

# COMPARISON OF YOUNGER AND OLDER DRIVERS' GLANCE BEHAVIOR AND PERFORMANCE IN A DRIVING SIMULATOR

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## ABSTRACT

As the use of in-vehicle technologies became more popular, there is concern about a concomitant increase in driver distraction. The risk of distracted driving is known to vary with age. Normally, older drivers can drive safely with their own rules learned from experiences, but in situations producing very high momentary workload, they sometimes fail with severe consequences.

In this study, glance behaviour and performance of younger and older drivers were compared in a driving simulator. To assess the differences in glance pattern and performance, 30 drivers, divided into younger (25–35) and older (60–69) age groups, drove on a simulated highway. At a specified location, subjects were asked to complete a series of visual searching tasks that consist of three levels of complexity. During the simulated driving, driver's eye movement were collected by a gaze tracking system.

Comparisons of younger and older drivers' glance behaviour, including mean glance duration, glance frequency, total glance duration and percent glance durations exceeding 2s, and driving performance, including forward and lateral controllability measures, were conducted. As a result, it was found that younger and older drivers' glance duration was significantly different with the visual task difficulty.

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## INTRODUCTION

Recent technological advances have enabled a wide variety of information systems to be integrated into a vehicle in order to increase safety, convenience and productivity. However, improperly deployed technology can increase driver's distraction and, consequently, degrade safety (Son, Lee, et al., 2011). The driver's distraction is a specific type of inattention that occurs when drivers divert their attention away from the driving task to focus on another activity instead (Ranney, 2008). These distractions can be from electronic distractions, such as navigation systems and cell phones, or more conventional distractions such as interacting with passengers and eating. These distracting tasks can affect drivers in different ways, and can be categorized into visual and cognitive distraction.

The cognitive distraction is difficult to measure directly because it is essentially internal to the driver. Thus, there have been efforts to monitoring driver's distraction using subjective measures, physiological measures (Mehler et al., 2010; Son, Mehler et al., 2011), eye movement measures (Reimer, 2010), and driving performance measures (Son, Lee, et al., 2011). However, the visual distraction, occurring when drivers look away from the roadway, is straightforward. It can be reasonably measured by the duration and frequency of glances away from the road. Because glance behaviours are associated with crash risk (Wierwille and Tijerina, 1998; Dingus et al., 2006), this paper focuses on gaze distributions of drivers engaged in a secondary visual task while driving. To assess age-related differences, comparisons of younger and older drivers' glance behaviour, including mean glance duration, glance frequency, total glance duration and percent glance durations exceeding 2s, and driving performance were conducted in a driving simulator.

## METHOD

### Subjects

Subjects were required to meet the following criteria: age between 25-35 or 60-69, drive on average more than twice a week, be in self-reported good health and free from major medical conditions, not take medications for psychiatric disorders, score 25 or greater on the mini mental status exam to establish reasonable cognitive capacity and situational awareness, and have not previously participated in a simulated driving study. The sample consisted of 30 males: 15 in the 25-35 age range ( $M=27.9$ ,  $SD=3.13$ ) and 15 in the 60-69 range ( $M=63.2$ ,  $SD=1.74$ ).

### Experimental setup

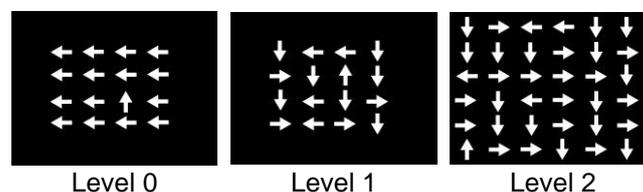
The experiment was conducted in the DGIST fixed-based driving simulator, which incorporated STISIM Drive™ software and a fixed car cab (see Figure 1). Graphical updates to the virtual environment were computed using STISIM Drive™ based upon inputs recorded from the OEM accelerator, brake and steering wheel which were all augmented with tactile force feedback. The virtual roadway was displayed on a 2.5m by 2.5m wall-mounted screen at a resolution of 1024 x 768. Sensory feedback to the driver was also provided through auditory and kinetic channels. Distance, speed, steering, throttle, and braking inputs were captured at a nominal sampling rate of 30 Hz. Physiological data were collected using a MEDAC System/3 unit and NeuGraph™ software (NeuroDyne Medical Corp., Cambridge, MA). A display was installed on the screen beside the rear-view mirror to provide information about the elapsed time and the distance remaining in the drive.



*Figure 1: The DGIST driving simulator*

### Secondary task

The arrow search task, which only required visual processing demand and minimal cognitive processing, was selected as surrogate tasks of visual distraction (Östlund et al., 2004). To create three levels of difficulty for the arrows task, i.e. level 0 (easiest), level 1 (moderate) and level 2 (hardest), three different arrangements of arrows were presented, each for 10s, forming a series of two minutes trials using 12 arrow pictures. On some occasions the upward pointing target arrow was present and on others it was not. The presentations of the displays are shown in Figure 2.



*Figure 2: Three levels of difficulty for the arrow task*

## Procedure

Following informed consent, sensor attachment and completion of a pre-experimental questionnaire, participants received 10 minutes of driving experience and adaptation time in the simulator. The simulation was then stopped and participants were trained in the arrow search task while remaining seated in the vehicle. When the simulation was resumed, participants drove in good weather through 37km of straight highway. Minutes 5 through 7 were used as a single task driving reference (baseline). Each arrow search task period was 2 minutes in duration. Presentation order of the three levels of task difficulty was randomized across participants. A 2-minute interval starting 30 seconds after the last task was used as the post-task reference period (recovery).

## Dependent variables

Scores on the arrow search task were used to confirm the extent to which different conditions represented periods of higher visual workload. Average forward velocity was selected as an indicator of compensatory behaviour, since drivers have been observed to reduce their speed to manage increasing workload (Harms, 1991; Horberry et al., 2006; Son et al., 2010). Standard deviation of lateral position is another frequently used driving performance measure (Sayer, Devonshire & Flannagan, 2007). Mean glance duration, glance frequency, total glance duration and percent glance durations exceeding 2 seconds were considered as glance behaviour measures (Victor et al., 2005).

## Analysis method

The significance of age and visual distraction on the dependent variables was assessed. Statistical comparisons were computed using a repeated measures general linear model (SPSS, Ver.17). A Greenhouse-Geisser correction was applied for models that violated the assumption of sphericity. Differences among significant main effects were assessed using pairwise t-tests with a least significant difference (LSD) adjustment for multiple comparisons.

## RESULTS

### Secondary Task Performance

Arrow searching scores on the different levels while driving appear in Table 1. Secondary task score significantly decreased with the visual task difficulty ( $F(1.752, 49.064) = 34.808, p < .000$ ). Although a main effect of age did not show a significant impact ( $F(1, 28) = 3.695, p = .065$ ), the older driver decreased in score relative to the younger group.

**Table 1: Secondary Task Scores**

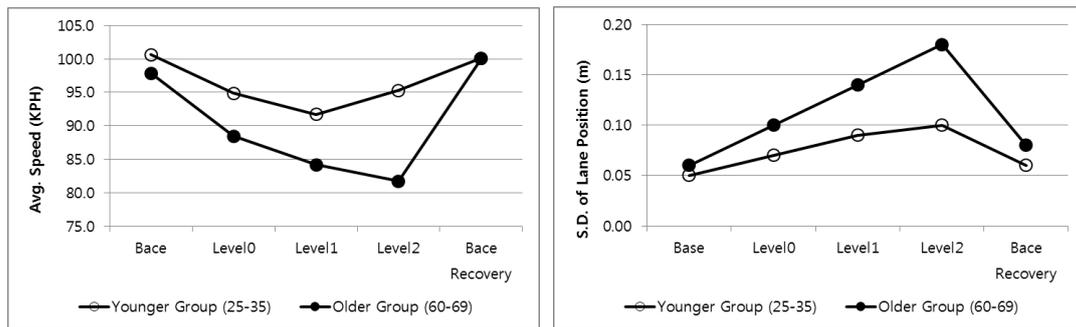
Total Score	Level 0	Level 1	Level 2
Younger (25-35)	11.8 (0.77)	10.9 (1.60)	9.5 (2.23)
Older (60-69)	11.5 (0.83)	10.2 (1.52)	8.4 (1.59)

\* Note: Means with standard deviations in parantheses.

### Driving Performance

To observe the compensatory behaviors and performance changes under different levels of visual distraction by age, forward velocity and standard deviation of lane position were examined. As shown in Figure 3, both age groups significantly decreased vehicle speed with the visual task difficulty ( $F(2.791, 78.154) = 38.957, p < .000$ ). Especially, the older group did show a simple correlation with the level of visual demand. Age also appears to have an impact on velocity ( $F(1, 28) = 10.630, p = .003$ ).

The standard deviation of lane position (SDLP) profiles showed a consistent correlation with the level of visual task difficulty in both age ( $F(2.675, 74.895) = 31.547, p < .000$ ). The SDLP was impacted by Age as well ( $F(1, 28) = 12.865, p = .001$ ).



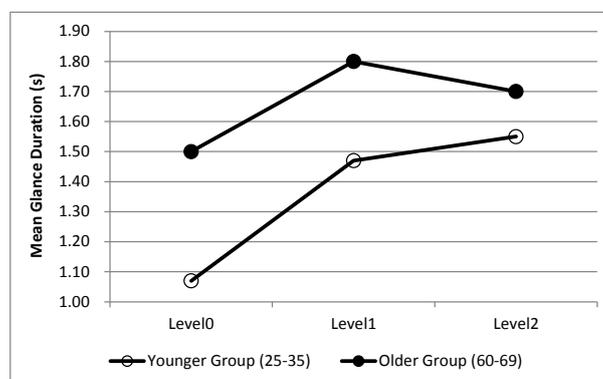
**Figure 3: Driving Performance Measures as a Function of Task Level: (a) Average Velocity and (b) Standard Deviation of Lane Position**

## Glance Behaviour

In order to observe age-related changes in glance behaviour under different levels of visual demand, mean glance duration, glance frequency, total glance duration and percent glance durations exceeding 2 seconds were examined.

### Mean glance duration

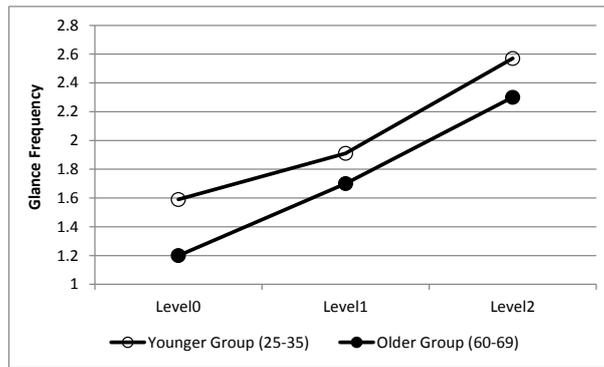
Glance duration refers to the time from the moment at which the direction of gaze moves towards the display for the visual tasks to the moment it moves away from it (Victor et al, 2005). As shown in Figure 4, mean glance durations significantly increase as a function of visual task difficulty in both age groups ( $F(1.731, 48.472) = 13.108, p = .000$ ). Age also appears to have an impact on mean glance duration ( $F(1, 28) = 4.767, p = .038$ ).



**Figure 4: Mean glance duration for the three visual task difficulty levels**

### Glance frequency

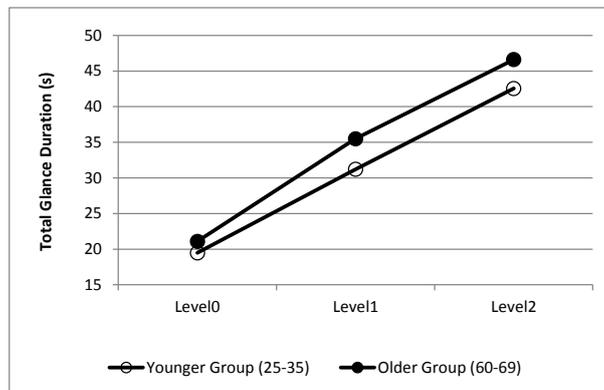
Glance frequency is the total number of glances made to the display during a visual task, where each glance is separated by at least one glance to a different target (Victor et al., 2005). As shown in Figure 5, glance frequency significantly increases with the visual task difficulty in both age groups ( $F(1.517, 42.467) = 100.983, p = .000$ ). However, a significant effect of age did not appear ( $F(1, 28) = 3.120, p = .088$ ).



**Figure 5: Glance frequency for the three visual task difficulty levels**

### Total glance duration

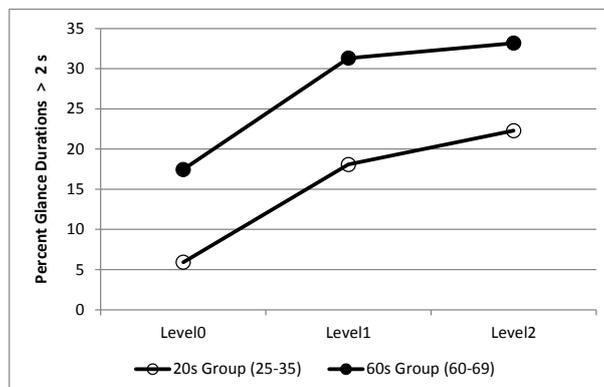
Total glance duration is the total amount of time which glances are associated with the display during a visual task (Victor et al., 2005). As shown in Figure 7, total glance duration significantly increases with the visual task difficulty in both age groups ( $F(1.812, 50.742) = 173.721, p = .000$ ). A significant effect of age does appear ( $F(1, 28) = 5.306, p = .029$ ).



**Figure 7: Total glance duration for the three visual task difficulty levels**

### Percent glance durations exceeding 2 seconds

Percent glance durations exceeding 2 s is the percentage of the total amount of glances toward the display during a visual task that had durations longer than two seconds (Victor et al., 2005). As shown in Figure 8, total glance duration significantly increases with the visual task difficulty in both age groups ( $F(1.578, 44.195) = 17.650, p = .000$ ). Although a main effect of age did not show a significant impact ( $F(1, 28) = 3.473, p = .073$ ), the older driver increased in percent glance durations exceeding two seconds relative to the younger group.



**Figure 7: Percent glance durations exceeding 2s for the three visual task difficulty levels**

## DISCUSSION

The ability to manage varying levels of visual demand is an essential aspect of safe driving. When demands on attention are high relative to available resources, one compensatory strategy for increasing safety margins is to moderate driving speed (Angell et al., 2006). This strategy is more pronounced for the older group, because an older driver's capacity to manage multiple tasks simultaneously is decreased with age (McDowd et al, 1991; Rogers and Fisk, 2001). The compensatory behaviour of the older group in this study was coincided with earlier findings.

Although the older drivers are self-regulated and conservative, they had different eye behavior patterns towards unsafe direction under higher visual demand. According to the results of this study, the older drivers looked at the in-vehicle display for longer duration and less frequently. As demonstrated by Wierwille and Tijerina (1998), an increase in in-vehicle glance duration is associated with increased crash risk. From this perspective, the results suggested that the older drivers have increased crash risk when interacting with in-vehicle devices.

As the visual task became more difficult, all eye behavioural measures clearly showed that drivers look more at the display and, consequently, less at the road ahead. Especially, in the situation of relatively high visual demand, the older drivers' mean duration time was longer than 1.6 seconds, which indicates that driving performance will be affected relative to baseline driving with no in-vehicle task (Bischoff, 2007), while the younger drivers' mean duration time was shorter than 1.6 seconds at all three difficult levels.

Based on the result, we found that older drivers show different visual attention management and driving performance compared with younger drivers. Therefore, in-vehicle interfaces need to be designed in consideration of these characteristics of the older drivers by avoiding a complex interface design.

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Dr. Joonwoo Son is a senior research scientist in the HumanLab at the Daegu Gyeongbuk Institute of Science and Technology (DGIST). He holds a B.S., an M.S. and Ph.D. from Pusan National University, South Korea. He has worked as a senior research engineer at Daewoo Precision Ind. Ltd. and SiemensVDO, and has been a visiting researcher at the Massachusetts Institute of Technology (MA, USA).

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