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Fundamental study for constructing a system to assist the left visual field of older drivers
- Effectiveness of the alternative of the left front side-view mirror by the central visual field -

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Abstract— **The purpose of this paper is to establish the basics of the systems that assist visibility of the left visual field for older drivers. The display was located either the left which corresponded to a left side mirror, or within the central effective visual field. Participants performed multiple tasks where tracking task using a steering wheel was a primary task, and judgment of situations using a left or front display was a secondary task. How the display location affected the judgment performance was explored for both young and older adults. We counted the number of the warning during the tracking task and measured the percentage correct reaction to displayed stimulus and reaction sensitivity. We investigated how these measures ware affected by age and display location. Mean warning number during the tracking tasks, the percentage correct recognition of situations and d' was affected age and display location. The central display was found to increase the percentage correct recognitions of situations.**

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, cognitive information processing, and manual responses[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. Previous research in the area of displays and controls for secondary devices in automobiles are notable for the lack of reported work on compatibility. Most research discusses design of the display or the control, but not the way in which they are to operate together, which includes effects of compatibility.

Lambel, Kauranen, Laakso, and Summala and Lambel, Laakso, and Summala discussed the relationship between display location and performance in car driving situations[3],[4]. Lambel, Laakso, and Summala reported that the driver's ability to detect the approach of a decelerating car ahead was affected by the display location[4]. Waller and Green[5] examined switch type and its location, and pointed out a lack of consensus as to where the control should be located. Proper control (switch) location must be one of the important factors to assure fast responses of drivers.

Makiguchi et al. [6] demonstrated that steering wheel mounted controls were more effective than controls on the instrumental panel. However, they did not examine the effectiveness of steering wheel-mounted switches by taking the display location factor into account. Although Wierwille[7] stated that in-car controls and displays should be designed by taking visual and manual demands into account, he did not give guidelines for where the displays and controls should be located. Murata and Moriwaka[8] investigated how the number and arrangement of steering wheel mounted switches interactively affected performance. They found that the cross-type arrangement with three switches provided best performance and highest psychological rating.

Older adults may have more difficulty in operating a vehicle than younger adults. There are many reports suggesting that older adults exhibit deficits in various cognitive-motor tasks[9]-[11]. These authors reviewed the literature in movement control and discussed the effects of age on cognitive-motor capabilities in driving, from the viewpoint of movement science. Imbeau et al. [12] discussed how the aging factor affected display design and driving performance. They made an attempt to provide designers with integrated performance data that helped them answer design questions and evaluate design alternatives. They presented a model that can predict performance (glance time of the display) using age, character size of the display, and contrast of the display. However, they did not discuss the effects of controls. Smith et al. [13] reviewed the current databases applicable to automobile design. They pointed out that design approaches and data used in automobile design are mostly for a young population. The design approach and data suitable for an older population has not been provided. They did however review data on the characteristics and problems of older drivers, including physical and motor, sensory and cognitive changes. It is pointed out that working memory of older adults is inferior to that of young adults.

A safety driving manual tells that we should pay attention to the information reflected in a side mirror. As the peripheral visual field becomes narrowed as one gets older, it is practically difficult for older adults to pay attention to a side mirror during driving. Therefore, it is important for us to compensate for this declined visual function (narrowing of peripheral visual field) of older adults. An intelligent system that can compensate for the declined visual function of older adults would be necessary. Presenting information imaged on the side mirror within the effective visual field must be one alternative to compensate for the declined visual function (narrowing of visual field) of older adults in order to enhance safety driving of older adults. However, as far as the authors know, there are few studies that made an attempt to compensate for the narrowed peripheral visual field of older adults by a method that presents information imaged on the side mirror within the effective visual field.

The aim of this study was to acquire basics for the development of a system that can compensate for the narrowed field of view of older adults. The display was located either on the left side which corresponded to a left side mirror, or within the central effective visual field. Participants performed simultaneously a primary task, and a secondary judgment task of situations using a display placed on the left side mirror location or within the central effective visual field (front display). For both young and older adults, it was explored how the display location (left or front) affected the performance of primary simulated driving task and the judgment performance of secondary task. The number of warnings during the tracking task and the percentage correct reaction to displayed stimulus on the left side mirror location or within the central effective visual field (front display) were used as evaluation measures. In such a way, we investigated the effectiveness of replacement of information imaged to left side mirror location by an image displayed within the central effective visual field (front display).

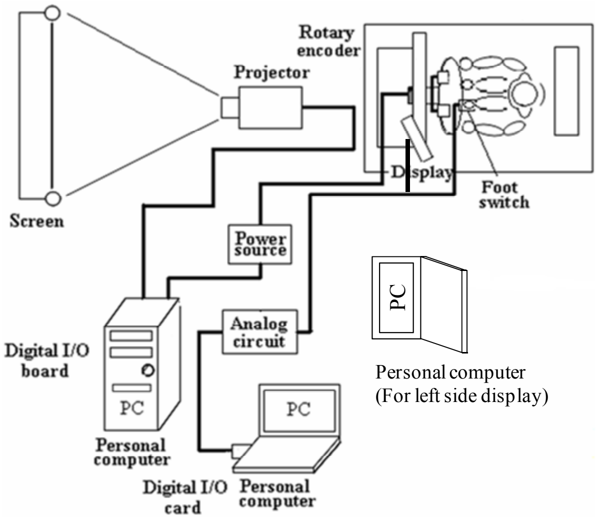

Fig.1 Outline of experimental system.

2. Method

2.1 Participants

Twenty participants took part in the experiment. Ten were male adults aged from 65 to 76 years. All had held a driver’s license for 30 to 40 years. Ten were male undergraduate students aged from 21 to 24 years and licensed to drive from 1 to 3 years. Stature of participants ranged from 160 to 185 cm. The visual acuity of the participants in both young and older groups was matched and more than 20/20. They had no orthopedic or neurological diseases.

2.2. Apparatus

The experimental system for the tracking task and the switch press task is nearly the same with than used in Murata et al. [14]. The main components were (i) a tracking system (a personal computer with an I/O board (Interface, PCI1213AL), rotary encoder (OMRON, E6F-AB3C), and steering wheel).This PC was connected to a projector (EPSON, EMP-S4) to display a tracking task in front of the participant, (ii) a personal computer equipped with an I/O card (Interface, PIO-24W(PM)) and used to enable the participant to operate a foot switch (Herga Electric, 6289-68274-CC), and (iii) two CRT displays to present dynamic images for monitoring

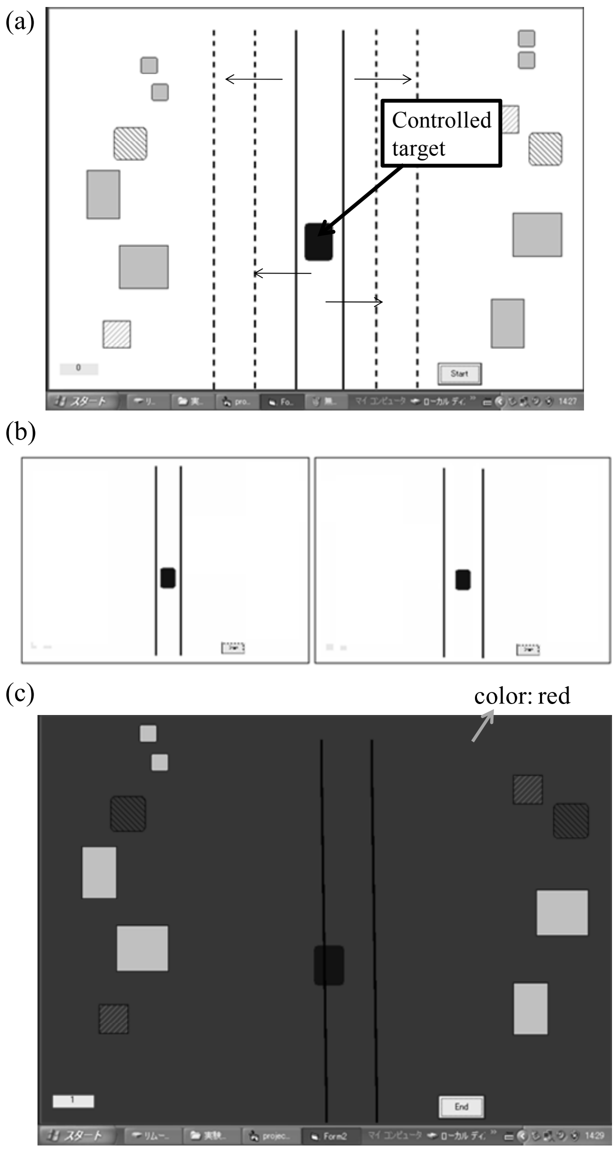

Fig.2 (a) Outline of tracking task, (b) Left: High workload condition, Right: Low workload condition, (c) Outline of tracking task (in case the target went outside of two lines)

task (One was used for the left peripheral visual field, and another was used for the central effective visual field). The outline of experimental system is depicted in Fig.1.

2.3 Task

(1) Tracking task

The participants were required to simultaneously carry out a tracking task (main task), a switch pressing task such as selection of light-on function, and a judgment task of important information which randomly appeared to the right or left peripheral visual field.

The outline of a tracking task is summarized in Fig.2(a), (b), and (c). The participant was required to keep the filled target within the two lines by a steering wheel. When the target went outside of two lines, the background color of the whole display changed to red (Fig.2(c)).

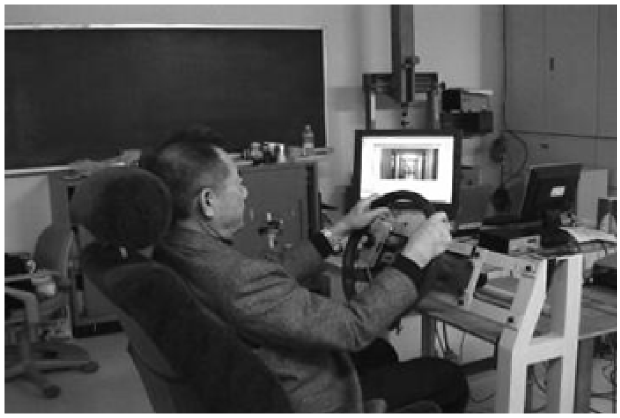

Photo.1 Outline of experimental situation.

(2) Monitoring task

The participant was required to carry out a monitor task. The monitor image was displayed either to the left-side 15-inch CRT (Sony SDM-N50) or to the central-left 15-inch CRT (Sony SDM-N50). The image was displayed to the area of 639 by 379 pixels. The following eleven different images were used in the monitor task: (1)with one's arm across one's chest, (2)raise one hand, (3)raise both hand, (4)cover one's face, (5)read a book, (6)turn around, (7)bend forward, (8)cross both hands, (9)put both hands on the head, (10)stretch one hand to one's side, and (11) make a circle on the head using both hands. These eleven images were randomly presented to the display above mentioned. Three images ((5), (6), (7)) out of eleven images were required to respond with a foot switch as soon as the participant noticed the appearance of these images. As for other eight images ((1)-(4), (8)-(11)), the participant was required to explain orally the type of the image.

2.4 Design and procedure

The experimental factors were participant age (young and older adults), the workload of tracking task (low and high) and the location of display (front display within the effective visual field and left side display corresponding to a left side mirror). Age was a between-subject factor; and the workload level and the location of display were within- subject factors.

The participant was asked to adjust his seat so that the task could be comfortably performed. Before the experimental task, the contents of the primary driving simulator task and the secondary monitor task were thoroughly explained to each participant.

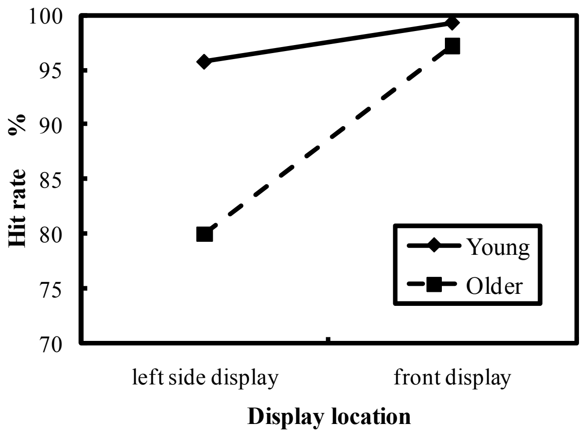

Fig.3 Percentage correct response (hit rate) as a function of age and display location.

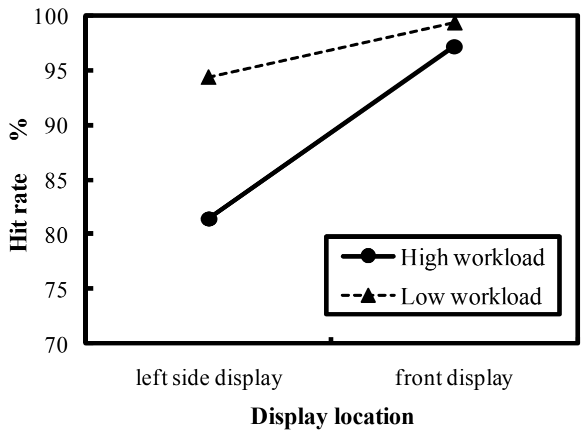

Fig.4 Percentage correct response (hit rate) as a function of workload and display location.

Participants were allowed to practice before performing experimental tasks. When the experimenter judged that the participant clearly understood how to perform the experimental task, the experiment was started. The order of four combinations of experimental condition (location display (front display and left side display) and workload (low and high)) was randomized across the participants. The participants were required to keep the primary task stable and also to perform the monitor task as fast and accurately as possible. Between experimental conditions, the participant was allowed to take a short break. The scene of experiment is summarized in Photo.1.

The following evaluation measures were used. The measures (1) and (2) are based on the tracking task, and the measures (3) and (4) are based on the monitoring task.

(1) Tracking performance: mean deviation between the center of two tracking lines and the center of controlled target.

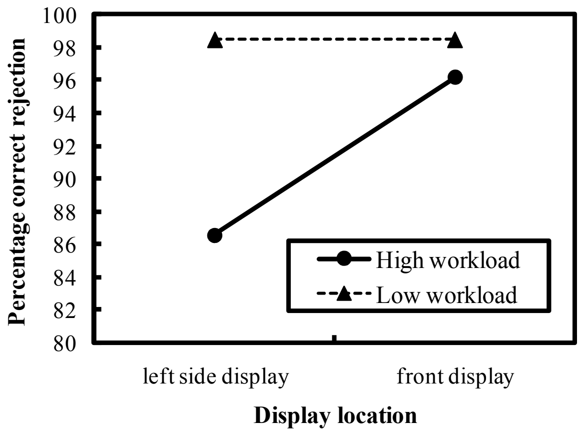

Fig.5 Percentage correct rejection as a function of workload and display location.

(2) Number of deviation from normal lane
(3) Percentage correct response (hit rate)
(4) Percentage correct recognition

3. Results

3.1Percentage correct response (Hit rate)

In Fig,3, the hit rate of monitor task is plotted as a function of display location and age. In Fig.4, the hit rate is shown as a function of display location and workload of tracking task. A three-way (age by workload by display location) ANOVA carried out on the hit rate revealed significant main effects of age ($\boldsymbol{F}(1,18)=7.239$, $\boldsymbol{p}<0.05$), workload ($\boldsymbol{F}(1,18)=5.161$, $\boldsymbol{p}<0.05$), and display location ($\boldsymbol{F}(1,18)=6.818$, $\boldsymbol{p}<0.05$). An age by display interaction ($\boldsymbol{F}(1,18)=7.944$, $\boldsymbol{p}<0.05$) and a workload by display location interaction ($\boldsymbol{F}(1,18)=6.818$, $\boldsymbol{p}<0.05$) were also found to be significant.

3.2 Percentage correct recognition

In Fig.5, the percentage correct recognition is plotted as a function of display location and workload level. A three-way (age by workload by display location) ANOVA carried out on the percentage correct recognition revealed significant main effects of age ($\boldsymbol{F}(1,18)=9.426$, $\boldsymbol{p}<0.01$), workload ($\boldsymbol{F}(1,18)=23.116$, $\boldsymbol{p}<0.01$), and display location ($\boldsymbol{F}(1,18)=8.614$, $\boldsymbol{p}<0.01$). An age by display interaction ($\boldsymbol{F}(1,18)=10.553$, $\boldsymbol{p}<0.01$) and a workload by display location interaction ($\boldsymbol{F}(1,18)=8.614$, $\boldsymbol{p}<0.01$) were also found to be significant.

3.3 Percentage of eye fixation duration

In Fig.6, the number of deviation from normal lane is plotted as a function of display location and age. In Fig.7, the number of deviation from normal lane is shown as a function of display location and workload level. A

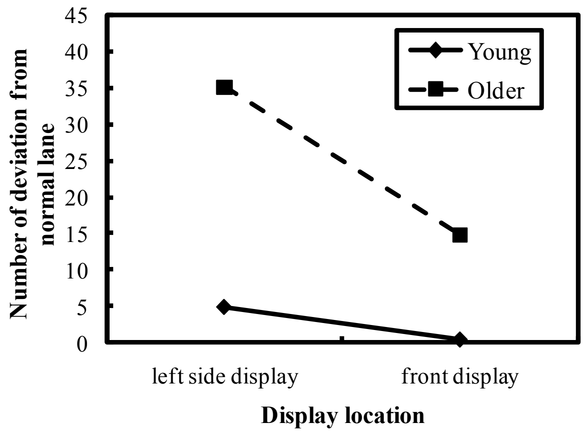

Fig.6 Number of deviation from normal lane as a function of age and display location.

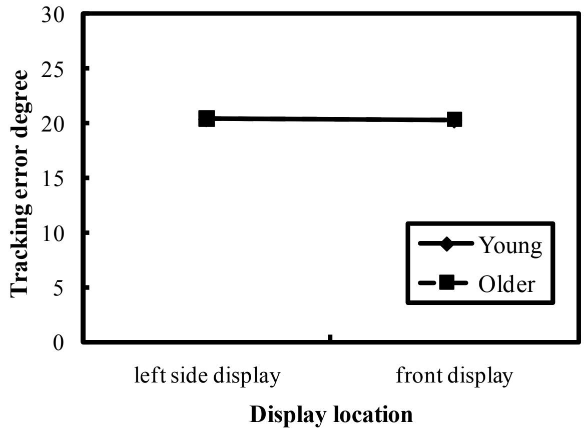

Fig.8 Tracking error as a function of age and display location (High workload).

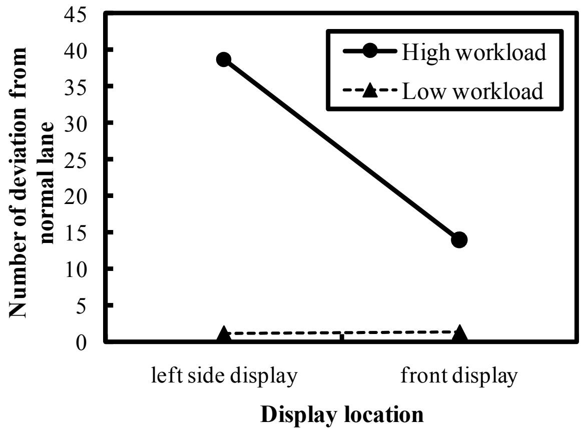

Fig.7 Number of deviation from normal lane as a function of workload and display location.

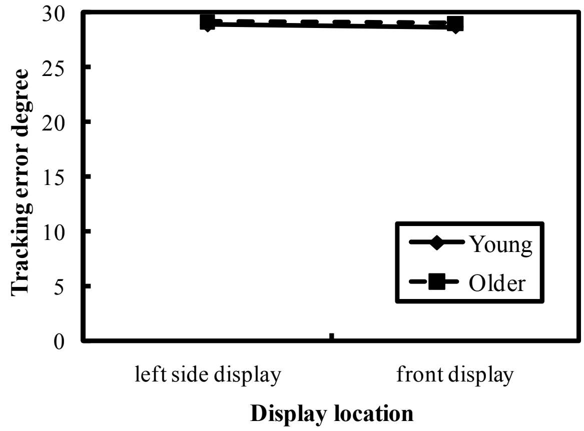

Fig.9 Tracking error as a function of age and display location (Low workload).

three-way (age by workload by display location) ANOVA carried out on the number of deviation from normal lane revealed significant main effects of age ($\boldsymbol{F}(1,18)=14.153$, $\boldsymbol{p}<0.01$), workload ($\boldsymbol{F}(1,18)=22.517$, $\boldsymbol{p}<0.01$), and display location ($\boldsymbol{F}(1,18)=45.782$, $\boldsymbol{p}<0.01$). The following interactions were also found to be significant: age by display interaction ($\boldsymbol{F}(1,18)=14.642$, $\boldsymbol{p}<0.01$), age by display location interaction ($\boldsymbol{F}(1,18)=19.126$, $\boldsymbol{p}<0.01$), workload by display location interaction ($\boldsymbol{F}(1,18)=45.538$, $\boldsymbol{p}<0.01$), and age by display location by workload ($\boldsymbol{F}(1,18)=18.887$, $\boldsymbol{p}<0.01$).

3.4 Tracking error

In Fig.8, the tracking error is plotted as a function of display location and age (high workload condition). In Fig.9, the tracking error is plotted as a function of display location and age (low workload condition). A three-way (age by workload by display location) ANOVA carried out on the tracking error detected significant main effects of workload ($\boldsymbol{F}(1,18)=4427.847$, $\boldsymbol{p}<0.01$).

4. Discussion

As shown in Fig.3, replacing the image of side mirror with the display within the central effective visual field led to higher hit rate. Such a replacement was not affected by the workload level as shown in Fig.4. For the left peripheral display, there was much difference of hit rate between young and older adults. On the other hand, when replacing such a display with the display placed within the central effective visual field did not lead to the difference of hit rate between young and older adults, which means that the declined peripheral vision of older adults can be compensated for by replacing the peripheral display with the central display within the effective visual field.

The percentage correct recognition for eight types of images which were not responded with a foot switch showed a similar tendency. As shown in Fig.5, the percentage correct recognition for the display within the central effective visual field led to higher value, and was not affected by the workload level. This is also indicative of the effectiveness of replacing the image of side mirror with the display within the central effective visual field led.

The number of deviation from normal lane also supported the effectiveness of replacing the image of side mirror with the display within the central effective visual field led. As shown in Fig.6, the central display within the effective visual field led to fewer numbers of deviations from normal lane. Moreover, as well as hit rate and percentage correct recognition, the number of deviation for the display placed within the central effective visual field was not affected by the workload level (See Fig.7).

Viewing from the viewpoint of tracking error, the effectiveness of replacing the image of side mirror with the display within the central effective visual field seems to be verified. For both work levels (low level (Fig.8) and high level (Fig.9)), the tracking error was affected not only by the aging factor but also by the placement of display. Observing Fig.8 and Fig.9 led to the finding that the tracking error of older adults when the display was placed within the central effective visual field is nearly equal to that of young adults for the left peripheral display.

On the basis of discussion above, the display installed within the central effective visual field was found to be effective especially for older adults from the viewpoints of hit rate, percentage correct recognition, number of deviation from normal lane, and tracking error. Replacing the peripheral visual field by the central effective visual field can compensate for the declined peripheral vision of older adults. Such a replacement is suitable not only for older adults but also for young adults.

In this study, only monitoring function by the display installed to the left peripheral vision or within the central effective visual field was taken into account. We sometimes use left mirror images to drive an automobile backwards as well as monitor traffic situations. Future research should examine how the replacement of the image of side mirror with the display within the central effective visual field affects such a more direct driving behavior as driving an automobile backwards using a display placed peripherally or within the central effective visual field.

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