Comparing Useful Field of View between Elderly and Young Japanese Drivers for Safety Considerations

Indri Hapsari Susilowati[1]* and Akira Yasukouchi[2]

1. Department of Occupational Health and Safety, Faculty of Public Health, Universitas Indonesia.
2. Department of Human Science Design, Graduate School of Design, Kyushu University.

Abstract

Elderly drivers are at increased risk of road crashes because of visual limitations. We compared the useful field of view between elderly and young Japanese drivers.

Participants included 10 young drivers (21–32 y, 23.3 + 3.33), and 2 groups of elderly drivers. Elderly group 1 consisted of 11 persons (60–65 y, 61.9 + 1.70) and elderly group 2 consisted of 14 persons (66–76 y, 69.5 + 3.01).

We assessed visual acuity and response to peripheral stimuli placed within the useful field of view (UFOV). Elderly group 1 drivers had a significantly longer UFOV response time than young drivers did.

Significantly longer response times, relative to stimuli shape, were found for elderly group 2 (>65 y). Time to response for stimuli within the upper peripheral view took longer when stimuli appearance was more than 60º (middle) of the peripheral diameter. It is better to avoid signs with slanted lines, located in the upper periphery. This delay also led to increased misjudgment at fixed eye points because the increased recognition times for peripheral objects carried over to fixed eye judgments.

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Introduction

In 2016, the World Health Organization (WHO) reported that global life expectancy was 71.4 years. Average Japanese life expectancy is greater than global life expectancy. Japanese females have the highest life expectancy in the world, at 86.6 years. For Japanese males, the average life expectancy is 80.5 years.[1] Since 2006, Japan's population has been called a "Super Aging Society" because elderly individuals comprise more than 20% of the total population (Figure 1). The United Nations recognizes Japan as a country with the highest percentage of elderly citizens; it is estimated that, by 2050, the percentage of elderly Japanese will be greater than 35%.[2]

Corresponding author:
Indri Hapsari Susilowati
Department of Occupational Health and Safety,
Faculty of Public Health, Universitas Indonesia,
Depok, Indonesia.
E-mail: indri@ui.ac.id

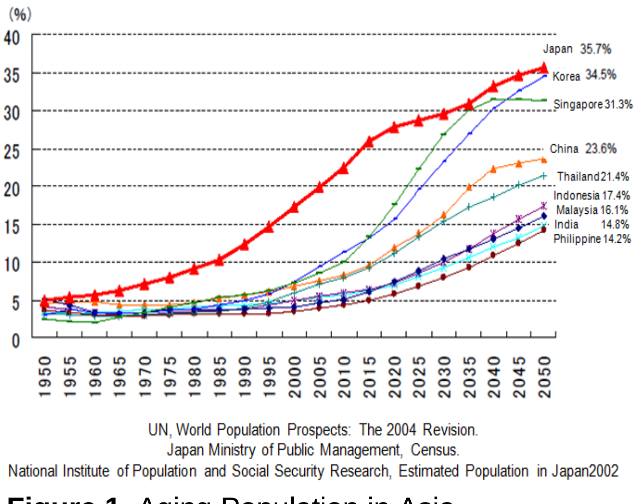


Figure 1. Aging Population in Asia.

These elevated life and health expectancies will certainly increase the number of elderly drivers. Data from the Japan Automobile Manufacturers Association (JAMA) shows that the number of elderly drivers (aged > 75 years old) had been increasing, and this increase was growing sharply since 2001; the elderly population was projected to continue this sharp growth in the following years (Figure 2).[3]

Based on JAMA's reports, accident causes can be divided among 3 groups: a) vision-specific factors, b) cognitive and judgmental factors, and c) physical motor factors. Vision-specific factors include below-normal visual acuity, including problems with: visual accommodation (focusing at varying vision ranges), eye movement and range of view, and night-time glare resistance/recovery. Human sight range for objects can be measured on a horizontal line in the field of sight. An object located within the field of sight and appearing under the horizontal sightline is more easily seen and focused upon than above-line objects within the same field. However, a driver's eyesight must not only capture below-line objects, but also above-line objects. Driving functions utilizing below-line sight include steering wheel control, manipulating other vehicle controls, and monitoring dashboard indicators. Driving functions utilizing above-line sight include attention to traffic signs/signals, monitoring ground-level objects and over-passing roads, and surveying other vehicles.

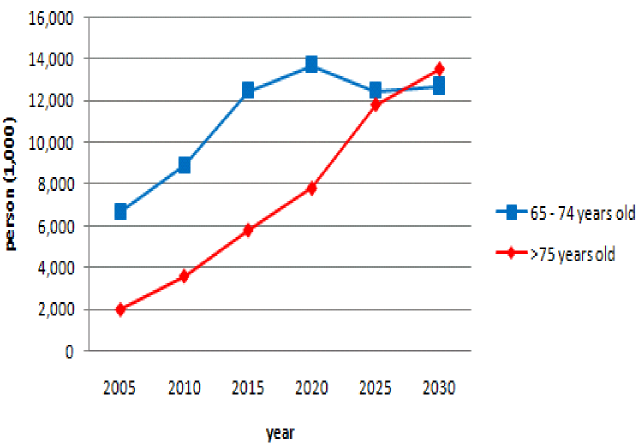


Figure 2. Number of elderly drivers in Japan.

The computer-administered and scored Useful Field of View (UFOV) is screening device that measures visual attention in elderly drivers'.[4] UFOV assesses declining visual sensory function, visual processing speed, and visual attention skills, and is a significant predictor of vehicle crashes involving elderly drivers.[5] The UFOV determines the visual field range over which a driver can process visual information that is presented rapidly.[5] The objective of this research was to compare the useful field of view between elderly and young Japanese drivers.

Materials and methods

This study was experimental study which the subjects were young and elderly drivers. The young drivers consisted of 10 university students (5 males and 5 females), aged 21–32 years (SD = +3.33). The older drivers were volunteers from the Silver Manpower Centre, an organization for people over 60. The subjects were 25 elderly persons (14 males and 11 females), divided between 2 age groups: elderly 1: 60 – 65 years old (=61.9 + 1.70), consisting of 11 persons (6 males and 5 females), and elderly 2: over 65 years old (66–76 years old, = 69.5 + 3.01), consisting of 14 persons (6 males and 8 females).

A Visual Basic program was used to measure UFOV. The field of view in the UFOV test was illustrated on a 19 x 19-inch computer monitor and divided into 8 radial spokes and 3 circles with diameters of 30, 60, and 90º from the eyes to the central monitor (Figure 3); thus, the test collected data for 24 positions. The distance between each subject's eyes and the monitor was 50 cm. The visual stimuli included colors (red, green, blue) with luminescence between 1.5 and 2.2 cd/m3, shapes (circle, triangle, and square), and numbers (0,1,2,3) with luminescence ranging from 1.5 to 1.7 cd/m^3. The height of each stimulus was 0.5 cm. The illumination was 380–400 lx. The position and stimulus would appear only over 100 ms, in random positions. Besides the target stimuli, approximately 25% of the total stimuli were distractors.

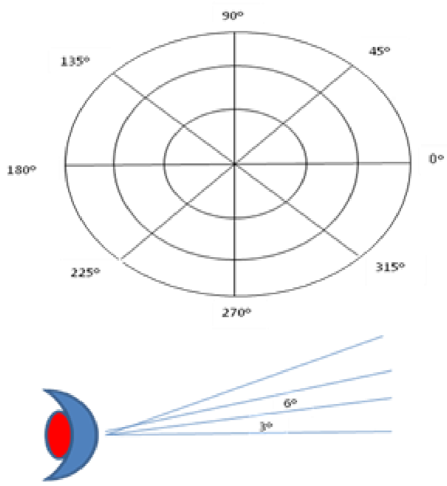


Figure 3. Measurement position of UFOV test.

Each data-point of color and shape stimuli on the UFOV test were presented at 9 conditions [3 diameters (30 º: inner, 60 º: middle, 90 º: outer) x 3 angles (horizontal: 0º, 180º; upper horizontal: 45º, 90º, 135º; and below horizontal: 225º, 270º, 315º)]. For example, the color red had 9 data-point conditions: red, inner, horizontal; red, inner, upper-horizontal; red, inner, below-horizontal; red, middle, horizontal; red, middle, upper-horizontal; red, middle, below-horizontal; red, outer, horizontal; red, outer, upper-horizontal; and red, outer, below-horizontal. Sequencing followed this same pattern for the other color and shape stimuli.

SPSS Version 17.0 was used to perform the statistical analyses. An ANOVA 2 and 3-way analysis were used to see the comparison. The p-value < 0.05 was considered as significant. The Ethical Committee of Faculty of Design, Kyushu University, Japan approved the study, and the approval number was 273.

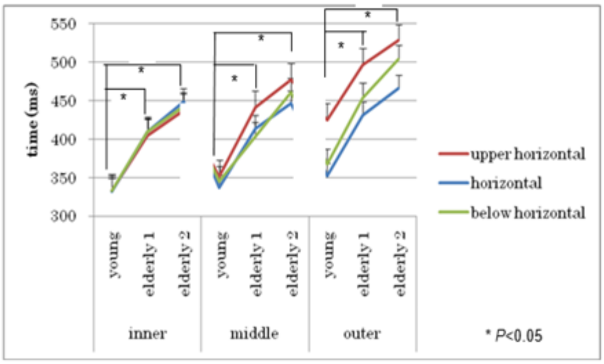
Results

Reaction time UFOV test data were obtained when subjects responded to each stimulus target which appeared at each of the 24 positions. ANOVA 3-way analysis indicated significant differences in each diameter (inner, middle, outer), age (young, elderly 1, elderly 2), and angle (upper horizontal, horizontal, and below horizontal).

The color stimuli results (red, green, and blue) showed significant differences in diameter, age, and angle. Besides that, significant interactions between diameter and angle were found for all color stimuli. With the age variable, there were significant differences between young and both elderly groups, for all diameters. Figures 4A-4C indicate the response times for elderly drivers were longer than those of young drivers.

Significant differences in angle were found between upper horizontal–horizontal [t = -28.246 (red), -21.030 (green), -14.688 (blue)], and upper horizontal–below horizontal [t = 18.983 (red), 25.234 (green), 18.329 (green)]. All drivers had prolonged reaction times when color stimuli appeared within the upper horizontal, as opposed to the below horizontal, positions.

Significant differences in diameters were found for all positions in red and blue: inner–middle [t = -13.916 (red), -12.087 (blue)], inner–outer [t = -54.188 (red), -31.880 (blue)], and middle–outer [t = -40.272 (red), -19.793 (blue)]. Particularly, the UFOV of green stimuli revealed significant differences between inner–outer (t = -40.389) and middle–outer (t = -35.126) (see Figure 4B). The longest reaction time was for the outer > middle > inner positions.



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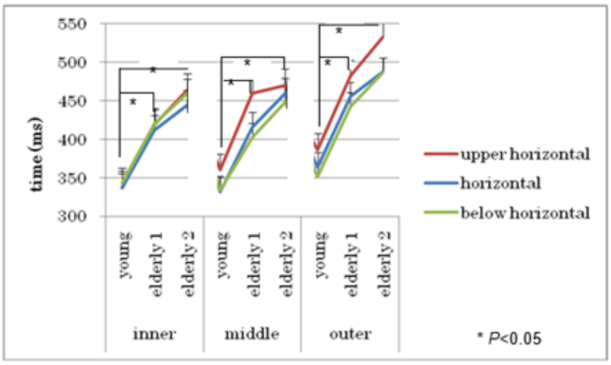

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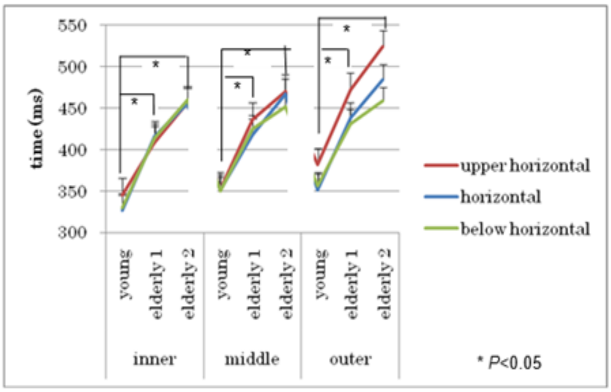

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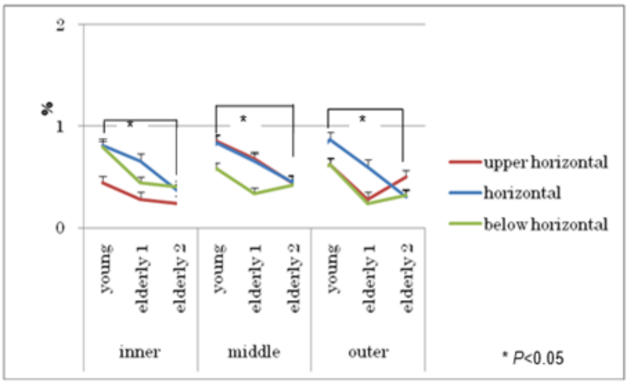
Figure 4. UFOV for: **A)** red stimuli; **B)** green stimuli; **C)** blue stimuli.

UFOV for shape stimuli (circle, square, and triangle) also showed significant differences between the young group and elderly group 2 [t =

-94.177 (circle), -96.155 (triangle), -106.199 (square)]. Elderly drivers > 65 years old took significantly longer to respond to shape stimuli than young drivers did. Figure 5A-5C show the significant interaction diameters and angles.



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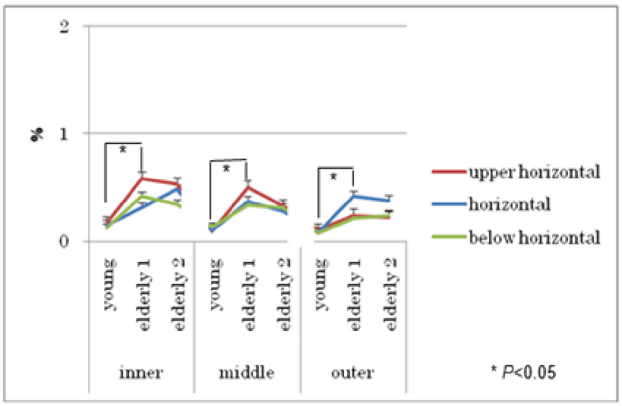

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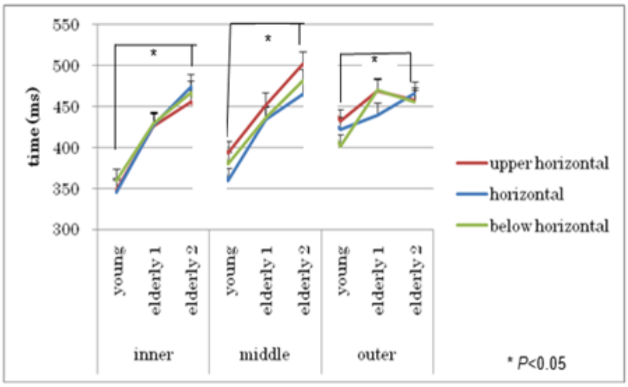

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Figure 5. UFOV for: **A)** circle stimuli, **B)** triangle stimuli; **C)** square stimuli.

Significant differences in diameters were found in the UFOV test for circle stimuli, particularly inner–middle (t = -19.743) and inner–outer (t = -30.765). However, there was no significant difference in angle (Figure 5A). Regarding total response times, the outer-view circle stimuli took the longest amount of time, followed by circles at the middle-, and then inner-, views.

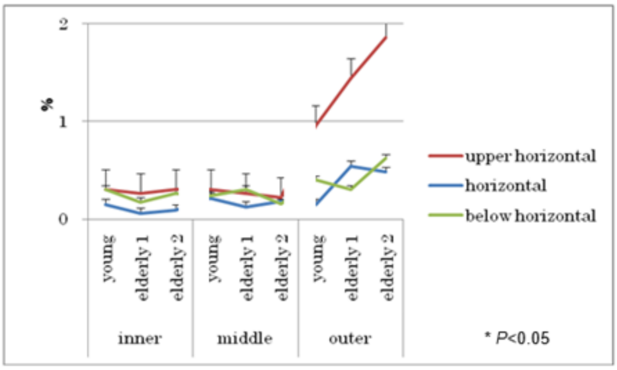
Significant differences in diameters were also found in UFOV for triangle stimuli such as inner–middle (t = -27.325), inner–outer (t = -58.819), and middle–outer (t = -31.493). The differences obtained resembled the circle stimuli results; in order, the longest total reaction times for triangle stimuli were outer > middle > inner-view.

Regarding shape stimuli, only the triangle showed significant differerences for angle, particularly between the upper horizontal–horizontal (t = 18.830), and upper horizontal–below horizontal (t = 11.629) (Figure 5B). The upper horizontal view response time was longer than the times for the below horizontal and horizontal views. In comparison, UFOV for square stimuli showed significant differences only for age; there were no differences found for angle or diameter (Figure 5C).

UFOV test errors consisted of of 3 types: wrong reaction, no reaction, and wrong number. Wrong reaction meant that the subject reacted to distraction stimuli. No reaction meant that the subject did not respond to target stimuli. Wrong number meant that the subject wrongly chose numbers that previously appeared in his or her target attention areas.

Figures 6A and 6B illustrate significant differences between the young group and elderly group 2 for color stimuli errors [t = 8.400 (wrong reaction), -12.271 (wrong number)]. This showed that those >65 years had a higher percentage of wrong number errors than young drivers. In contrast, young drivers had a higher percentage of wrong reaction errors than elderly group 2 subjects.

In the area of no-reaction errors for color stimuli, all the age groups performed similarly (Figure 6C); no significant age differences appeared for this error type. However, a significant difference between angles, such as upper horizontal–horizontal (t = -0.134), horizontal–below horizontal (t = -15.073), and upper horizontal–below horizontal (t = -14.940) was found; upper horizontal view had the highest no reaction errors, followed by the horizontal and below horizontal views.



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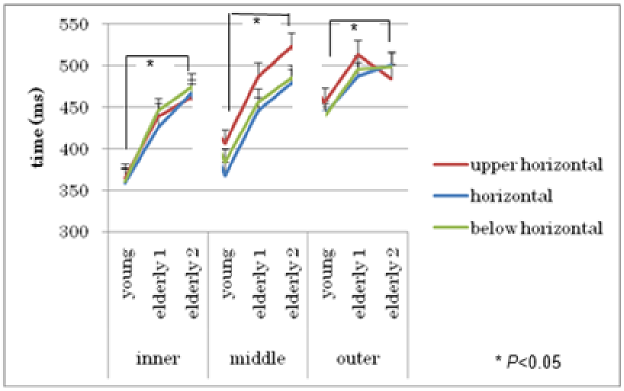

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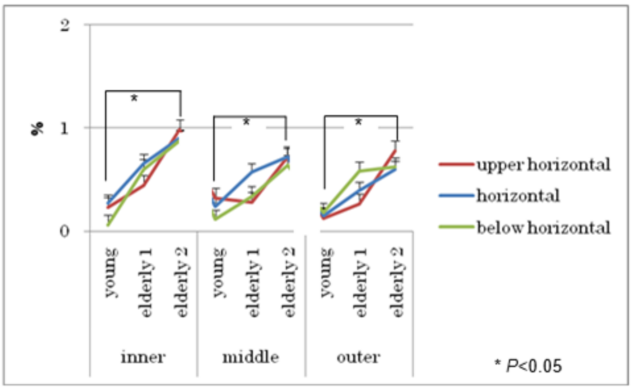

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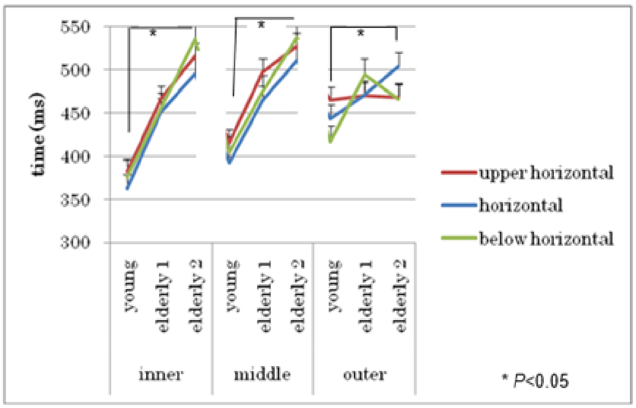
Figure 6. **A)** Wrong reaction for color stimuli; **B)** Wrong number for color stimuli; **C)** No reaction for color stimuli.

Wrong reaction and wrong number for shape stimuli data revealed significant differences for diameter, age, and angle. A significant interaction was also found for diameter and angle (Figure 7A and 7B); however, the comparison of parameter results was different between errors of wrong number and wrong reaction.

A significant difference in wrong reaction was found between the young group and elderly group 2 (t = 9.750); however, for wrong number, the significant difference was found between the young group and elderly group 1 (t = -6.781). These results mirrored those for wrong reaction to color stimuli; young drivers had a higher number of errors than elderly group 2, while group 1 had a higher percentage of wrong number errors than young drivers did (Figure 7A and 7B).

The effect of diameter on the wrong reaction rate was significant in all positions: inner–middle (t = -4.555), inner–outer (t = -12.286), middle–outer (t = -7.730). The results showed that the percentages of wrong reactions from highest to lowest were outer > middle > inner view (Figure 7A).

The effect of angle on the wrong reaction rate was significantly different between horizontal–upper horizontal (t = -5.297) and horizontal–below horizontal (t = -5.050). This showed that the below- and upper-horizontal views were harder to see than the horizontal (Figure 7A).



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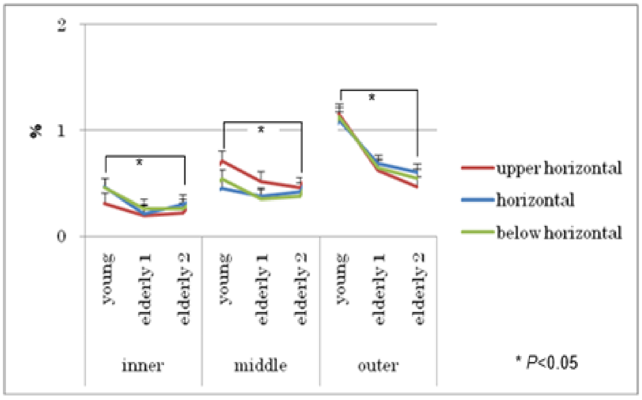

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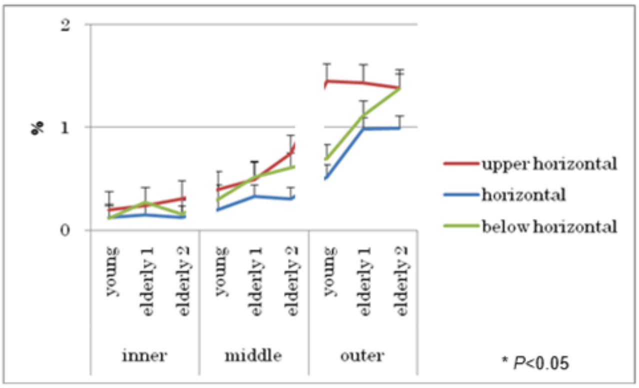

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Figure 7. A) Wrong reaction for shape stimuli, **B)** Wrong number for shape stimuli, and **C)** No reaction for shape stimuli.

Significant differences in angle shown in the wrong number results for shape stimuli (Figure 7B) were found between horizontal–upper horizontal (t = -3.421), and in diameter between inner–outer (t = -3.422). This meant that identification and rejection of distraction stimuli was more difficult when a stimulus appeared within the upper horizontal, rather than the horizontal view.

The error of no reactions for shape stimuli, as shown in Figure 7C, revealed results similar to color stimuli, which showed no significant difference by age group. We found significant differences between angles: horizontal–upper horizontal (t = -12.883), horizontal–below horizontal (t = -8.472), and between upper horizontal–below horizontal (t = 4.411). The outcomes showed different tendencies. For no reaction for color stimuli: the upper-horizontal view had the highest error rate, followed by the below horizontal, then, horizontal views.

Discussion

Considering infrastructure placement, positioning traffic signs within the upper part of the peripheral-from-horizontal view is believed to be optimal, since many accidents involving elderly drivers were caused by traffic sign oversights; these missed signs were placed in the usual upper horizontal view. Therefore, our attention to the angle of sign placement focused on the upper-horizontal and lower-horizontal sites, combined with the peripheral/outer position, relative to the typical location of the normal driver's eyes.

UFOV is defined as the region of the visual field from which an observer can extract information at any 1 time.[6] The UFOV is constrained by both sensory and cognitive factors, and its extent depends on the nature of the tasks being performed and the stimuli used to measure it.[6] This research shows that elderly group 1 drivers had a significantly longer UFOV response times than young drivers did. Significantly longer response times for shape were found in the group 2 (>65 years). The upper peripheral view seemed to take longer when stimuli appeared beyond 60° (middle) of the peripheral; meanwhile, the difference was greater when colored stimuli appeared beyond 90°. On the other hand, there was no significant difference between the peripheral field for circle and square shapes, although a significantly longer time was found for triangles within the upper middle (60°).

According to Mikiko (2001), response times and the number of wrong responses increased when the target shape consisted of slanted lines (like triangles and diamonds) and when shapes like these appeared within the upper peripheral view.[7] These findings support our triangular shape results, obtained from UFOV. Therefore, the location of traffic signs that include slanted lines should be in the horizontal and below horizontal fields of view.

For the UFOV error response results, in elderly group 2, wrong reaction rates for both color and shape were significantly lower than those of young drivers, while longer responses to peripheral targets were noted for the elderly, compared to young subjects. The upper and lower peripheral views did not appear to affect color responses; however, young drivers' error responses for shapes were high at 9o of the periphery. Elderly drivers tended not to respond when they did not see clearly or were otherwise unsure about the stimuli appearing in the peripheral view. This was illustrated by the great number of no reaction errors in the peripheral view for elderly drivers (Figure 6C and 7C). The opposite was true for young drivers when they tried to respond to stimuli in the peripheral view; these drivers, when unsure, tended to respond nonetheless and, thus, produced wrong reaction errors.

A previous study by Susilowati (2016) found that elderly drivers were frequently confused about traffic signs/signals and responded late when traffic patterns changed.[8] This was because traffic signs/signals were mostly located in the peripheral view. These errors affected the performance of elderly drivers, particularly when maintaining the lane. Here, the drivers tended to drive in the left or out of lane when changing lanes.

Regarding the no-response results (which were considered missed signs), there were no differences in the rates of no-responses, as to both color and shape stimuli, between the age groups at all diameters; however, no-response rates greatly increased when stimuli were presented in the upper fields, at diameters of 90º. This was particularly true for elderly drivers >65 years old. Thus, the risk of missing a traffic sign increases when the sign is located in the upper visual field, at over 90 cm from the peripheral view.

The results of wrong number responses to colors or shapes might reflect the rate of misjudgment when fixing the eyes on the center view. As Figure 6B shows, the rate of misjudgment in group 2 was always high, independent of the location of the color target at the periphery, even if the target appeared within 3° of the diameters. In the case of shapes (Figure 7A), in elderly group 1, increased misjudgment was significantly higher than in the young group, especially when the elderly paid attention to targets appearing at the upper site within 3º of the peripheral view. Elderly drivers were prone to misjudgments, even at fixed eye points, and these errors tended to increase for objects of wider diameters. The elderly took a long time to recognize stimuli appearing within the peripheral view. This led to prolonged responses and increased misjudgments at fixed eye points since they took longer to recognize peripheral stimuli.

Sekuler, Bennett and Mamelak (2000) found that peripheral localization tasks produced significant main effects for age group and attention. Furthermore, there was a significant interaction between age and attention.[6] Post hoc analysis of peripheral difference scores showed the deterioration in UFOV begins early in life (by 20 years or younger). In the central letter identification task, the error rate was stable until about age 40, gradually increasing thereafter. The diminished efficiency among elderly observers was exacerbated when conditions required divided attention between central and peripheral tasks.

Ball et al. (1988) directly examined the effect of foveal load on peripheral localization in young, middle-aged, and old observers, and reported that central task's difficulty did not significantly alter radial localization error rates for observers younger than 60 years of age.[4] There was a slight difference in performance between young (22–33 years old) and middle-aged observers (40–49 years old). However, there were quite large performance differences between these groups and the oldest group (60-75 years old). Seiple et al., (1996) found similar performance disparities between young (22–36 years old) and middle aged (40–58 years old) subjects.[9]

The oldest observers performed poorly on the focused attention task. The diminished efficiency among elderly observers exacerbates when conditions require distinguishing between central and peripheral tasks. This seems to yield the same result as the above-cited research, where the elderly experienced difficulties when called upon to attend to both the central and peripheral fields of view.

Study from Tarawaneh, et al. (1993) found that better driving performance was associated with better visual perception.[10] Visual perception is an indicator of the ability to manipulate objects so that they are recognized quickly and accurately. Compared to vision factor correlations, visual perception has a greater bearing on driving performance among older drivers. Both depth perception and peripheral vision showed significant correlations with driving performance in older drivers.[10] The UFOV test works as an independent predictor of driving mobility, similar to visuospatial abilities and memory, considering age, vision, and physical performance.[11] This research supports this view of the UFOV. Elderly Japanese elderly drivers take longer to react, and target-capturing declined due to divided attention; this was true not only in peripheral and eccentric views, but also in above- and below-horizontal views

Conclusions

The elderly of 60 – 65 years old had a significantly longer UFOV response time than young drivers. A significantly longer response time as to shape was found for the over-65 subject group. The upper peripheral view seemed to take longer when stimuli appearance was more than 6° (middle) of the peripheral, particularly for triangle shape. Therefore, the location of traffic sign in slanted-line shaped should be in the horizontal and below horizontal of view.

Declaration of Interest

There are no conflicts of interest to declare. All authors have made substantive contribution to this study and/or manuscript, and all have reviewed the final paper prior to its submission. This research and publication were funded in part by the Directorate General of Higher Education, Ministry of National Education, Indonesia and Kyushu University, Japan.

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