Journal of the Ergonomics Society of Korea
Vol. 29, No. 4 pp.611-617, August 2010 DOI:10.5143/JESK.2010.29.4.611

The Characteristics of Elderly Drivers' Driving Behavior on Intersection Using Graphic Driving Simulator

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ABSTRACT

To find out why elderly drivers have more frequent traffic accidents on intersection than any other one, this study was conducted to examine the characteristics of elderly drivers' driving behavior on intersection using a multifaceted driving behavior indicator. To do that, the driving behavior of both young adult drivers and elderly drivers were compared and analyzed, using a graphic driving simulator. As a result, compared with young adult drivers, elderly drivers showed a poor driving performance, and a high ratio of visual scanning time on the specific direction regardless of driving situation. Also, compared with young adult drivers, elderly drivers had a high overall level of arousal, and the phasic arousal activity on the specific stimulus was low. These results imply that through the intervention which induces the change in multifaceted indicators mentioned earlier, they could be helped to drive more safely on intersection.

Keywords: Elderly Drivers, Intersection, Driving Performance, Eye-Movement, Physiological Response

1. Introduction

The records of traffic accidents in elderly drivers indicated that the increase rate on the single route was by 1% each year, while it was by 6% on intersection (Kim et al., 2009). Meanwhile, according to the 2008's report of NHTSA (National Highway Traffic Safety Administration) only for elderly drivers, the accidents by elderly drivers consisted of 59% of the whole fatal crashes, and 25% of that happened on intersection. This result suggests that intersection is a relatively dangerous situation to elderly drivers.

Why are elderly drivers exposed to the danger on intersection more easily like this? Two things can be considered as the causes, that is, one is the characteristics of intersection driving situation, and the other is the characteristics of elderly drivers' driving behavior. In other words, the physical property of intersection driving situation might induce elderly drivers to have accidents, or the inherent property possessed by elderly drivers, not external one, that is, the characteristics of driving behavior, could bring about more traffic accidents on intersection. However, as physical elements, such as the complexity and danger of intersection driving situation, are the parts which may be applied to drivers of all ages, as well as elderly drivers in common, it is improper to infer that they cause elderly drivers to have more accidents on intersection. In the end, it is proper to find out the reason for the accidents on

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intersection of elderly drivers in the characteristics of driving behavior which they have.

Therefore, in this study, the driving behavior of elderly drivers over a intersection driving scenario, that is, the characteristics of driving performance, eye movements and physiological reaction, was examined in comparison with young adult drivers using a graphic driving simulator.

2. Method

2.1 Participants

Those who participated in the experiment were 26 elderly men, who lived in Daejeon Metropolitan City, had over 1 year driving experience and were 65 years old and more. The average age of them was 71.19±3.59, and they had normal or corrected eyesight with which they had no difficulty in perceiving the stimulus presented by a monitor. All of them had been driving for over 9 years. And also, as a control group, those who participated in the experiment were 22 male adults in twenties whose driving experience was over 1 year. The average age of them was 27.73± 2.69, and like the elders, they had normal or corrected eyesight with which they had no difficulty in perceiving the stimulus presented by a monitor. They had a driving experience like this: 2 persons were under 3 years, 12 under 6 years, 4 under 9 years, and 4 over 9 years.

2.2 Apparatus

GDS-300S manufactured by Gridspace Co. (Korea) was used as a driving simulator, which was configured to provide left/right situation information required in driving through three 32" LCD monitors (Figure 1).

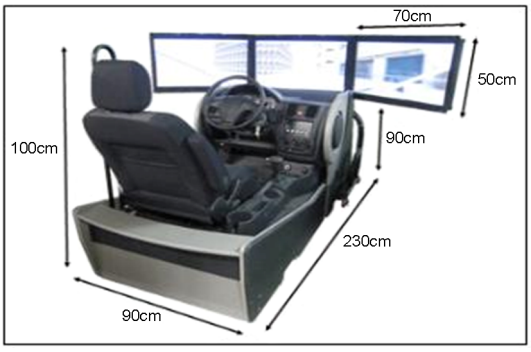

Figure 1. Graphic driving simulator

EMR-8B manufactured by NAC Image Technology Inc. (Japan) was used as the measuring equipment of eye movements. A front sight lens is installed on the top of a baseball cap, and eye mark detection unit is done on the left/right side. This unit does a role to detect the pupil movement of both eyes (Figure 2).

Figure 2. Eye marker

Biopacamp manufactured by Biopac System Inc. (USA) was used as autonomic nervous system measuring system, and AcqKnowledge (ver. 3.91) of MP100WS was used to input and analyze data. ECG (electrocardiogram) was measured with reference electrode attached to the right chest, which was symmetric with + electrode, and through CM5 inducing method that +/− electrode was attached to the left chest and the top of breastbone, respectively (Figure 3). And, EDA (electrodermal activity) was measured under the ankle bone inside the left foot so as to minimize the movement during driving situation (Ryu et al., 2005).

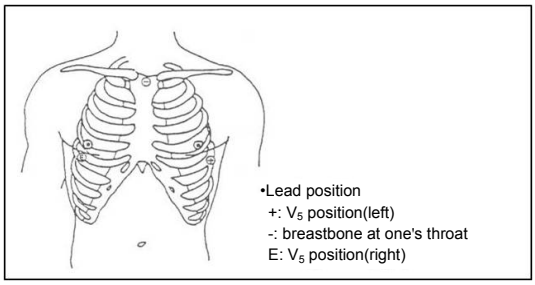

Figure 3. CM5 inducing method (Miyake, 2001)

2.3 Procedures

Before implementing the main experiment, the electrode

for measuring autonomic nervous system was attached to all the participants of the experiment, and they performed practice driving about for 5 min to adapt to the driving simulator. In the main experiment, the participants of the experiment drove the downtown course of a 2-lane road about for 10min. The driving scenario included the condition of 5 times left turn and right turn on intersection, respectively (Figure 4).

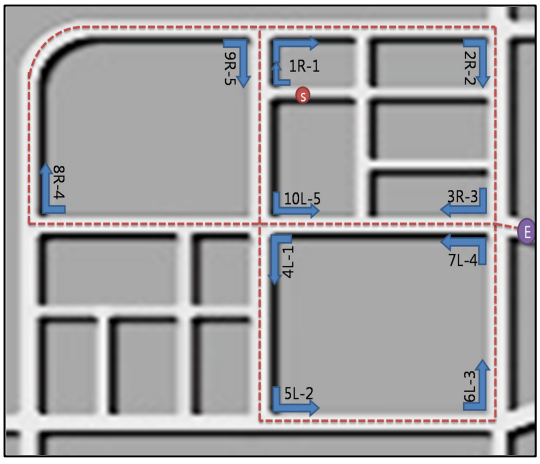

Figure 4. Driving scenario

2.4 Dependent variables

As dependent measures for measuring driving performance, intersection passing time, intersection approaching velocity, and speed & steering variation when passing through intersection were used. Also, as dependent measures of eye movements, a ratio of visual scanning time of forward direction, left direction and right direction was used. Finally, HR (heart rate), which means the number of heartbeats for a minute, was used as a detailed indicator of ECG, SCL (skin conductance level) which means the tonic activity of EDA, SCR (skin conductance response), which means the phasic activity on the stimulus, and NSCR (number of skin conductance response) were used as the detailed indicators of EDA. With the consideration of latency of response, by dividing it into 15 seconds before approach as stabilized state (base), and 15 seconds after approach as turning state (stimulus), this physiological data was analyzed (Kim et al., 2009).

3. Results

3.1 Driving performance

First, to examine the difference in intersection passing time according to turn type and group, 2×2 mixed ANOVA was conducted. As a result, the main effect of turn type and group was significant [$F_{(1,46)}$=7.22, p<.05; $F_{(1,46)}$=58.75, p<.001] (Figure 5). That is, it took longer to pass through intersection during left turn condition than right turn condition on intersection. Also, it took longer for elderly drivers to pass through intersection than young adult drivers.

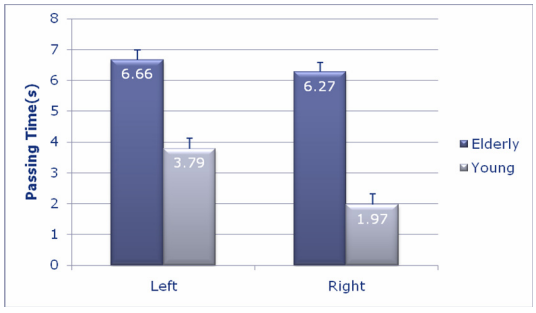

Figure 5. Differences in passing time between age groups

Next, intersection approaching velocity according to turn type and group was examined. As a result, the main effect of group was significant [$F_{(1,46)}$=6.93, p<.05] (Figure 6). That is, it appeared that young adult drivers approached intersection with a faster speed than elderly drivers.

Figure 6. Differences in approaching velocity between age groups

Meanwhile, as a result of examining the difference in speed variation when passing through intersection according to turn type and group, the main effect of turn type [$F_{(1,46)}$

=11.02, p<.01] and the interaction effect of turn type and group were significant [$F_{(1,46)}$=4.28, p<.05] (Figure 7). That is, though both elderly drivers and young adult drivers showed a larger decrease in speed variation during right turn than left turn, the extent of decrease of it in young adult drivers was larger than in elderly drivers.

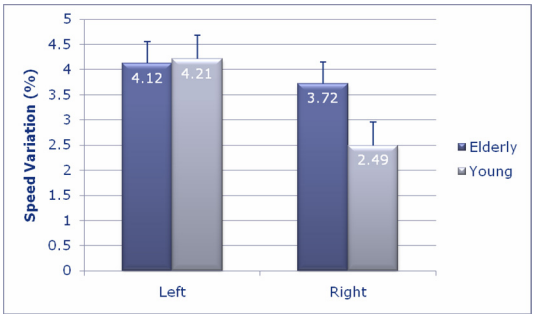

Figure 7. Differences in speed variation between age groups

Finally, the difference in a steering variation when passing through intersection according to turn type and group was examined. As a result, both the main effect [$F_{(1,46)}$=29.19, p<.001; $F_{(1,46)}$=43.61, p<.001] and interaction effect of turn type and group were significant [$F_{(1,46)}$=8.49, p<.01] (Figure 8). That is, it appeared that elderly drivers steered more frequently than young adult drivers, and during right turn than left turn. However, there was a large increase in a ratio of steering according to turn type in elderly drivers, compared with young adult drivers.

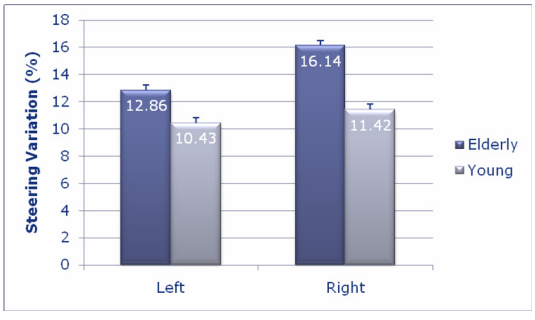

Figure 8. Differences in steering variation between age groups

3.2 Eye movements

First, the difference in a ratio of visual scanning time of forward direction according to turn type and group was examined. As a result, the main effect of turn type [$F_{(1,46)}$ =7.00, p<.05] and the interaction effect of turn type and group were significant [$F_{(1,46)}$=16.12, p<.01] (Figure 9). That is, a ratio of visual scanning time of forward direction largely increased during right turn, compared with left turn, and in young adult drivers, compared with elderly drivers.

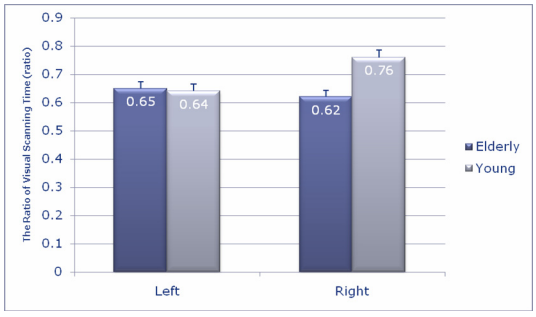

Figure 9. Differences in the ratio of visual scanning time of forward direction between age groups

Next, as a result of examining the difference in a ratio of visual scanning time of left direction according to turn type and group, the main effect of turn type was significant [$F_{(1,46)}$=116.53, p<.001] (Figure 10). That is, it appeared that there was a higher ratio of visual scanning time of left direction during left turn than right turn.

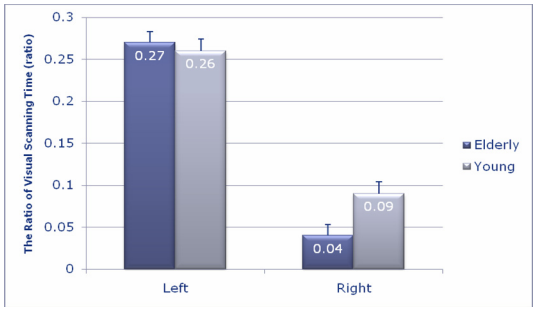

Figure 10. Differences in the ratio of visual scanning time of left direction between age groups

Finally, the difference in a ratio of visual scanning time of right direction according to turn type and group was examined. As a result, both the main effect [$F_{(1,46)}$=64.95, p<.001; $F_{(1,46)}$=13.52, p<.01] and interaction effect of turn type and group were significant [$F_{(1,46)}$=48.18, p<.001] (Figure 11). That is, young adult drivers showed no change in a ratio of visual scanning time of right direction in

young adult drivers as turn type changed, while elderly drivers showed a large increase in a ratio of visual scanning time of right direction during right turn than left turn.

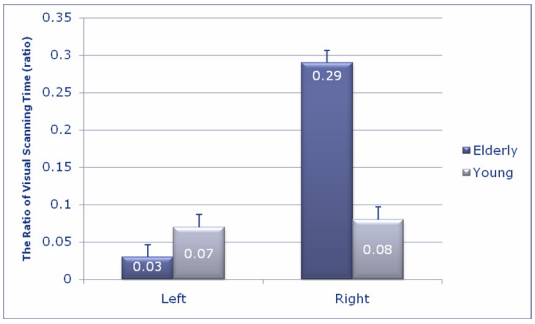

Figure 11. Differences in the ratio of visual scanning time of right direction between age groups

3.3 Physiological response

To examine the difference in ECG according to turn type, group, and state condition (base & turn), mixed ANOVA was conducted on HR, the detailed indicator of ECG. As a result, it appeared that the main effect of turn type and state condition was significant [$F_{(1,46)}$=4.30, p<.05; $F_{(1,46)}$=55.47, p<.001] (Figure 12). That is, every driver showed a faster heartbeat during right turn than left turn on intersection, and in turning state than in stabilized state.

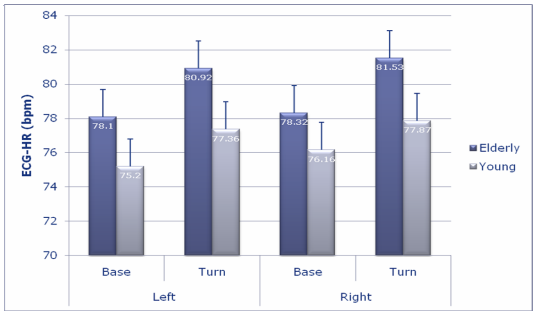

Figure 12. Differences in the HR between age groups

Next, on SCL of the detailed indicators of EDA, the difference according to turn type, group, and state condition was examined. As a result, the main effect [$F_{(1,46)}$=18.77, p<.001; $F_{(1,46)}$=25.56, p<.001] and interaction effect of group and state condition were significant [$F_{(1,46)}$=4.83, p<.05] (Figure 13). That is, elderly drivers, compared with young adult drivers, showed a higher SCL, while young adult drivers showed a larger extent of change in SCL than elderly drivers as state condition changed from stabilized state to turning state.

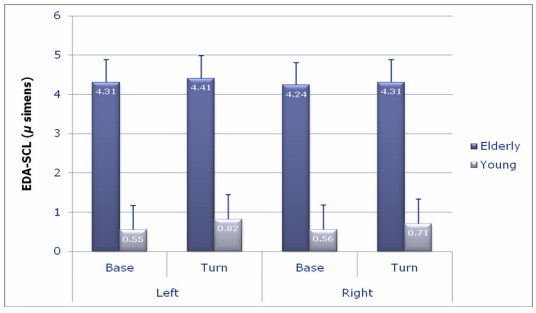

Figure 13. Differences in the SCL between age groups

Meanwhile, as a result of examining the difference according to turn type, group and state condition about the SCR of the detailed indicators of EDA, the main effect of groups and state condition [$F_{(1,46)}$=36.27, p<.001; $F_{(1,46)}$= 12.12, p<.01] and the interaction effect of turn type and state condition were significant [$F_{(1,46)}$=4.76, p<.05] (Figure 14). That is, young adult drivers, compared with elderly drivers, responded to the stimulus of the external environments more sensitively, and such a phasic activity was larger in turn state than stabilized state. Especially, during left turn, it appeared that SCR increased in turning state in a large extent, compared with stabilized state.

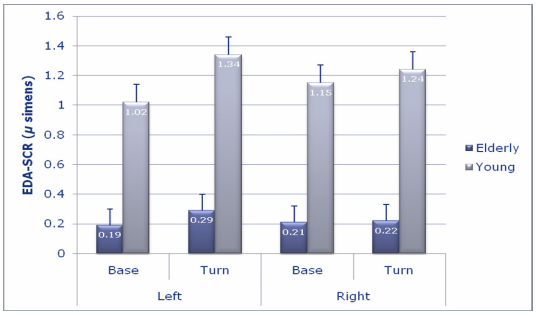

Figure 14. Differences in the SCR between age groups

Finally, the difference according to turn type, group and state condition in NSCR of the detailed indicators of EDA was examined. The result was that the main effect of turn type and state condition [$F_{(1,46)}$=7.83, p<.01; $F_{(1,46)}$=12.67,

p<.01] and the interaction effect of group and state condition were significant [$F_{(1,46)}$=4.86, p<.05] (Figure 15). That is, the number of phasic activities on the stimulus of the external environments increased during right turn, compared with left turn, and in turning state rather than stabilized state. Meanwhile, the difference in NSCR according to change in this state condition was remarkable in young adult drivers.

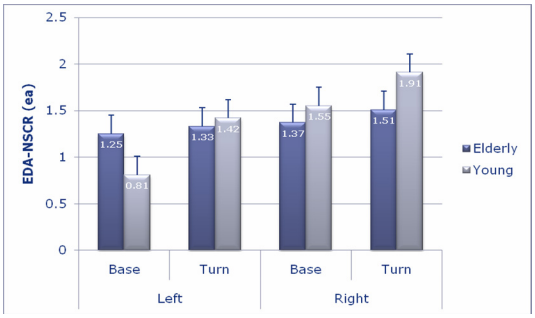

Figure 15. Differences in the NSCR between age groups

4. Discussion

In this study, what kinds of characteristics of driving behavior elderly drivers show in intersection situation, compared with young adult drivers, is examined using a multifaceted driving behavior indicator. As a result, in driving performance, compared with young adult drivers, it took longer for elderly drivers to pass through intersection, and when they approached intersection, they did with a slower speed. And, though elderly drivers stepped on the accelerator, decelerator pedals to accelerate and decelerate when they passed through intersection, such a process didn't appear different according to turn type. Also, in steering, it appeared that elderly drivers steered as frequently as unexperienced drivers. This result can be interpreted as a result of compensated driving behavior according to the low level of confidence (Hong et al., 2009).

Along with this, in eye movements, a ratio of visual scanning time of forward direction increased when young adult drivers turned right, while elderly drivers showed an increase in a ratio of visual scanning time of right direction. This result suggests the advantage and disadvantage to elderly drivers. The advantage is that elderly drivers can fast cope with the objects which suddenly appear from the turn direction, as they keep the focus on the right turn direction for a long time (Kim et al., 2009). However, the disadvantage is that when elderly drives turn right, they are highly likely to have traffic accidents as they don't find the vehicles which approach in the right turn direction from forward and left direction.

Next, in the physiological reaction, compared with young adult drivers, it appeared that elderly drivers are maintaining the aroused condition by and large while driving, and that the arousal reaction on the specific stimulus of them was not brought out, if any, it was very weak. Physiological arousal makes one prepare for the perception of the danger and response to it (Vianna & Tranel, 2006), which suggests that the arousal which has increased regardless of the degree of danger can make a driver not respond sensitively in an actual dangerous situation. Also, in that the excessive level of arousal could bring about the increase in mistake rather than the optimal performance results, it is likely to work as a cause which induces the poor driving performance of elderly drivers.

In conclusion, when the intervention is applied to cause the change in multifaceted indicators of driving behavior mentioned above, it is expected that elderly drivers could drive on intersection more safely.

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Date Received : June 25, 2010
Date Revised : July 19, 2010
Date Accepted : July 26, 2010