

Effects of location of information presentation in pedestrian detection system on visibility and performance

Atsuo MURATA, Shinsaku ARATAMA and Makoto MORIWAKA
Dept. of Intelligent Mechanical Systems, Division of Industrial Innovation Sciences,
Graduate School of Natural Science and Technology, Okayama University
3-1-1, Tsushimanaka, Kita-ku, Okayama-shi, Japan
E-mail: {murata, aratama, moriwaka}@iims.sys.okayama-u.ac.jp

Abstract— A few pedestrian warning systems for automobiles are in practical use. It has not been clarified where is best suited for the location of pedestrian information presentation. The most effective location of information presentation in pedestrian detection system was investigated. In other words, the location that assured the fastest cognition of pedestrian information was clarified. The locations of information presentation in pedestrian detection system were front glass, front display of cockpit module, and left side display of cockpit module (like car navigation system). The participants were required to pay attention to the predetermined front area as well as the randomly presented pedestrian information while carrying out a virtual driving task (tracking task) and a secondary switch pressing task such as selection of wiper function. We also investigated the effect of alarm sound presented to the participants together with the visual pedestrian information on the cognition time of pedestrian information. As a result, the front glass was most suitable for the presentation of pedestrian information. The presentation of pedestrian information to the front glass led to high visibility and faster pedestrian cognition time.

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 is 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.

These studies did not take the memory factors into account to the design of display with layered structures. The display design also should consider the findings on eye movement characteristics that horizontal eye movement is faster and easier than vertical eye movement. Although Murata and Moriwaka^[8] investigated how the control should be designed without taking the display factors into account, the interaction between display and control factors must be investigated

in order to obtain a more proper design guideline.

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.

As the display and control systems of automobile is becoming more and more complex, it is predicted that older drivers are distracted by these systems and cannot cope with such situations. A few automotive manufactures put a pedestrian detection system such as Night vision or Eyesight to practical use to reduce the accident during the night.

However, in these practical applications, the loss of visual information processing when the attention is moved towards the pedestrian detection display is not systematically explored. When the driver is paying attention to the central road situation and the pedestrian detection system detects the pedestrian, the driver must make saccadic eye movements. During saccadic eye movement, information processing is suppressed^{[14]-[16]}. Therefore, a system where saccade suppression does not occur is desirable. Although the pedestrian detection system seems to be appealing from the viewpoint of safe driving, such a system must be developed on the basis of the ergonomic data or findings such as the placement of pedestrian detection display or an effective method for avoiding saccadic depression.

The aim of this study was to acquire basics for the development of pedestrian detection system. The most

effective location of information presentation in pedestrian detection system was investigated. The locations of information presentation in pedestrian detection system were front glass, front display of cockpit module, and left side display of cockpit module (like car navigation system). An attempt was made to identify the display location of result of pedestrian detection that assured the fastest cognition of pedestrian information.

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 the same with than used in Murata et al. [18]. The main components were (i) a pursuit tracking system (a personal computer with an I/O board, rotary encoder, and steering wheel). This PC was connected to a projector to display a tracking task in front of the participant.), (ii) a personal computer that was used to display speedometer and operational information, (iii) a personal computer equipped with an I/O card and used to enable the participant to operate switches. The CRT was in front of the participant.

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.1. 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.

(2) Switch pressing task

In the switch pressing task, the participant was required to select one of the following items using a switch (control) placed around the left side on the

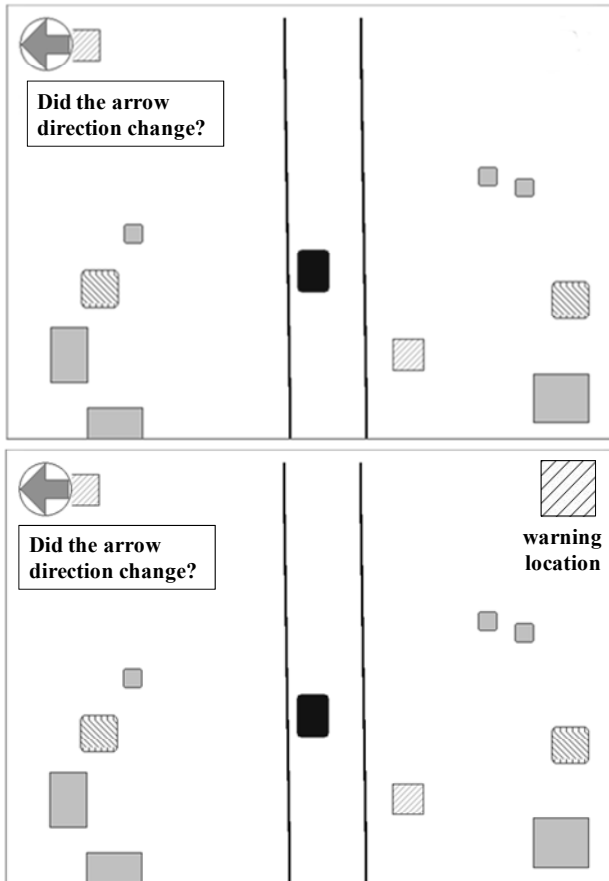


Fig.1 Warning location (screen (corresponding to front glass): right)

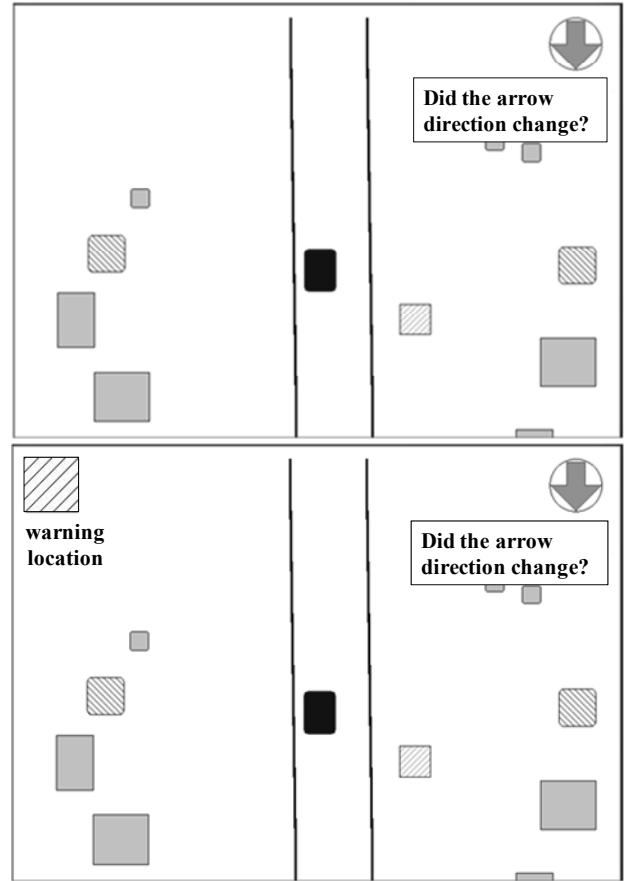


Fig.2 Warning location (screen (corresponding to front glass): left)

steering wheel. The sample of display is the same with that of Murata^[18].

(3) Spatial monitor task and reaction task

The participant was required to carry out a visual monitor task that judges whether the arrow placed to the left or right peripheral visual field. The participant was also required to respond as quickly and accurately as possible when the warning area was turn on. The warning location corresponded to where the result of pedestrian detection is displayed in a real-world vehicle system. Five warning areas were selected as shown in Fig.1-Fig.4.

2.4 Design and procedure

The experimental factors were participant age (young and older adults), the location of detected signal (front glass, front display of cockpit module, and left side display of cockpit module), the location of attention area (right and left peripheral visual field) and the auditory cue (without cue and with cue). Age was a between-subject factor; the location of detected signals, the location of attention area, and the auditory cue were within- subject factors.

The participant was asked to adjust his seat so that the task could be comfortably performed and the left-side console switches and the foot switch could be pressed by reaching his hand or foot naturally. Before the experimental tasks, the contents of the primary driving simulator task and secondary tasks (switch pressing task and spatial monitor and reaction task) were thoroughly explained to each participant.

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 five combinations of experimental condition (no warning, auditory warning without directional cue, auditory warning with directional cue, tactile warning without directional cue, and tactile warning with directional cue) was counterbalanced across the participants. The participants were required to keep the primary task stable and also to perform the switch pressing and the spatial monitor and reaction task as fast and accurately as possible. The outline of experimental situation is summarized in Photo. 1.

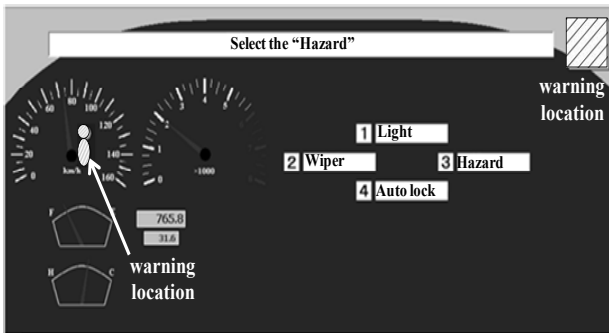


Fig.3 Warning location (front display: right or left)



Fig.4 Warning location (left-side display: right or left).

The following evaluation measures were used.

- (1) Tracking error: mean deviation between the center of two tracking lines and the center of controlled target.
- (2) Percentage correct of switch pressing
- (3) Reaction time of switch pressing
- (4) Reaction time of spatial monitor task
- (5) Percentage correct of spatial monitor task
- (6) Percentage correct of reaction task (reaction to warning area)
- (7) Percentage correct of reaction task (reaction to warning area)
- (8) 5-point psychological rating on visibility of warning area (1=very low visibility, 5=very high visibility)

3. Results

3.1 Tracking task

A four-way (age (young and older adults) by location of detected signal (front glass, front display of cockpit module, and left side display of cockpit module) by location of attention area (right and left peripheral visual field) by auditory cue (without cue and with cue)) ANOVA conducted on the tracking error revealed only a main effect of age.

3.2 Switch pressing task

A four-way (age (young and older adults) by location of detected signal (front glass, front display of cockpit

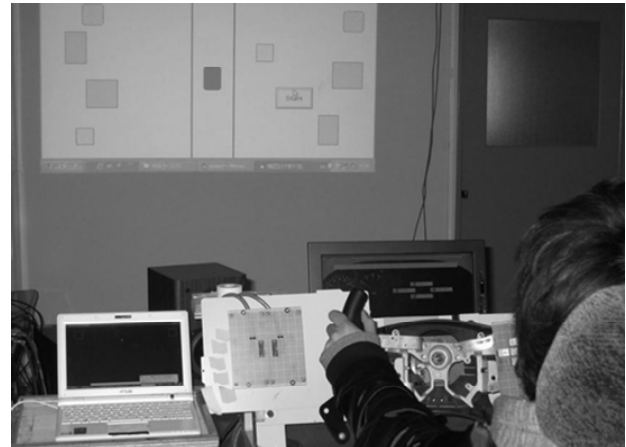


Photo1. Outline of experimental setting.

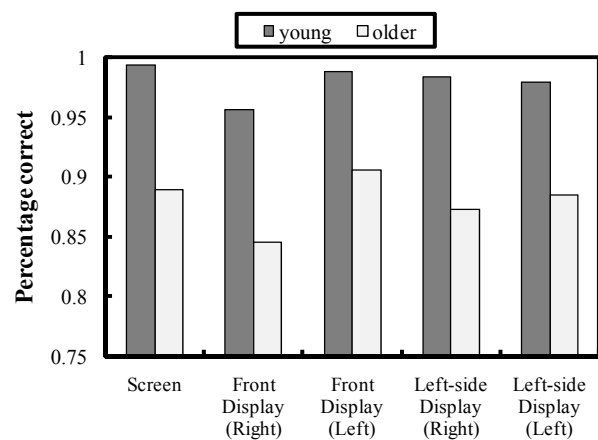


Fig.5 Percentage correct of switch pressing task as a function of age and location of detected signal.

module, and left side display of cockpit module) by location of attention area (right and left peripheral visual field) by auditory cue (without cue and with cue)) ANOVA conducted on the tracking error revealed only significant main effects of location of attention area ($F(1,16)=27.105$, $p<0.05$) and location of detected signal ($F(4,64)=2.544$, $p<0.05$). The mean percentage correct is plotted as a function of age and location of detected signal in Fig.5. A similar four-way ANOVA carried out on the reaction time revealed only a significant main effect of age ($F(1,17)=20.187$, $p<0.01$).

3.3 Spatial monitor task and reaction task

First, the results of spatial monitor task are summarized. A four-way (age by location of detected signal by location of attention area by auditory cue) ANOVA carried out on the reaction time revealed only a significant main effect of age ($F(1,15)=10.122$, $p<0.01$). A similar four-way ANOVA carried out on the reaction time revealed only a significant main effect of age ($F(1,15)=15.870$, $p<0.01$).

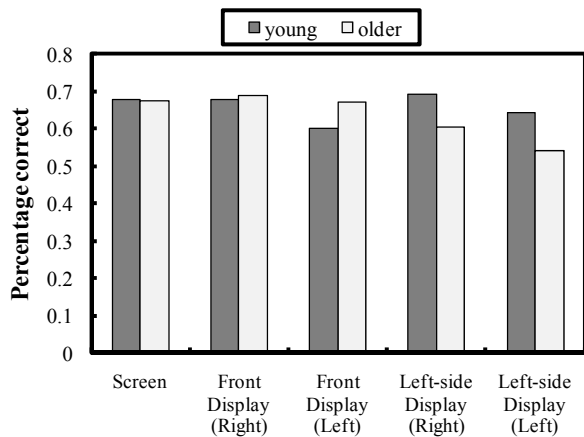


Fig.6 Percentage correct of reaction task as a function of age and location of detected signal.

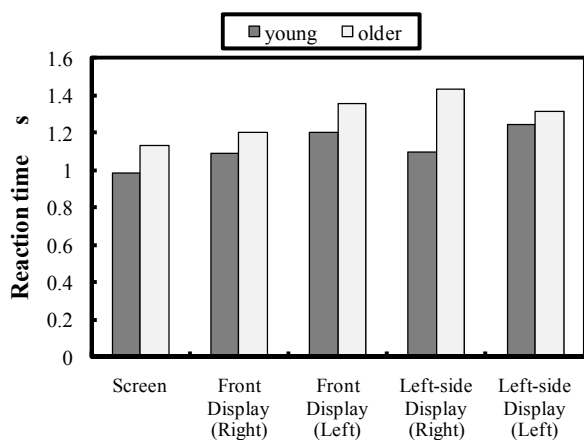


Fig.7 Reaction time of reaction task as a function of age and location of detected signal.

Second, the results of reaction task are mentioned. A four-way (age by location of detected signal by location of attention area by auditory cue) ANOVA carried out on the percentage correct revealed main effects of location of attention area ($F(1,17)=5.672$, $p<0.01$) and auditory cue ($F(1,17)=14.054$, $p<0.05$). A similar four-way ANOVA carried out on the reaction time detected significant main effects of location of detected signal ($F(4,68)=3.784$, $p<0.05$) and auditory cue ($F(1,17)=41.068$, $p<0.01$) and a significant location of detected signal by location of attention area interaction ($F(4,68)=3.129$, $p<0.05$). In Fig.6, the percentage correct of reaction task is plotted as a function of age and location of detected signal corresponding to the pedestrian detection. In Fig.7, the reaction time of reaction task is plotted as a function of age and location of detected signal corresponding to the pedestrian detection.

3.4 Psychological rating on visibility of warning area

In Fig.8, the psychological rating on visibility of warning area is plotted as a function of age and location

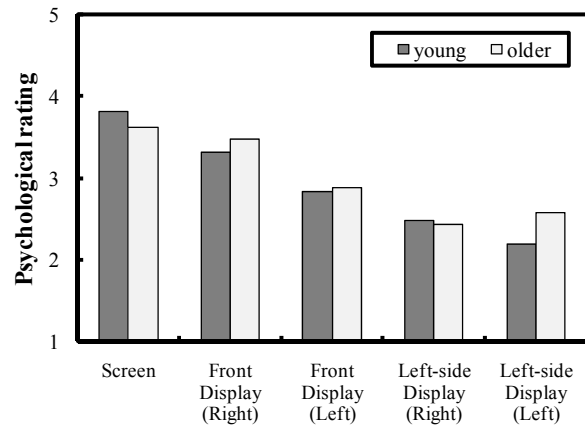


Fig.8 Psychological rating as a function of age and location of detected signal.

of detected signal corresponding to the pedestrian detection. For all age group, the psychological rating on visibility of warning area was analyzed using Kruskal-Wallis and Man-Whitney non-parametric tests. As a result, the auditory cue ($p<0.05$) and the location of detected signal ($p<0.01$) were found to be significant. For each age group, a similar non-parametric test was conducted. For both age group, the location of detected signal ($p<0.01$) were found to be significant. For older adults, auditory cue was found to be significant ($p<0.05$).

4. Discussion

Although a few automotive manufactures put a pedestrian detection system such as Night vision or Eyesight to practical use to reduce the accident during the night, the loss of visual information processing when the attention is moved towards the pedestrian detection display or the proper location of displaying detected results is not systematically explored in these practical applications. Such a system must be developed on the basis of the ergonomic data or findings such as the placement of pedestrian detection display or avoidance of saccade depression due to movement of eye-gaze. Thus, the present study aimed at obtaining such basis for designing a more effective pedestrian detection system.

The auditory cue improved the efficiency of spatial monitor task and reaction task for both age groups. Although the effect of auditory cue was not so remarkable, the auditory cue improved the efficiency of spatial monitor task and reaction task to a larger extent for older adults. This definitely shows that the decline perceptual, cognitive, and motor function of older adults [9]-[13] can be compensated for by using auditory cue. As for the location of attention area (right and left peripheral visual field), the percentage correct of switch press task

and reaction task was better on the right peripheral visual field than on the left peripheral visual field. This might be due to the dominant eye of participants (right dominant eye for 19 out of 20).

As shown in Fig.5 (percentage correct of switch pressing task), Fig.6 (percentage correct of reaction task), Fig.7 (reaction time of reaction task), and Fig.8 (psychological rating on visibility of warning area), the location of detected signal (front glass, front display of cockpit module, and left side display of cockpit module) significantly affected the performance of reaction task. On the basis of the performance measures above, the location at screen corresponding to the front glass was superior to other location. In particular, the screen location of the display of detection result enhanced the reaction of older adults. The pedestrian detection system that is friendly and usable for older adults should be located not to the front display of cockpit module, and left side display of cockpit module such as Night Vision or Eyesight, but to the front glass. Installing the pedestrian detection system to the front glass would also help compensate for the declined perceptual ability of older adults. In summary, the results show that the front glass was most suitable for the presentation of pedestrian information. The presentation of pedestrian information to the front glass led to high visibility and faster pedestrian cognition time.

When the driver is paying attention to the central road situation and the pedestrian detection system detects the pedestrian, the driver must make saccadic eye movements. During saccadic eye movement, information processing is suppressed^{[14]-[16]} (saccade depression). Therefore, a system where saccade suppression does not occur remarkably is desirable, because the visual information processing is depressed and not carried out during saccades. Although the pedestrian detection system seems to be appealing from the viewpoint of promoting quick response, an effective method for avoiding saccadic depression must be investigated in future research. For example, a visual guidance system which makes the eye movement smooth as much as possible in order to avoid abrupt saccadic eye movement might be promising.

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