DIVIDED ATTENTION ABILITY OF YOUNG AND OLDER DRIVERS

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INTRODUCTION

This study formulates a divided attention task that measures the capacity of drivers to use in-vehicle Advanced Transportation Information Systems (ATIS). Henderson and Suen (1999) have suggested that an ATIS is a two-edged sword for older drivers because with advancing age drivers experience diminished perceptual and cognitive abilities that make it difficult to use in-vehicle displays. When using an in-vehicle display to obtain potentially useful information, a driver usually 1) makes a small head movement to the right accompanied by an eye-movement of about 30-35 degrees and 2) adjusts his/her eye for close vision which involves convergence eye movements and accommodation of the eye lenses. For people who are 60 years or older these processes take longer and thus older drivers spend more time than young drivers acquiring information from an in-vehicle display.

While driving, the primary task is to monitor the driving scene to obtain information for vehicle control and to monitor for potential hazards. A driver who spends long periods of time reading information from an in-vehicle display may be unable to properly control the vehicle. Instead, a driver timeshares the tasks of monitoring the driving scene and the acquiring of information from in-vehicle displays by making frequent glances back and forth. In the present study we measure drivers' ability to obtain information while constantly switching between near and far visual tasks. We hypothesize that older drivers will not perform as well as younger drivers on this simple divided attention task. Secondly, we measure the drivers' vehicle steering ability while performing the divided attention task. Here, we attempt to quantify the capacity to obtain information from an in-vehicle display by varying the time between stimuli presentations. In addition we compare driver performance relative to two display formats. One format uses an in-vehicle display, while the other presents information that is superimposed on the virtual driving scene. Since drivers do not have to switch between near and far vision to obtain superimposed information, their performance should be better.

METHOD

Subjects

Twenty subjects, all with valid driving licenses and vision (corrected or uncorrected) of at least 20/40 for far visual acuity participated in the study. The ten young drivers ranged in age from 23 to 46 years of age. The ten older drivers ranged in age from 58 to 76. All subjects were given a ten-dollar honorarium for their participation.

Apparatus

As shown in Figure 1, subjects sat in the cab of a 1985 Dodge Caravan and could view an in-vehicle display as well as information superimposed on the driving scene located 11 feet in front of them. For a driver of normal height, the in-vehicle display was 18 degrees below his/her straight-ahead plane and 32 degrees to the right.

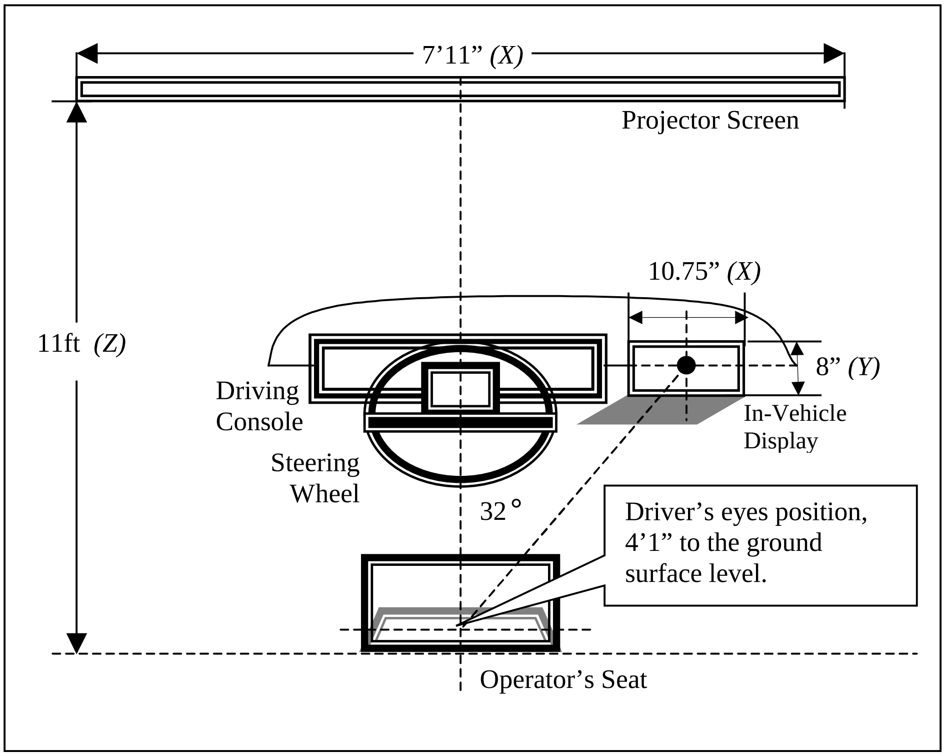

Figure 1. Virtual Environments Driving Simulator with an in-vehicle display.

The virtual environment used for the driving activity consisted of a roadway that was 1.75 miles long and contained 4 curves. The lane width was 12 feet. An example of the scene with superimposed digits is shown in Figure 2. Java 3D was used to generate the virtual environment.

Figure 2. Roadway environment with superimposed digits.

The In-Vehicle display was located 32 degrees to the right and 18 degrees down when a driver was looking straight ahead. A close-up of digits on the In-Vehicle display is shown in Figure 3.

Figure 3. Digits on the In-Vehicle display.

Procedure – Divided Attention Testing

Subjects were given one practice run with an inter-stimulus interval of 1.6 seconds. The duration of each stimulus presentation was 8oo milliseconds. On each of 25 trials in the practice run a subject was to report the four random digits that were superimposed on the static road scene (11 feet in front of the vehicle) and the four random letters that appeared on the In-Vehicle display. The practice run was used to familiarize a subject with the experimental protocol. Run 1 of the divided attention test consisted of the same conditions as above with the subject's verbal responses being tape-recorded for future analysis. For the 25 trials of run 2, the inter-stimulus interval was set to 1 second and the duration of the stimuli was 500 milliseconds.

Experimental Design – Driver Steering Task

A three factor experimental design was used for the driver steering task. The two within subject factors were type of display (Superimposed and In-Vehicle) and time between stimuli (2.4, 1.8, 1.2, and 0.6 seconds). The between factor was age of subjects (Young or Older). All stimuli were presented at a constant duration of 300 milliseconds.

Procedure – Driver Steering Task

Each subject adjusted the vehicle's power seat to a suitable driving position. Simulation software controlled the vehicle's velocity of 35 mph. It was the driver's task to steer the vehicle and keep it in the center of its lane. One practice run was given for the subject to become familiar with the vehicle's handling characteristics. Subjects then drove the 1.75 mile route four times at inter-stimuli intervals of 2.4, 1.8, 1.2, and 0.6 seconds. During each run the subject was to report the four digits that were superimposed on the road scene and steer the vehicle as best as possible. On the second set of four runs (at the same inter-stimuli intervals), the digits were presented on the In-Vehicle display. The vehicle's position with respect to the center of its lane was automatically recorded. A tape recorder was used to record subjects' vocalization of the digits.

RESULTS

Divided Attention Scores

In Figure 4 are the average percent correct responses made by young and older drivers when stimuli where presented at inter-stimuli times of 1.6 and 0.8 seconds. When the inter-stimuli time was large (1.6 seconds) the young drivers averaged 99% correct and the older drivers 89%. This difference was statistically significant ($p < .001$). When the time between stimuli was 1.0 seconds, the young drivers averaged 72.8% correct responses while the older drivers averaged 58.7% correct responses. Again, the difference was highly significant ($p < .001$).

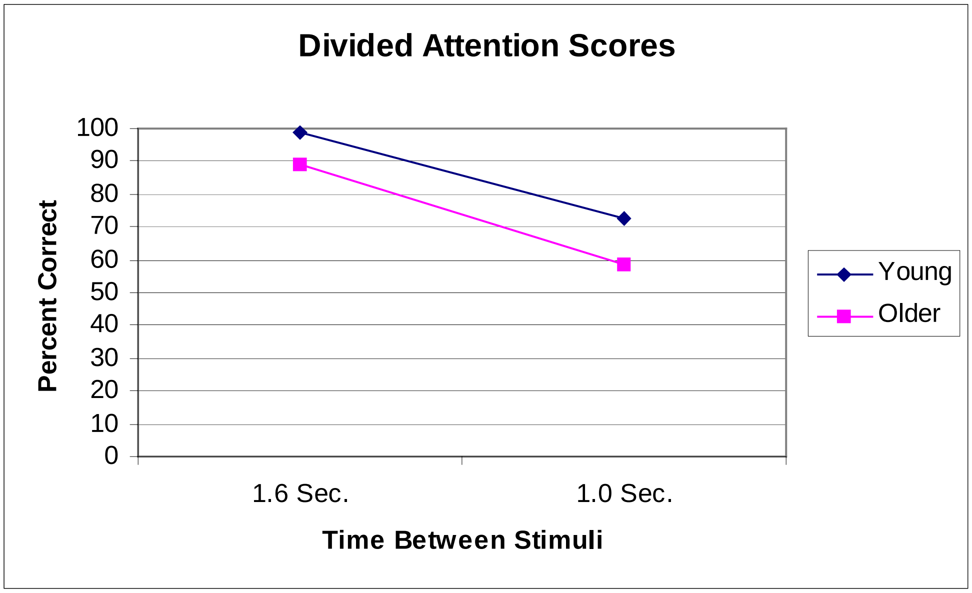

Figure 4. Average Percent Correct By Time Between Stimuli.

The average percent correct response for the 1.0-second inter-stimulus interval (Run 2) as a function of the Superimposed and In-Vehicle displays is shown in Figure 5.

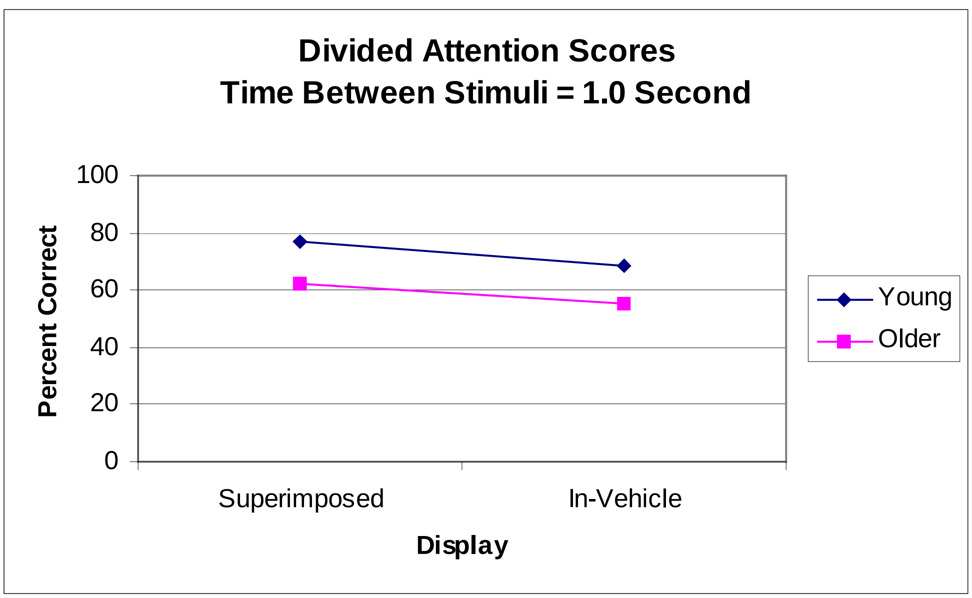

Figure 5. Average Percent Correct By Display Type.

While using the Superimposed display, the young drivers averaged 76.8% correct and the older drivers 62% correct. The difference was statistically significant at $p < .002$. For the In-Vehicle display, the young drivers averaged 68.8% correct and the older drivers 55.5%. Again this was statistically significant at $p < .008$. The difference between the Superimposed (69.4% correct) and the In-Vehicle (62.1% correct) scores was statistically significant at $p < .04$. Note that the type of stimuli, digits and letters, was confounded with display type, Superimposed and In-Vehicle, respectively. Thus, the poorer performance when reading from the In-Vehicle display may be due to the type of stimuli.

In order to determine if drivers' performance while using the In-Vehicle display was similar to that of reading the Superimposed information, we calculated correlation coefficients. For young drivers the correlation was .82 and for older drivers it was only .42 when the time between stimuli was 1.0 seconds. Plots are shown in Figures 6 and 7.

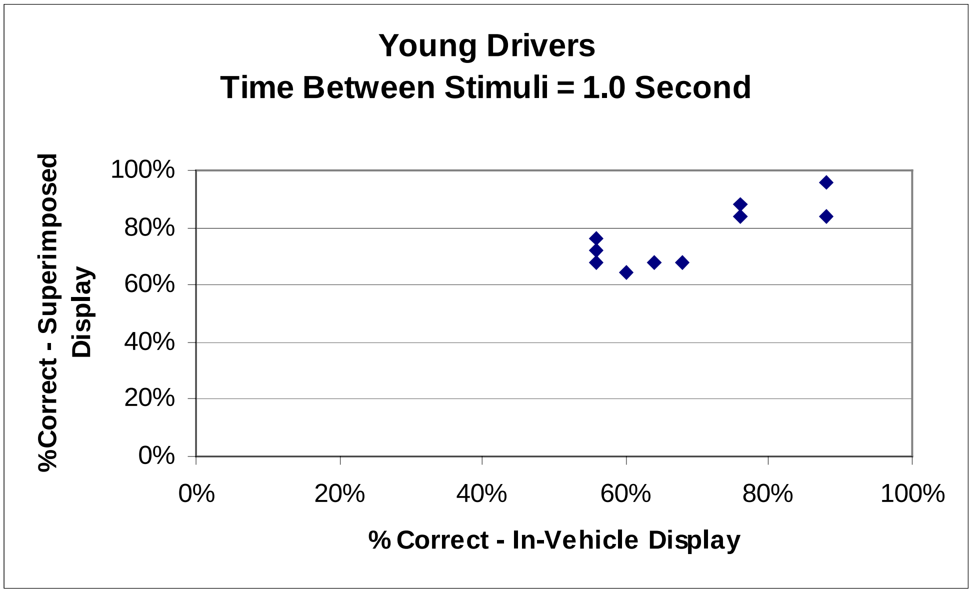

Figure 6. Correlation of Superimposed and In-Vehcile Scores – Young Drivers.

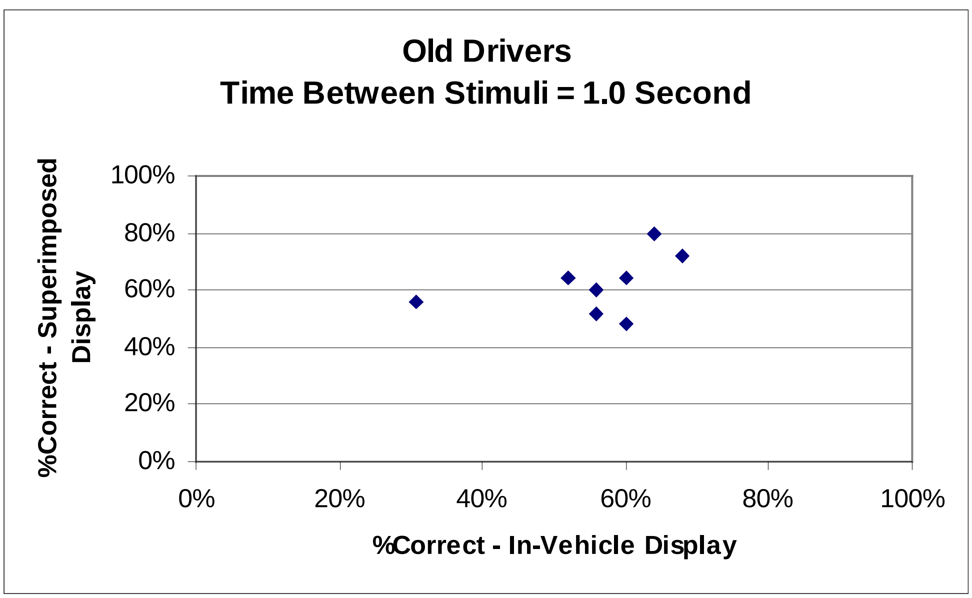

Figure 7. Correlation of Superimposed and In-Vehcile Scores – Older Drivers.

Percent Correct While Driving

Figure 8 shows the percent correct responses as a function of time between stimuli when subjects were required to steer the vehicle and report digits that were superimposed on the road scene. At the inter-stimuli intervals of 2.4 and 1.8 seconds there were no statistical differences between young and older drivers. When the times between stimuli was 1.2 seconds and 0.6 seconds, differences between young and older drivers were statistically significant, $p < .04$ and $p < .001$, respectively.

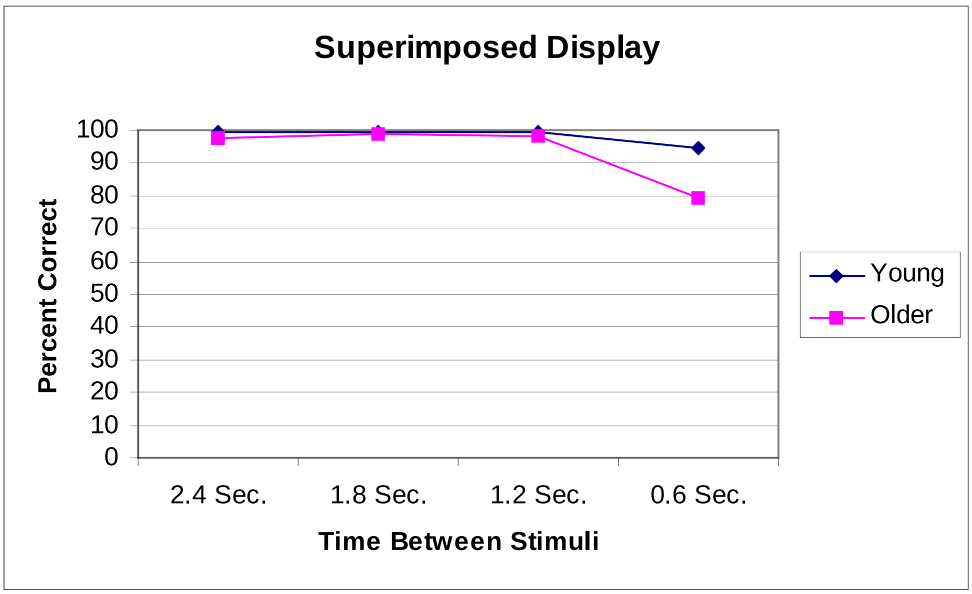

Figure 8. Percent Correct by Time Between Stimuli – Superimposed Display.

Figure 9 shows the percent correct responses as a function of time between stimuli when subjects were required to steer the vehicle and report digits that were shown on the In-Vehicle display. At all levels of time between stimuli the differences between the young and older drivers were highly significant ($p < .001$). The surprising result was that for both the young and older drivers, the poorest performance occurred when the time between stimuli was the longest, i.e. 2.4 seconds.

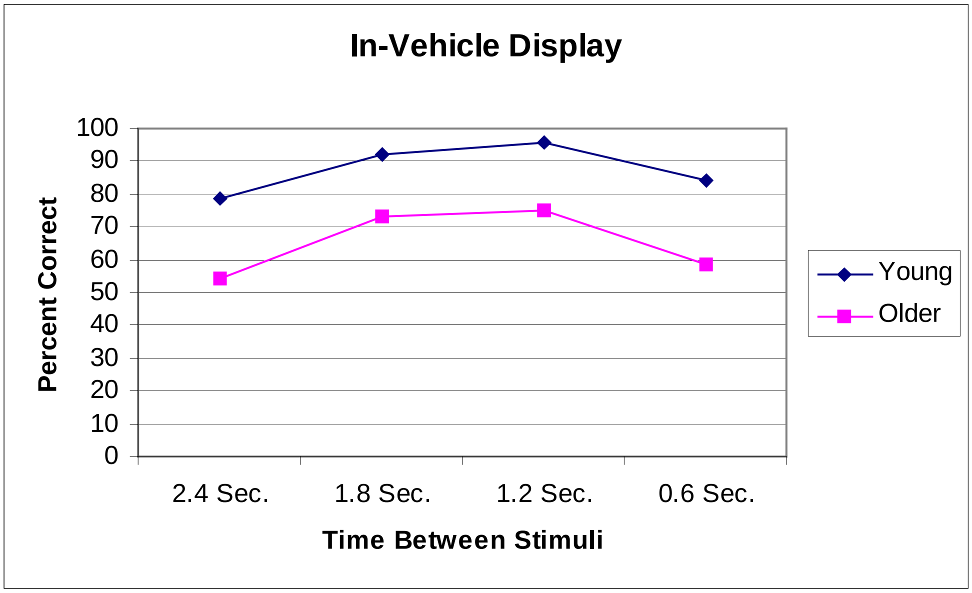

Figure 9. Percent Correct by Time Between Stimuli – In-Vehicle Display.

Average Lane Position Error

Figure 10 shows that the average lane position error did not change as a function of decreasing time between stimuli when digits were superimposed on the driving scene.

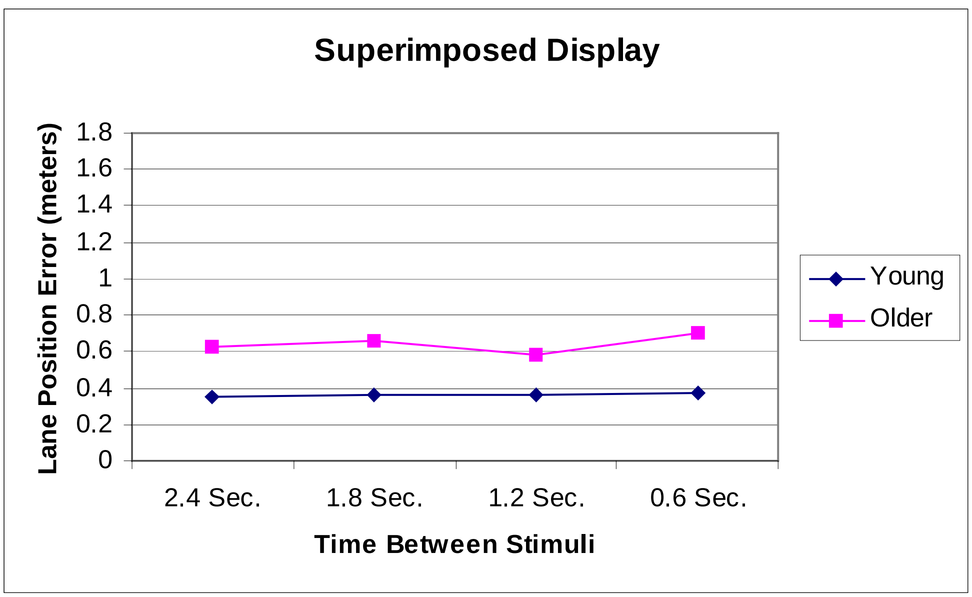

Figure 10. Lane Position Error by Time Between Simuli – Superimposed Display.

For all inter-stimuli intervals, the average performance of the young drivers was significantly better than that of the older drivers ($p < .05$). For the older drivers, the increase in lane position error between 1.2 seconds and 0.6 seconds approached statistical significance ($p < .06$).

When reading digits from the In-Vehicle display, average lane position error increased as the inter-stimuli intervals decreased (Figure 11). Again, for all inter-stimuli intervals the average performance of the young drivers was significantly better than that of the older drivers ($p < .05$). However, for the older drivers the increase in lane position error between 1.2 seconds and 0.6 seconds was not statistically significant.

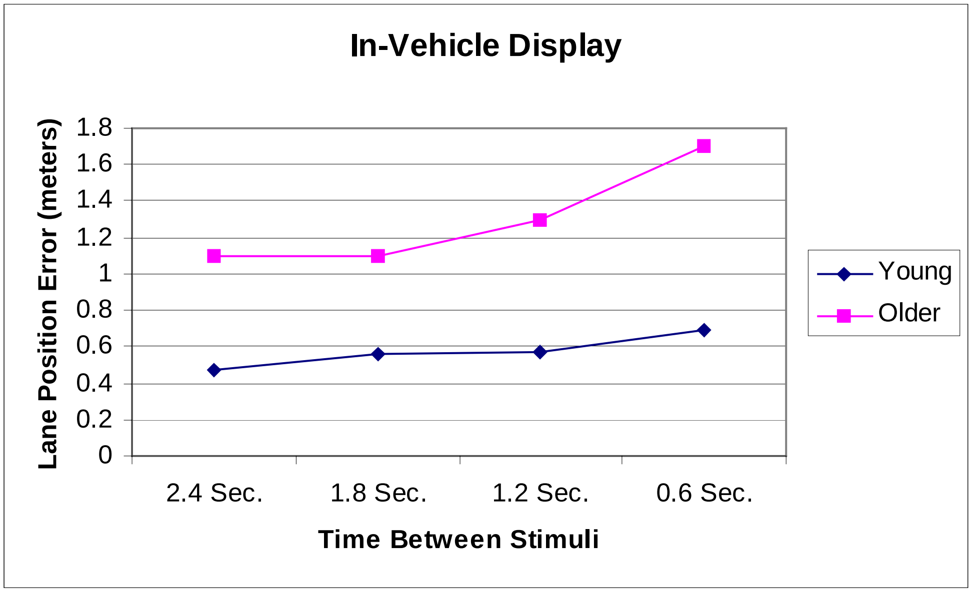

Figure 11. Lane Position Error by Time Between Simuli – In-Vehicle Display.

Time Vehicle was Partially or Totally Outside of the Lane.

When using the Superimposed display the average time any wheel of the vehicle was outside of its lane is shown in Figure 12. As can be seen, the vehicle was almost always in its lane for both the young and older drivers.

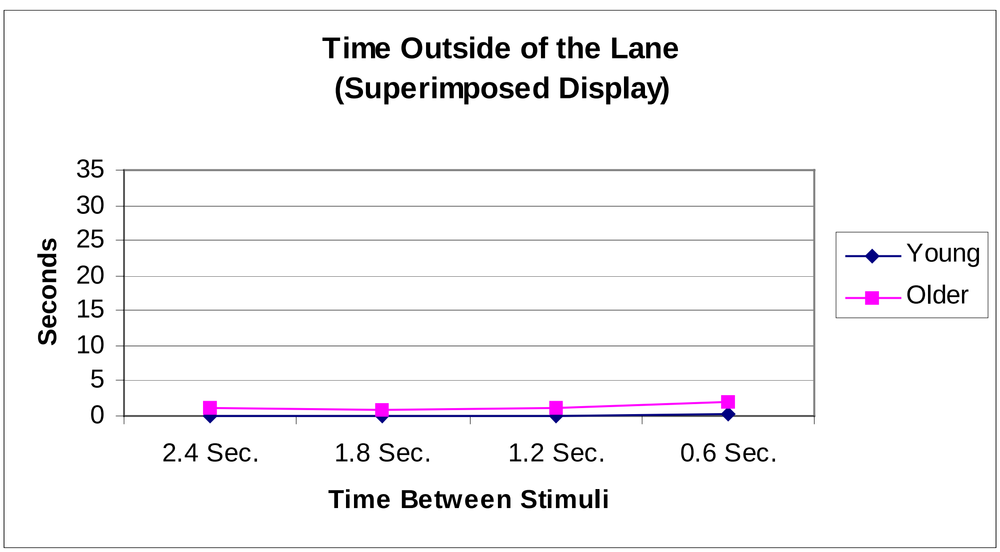

Figure 12. Time Outside of the Lane – Superimposed Display.

However, as shown in Figure 13 below, some older drivers were unable to keep the vehicle in the lane when using the In-Vehicle display. At every inter-stimuli interval, the performance of the young drivers was statistically better than that of the older drivers ($p < .05$). The older drivers spend significantly more time outside of their lane during the 1.2 and 0.6 seconds time between stimuli trials than during the 1.8 seconds trial, ($p < .05$).

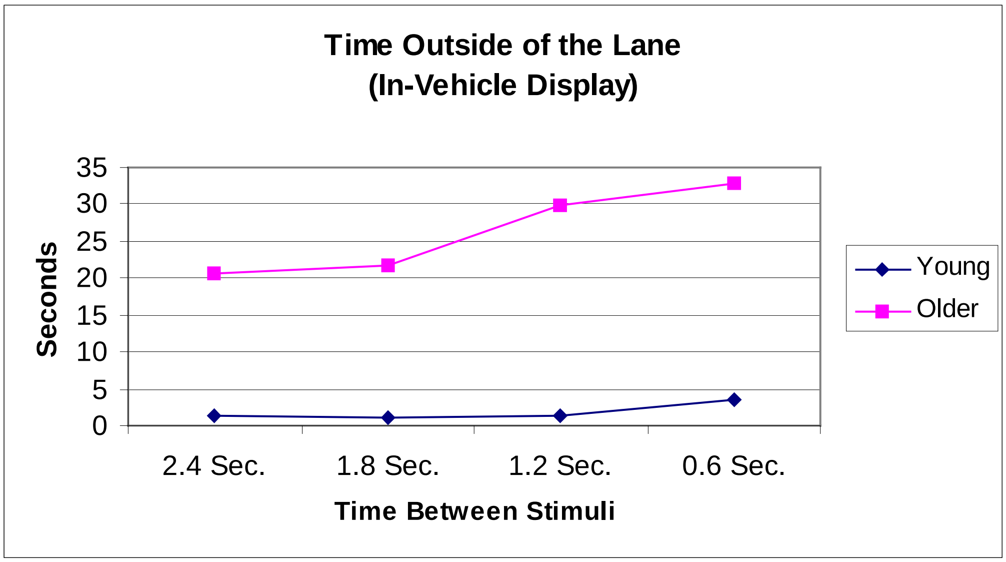

Figure 13. Time Outside of the Lane – In-Vehicle Display.

DISCUSSION

<u>Divided Attention Task (No Driving)</u>

As hypothesized, older drivers performed more poorly than the young drivers when attaining information from inside the vehicle. However, they also performed more poorly when reading the information that was superimposed at a far distance. This suggests that for older drivers the constant switching between near and far vision affects both the acquisition of information inside and outside of the vehicle. In addition, the amount of the difference between young and older drivers increased with task difficulty.

<u>Performance While Driving</u>

Fox (1998) reported that young drivers made more lane excursions than older drivers when using an ATIS display. In contrast, we measured total time of lane excursions and found it to be much greater for older drivers. This may be due to the interaction between vehicle velocity and the ability to keep a vehicle in its lane. Fox also found that older drivers decreased vehicle velocity when using the ATIS. Perhaps that helped them maintain vehicle lane position. In the present study, vehicle velocity was a constant 35 mph for both young and older drivers since it was computer controlled.

When studying the data collected for the four inter-stimuli intervals of the in-vehicle display condition, a surprising result was found. For both young and older drivers the percentage of correct responses at the 2.4-second time between stimuli condition was less than that at all lower times between stimuli. This may be due to the time between stimuli being too large and drivers making unnecessary glances to the in-vehicle display. In addition, since the duration of stimulus presentation was held constant at 300 milliseconds, drivers may have missed all or part of it, if they had just returned to monitor the forward scene before its onset. This phenomenon needs to be studied in more detail, since designers of ATIS need to know the duration at which information should be displayed.

REFERENCES

Fox, J.E. (1998). The effects of age and ATIS use on driving performance: a simulator study. Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting. 1276-1280.

Henderson, S. and Suen, S.L. (1999). ITS: a two-edged sword for older drivers? 78th Annual Meeting of the Transportation Research Board. 1-14.