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The Effect of Changing Driving Brightness on Older Drivers

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ABSTRACT

The traffic accidents of the aged are increasing because old people generally experience a decline of physical functions and judgment but their dependence on automobiles increases. In order to investigate the older drivers' response to traffic signs and surrounding environment according to changing driving brightness, this study measured the visual cognitive behavior, driving behavior, and subjective evaluation while the driving brightness was changed using a driving simulator. Furthermore, the drivers who recognized traffic signs and those who did not were compared. As a result, it was found that some older drivers had declined ability of cognition, some failed to adapt to rapid brightness change even if sufficient attention was given to traffic sign, and some could not safely control the vehicle when approaching intersections. Therefore, the development of support systems for aged drivers in traffic environment is necessary in the future.

Keywords: Dark adaptation, Older driver, Recognition

1. Introduction

With decreasing birth rate and the development of medicine, the length of life is continuously increasing. Aging is a general trend of the world that causes great changes in this period of times. While the world population including Asian people is rapidly aging, Korea is experiencing faster aging than other courtiers. The percentage of the aged is expected to grow from 9.4% in 2005 to 14.4% in 2019, and then will reach 35.1% in 2050. Korea is not only aging faster than any other country in the world, it is expected to become the most aged country by mid-21st century [Paul Hewitt, 2009]. Meanwhile, aging is a serious problem in Japan as well. Among the total population of 127.69 million (as of October 2008), the population over 65 is 28.22 million, or 22.1% of the total population. It has become a super aged society in which one in five is an aged person. In this aging society, the number of driver's license holders who are over 65 has doubled compared to 10 years ago, and they account for 14.7% of total driver's license holders. In particular, driver's license holders over 85 have increased 14.6% compared to 2007 [National Police Agency of Japan, Statistics of driver's license, 2008].

Furthermore, the number of traffic accidents inflicted by or on the aged has been gradually increasing for the last 10 years as shown in Fig. 1 [National Police Agency of Japan, 2010].

Moreover, the damages of traffic accidents to the aged are also serious. The percentage of the aged in the deaths from traffic accidents in Japan is 47.5% which is much higher than other generations (age groups) [Minobe, 2009].

One of the causes of the traffic accidents of the aged is the decline of physical functions due to older age. The abilities for driving decline with age. For static visual acuity, they have difficulty seeing the dashboard while driving; for

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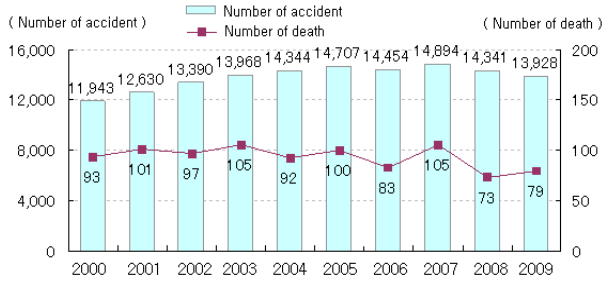


Figure 1. Trend of traffic accidents involving the aged for the last 10 years (Japan)

dynamic visual acuity, they have difficulty detecting objects that appear from left or right while driving watching the front. While driving at night they cannot clearly see front objects. Their visual abilities can decline and their field of visions can become narrower due to cataract, glaucoma or other diseases related to old age. Furthermore, the aged experience decline in auditory functions and power of judgment, operation of accelerator pedals, and physical strength. Almost everyone experiences decreasing visual function with age, and the dark adaptation of people aged 55 or older decreases approximately 36% compared to that of 20s [Jeong, 2007].

In a study on dark adaptation, Park et al. (2009) analyzed the effect of illumination intensity level and object size on the visual detection time in an environment with decreasing brightness, and found that the illumination intensity of minimum 20 lux was the appropriate level in a dark adaptation environment. However, they did not examine the dark adaptation characteristics of the aged drivers.

The main purposes of driving by the aged are sending off and meeting people, visiting hospitals, shopping, and eating out. Most accidents of the aged drivers generally occur around the dusk between 5 pm and 8 pm; the accidents in these hours are over 15.0% of the daily traffic accidents [Annual report on the aging society of Japan, 2009].

The driving accidents of the aged are gradually increasing. It is believed that the low adaptation ability to the driving environment plays a large part in these accidents. This study investigated the recognition ability of the aged drivers for traffic signs when the brightness suddenly drops while driving.

2. Experiment

2.1 Experimental apparatus

A driving simulator was used to change the brightness in driving environment. As shown in Fig. 2, the driving simulator consists of an actual car with automatic transmitter, a 150 inch screen, DLP projectors, a 6-DOF motion system, etc. The screen had 8 surfaces, and 10 DLP (Digital Lighting Processing) projectors were used to project driving scenes so as to provide a 360 degree vision for driver. The driver behaviors such as the operation of steering wheel, accelerator pedal, and brake were collected by a computer. A 7-inch wide display was installed in the dashboard to provide vehicle information such as velocity and the location of transmission.

Furthermore, an electric motion system was installed at the bottom of the vehicle to simulate the vibration and acceleration during driving.

According to the study of Lee et al. (2009), the effect of secondary task during driving is greater in the downtown area than in the expressways for older drivers. Thus, the driving simulator used a database which closely reproduced the Minato-Mirai district in the downtown of Yokohama, Japan, and the driving situation was set to free traffic during the daytime.

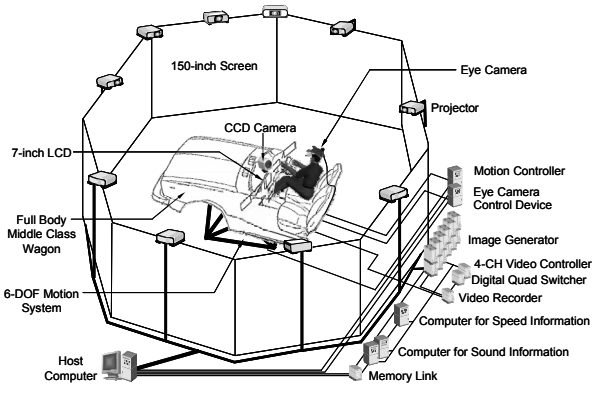


Figure 2. A schematic diagram of the driving simulator

2.2 Evaluation and analysis

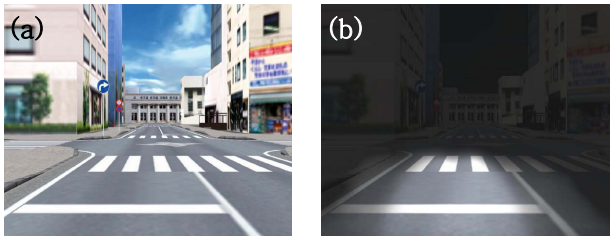
2.2.1 Glancing traffic signs

The eye mark recorder, EMR-8, NACTM shown in Fig. 3 was used to measure the glance of traffic signs and objects

of driving environment while the driver was approaching at the target intersection with varying brightness. The driving course at the target intersection was a two-lane office building street corresponding to a general trunk road with the speed limit of 30 km/h and with no median strip.

Figure 3. Eye mark recorder for vision tracking

Fig. 4 shows the bright and dark driving environments at the target intersection, and the traffic sign for turning direction is at the left of the lane (traffic keeps to the left in Japan).



(a) Bright driving environment (b) Dark driving environment

Figure 4. Changing brightness in the driving environment at the intersection

2.2.2 Driving behaviors

To examine the vehicle operations by drivers while approaching the intersection in different brightness of the driving environment, the speed changes and brake movements were analyzed.

2.2.3 Subjective evaluations

The attention levels of the drivers for the objects of attention in the driving environment such as pedestrians, preceding vehicles, opposite vehicles, and road signs in different brightness levels were examined by the scale of 7 degrees (0: no attention, 7: extreme attention).

2.3 Experimental procedure

The details of experiment, safe driving, driving rules, and cautions were explained to the subjects and they performed sufficient driving practices to familiarize themselves with the driving simulator. During the driving practice, brightness in the driving environment was changed. The experimenter and subjects were evaluated for their perception of traffic signs, observance of traffic regulations, and their skill level for using the driving simulator. Then the experiment was conducted.

It was confirmed that the subjects recognized the traffic signs in bright driving environment. After the driving, a survey of the subjects was conducted regarding their level of attention to the road and driving environment. Then, the turning direction at the intersection of the traffic sign was changed and the perception of traffic signs while the subjects were driving in dark condition was experimented. After the experiment, a survey of the subjects was conducted regarding their level of attention to road and driving environment in the same way as for the bright driving environment.

2.4 Subjects

The subjects were six aged persons who had driver's licenses. Their average age was 67.5±4 and they usually drove 2~3 times a week. They were all healthy and had no inconvenience in daily life due to eyesight. They all lived in Yokohama.

3. Results

3.1 Results for perception of traffic signs

In the bright road environment, all the subjects observed the traffic sign and made the correct turn at the intersection. In dark condition, however, two subjects failed to recognize the changed traffic sign and drove. Even if the ages of the subjects were similar, the adaptation ability to changing brightness during driving varied by person.

3.2 Glancing behavior

The subjects' recognition behavior for traffic signs, road and traffic environment during driving were analyzed in bright and dark conditions. Fig. 5 shows the mean glance time and glance count for traffic signs in bright and dark conditions. Two of six subjects failed to adapt to the driving environment with suddenly lowered brightness, it is difficult to find the locations of traffic signs.

Among the subjects who recognized the traffic sign, the glance time and count increased for all the subjects except for Sub. 6. For Sub. 3, the glance count did not change but the glance time increased more than two-fold. For Sub. 4, the glance count increased.

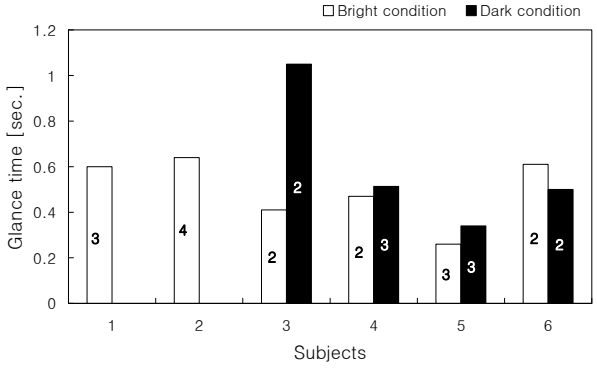


Figure 5. Average glance time and count by brightness condition

Fig. 6 shows the glancing rates of the subjects who failed to recognize the traffic sign in bright condition, and Fig. 7 shows the glancing rates of the subjects who failed to recognize the traffic sign in dark condition. In the bright condition, most drivers showed the same glancing rates for left, right, the road center and the traffic sign. In the dark condition, the glancing rates of the subjects who recognized the traffic sign did not change greatly from the bright condition. The subjects who failed to recognize the traffic sign, however, showed higher rate of front glancing and revealed an effort to perceive the traffic sign by moving their eyes to the location of the traffic sign.

3.3 Driving behavior

Fig. 8 shows the vehicles speeds of the subjects at the intersection in dark condition. Most subjects reduced speed at around 10 m before the intersection, indicating the fact

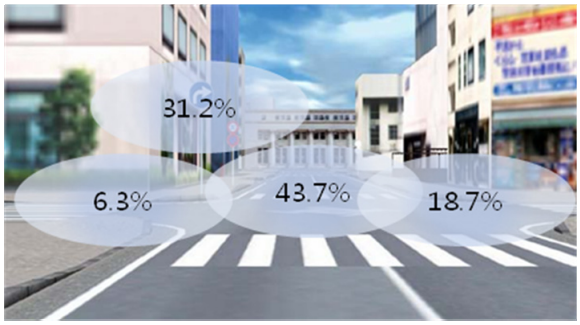


Figure 6. Glancing rates of subjects who failed to recognize the traffic sign in bright condition

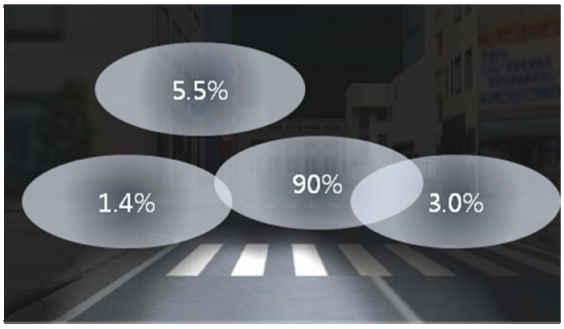


Figure 7. Glancing rates of subjects who failed to recognize the traffic sign in dark condition

that they pay much attention to the traffic sign and traffic environment (situation). According to the results, however, two subjects failed to recognize and did not observe the traffic sign.

Unlike most other subjects who reduced speed in advance before approaching the intersection, the subjects who failed to recognize the traffic sign suddenly reduced speed at around 3 m before the intersection (Sub. 1), or drove straight

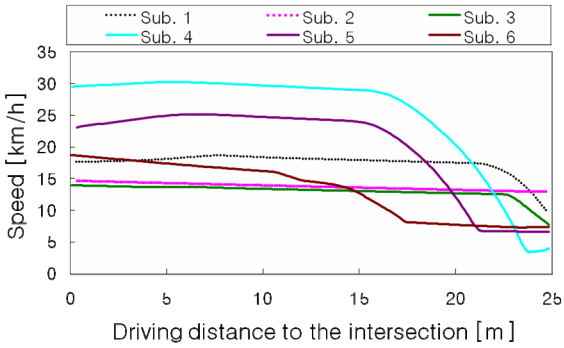


Figure 8. Vehicle speed until the intersection where subjects must make a turn

at low speed (Sub. 2).

Fig. 9 compares the break operations between subjects who recognized the traffic sign and those who failed to recognize it until the intersection where they must make a turn. When the brightness in the environment suddenly changed, four subjects who recognized the traffic sign tended to press the break at around 20 m before the intersection, but the other two subjects (Sub. 1 and 2) who failed to recognize the traffic sign pressed the break at around 8 m before the intersection.

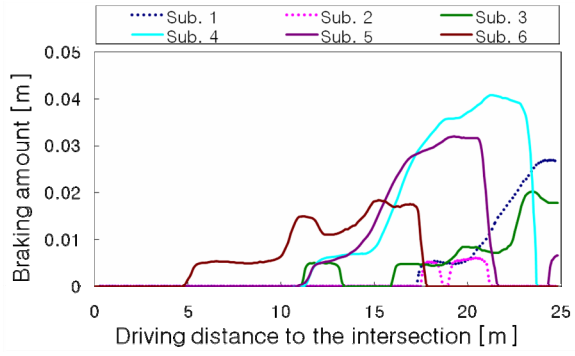


Figure 9. Break operation until the intersection where subjects must make a turn

3.4 Subjective evaluations

Fig. 10 shows the results of a survey on the level of attention to the traffic environment and situation condition in the scale of 7 degrees in different brightness conditions. The level of attention was generally high in dark condition. Although the level of attention to following vehicles and the left and right traffic situations at the intersection were lower in the dark condition compared to the bright condition, they paid more attention to pedestrians, preceding vehicles, traffic signs, and traffic lights.

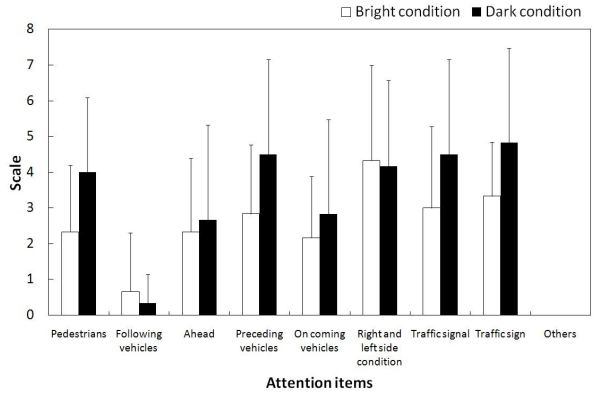


Figure 10. Level of attention of subjects in different brightness conditions

4. Discussion

The subjective evaluations showed that the subjects paid more attention in dark driving environment. According to the driving results, however, two of the six subjects failed to adapt to the sudden darkness and did not recognize the traffic sign. Furthermore, the subjects who failed to recognize traffic sign also distributed their attention to many directions and paid attention to the traffic sign similarly to the subjects who recognized the traffic sign, but despite their effort to perceive the traffic sign, they failed to recognize it.

Adaptation ability to suddenly lowered brightness in the driving environment (dark adaptation) can vary by individual. Although the ages of the subjects were similar in this study, two subjects failed to adapt to the changing brightness in the environment. One subject was 75 years old which was higher than the average age, but the other subject was younger than the average age.

The aged drivers can experience higher danger in road environment because their adaptation ability can be lower due to decreased eyesight compared to younger drivers. Driving in situations with high changes in bright adaptation and dark adaptation such as before sunset when the sky is still bright but the road is dark, in shades of trees or geographical features in mountains or in shades of high-rise buildings in urban environment can be highly dangerous for the aged drivers.

Since the dependence of aged people on driving is increasing in spite of the fact that it poses many risks due to decreasing eyesight, hearing, physical strength, judgment, and concentration, we need to come up with ergonomic evaluations and countermeasures in consideration of the physical and mental characteristics of aged drivers.

5. Conclusions

As the aged drivers experience decreasing physical abilities such as eyesight in particular, this study evaluated the ability of the aged drivers to recognize traffic signs when the driving environment suddenly becomes dark. The aged drivers reported that they paid more attention to the traffic signs and traffic situations at the intersection in an environment where the brightness suddenly decreased, but in actual driving, they failed to recognize traffic signs and did not operate the vehicle appropriately according to the changing environment. Furthermore, they tended to glance at the center of the road compared to bright driving environment because they could not adapt to the dark condition quickly. Even the aged drivers who recognized the traffic sign experienced increased glance count and glance time for traffic signs in dark condition compared to the bright condition.

Therefore, the development of support systems for aged drivers in traffic environment is necessary in the future.

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