DRIVER WORKLOAD ASSESSMENT OF ROUTE GUIDANCE SYSTEM DESTINATION ENTRY WHILE DRIVING: A TEST TRACK STUDY

Louis Tijerina and Edwin Parmer
Transportation Research Center Inc.
10820 SR 347
East Liberty, OH 43319-0337
Ph: (937) 666-4511 Fax: (937) 666-3590
E-mail: ltijerina@nhtsa.dot.gov

Michael J. Goodman
US Dept of Transportation, NHTSA
400 7th St., S.W., NRD-50
Washington, DC 20590
Ph: (202) 366-5677 Fax: (202) 366-7237
E-mail: mike.goodman@nhtsa.dot.gov

In

Proceedings of the 5th ITS World Congress, Seoul, Korea, October 12-16, 1998 (Compact Disc).

DRIVER WORKLOAD ASSESSMENT OF ROUTE GUIDANCE SYSTEM DESTINATION ENTRY WHILE DRIVING: A TEST TRACK STUDY

Louis Tijerina and Edwin Parmer
Transportation Research Center Inc.
10820 SR 347
East Liberty, OH 43319-0337
Ph: (937) 666-4511 Fax: (937) 666-3590
E-mail: ltijerina@nhtsa.dot.gov

Michael J. Goodman
US Dept of Transportation, NHTSA
400 7th St., S.W., NRD-50
Washington, DC 20590
Ph: (202) 366-5677 Fax: (202) 366-7237
E-mail: mike.goodman@nhtsa.dot.gov

SUMMARY

This study examined destination entry while driving with four commercially available route guidance systems. Three of the systems involved various visual-manual demands while the fourth involved voice input and output. Cellular phone dialing and radio tuning were included as comparison tasks. Test participants drove an instrumented passenger car, accompanied by an experimenter, on a 7.5 mile multilane test track with light traffic. Results indicated that, on average, all three systems with visual-manual methods of destination entry were associated with lengthier completion times, longer eyes-off-road-ahead times, longer and more frequent glances to the device, and greater numbers of lane exceedences than the voice system. However, the voice system was associated with substantially longer and more frequent glances away from the road scene to a containing destination information. Performance differences between younger and older test participants tended to be reduced with the voice system. Regardless of system, the destination entry task took substantially longer to complete than 10-digit cellular telephone dialing or radio tuning to a specific frequency. Voice recognition technology appears to be a viable alternative to manual destination entry while driving but other subtle safety issues remain and are discussed.

INTRODUCTION

No published data exists on the demands of route guidance system destination entry while driving. Many believe that destination entry while driving is simply too distracting to be carried out safely, but many commercially available systems allow it. Some commercially available route guidance systems provide cautions to avoid distraction while driving but do not lock out such functions while the vehicle is moving. Others systems include a motion sensor that locks out such functions, but this is the exception rather than the rule. Still other systems provide no cautions or lockouts at all. Green (1997) has pointed out several scenarios wherein destination entry or retrieval en route might be attempted: the driver is in a hurry, knows the general direction in which to start, and adds the destination information later; the route guidance system does not use congestion information and a radio announcement indicates the current route is problematic; the driver enters the wrong destination initially and does not wish to stop the vehicle to correct it; or the driver does not know the exact destination at the beginning of the trip, enters an interim destination known to be close by, then enters the actual destination at a later time.

The objective of this study was to examine four commercially available route guidance systems, representing alternative destination entry and retrieval methods, in terms of driver visual allocation, driver-vehicle performance, and driver subjective assessments. No study has examined this problem in a real world driving context, in part because of the very safety concern that prompts an interest in the topic. Therefore, a test track study was conducted with light traffic present and a vigilant ride-along observer in the test vehicle.

APPROACH

Test Participants: Sixteen (16) test participants were recruited from the Transportation Research Center Inc. pool of entry-level test drivers in equal numbers of males and females in each of two age categories: Younger (35 years or younger) and Older (55 years or older). These drivers were hourly employees with valid driver's licences and generally less than 2 years of TRC driving experience. None of the test participants owned or had significant prior experience with route guidance systems prior to this study.

Test Vehicle and Instrumentation: The test vehicle was a 1993 Toyota Camry, equipped with Micro-DAS instrumentation (Barickman, 1998) which captured travel speed, lane position, and lane exceedences, as well as video of the road scene and driver eye glance behavior at a 30-Hz sampling rate. Eye glance video was later manually reduced.

Route Guidance Systems: Four (4) unmodified, commercially available route guidance systems, each with a different destination entry and retrieval logic and driver interface, were used in the test. The dash mounted Delco Telepath 100® consisted of a 3-line LCD display to present menu items, scrolled by means of a bezel-mounted rotary knob and selected by pressing an Enter key. The Alpine NVA-N751A® incorporated a free-mounted 5.6 inch active matrix color display without bezel keys. It displayed an alphanumeric keyboard and entries were made by scrolling from key to key with a joystick mounted on a remote control unit; pressing down on the joystick registered a character or selection. If sufficient alphanumerics were entered for the system to estimate candidate destinations, these were presented as an alphabetized scrolling list of 3 items at the bottom of the display of the alphanumeric keyboard screen. The Zexel Navmate® consisted of a free-mounted 4 inch diagonal full color LCD screen with a set of bezel control keys, including a central "left, right, up, down" key and an Enter key. Both the Zexel and Alpine systems were mounted on a gooseneck pedestal bolted to the floor board between the driver and passenger. The Zexel system presents menu options for destination entry type and city, followed by a scrolling display of numerically and alphabetically arranged destinations generally presented 11 to13 lines at a time. The driver presses the Enter key to make a selection. Finally, the dash mounted Clarion Eclipse® Voice Activated Audio Navigation (VAAN) system used voice recognition and output exclusively; there was no visual display. Keywords would activate the VAAN for destination entry. Destinations were entered by spelling them. The VAAN emphasized precise spelling of a destination; each letter uttered by the driver would be proceeded by a beep to acknowledge receipt of the input. The driver uttered "verify" to conclude an entry. The system would eventuate in a spoken list of best-guess candidate destinations for selection by the driver via YES or NO verbal responses.

The last three of these systems allowed for entry of a street address, intersection, or point of interest (attraction, restaurant, hotel, etc.). Thus, three types of tasks (address, intersection, point of interest) were included as suitable for comparisons among the systems. The Delco system only supported point of interest selection. Also, two additional tasks were included for comparison purposes: tuning a radio to a specific band and frequency with a modern "Seek" function on the Clarion Eclipse system; or manually dialing a cellular telephone (a 10-digit number on a handwritten note card) using a cordless AUDIOVOX Model MVX-500.

Test Route: The Transportation Research Center Inc. (TRC) 7.5-mile multi-lane test track is in the form of an oval with banked curves at either end and with unbanked straightaways that measure approximately 2.0 miles each. The test track is comprised of three 12-ft wide concrete lanes with a fourth inner blacktop lane for use in the event of vehicle breakdowns or required stops. The test vehicle for this study operated in lane 1 (adjacent to the innermost blacktop lane) and changed lanes only as needed for normal track operations and safety. The test participant was asked to drive at approximately 45 mph on the straightaways and accelerate to 60 mph on the curves, provided that any requested tasks are completed by the time the test vehicle enters a curve. Otherwise, the driver was to maintain 45 mph and attempt to complete the requested in-vehicle task. Traffic density tended to be light relative to open road driving. However, travel speeds for other vehicles of the track might vary greatly, vehicles involved with other testing could slow, stop, or move to the blacktop lane abruptly, and track repair and roadside obstructions had to be avoided. Faster traffic drove on the outer lanes of the oval. Data collection was scheduled for between 8:00 am and 4:30pm weekdays.

Independent Factors, Dependent Measures, and Study Design: A two-between, three-within mixed factors experimental design was used for this study. The between-factors were Age category and Gender. The within factors were: Route Guidance System (Zexel, Clarion Eclipse VAAN, Alpine NVA-N751A, and Delco Telepath 100); Destination Category (Street address, Cross street, or Point of Interest), and Destination Targets (Target 1, Target 2, different for each destination type but the same targets across each route guidance system). In addition, two non-destination entry tasks were included for comparison: dialing an unfamiliar 10-digit number on a cellular phone and manually tuning a radio to a specific frequency on the

AM and FM bands. The dependent measures of interest for this study were: Visual Allocation (mean glance duration, mean glance frequency, and total glance time to road ahead, in-vehicle device, and note card); Driver-Vehicle Performance (number of lane exceedences, lane exceedence duration); and Trial Time (i.e., destination entry task completion time). Driver preferences and impressions of safety were also collected, among other subjective assessments.

Procedure: Prior to the data collection runs, the experimenter familiarized the test participant with each navigation system. Each test participant then completed 12 practice data entry tasks per system (four for each destination category), entered while the vehicle was parked. This training was done in two phases (morning and afternoon); so, two systems were reviewed prior to each half of the test track trials. On the 7.5 mile track, the order of trials were counterbalanced across the four route guidance systems (Zexel, Alpine, Delco, and VAAN), destination entry category (point of interest, intersection, and street name targets), and target (Target A or Target B within a category). All trials with a given system were executed before moving on to another system; the destination type and targets within destination type were counterbalanced to control for order effects. The cellular phone and radio tuning tasks were interspersed between destination entry trials on an opportunistic basis by the experimenter in a quasi-random fashion. Prior to leaving for the test track, the destinations were presented to the test participant in 18-point Times Roman font and the test participant was asked to write in his or her own hand each destination on a separate index card, as well as the 10-digit unfamiliar telephone number, such that they would be able to read from it while driving. A task began when the ride-along experimenter gave the driver a hand-written card or a radio tuning task was requested orally by the ride-along experimenter. The task ended when the request had been fulfilled, as indicated by an event marker triggered by the experimenter. Requests for tasks were generally made when the test participant was exiting a curve onto a straightaway segment of the test track. After test track data collection was completed, the test participant answered the subjective assessment questions and was released.

Data Analysis: The data were analyzed by means of the analysis of variance for split-plot designs using the SAS® Proc GLM routine, Type III Sums-of Squares. Prior to ANOVAs, appropriate transformations were applied (e.g., log transforms of glance durations, square root transforms of lane exceedence counts) to both normalize the data and stabilize what were often heterogenous variances. Outliers were not deleted from the data set unless they were clearly erroneous (e.g., a verified manual data reduction error for eye glance data).

RESULTS

Only Point-of-Interest (POI) destination entry results will be presented here. This choice is made because a) there is insufficient space to present all of the study results, b) all four systems were capable of this type of transaction, and c) the results generally follow the same trends as those for a companion analysis that included destination category (street address, intersection, point-of-interest) but did not include the Delco system due to its limited capability. Since the specific destinations were not meant to be comprehensive, but merely a methodological convenience, specific target effects are not presented here. All results to be presented and discussed were significant at an $\alpha < 0.05$. All other results are considered insignificant.

Figure 1 shows the effects of the different systems and tasks in terms of trial time or task completion time. Panel 1A indicates a significant effect of Age on destination entry trial time, with older drivers averaging almost twice as long as younger drivers. Panel 1B shows the average trial times for POI entry as a function of system, with the 10-digit cell phone dialing and radio tuning tasks included for comparison purposes. The longest completion time, on average, was with the Alpine system (118 seconds, approximately), the shortest average completion time was with the VAAN and Delco (approximately 75 and 78 seconds, respectively). Note also that all of the POI destination entry tasks took significantly longer than manually dialing an unfamiliar 10-digit number (approximately 28 seconds) or manually tuning a modern radio (approximately 22 seconds). Panel 1C is significant in that the Age difference is "neutralized" by the use of the VAAN voice data entry system.

Figure 2 presents the average glance frequency and mean single glance duration data associated with device and note card for this study. A main effect for age found older test participants made significantly greater numbers of glances per POI destination entry than younger participants (approximately 31 vs. 16 glances, respectively). Panel 2A shows, not surprisingly, that the average number of glances per transaction were trivial for the VAAN in comparison with other route guidance systems, and even lower than the cellular telephone dialing and radio tuning tasks. No interaction between Age and Device was found. Panel 2B, on the other hand, reveals that the VAAN was associated with over twice as many glances to the note card, on average, than any other system. Presumably, the greater precision required to spell the destination correctly prompted such behavior. Panel 2C depicts the average mean single glance durations to the device; the average glance duration for the VAAN is around1.0 seconds, as compared with between about 2.5 seconds and 3.2 seconds for the other systems and comparison tasks. These mean single glance durations are disturbingly long. Finally, Panel 2D indicates that, on average, the mean single glance duration to the note card during a destination entry trial with the VAAN was substantially longer than for the other systems or the cellular telephone task.

Lane exceedences represent one measure of degraded vehicle control that may be associated with driver inattention or distraction. Figure 3 presents the lane exceedence count averages per trial for the POI destination entry. Panel 3A indicates that age had a significant effect on lane exceedences. Older drivers in the study had, on average, about 8 lane exceedences per 10 trials, as opposed to younger drivers who had a little less than 2 lane exceedences per 10 trials. Panel 3B depicts the average number of lane exceedences per trial as a function of route guidance system device, with 10-digit cellular telephone dialing and manual radio tuning included for comparison purposes. Perhaps the most striking aspect of this panel is that the VAAN was associated with no lane exceedences.

Figure 4 shows mean Eyes-off-Road-Time (EORT) results. EORT is the average cumulative length of a trial time spent with the eyes off the road ahead (e.g., looking at the device, note card, etc.). Panel 4A shows older test participants spent about twice as long as younger test participants looking away from the road scene ahead. Panel 4B indicates that, among the route guidance systems, the VAAN was associated with the least amount of EORT, on average, only slightly higher than that for manual 10-digit cellular telephone dialing or radio tuning. Panel 4C again shows the voice destination entry feature of the VAAN served to minimize the differences between older and younger drivers. Panel 4D presents the average single glance duration to the road scene ahead during the in-vehicle transactions. As can be seen, the VAAN was associated with longer glance durations to the road scene ahead than to any other route guidance system or comparison task. As in-vehicle task demands grow, the driver is often prompted to shorten intermittent glances back to the road scene (perhaps to reduce working memory load), potentially missing safety-relevant objects and events.

CONCLUSIONS

These data suggest voice recognition technology is a viable alternative to visual-manual destination entry while driving. This result is highlighted in test participant subjective assessments that favored voice input over visual-manual methods. However, this study ideally would be replicated and field validated. Further research must also be conducted to examine the effects of voice interaction on the selective withdrawal of attention that degrades object and event detection while leaving visual allocation to the road ahead and vehicle control largely intact. In the interim, these data suggest that destination entry with visual-manual methods is ill-advised while driving.

ACKNOWLEDGMENTS

The views expressed in this paper are those of the authors and do not necessarily represent the views of the U.S. Department of Transportation. The authorst hank Frank Barickman, Duane Stoltzfus, Mark Gleckler, Karin Tillman, Heath Albrecht, Adam Andrella, and Scott Johnston of the Transportation Research Center Inc. for their valuable contributions to this research.

REFERENCES

Barickman, F. (1998). Intelligent data acquisition for intelligent transportation research (SAE Technical Paper No. 981198). Warrendale, PA: Society of Automotive Engineers

Green, P. (1997). *Potential safety impacts of automotive navigation systems*. Paper presented at the Automotive Land Navigation Conference, June 18, 1997

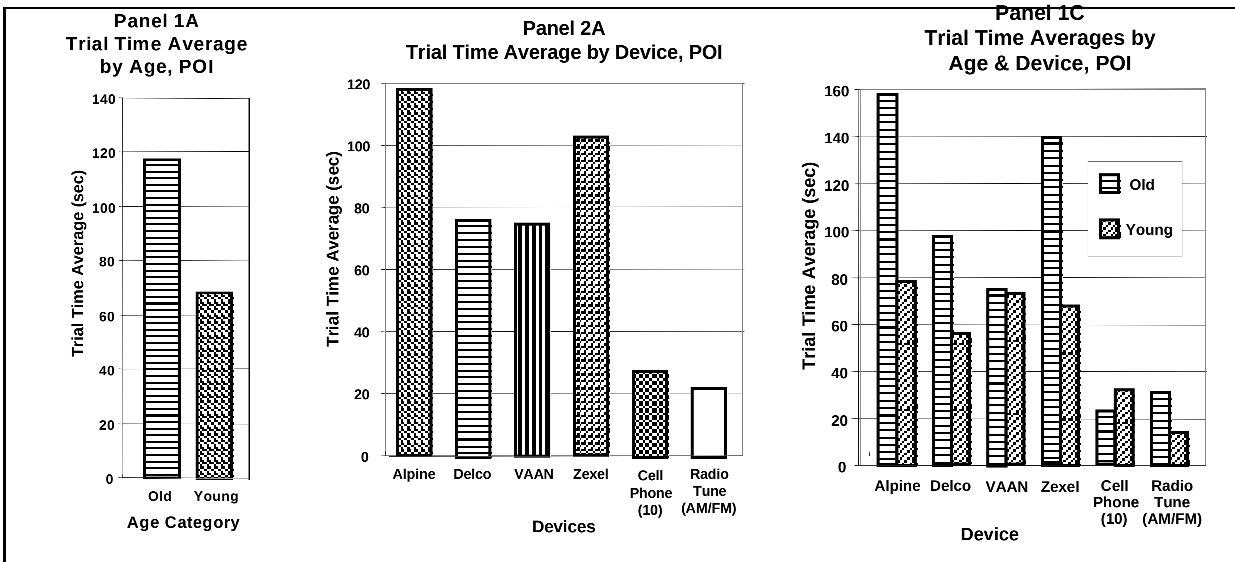

Figure 1. Age and Device Effects on Trial Time (i.e., Task Completion Time).

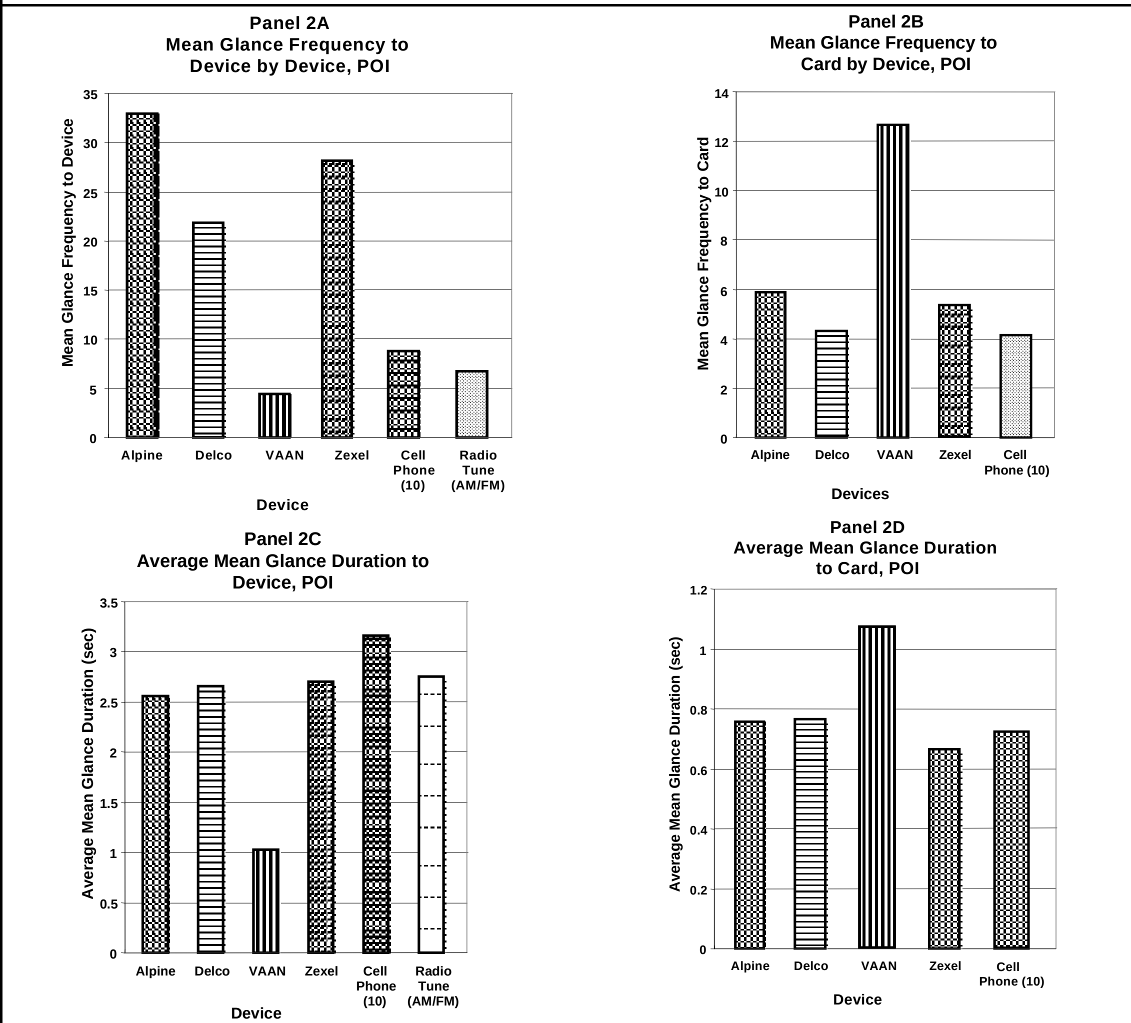

Figure 2. Device and Note Card Effects on Glance Frequency and Duration.

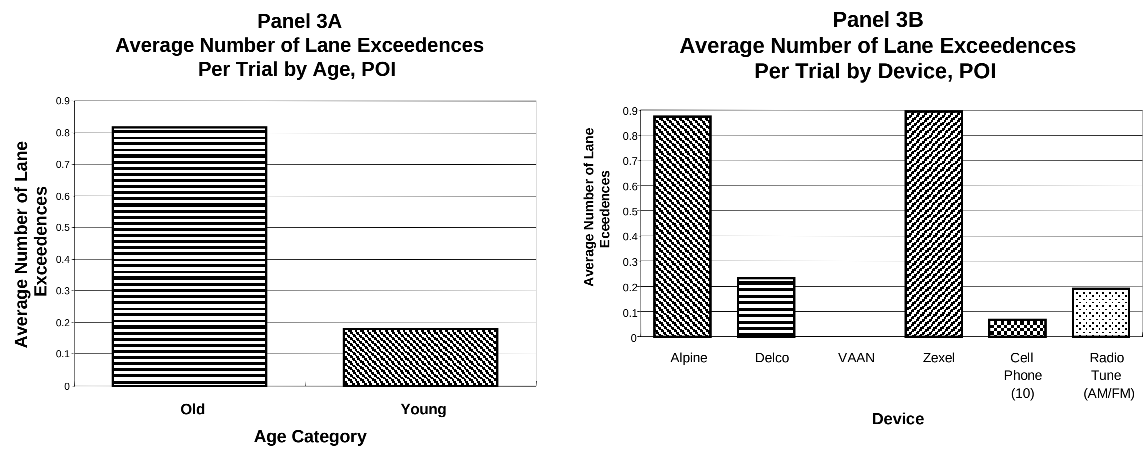

Figure 3. Age and Device Effects on Number of Lane Exceedences per Trial.

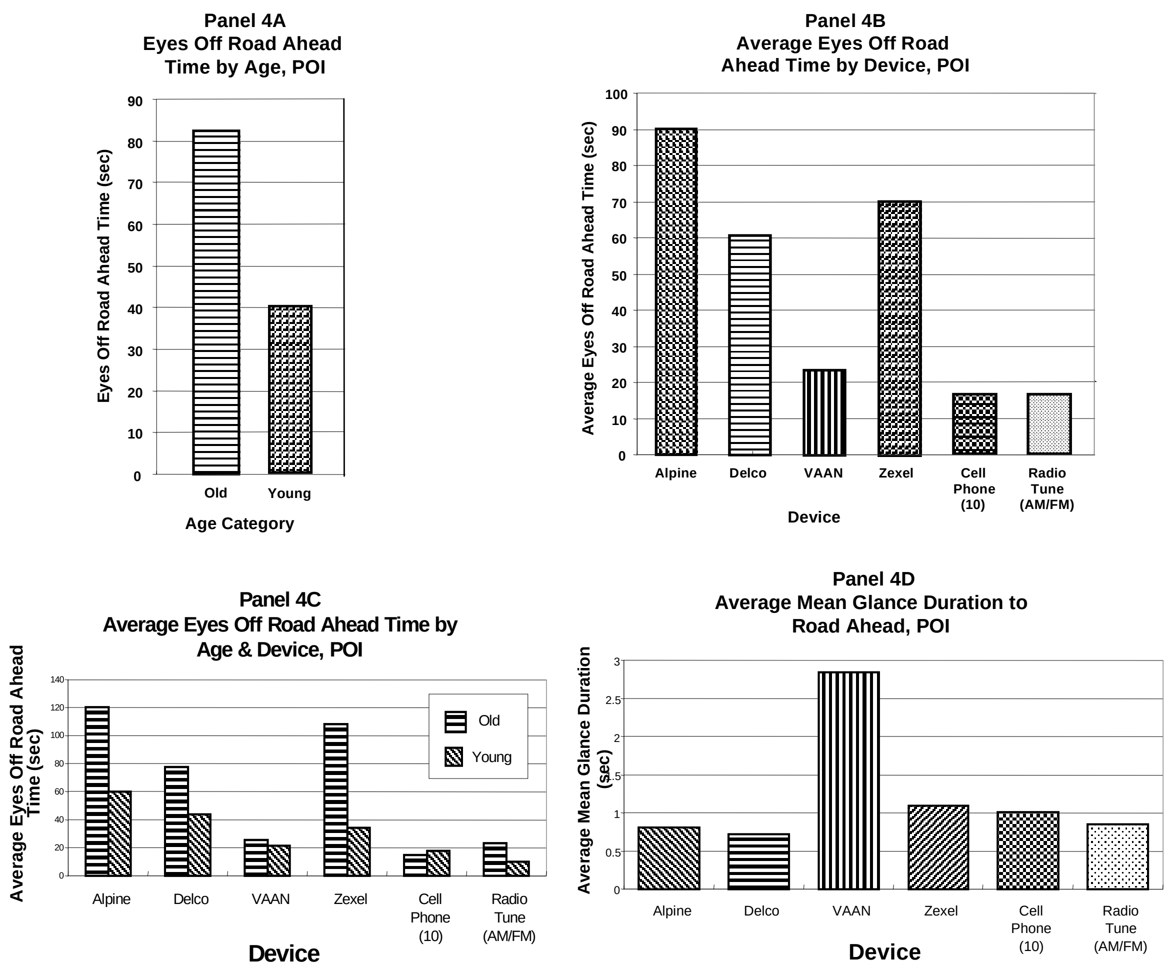

Figure 4. Age and Device Effects on Eyes-Off-Road-Ahead Time and Road Glance Duration.