Cognitive and Driving Performance of Young and Elderly Driver’s on Unexpected Event

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ABSTRACT

Objective: The cognitive and driving performance of both young adult drivers and elderly drivers during unexpected driving situations were compared and analyzed, using a graphic driving simulator. Background: An unexpected event described as while driving, the lead-vehicle stops unexpectedly the participant vehicle needs to apply last minute braking to avoid accident. The physiological stress and responses involved during unexpected event are studied very little. Aging makes people do less social, physical and psychological activities. Method: The cognitive parameters considered were percentage of relative beta spectrum power, measured from Fz and O2 area using electroencephalogram, and R-R interval measured using an electrocardiogram. The driving performances measured from the driving simulator were: crash rate, inter vehicle distance, reaction time, full braking time and participant vehicle approaching velocity to the unexpected event. There were two groups of participants employed in this study. The younger group 26.3±2.0 years of age and older group were 65.6±5.0 years of age. Nineteen participants were assigned to each group, and these groups included only male drivers. All the participants were experienced two unexpected driving situations, one while driving at 70 km/h and another at 90 km/h. Results: Compared with young drivers, elderly drivers showed longer and greater cognitive stain during unexpected events. Electroencephalogram analysis showed significant difference (p < 0.05) in relative beta spectrum power before and after the unexpected event, and also a significant difference (p < 0.05) between driving situations. Young drivers reacted quicker to the sudden event than elderly drivers. Therefore, the crash rates were higher by the elderly drivers in both driving situations. Conclusion: Elderly drivers showed the different physiological responses under unexpected events and may need different guides for the safer driving.

Keywords: Cognitive Performance, Driving Performance, Driving Simulator, Unexpected Event, Aging

1. Introduction

These days long-time driving is encountered quite often in congested circumstances associated with speed, and accidents such as collisions and rollovers may occur [Lee et al., 2003]. Rear-end collisions account for over 28 % of all motor vehicle involved fatalities in the United States [Prasad et al., 1997]. Neck injuries are the most frequent damage from rear end collisions. In a Japanese study conducted at the beginning of the 1990s, neck injury occurs for 80 % of rear end collection [Cesarini et al., 1996]. Aging makes people do less societal activity, physical and psychological activities. Researches on age-related driving concerns have shown that at around the age of 65 drivers faces an increased risk of being involved in accidents. The number of older drivers is increasing as the population in the developed world is aging [Park and
Lim, 2011; Moon et al., 2013]. 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 [Jeon and Shin, 2010]. 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, 2009]. The number of traffic accidents by the elderly drivers has gradually been increasing for the last 10 years. In Korea, as of the end of 2011 it was reported that a total of 5,229 mortalities and 1,434,786 injured in the traffic accidents [KoROAD, 2012]; in that 5,229 fatal cases 39.5% were elderly age above 60 years. Researchers reported that one of the main causes of the traffic accidents by the elderly drivers is the decline of physical function [Unverzagt et al., 2009; Bilban, 1997]. Researches on the senior drivers showed that the senior drivers the highest crash and fatality rate per mile than all but the youngest drivers [Hakamies et al., 1996]. There are many behavioral factors may contribute to these statistics such as poor judgments in making left-hand turns, drifting with the traffic lane, and decreased ability to change behavior in response to an unexpected or rapidly changing situation. An unexpected event described as while the lead-vehicle stops unexpectedly the subject vehicle needs to apply last minute braking. In particular, accident rate due to last-minute braking is rapidly increasing among Korean older drivers’ comparing with younger drivers’. Not many studies were found regarding a senior driver behavior as well as physiological changes when they meet an unexpected event while driving. With this yet very little is known about the physiological stress and responses involved in last-minute braking situations. In this study, the cognitive and driving performance of both young adult drivers and elderly drivers during unexpected driving situations were compared and analyzed, using a graphic driving simulator. Driver perception and behavior can be evaluated by traffic modeling and simulation, and field studies using a driving simulator. Field data collection can test a limited number of traffic control devices. Driving simulator studies, however, permit the study of hazardous driving situations that cannot be safely replicated during field tests. Such studies can be efficient and facilitate the collection of a wide range of data. They are also repeatable, and permit easy and safe replication of numerous scenarios to evaluate subjects’ reaction to multiple traffic control devices.

2. Method

2.1 Participants

There were two groups of participants employed in this study. The younger group 26.3±2.0 years of age and older group were 65.6±5.0 years of age. The participants have enough driving experience younger groups (more than 3 years) and older groups (more than 30 years). Nineteen participants were assigned to each group, and these groups included only male drivers. All participants have no clinical history of mental diseases and visual problem to drive a car in the driving simulator (Fig. 1). They gave their informed consent after having been informed about the main contents of the experiment but not about the objectives.

Figure 1. Driving simulator used in this study

2.2 Driving Simulator and Driving Scenario

A graphical driving simulator located in the Korea Automobile Technology Institute (KATI) was used (Fig. 1). A ten minute practice was allowed for each participant to adjust to the simulator and ample rest time was given between practice and real test. In the real test, participants were instructed to drive a car in a driving simulator at the speed of 50, 70, 90, 110 km/h for one minute each. Each participants were performed the test for two times, one for last minute braking event while driving at 70 km/h and another last minute braking event at 90 km/h. Ample rest time was given between two tests.
2.3 Subjective Evaluation

A subjective evaluation comprises 30 questions regarding the simulation sickness and sensation. Subjective evaluation was conducted from participants after completing two tests. Visual analogue scale was used to measure the simulation sickness and sensation with 10 as the highest score. The higher score represents the highest discomfort level of simulation sickness and sensation.

2.4 Cognitive Performance

The cognitive parameters considered were percentage of relative beta spectrum power \(\frac{\beta}{\alpha+\beta+\theta+\delta}\), measured from \(F_z\) and \(O_2\) area using electroencephalogram, and R-R interval measured using an electrocardiogram. Heart period was calculated as the time between successive R-peaks (i.e., R-R interval) of the electrocardiogram, so that an increase in heart rate results in shortening of heart period. The data were measured using one system (GRASS and Biopac MP100 system, USA), and an AcqKnowledge was used for analysis. The sampling frequency for measuring physiological signals was set at 512Hz. Skin impedance was under 10 kΩ.

2.5 Driving Performance

The driving performances measured from the driving simulator were: crash rate, inter vehicle distance, reaction time, full braking time and participant vehicle approaching velocity to the unexpected event.

3. Results and Discussion

3.1 Subjective Evaluation

The older group showed stronger discomfort, while the younger group showed mild to moderate discomfort for the simulation sickness. In terms of sensation, the older group showed 35 ~ 60 % higher discomfort for headache, fatigue, concentration, visual focus, vague outline, and dizziness than the younger group. For the sensation of speed and reality, the older group gave higher score 5.4 and 5.8, than the younger group gave 3.0 and 4.5, respectively.

3.2 Cognitive Performance

Both age groups of participants showed rapidly increased relative beta spectrum power ratio right after an unexpected event during 70 km/h driving. However, the case was different while driving at 90 km/h. The relative beta spectrum power ratio of age groups before and after the event during 90 km/h driving is shown in Fig. 2. The difference in the relative beta spectrum power ratio between before and after the event is presented in Fig. 3, for the 90 km/h driving situation. From Fig. 3, it is clear that older group’s beta spectrum power increased significantly \((p < 0.05)\) after the unexpected event, which shows elders stressed more than younger groups.

![Figure 2](image)

**Figure 2.** Percentage of relative beta spectrum power ratio before and after the unexpected event.

![Figure 3](image)

**Figure 3.** Difference in relative beta spectrum power ratio before and after the unexpected event.
R-R interval of the younger and elder groups during 70 km/h driving.

R-R interval of the older groups was longer before driving than the younger groups and it goes shorter right after starting driving (Fig. 4). After the unexpected event, the R-R interval went down for both age groups. Both age groups felt strain after the unexpected event.

### 3.3 Driving Performance

<table>
<thead>
<tr>
<th>Event: 70 km/h</th>
<th>Event: 90 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Younger</strong></td>
<td><strong>Older</strong></td>
</tr>
<tr>
<td>E.S.</td>
<td>65.59</td>
</tr>
<tr>
<td>I.V.D.</td>
<td>51.36</td>
</tr>
<tr>
<td>F. B. T.</td>
<td>0.94</td>
</tr>
<tr>
<td>R.T.</td>
<td>1.5</td>
</tr>
<tr>
<td>A.R.</td>
<td>31.6 %</td>
</tr>
</tbody>
</table>

The driving performances of the younger and elder groups are shown in Table 1. The average entering speed (E.S) of the participants vehicles to the last minute braking events showed that younger groups vehicle speed were higher than elderly. That is, the younger’s approached the event with a faster speed than elderly. The average inter vehicle distance (I.V.D) during the last minute braking events showed that elderly maintained the higher distance than the younger’s. The average full braking time (F.B.T) of the subject vehicles at the last minute braking events showed that elderly applied quicker than the younger’s. The average reaction time (R.T) for the last minute braking events showed that younger’s reacted/responded quicker than the elderly regardless of the event speed. The accident rate (A.R) due to the last minute braking events were measured. The elderly encountered higher percentage of accidents than the younger.

### 4. Conclusions

In this study, we measured and analyzed cognitive characteristics of the elderly and young drivers when a last minute braking situation appears while driving on the highway. Both age group drivers showed significant changes in their cognitive data (relative beta spectrum power ratio) by the last minute braking event but the elderly people showed greater changes and longer duration. In terms of R-R interval, both age group drivers felt stain after the unexpected event, comparatively elders felt more strain. Guidelines for driving on the highway as well as any public roads may need to be changed for the elderly people for their safer driving such as the distance between two cars going in the same direction on the same lane.

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