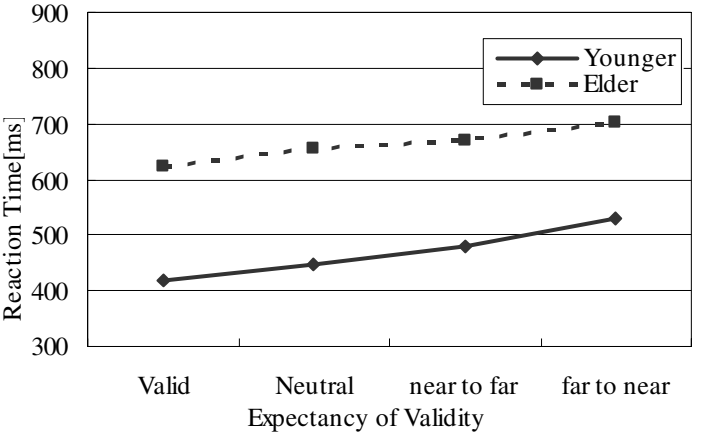

Fig. 2. Reaction Time of each cue

3 Influence of Illuminance Given to Characteristic of Depth Attention

3.1 Method

According to results of experiment, analyze influence of illuminance given to characteristic of depth attention.

Subjects: In this experiment, 13(high visual adaptability group: 6, low visual adaptability group: 7) students of Kagawa University participated as subjects.

Apparatus and stimuli: The apparatus and stimuli were the same except peripheral illluminance. Peripheral illluminance of this chapter was dawn condition (5-8lx), twilight condition (95-135lx), and daylight condition (480-680lx).

Design: Four independent variables were examined: cue validity (valid, neutral, and invalid), asymmetry (“far to near” or “near to far”), illuminance (daylight, twilight and dawn) and subjects group (visual adaptability was high group and low group).

Procedure: The basic procedure of this chapter was the same as chapter 2.

3.2 Results and Discussion

Subjects were categorized two groups: visual adaptability was low group and high group like Fig.3. Fig.4 showed RT of low group and standard deviation in three kinds of cue (valid, neutral and invalid). There were significant differences in RT of each cue[$F(2,22)=27.63$ $p=.000$] and asymmetry[$F(1,11)=35.91$ $p=.000$]. From this result, RT was slower when subjects' attention was shifted "near to far" than "far to near". In additional analyses of multiple comparison, RT of each cue was slower in invalid than valid ($p=.000$) and neutral ($p=.000$), and faster in valid than neutral ($p=.016$). These results are consistent with the preceding study. However, in this experiment, there

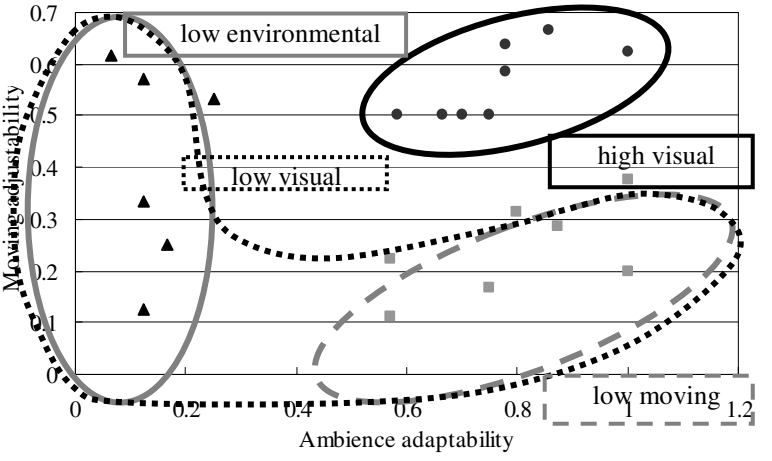

Fig. 3. Moving and Ambience adaptability

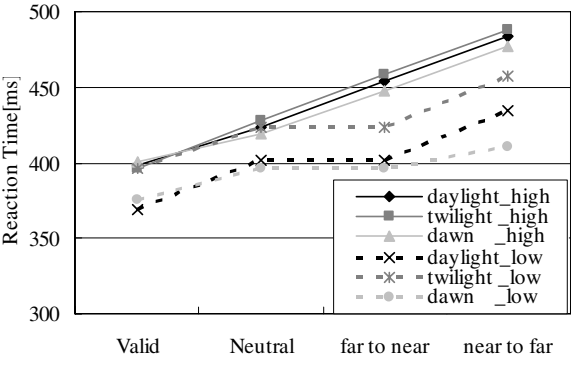

Fig. 4. Reaction Time of each cue

were no significant differences in RT of illuminance[$F(2,22)=1.07$ $p=.360$]. Therefore, main effect of illuminance was examined in respective visual adaptability groups. In high visual adaptability group, there were no significant differences in RT of illuminance[$F(2,10)=0.05$ $p=.956$]. In low visual adaptability group, there were no significant differences in RT of illuminance[$F(2,12)=1.77$ $p=.212$] too. However, seen in Fig.4 and analysis result, these results suggested that low visual adaptability group was susceptible to illuminance than high visual adaptability group.

4 Influence of Display Color Given to Characteristic of Depth Attention

According to results of experiment, analyze influence of display color given to characteristic of depth attention.

Ⅰ Influence of Colors' Combination Given to Depth Attention Characteristic

1 Method

According to results of experiment, analyze influence of colors' combination given to depth attention characteristic.

Subjects: The subjects were 10 volunteers participated at Kagawa University. All the subjects have normal vision or corrected to normal vision.

Apparatus and Stimuli: The apparatus and stimuli were the same as chapter 2 except the color of the fixation point and targets. The fixation point was a red (10cd/m^2) and green (18cd/m^2) LED in brightness, and the targets were red (5.5cd/m^2) and green (5.0cd/m^2) LED in brightness.

Design: Four independent variables were examined: condition (static and dynamic), cue validity (valid, neutral, and invalid), asymmetry ("far to near" or "near to far") and combination of colors (cue-target: red-red, green-green, red-green and green-red).

Procedure: The procedure was the same as chapter 2 except the condition, the number of trials and the way of presenting the cue. The observing condition was dynamic (0.44m/s) and static. The entire experiment consisted of a unique session of 640 trials. The subjects experimented by 320 trials separately in two days. The information of target location was presented in the fixation point by digital LED (in front: U, in behind: inverse U and Neutral: H).

2 Results and Discussion

Fig.5 showed RT and standard deviation in three kinds of cue cases (valid, neutral and invalid) in dynamic condition. There were significant differences in RT of each cue[$F(2,18)=4.50$ $p=.026$], asymmetry[$F(1,9)=16.06$ $p=.003$], combination of colors[$F(3,27)=5.52$ $p=.004$] and cue-colors' combination interaction [$F(6,54)=2.54$ $p=.031$]. In additional analyses of multiple comparison, RT of each cue was slower in invalid than valid ($p=.017$) and neutral ($p=.019$). There were no significant differences in RT between valid and neutral ($p=.952$). This result was attributed to the fact that range cue (attention allocation by top-down process) was used such as "in front" and "in behind". In addition, RT of each colors' combination was faster in green-red combination than green-green ($p=.003$) and red-green combination ($p=.002$). In uncomplicated main effect as additional analyses, there were significant differences in RT of combination of colors in invalid[$F(3,81)=8.44$ $p=.000$]. In multiple comparison, there were significant differences in RT between green-green and green-red combination ($p=.000$), green-green and red-red combination ($p=.001$), red-green and green-red combination ($p=.001$) and red-red and red-green combination ($p=.010$).

From the above result, it was indicated that RT was slower when subjects' attention was shifted "near to far" than "far to near", and RT when the subjects was turned one's mind to the place that was not appearance position was slower than when the cue was not presented. These results are consistent with the preceding study. In addition, RT was faster when the target color was red than green. In fact, this result suggested that main effect of cue was dependent on target colors than colors of fixation point.

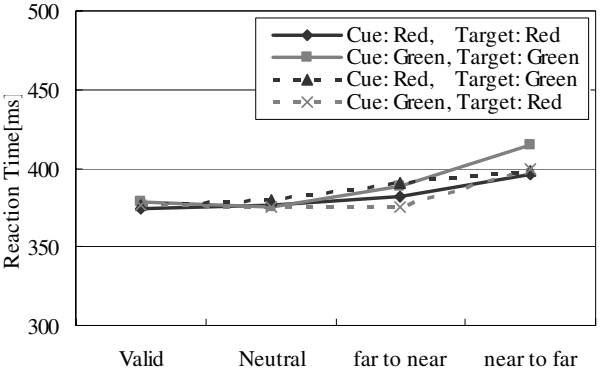

Fig. 5. Reaction Time of each cue in dynamic condition

Ⅱ Influence of Display Colors of the Same Luminance Given to Depth Attention Characteristic

1 Method

According to results of experiment, analyze influence of display colors of the same luminance given to depth attention characteristic.

Subjects: The subjects were 27(male: 12, female: 15) volunteers participated at Kagawa University. All the subjects have normal vision or corrected to normal vision. One subject's data was excluded, because of cull rate of error was over 20%.

Apparatus and Stimuli: The apparatus and stimuli were the same as experiment Ⅰ except the color of the fixation point and targets. The fixation point was a red, green and blue (8.2-8.5cd/m^2) LED in brightness, and the targets were red (7.4cd/m^2) LED in brightness.

Design: Five independent variables were examined: gender, condition (static or dynamic), cue validity (valid, neutral, and invalid), asymmetry ("far to near" or "near to far") and display colors (red, green and blue).

Procedure: The procedure was the same as experiment Ⅰ except the rate of cue validity type and the number of trials. 64% of all trials were valid, 14% were invalid and 22% were neutral. The entire experiment consisted of a unique session of 336 trials.

2 Results and Discussion

Fig.6 showed RT and standard deviation in three kinds of cue cases (valid, neutral and invalid) in dynamic condition. There were significant differences in RT of each cue[$F(2,48)=50.71$ $p=.000$] and condition-asymmetry interaction [$F(1,24)=6.62$ $p=.017$], and had a tendency of gender-condition-display colors' interaction [$F(2,48)=2.73$ $p=.075$]. In additional analyses of multiple comparison, RT of each cue was slower in invalid than valid ($p=.000$) and neutral ($p=.000$). There were no significant differences in RT between valid and neutral ($p=.170$). The result was attributed to the fact that range cue (attention allocation by top-down process) was used such as

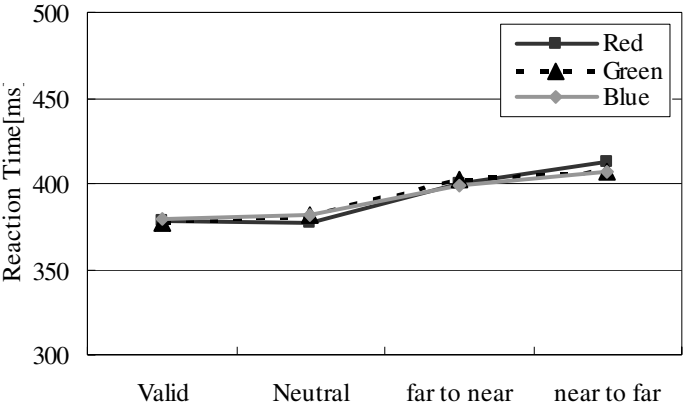

Fig. 6. Reaction Time of each cue in dynamic condition

in front" and "in behind". This result is consistent with the experiment Ⅰ. In uncomplicated main effect as additional analyses, there were significant differences in RT of asymmetry in dynamic condition[$F(1,48)=7.69$ $p=.008$]. From these results, it was indicated that RT was slower when subjects' attention was shifted "near to far" than "far to near" in dynamic condition, and RT when the subjects was turned one's mind to the place that was not appearance position was slower than when the cue was not presented.

Ⅲ Influence of Display Colors of the Same Amount of Energy Given to Depth Attention Characteristic

1 Method

According to results of experiment, analyze influence of display colors of the same amount of energy given to depth attention characteristic.

Subjects: The subjects were 14(male: 7, female: 7) volunteers participated at Kagawa University. All the subjects have normal vision or corrected to normal vision.

Apparatus and Stimuli: The apparatus and stimuli were the same as experiment Ⅱ except the luminance of the fixation point. The fixation point was a red (11cd/m^2), green (13cd/m^2) and blue (13cd/m^2) LED in brightness.

Procedure and Design: The procedure and design were the same as experiment Ⅱ.

2 Results and Discussion

Fig.7 showed RT and standard deviation in three kinds of cue cases (valid, neutral and invalid) in dynamic condition. There were significant differences in RT of each cue[$F(2,24)=32.56$ $p=.000$], display colors[$F(2,24)=12.26$ $p=.000$], gender-display colors interaction[$F(2,24)=3.98$ $p=.032$] and cue-display colors interaction [$F(4,48)=9.94$ $p=.000$]. In additional analyses of multiple comparison, RT of each cue was slower in invalid than valid ($p=.000$) and neutral ($p=.000$). There were no

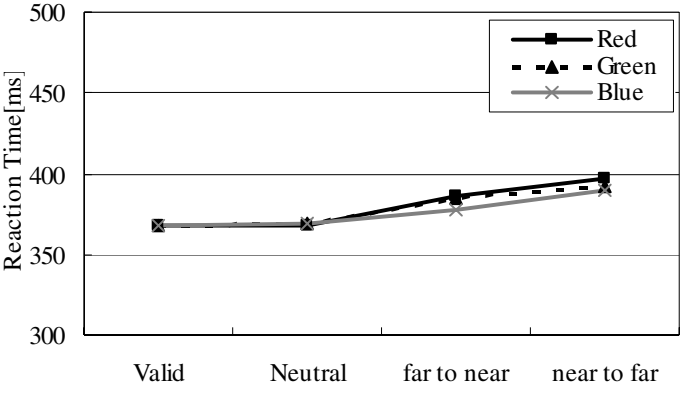

Fig. 7. Reaction Time of each cue in dynamic condition

significant differences in RT between valid and neutral (p=.511). This result is consistent with the experiment Ⅰ. In addition, RT of each colors was slower when the color was red than green (p=.004), and blue (p=.000). From this result, it was indicated that RT was slower when cue presented subjects with red than green and blue. In uncomplicated main effect as additional analyses, there were significant differences in RT of display colors in invalid[$F(2,72)=31.62$ p=.000], and female [$F(2,24)=15.10$ p=.000]. In multiple comparison of invalid, there were significant differences in RT between red and green (p=.000), red and blue (p=.000) and green and blue (p=.006). In multiple comparison of female, there were significant differences in RT between red and green (p=.002), red and blue (p=.000), and had a tendency between green and blue (p=.068).

From the above result, RT was slower when the subjects was turned one's mind to the place that was not appearance position than when the cue was not presented. These results are consistent with the preceding study. In addition, RT was faster when the display color was blue than green, and slower when the display color was red than green. Furthermore, these results suggested that invalid and female were susceptible to the display color.

5 General Discussion

Reaction adaptability of some young drivers was still faster than elder drivers, although visual function of them decline due to retinal degeneration. RT was slower in invalid cases than valid and neutral cases. This implies that it was dangerous when elderly driver driving due to their RT was slower than young driver with dark filed.

The luminance of peripheral environment has had an influence on the response adaptability of drivers while driving. These attention characteristic appears more remarkably in twilight condition than in daylight and dawn condition for drivers having low visual adaptability. That is, reaction time in each cue cases is slowest in twilight condition than either daylight or dawn condition.

The display color has had an influence on the response adaptability of drivers while driving. These attention characteristic appears more remarkably in invalid condition and female drivers and be susceptible to the display color.

The shift of depth attention had asymmetry, that is, RT as different when the shift of depth attention was from nearer to further space and from further to nearer space. RT was slower in "near to far" than in "far to near", and this tendency stood out in dynamic condition. On the other hand, this tendency became weak when the target color was red.

Visual perception will be examines based on the characteristic of ocular convergence and people's the depth visual function for the future. In addition, it will be examined when bright and color of the targets will be changed, and though the test of the brain wave of the subjects, the feasibility of evaluation the impact of the road traffic environment on driver's comfortableness by using the fluctuation law of the brain wave is discussed in the future.

Moreover, driving safety application research will develop for road traffic safety, for example, the traffic safety educational system in driving for the aged driver base on the studies above in future.

From these considerations, it must to be clarified to prevent the traffic accidents that we should understand the delay of reaction caused by the lack of understanding the context of the traffic and foresight of the coming danger in the frontal scene.

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