Measuring the Divided Attention Capability of Young and Older Drivers – 01-2239

Ronald R. Mourant, Feng-Ji Tsai, Talal Al-Shihabi, and Beverly K. Jaeger

Virtual Environments Laboratory

334 Snell Engineering Center, Dept. of MIME

Northeastern University

Boston, MA 02115

Phone: (617) 373 3931

FAX: (617) 373 2921

mourant@coe.neu.edu

fengji@coe.neu.edu

talshiha@coe.neu.edu

bkjaeger@coe.neu.edu

Measuring the Divided Attention Capability of Young and Older Drivers

Ronald R. Mourant, Feng-Ji Tsai, Talal Al-Shihabi, and Beverly K. Jaeger
Virtual Environments Laboratory
334 Snell Engineering Center, Dept. of MIME
Northeastern University
Boston, MA 02115

ABSTRACT

A divided attention task was used to measure the ability of young and older drivers to obtain information from an in-vehicle display. Performance with the in-vehicle display was compared with that of superimposing information on the driving scene. Ten young and ten older drivers drove on a curvy road using a fixed-based driving simulator. As compared to young drivers: 1) the accuracy of older drivers obtaining information from the in-vehicle display was less, 2) the average lane position error of older drivers was greater, and 3) older drivers spend more time driving outside of their lane. These results suggest that the use of in-vehicle displays, in their present configuration, is not appropriate for older drivers. When viewing information superimposed on the driving scene, older drivers did much better in terms of accuracy and controlling their vehicle. This indicates that the poor performance of older drivers with the in-vehicle display was due to vision related changes, such as longer eye accommodation times, rather than cognitive processes.

INTRODUCTION

A driver's attention may be considered a scare resource. In particular, drivers unfamiliar with their route display vastly different search and scan patterns than familiar drivers (1). A driver's inattention to the primary task of safely controlling the vehicle has been called driver distraction. The high use of mobile telephones and the displaying of route guidance and other information to the driver are additional and competing sources for a driver's attention. Recently, the National Highway Traffic Administration focused on this by hosting an Internet forum on driver distraction (2). Other recent studies of driver distraction include a synthesis of the literature (3), and studying distraction in a critical driving maneuver (4). Researchers have also incorporated the management of attention (5) into driver decision-making, and attention into models of driver behavior (6).

This study used a divided attention task to measure the capacity of drivers to use an in-vehicle display. The in-vehicle display was located where information from an Advanced Transportation Information Systems (ATIS) could be presented. Henderson and Suen (7) 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 measured drivers' ability to control the vehicle's path while obtaining information from either an in-vehicle or a superimposed display. We hypothesized that older drivers will not perform as well as younger drivers on these simple divided attention tasks. Secondly, we attempted to quantify the capacity of drivers to obtain information from the displays by varying the time between stimuli presentations. Large times between stimuli presentations represent low attention demand and short times high attention demand.

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 whose height is 5 feet 8 inches, the in-vehicle display was 18 degrees below his/her straight-ahead plane and 32 degrees to the right.

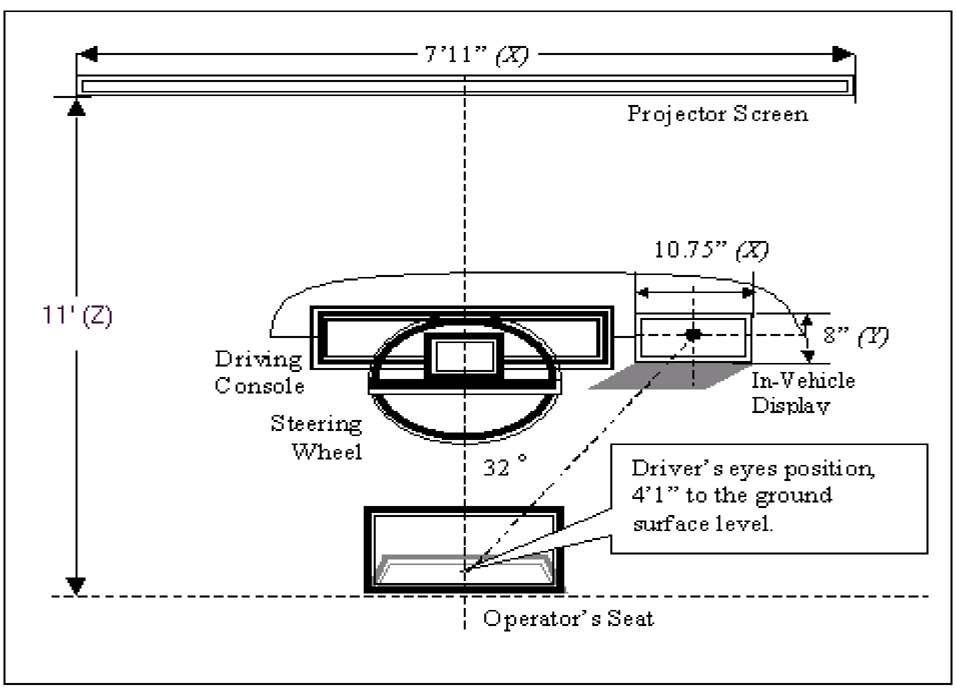

FIGURE 1. Virtual Environments Driving Simulator with an in-vehicle display.

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 the AASHTO (8) standard of 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.

We simulated an In-Vehicle display by using the screen of a portable computer as shown in Figure 3 below. The In-Vehicle display was located 32 degrees to the right and 18 degrees down when a driver was looking straight ahead for a driver whose height was 5 feet 8 inches.

FIGURE 3. Digits shown on the In-Vehicle display.

Procedure – No-Driving

Subjects were first tested on reading digits superimposed on the visual scene versus reading letters on the In-Vehicle display while not driving. A run consisted of 25 consecutive trials. On each trial a subject reported the random digits shown on the superimposed display followed by the random letters shown on the In-Vehicle display. A practice run of 25 trials was given to familiarize subjects with the task. During the practice run the stimulus duration was 800 milliseconds and the time between stimuli was 1.6 seconds. Thus there were 800 milliseconds between stimulus offset and stimulus onset.

On the first test run the stimulus duration and time between stimuli were 800 milliseconds and 1.2 seconds. On the second test run the stimulus duration was reduced to 500 milliseconds and the time between stimuli was 0.75 seconds. The 20 subjects (10 young and 10 older) were given the practice run followed by the two test runs. Thus the experimental design consisted of two within group factors, (time between stimuli (1.2 and 0.75 seconds) and display types (superimposed and in-vehicle)) and one between factor (young and older groups).

RESULTS – No Driving

An analysis of variance of the percent correct scores found all main effects to be statistically significant. No interactions were statistically significant. The means of the levels of the main effects and their associated levels of significance are shown in Table 1.

TABLE 1. Main Effects for Percent Correct

Main Effects	Levels of Main Effects	Mean Percent Correct
Time Between Stimuli ($p<.001$)	1.2 seconds	94.0%
	0.75 seconds	65.6%
Display Type ($p<.05$)	Superimposed	82.2%
	In-Vehicle	77.5%
Age ($p<.001$)	Young	85.9%
	Older	73.9%

In Figure 4 are the average percent correct responses made by young and older drivers with time between stimuli of 1.2 and 0.75 seconds. When the time between stimuli was large (1.2 seconds) the young drivers averaged 99% correct and the older drivers 89%. When the time between stimuli stimuli was 0.75 seconds, the young drivers averaged 72.8% correct responses while the older drivers averaged 58.7% correct responses. Thus, the young drivers performed better than the older drivers at both times between stimuli.

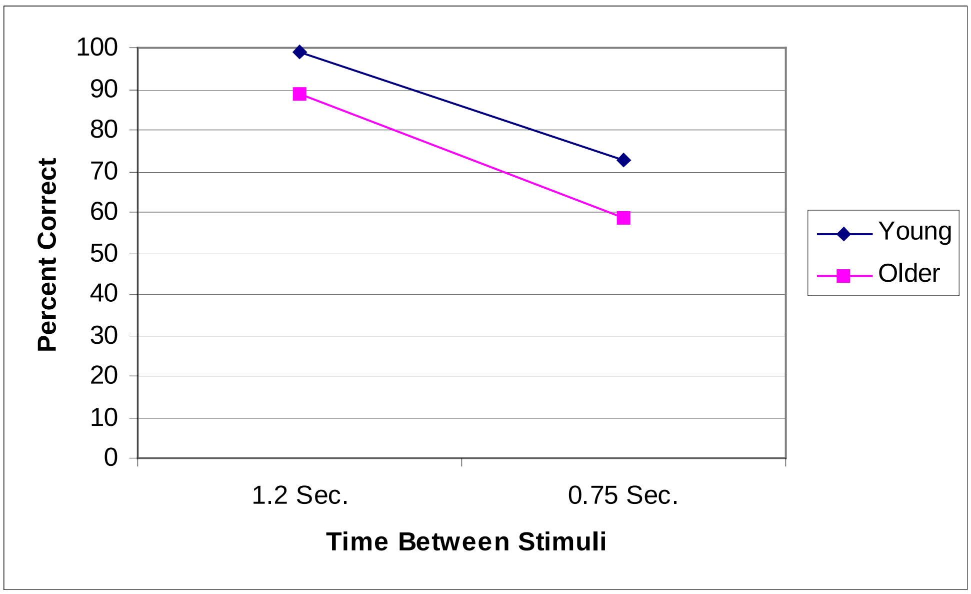

FIGURE 4. Average percent correct by time between stimuli.

Figure 5 shows the average percent correct for the 0.75-second time between stimuli condition (Run 2) as a function of the Superimposed and In-Vehicle displays.

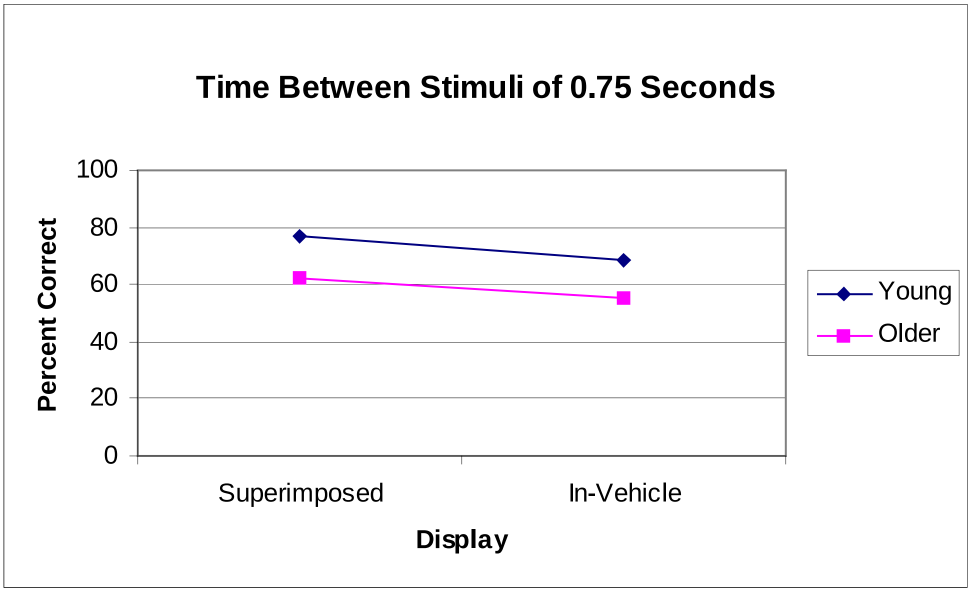

FIGURE 5. Average percent correct by display type.

While using the Superimposed display, the young drivers averaged 76.8% correct and the older drivers 62% correct. For the In-Vehicle display, the young drivers averaged 68.8% correct and the older drivers 55.5%. 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. We choose letters for the in-vehicle display because they are likely to be shown on real-world in-vehicle displays.

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 inter-stimulus interval was 0.75 seconds. Plots are shown in Figures 6 and 7.

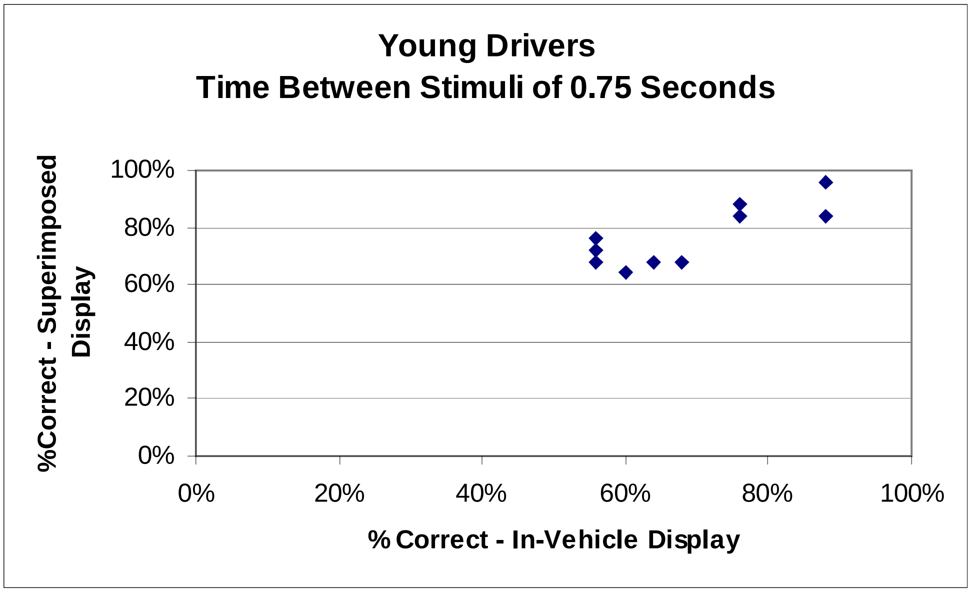

FIGURE 6. Correlation of superimposed and in-vehicle scores for young drivers.

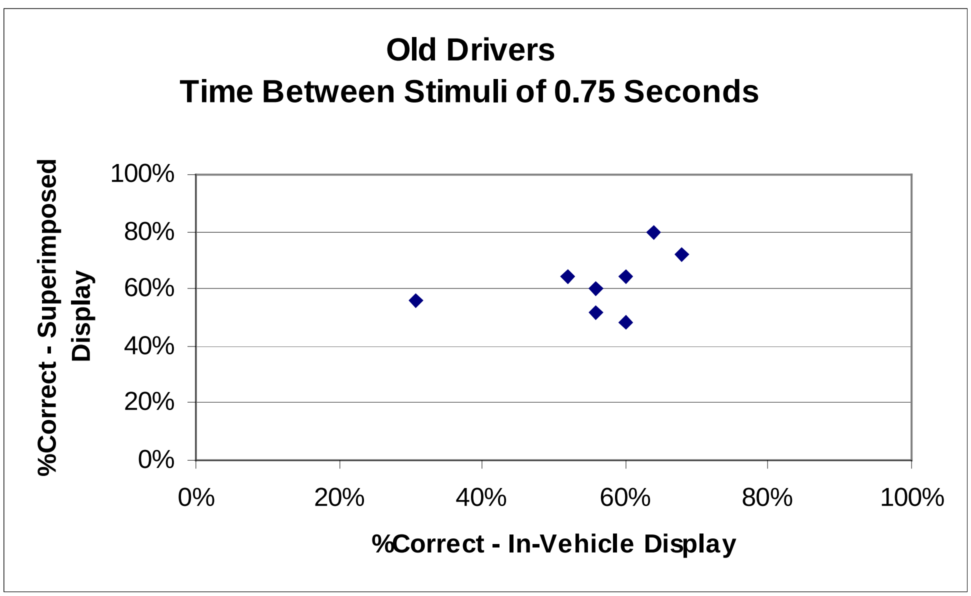

FIGURE 7. Correlation of superimposed and in-vehicle scores for older drivers.

Procedure – Driver Steering Task

Now the subjects were given the divided attention task of steering the vehicle were reading either digits from the superimposed display or letters from the in-vehicle display. 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 time between stimuli 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 time between stimuli), the letters 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.

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.

RESULTS – While Driving

Again, an analysis of variance of the percent correct scores for the divided attention task scores found all main effects to be statistically significant. The means of the levels of the main effects and their associated levels of significance are shown in Table 2 below.

TABLE 2. Main Effects of Percent Correct While Driving

Main Effects	Levels of Main Effects	Mean Percent Correct
Time Between Stimuli (p<.001)	2.4 seconds	82.4%
	1.8 seconds	90.9%
	1.2 seconds	92.1%
	0.6 seconds	79.2%
Display Type (p<.001	Superimposed	95.9%
	In-Vehicle	76.5%
Age (p<.001)	Young	92.9%
	Older	79.4%

There was a significant interaction between Display Type and Age (p<.001). This is shown in Figure 8 below.

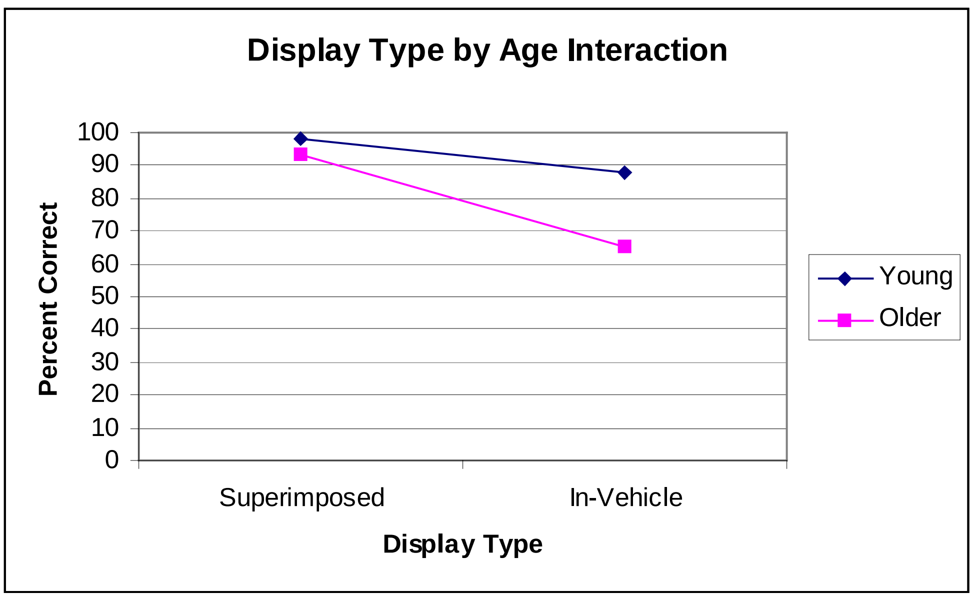

FIGURE 8. Percent correct for the display type by age interaction.

The interaction occurred because the difference between the young and older drivers was greater for the In-Vehicle display than the Superimposed display. Older driver made many more errors with the In-Vehicle display than young drivers.

The analysis of variance also resulted in a significant Display Type by Time Between Stimuli interaction. This is shown in Figure 9.

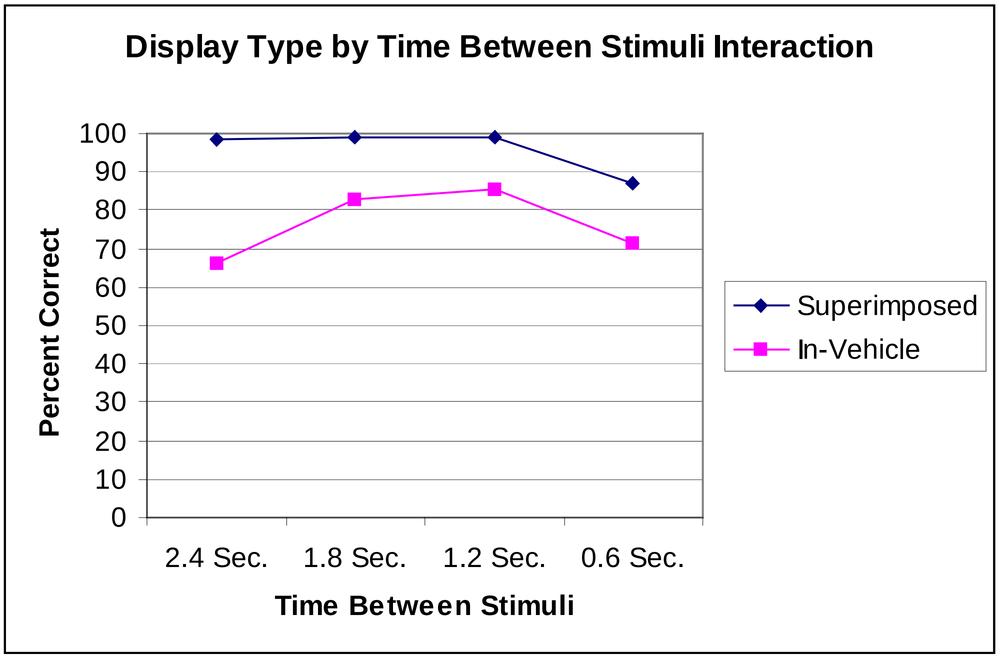

FIGURE 9. Percent correct for the display type by time between stimuli interaction.

Note that the difference between the superimposed and in-vehicle displays is greatest at the 2.4 seconds interval. This suggests that when people are more uncertain about the time of information presentation, their performance with an in-vehicle display deteriorates. Figure 9 also shows that at all levels of Time Between Stimuli, performance was better with the Superimposed display.

Average Lane Position Error

An analysis of variance of lane position error found the main effects of Display Type and Age to be statistically significant. These results are presented in Table 3.

TABLE 3 Main Effects for Lane Position Error

Main Effects	Levels of Main Effects	Average Lane Position Error (meters)
Display Type (p<.001)	Superimposed	0.50
	In-Vehicle	0.88
Age (p<.001)	Young	0.47
	Older	0.92

The interaction between Display Type and Age was also statistically significant at $p < .01$ and is shown in Figure 10.

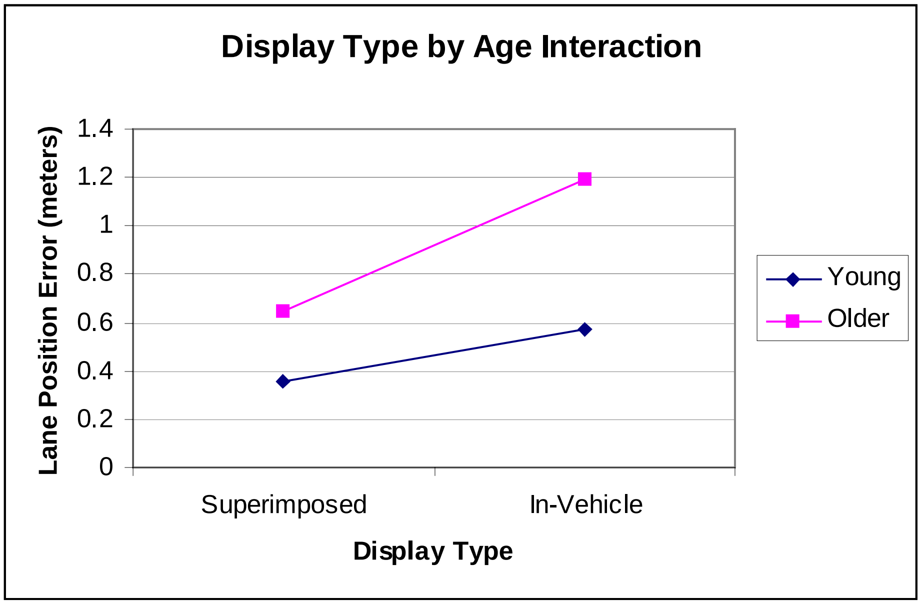

FIGURE 10. Display type by age interaction for lane position error.

When older drivers used the In-Vehicle display their average lane position error was considerably higher than when they used the Superimposed display.

An interesting finding was that average lane position error did not vary with decreasing time between stimuli. This may be due to participants considering their vehicle lane position to be of primary importance and the obtaining of information from the display to be of secondary importance.

Figure 11 shows average lane position error for the Superimposed display as a function of time between stimuli and Figure 12 shows the corresponding data for the In-Vehicle display. It appears that average lane position error increased as a function of time between stimuli for the In-Vehicle display. However, this trend was not statistically significant. Note that the older drivers had higher lane position errors when using the in-vehicle display rather than the superimposed display at all times between stimuli.

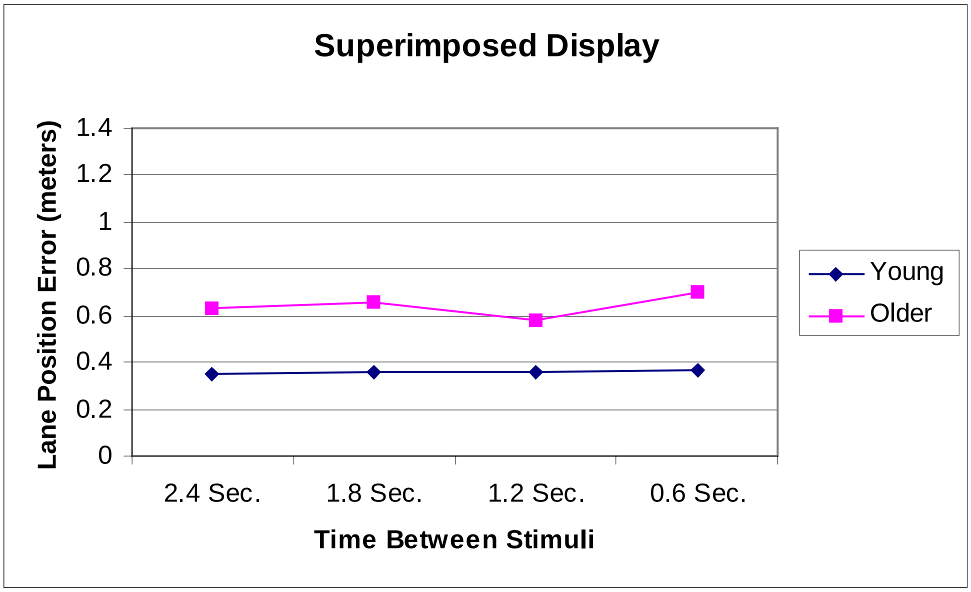

FIGURE 11. Average lane position error for the superimposed display.

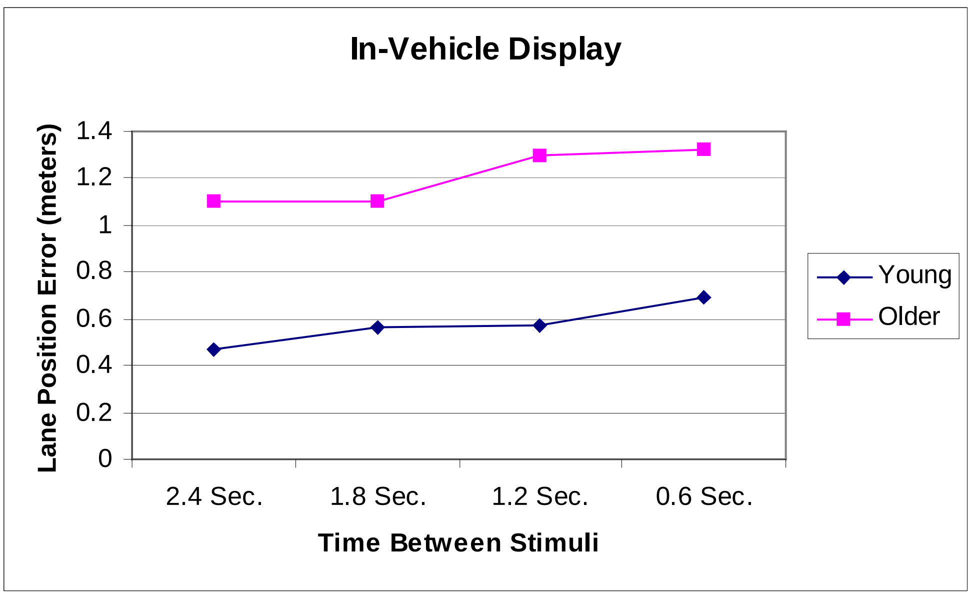

FIGURE 12. Average lane position error for the in-vehicle display.

Time Vehicle was Partially or Totally Outside of the Lane.

An analysis of variance for time outside the lane found the main effects of Display Type and Age to be statistically significant. These results are presented in Table 4.

Table 4 Main Effects for Time Outside the Lane

Main Effect	Levels of Main Effects	Mean Time Outside the Lane (seconds)
Display Type ($p<.001$)	Superimposed	0.64
	In-Vehicle	14.55
Age ($p<.001$)	Young	0.98
	Older	13.72

The interaction between Display Type and Age was also statistically significant at $p < .001$ and is shown in Figure 13.

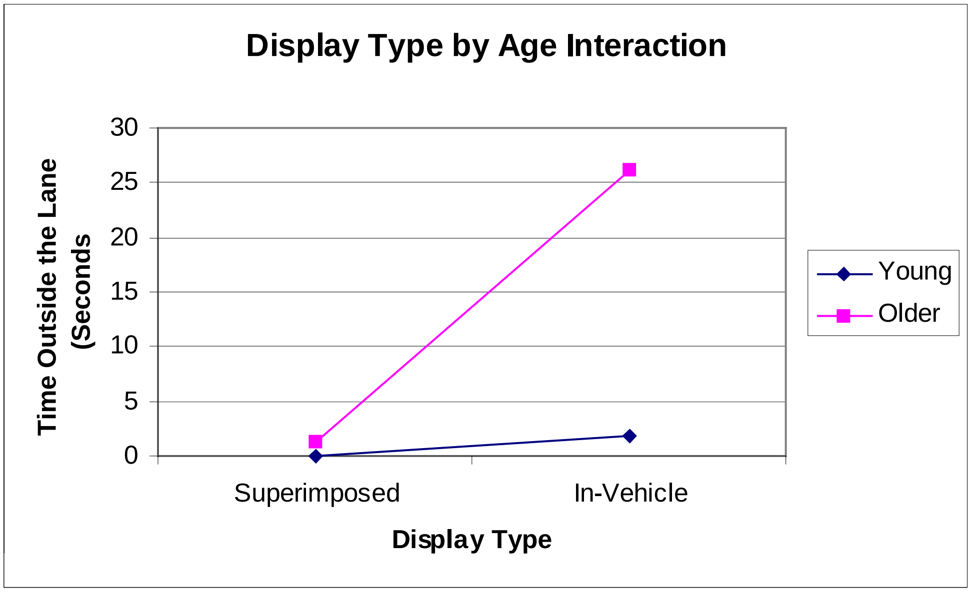

FIGURE 13. Mean time outside the lane for the display type by age interaction.

As shown in Figure 13, both the young and older drivers stayed in their lane when using the Superimposed display. However, older drivers had considerable difficulty staying in their lane when using the In-Vehicle display.

Below, Figure 14 shows that for all time between stimuli values, the performance of the older drivers was just slightly worse than that of young drivers when using the Superimposed display.

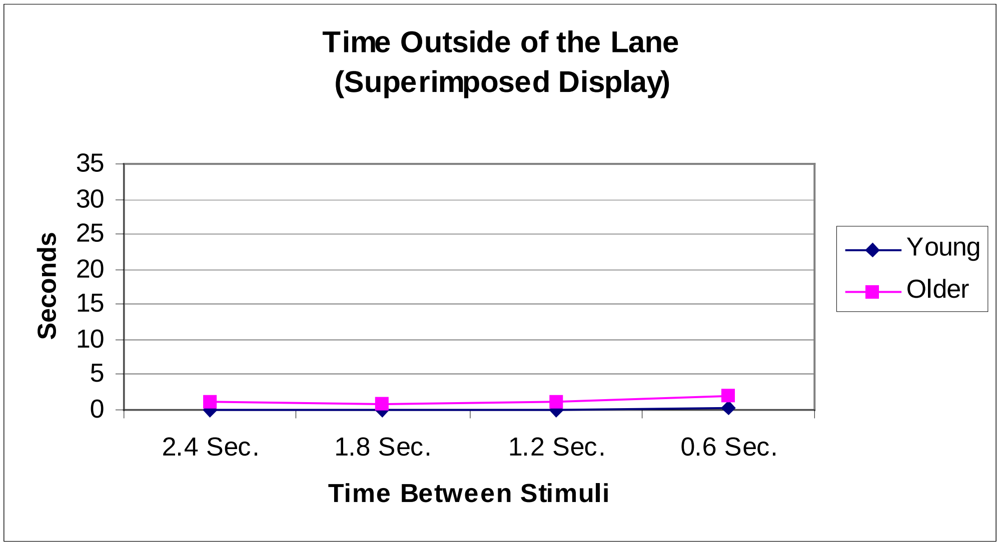

FIGURE 14. Time outside of the lane when using the superimposed display.

However, as shown in Figure 15 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 spent 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, ($p < .05$).

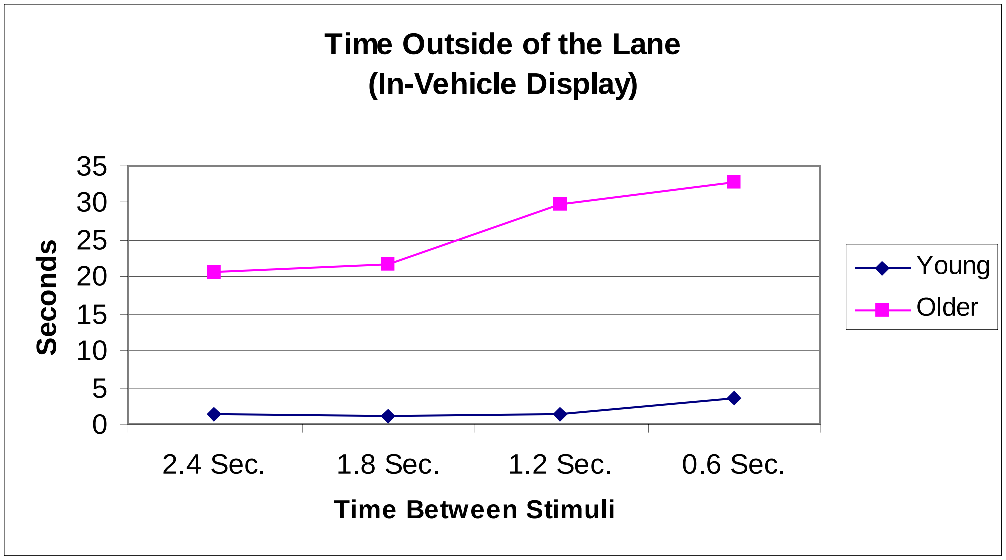

FIGURE 15. Time outside of the lane when using the in-vehicle display.

DISCUSSION

Divided Attention Task (No Driving)

As hypothesized, older drivers performed poorer than the young drivers when attaining information from inside the vehicle. However, they also performed worst 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.

Performance While Driving

Fox (2) 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 seconds 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 stimuli presentations 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

1. Mourant, R.R., Rackoff, N.J., and Rockwell, T.H., "Drivers' Eye Movements and Visual Workload", *Highway Research Record*, 1969, Number 292, 1-11.

2. Llaneras, R. E., "NHTSA Driver Distraction Internet Forum: Summary and Proceedings", Report DTNH22-99-D-07005, NTIS, November, 2000.

3. Streff, F., and Spradlin, H., "Driver Distraction, Aggression, and Fatigue: A Synthesis of the Literature and Guidelines for Michigan Planning" Report No: HS-043 067 ,UMTRI-2000-10, March, 2000.

4. Hancock, P.A., Simmons, L., Hashemi, L., Howarth, H., and Ranney, T., "The Effects of In-Vehicle Distraction on Driver Response During a Crucial Driving Maneuver". Transportation Human Factors, Vol. 1, No 4, 1999, pp. 295-316.

5. Boer, E.R., Hildreth, E.C., and Goodrich, M.A., "A Driver Model of Attention Management and Task Scheduling: Satisficing Decision Making With Dynamic Mental Models", *17th Europen Annual Conference on Human Decision Making and Manual Control*, Dec. 14-16, 1998.

6. Ranney, T.A. "Models of Driving Behavior: A Review of Their Evolution", *Accid. Anal. and Prev.*, Vol. 26, No. 6, 1994, pp. 733-750.

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

8. *A Policy on Geometric Design of Highways and Streets*. AASHTO, Washington, D.C., 1994.

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