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Further On-the-Road Tests of Driver Interfaces: Examination of a Route Guidance System and a Car Phone

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16. Abstract

In this experiment 8 drivers (4 younger, 4 older) drove a 19 turn, 35-minute route. The route included sections through residential neighborhoods, on city streets, and on expressways. They were guided by an experimental navigation system that provided turn-by-turn instructions via a display mounted on the instrument panel. During the trip each driver was asked to dial a phone number and participate in a simulated phone conversation. At the end of the trip drivers were asked to rate the difficulty of a variety of driver-information-system-related tasks.

The instrumented car recorded lateral position in the lane, speed, throttle position, steering wheel angle, eye fixation location, and other measures. Typical lateral standard deviations were 0.5 feet and decreased with speed. Speed standard deviations were slightly in excess of 1 mile per hour. Using the phone and navigation systems resulted in slight increases in the standard deviation of throttle position and the standard deviation of steering wheel angle.

There were 8 navigation errors in this experiment, comparable to the 25 errors from 30 drivers in a previous experiment, a fairly low number.

This experiment demonstrated that repeatable and reliable measures of driver performance and behavior could be obtained using the test protocol employed in this experiment

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PREFACE

The United States Department of Transportation (DOT), through its Intelligent Vehicle-Highway Systems (IVHS) program, is aiming to develop solutions to the most pressing problems of highway travel. The goals are to reduce congestion and improve traffic operations, reduce accidents, and reduce air pollution from vehicles by applying computer and communications technology to highway transportation. If these systems are to succeed in solving the nation's transportation problems, they must be safe and easy to use, with features that enhance the experience of driving. The University of Michigan Transportation Research Institute (UMTRI), under contract to DOT, carried out (as one aspect of IVHS) a project to help develop driver information systems for cars of the future. This project concerns the driver interface, the controls and displays that the driver interacts with, as well as their presentation logic and sequencing.

The driver interface project had three objectives:

- Provide human factors guidelines for the design of in-vehicle information systems.
- Provide methods for testing the safety and ease of use of those systems.
- Develop a model that predicts driver performance in using those systems.

Although only passenger cars were considered in the study, the results apply to light trucks, minivans, and vans as well, because the driver population and likely use are similar to cars. Another significant constraint was that only able-bodied drivers were considered. Disabled and impaired drivers are likely to be the focus of future DOT research.

A complete list of the driver interface project reports and other publications is included in the final overview report, 1 of 16 reports which documents the project.[1] (See also Green, Serafin, Williams, and Paelke, 1991 for an overview.)[2] To put this report into context, the driver interface project began with a literature review and focus groups examining driver reactions to advanced instrumentation.[3,4,5] Subsequently, the extent to which various driver information systems might reduce accidents, improve traffic operations, and satisfy driver needs and wants, was analyzed.[6,7] That analysis led to the selection of two systems for detailed examination (traffic information and cellular phones) and contractual requirements stipulated three others (navigation, road hazard warning, and vehicle monitoring).

Each of the five systems selected was examined separately in a sequence of experiments. In a typical sequence, patrons at a local driver licensing office were shown mockups of interfaces, and driver understanding of the interfaces and preferences for them was investigated. Interface alternatives were then compared in laboratory experiments involving response time, performance on driving simulators, and part-task simulations. The results for each system are described in a separate report. (See references 8, 9, 10, 11, 12, 13, and 14.) To check the validity of those results, several on-road experiments were conducted in which performance and preference data for the various interface designs were obtained.[15,16]

Concurrently with that work, UMTRI developed test methods and evaluation protocols, UMTRI and Bolt Beranek and Newman (BBN) developed design guidelines, and BBN worked on the development of a model to predict driver performance while using in-vehicle information systems. (See references 17, 18, 19, 20, and 21).

Many of the reports from this driver interface project were originally dated May, 1993, the contractual end date of the project whereby reports were to be delivered. However, the reports were actually drafted when the research was conducted; more than two years earlier for the literature review and feature evaluation, and a year earlier for the laboratory research and methodological evaluations. While some effort was made to reflect knowledge gained as experiments were completed, the contract plan did not call for rewriting reports (such as the interface certification protocol) to reflect recent findings.[18]

This report describes driver performance and behavior when using an in-vehicle route guidance system, and a manually dialed car phone. It also provides normative data for driving without use of an in-vehicle information system. Description of the route guidance system, and drivers' preferences, are also included.

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

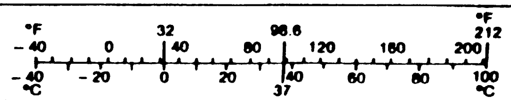
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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INTRODUCTION

The best test of any product is one based on customer reactions. Is it safe to use? Can customers use it? Is the product useful? Do they like it? For automotive products, the ultimate evaluation is real-world, on-road measurement of driving behavior. This report describes research that was conducted to help develop product evaluation tests and to collect representative data on the use of information systems that are likely to appear in cars of the future.

In particular, as stipulated by the contract, this experiment was primarily designed to validate a specific test protocol and its acceptance criteria, a test intended to evaluate the safety and ease of use of Intelligent Vehicle-Highway Systems (IVHS) driver interfaces.[17] Preliminary data applicable to that test protocol are reported in Green, Hoekstra, Williams, Wen, and George.[15] In this subsequent experiment, additional data were collected on the use of the navigation system as a check of the reliability of the test protocol and enhancements to it. Also, to expand the domain of applications, data were collected on the use of a car phone. The data collected in this validation experiment could eventually be used to further calibrate the Integrated Driver Model, a model developed as part of this project to predict driver performance and behavior while using in-vehicle systems.[19,20]

As noted above, this validation experiment builds upon the results reported in Green, Hoekstra, Williams, Wen, and George.[15] An initial experiment was run to find major usability problems with the interfaces. Six pairs of drivers drove an instrumented car over a 35-minute test route in southeastern Michigan. While driving, four in-vehicle information systems were used. They included: (1) a route guidance system, (2) an in-vehicle safety advisory and warning system (IVSAWS) that presented information about road hazards, (3) a vehicle monitoring system, and (4) a traffic information system. Three versions of the route guidance system were examined: an instrument-panel-mounted (IP) display, a head-up display (HUD), and an auditory implementation. Only one version of the three other information systems was considered: mixed text and graphics for the IVSAWS and vehicle monitoring systems, and text alone for the traffic information system. There were few navigation errors and drivers were able to complete the test route with minimal assistance from the experimenter, suggesting the interface was sufficient (and safe enough) for more rigorous testing. There were no major problems with the test protocol.

In a subsequent experiment, 43 people, one at a time, drove the same car over the same route. The three information systems and the three versions of the route guidance system were identical to those in the previous experiment. Dependent measures for that experiment were the means and standard deviations of four characteristics: lateral position in the lane, speed, throttle percent, and steering wheel angle. Also examined were eye fixation duration and frequency to various locations, as well as safety, usability, and driver preference ratings.[15]

Also, as part of this driver interface project, three experiments on the design of car phones were completed prior to the on-the-road experiments.[11,22] In the first, 19 drivers at a local driver licensing office were shown a HyperCard simulation of a car phone and asked to provide abbreviations for 7 functions. In a subsequent experiment, seven people were shown abbreviation sets developed from the previous experiment. An abbreviation set generated from mixed rules was preferred over sets generated by the vowel deletion rule or the truncation rule (using the first few characters) alone.

In a third experiment 12 drivers used a simulated phone to place calls and engage in phone conversations, while "parked" in a driving simulator and while operating the simulator. Driving performance was not affected by conversation tasks, but was degraded by the dialing task. Voice dialing times were much less than manual dialing times for unfamiliar phone numbers but not for familiar numbers. The limited amount of eye glance data examined supported this, suggesting that voice dialing is preferable, especially for unfamiliar numbers. Thus, voice dialing led to better performance only when the task was difficult, but the effect was not significant enough to mandate the use of voice dialing. The primary outcome of these experiments was the development of a reasonable phone interface and estimates for dialing times and eye fixations needed for human performance modeling. In the experiment described in this report, some of those tasks were repeated on the road.

METHOD

Test Participants

Eight licensed drivers participated in this experiment: four younger (under 30 years old) and four older (60 or older). There were an equal number men and women in each age category. Older drivers ranged in age from 62 to 75, with a mean of 68, while younger drivers ranged from 20 to 23, with an average of 22. The corrected visual acuity of all participants ranged from 20/17 to 20/70 based on a Titmus vision test.

None of the drivers had participated in the previous on-road or laboratory experiments with the route guidance system, nor had any subject ever placed more than two in-car telephone calls. Subjects were recruited from existing subject lists, or through acquaintances of the experimenters.

Test Materials and Equipment

Test Vehicle

The instrumentation was installed in an air conditioned 1991 Honda Accord LX station wagon with an automatic transmission. (Since the sedan version of the Accord, quite similar to the station wagon in performance, was the most popular model in the U.S. for five years in a row, this is a very typical car for Americans to drive.) All of the major pieces of research equipment (computers, power conditioners, etc.) were hidden from view in the back seat, or in the cargo area which had its own retractable vinyl cover. From the outside, the instrumented car resembled a normal station wagon. The vehicle had the following sensors:

<u>Lane tracker</u> - The driver's outside mirror had been replaced with a mirror from a late model Ford Taurus. Embedded inside the over-sized mirror housing was a black and white CCD camera with an auto iris lens. Only the tip of the lens barrel housing was visible from the outside. The camera was connected to a frame buffer in an 80486-based computer. Custom computer software was written to detect lane markings and store the lateral deviation, to the nearest tenth of a foot, at a rate of 10 Hertz (Hz).

<u>Steering wheel position sensor</u> - A string potentiometer was mounted to the steering column under the dashboard. The potentiometer signal was fed through an interface box to the analog board in an 80486 computer. Steering wheel position was recorded to the nearest 0.3 degrees at 30 Hz.

<u>Speed sensor</u> - Built into the left front wheel (for use by the vehicle's engine and transmission controller) was a sensor that pulsed every one-quarter wheel revolution. Using the pulse interval times, speeds could be measured to the nearest 0.1 mi/h at 10 Hz for speeds in excess of 12 mi/h.

<u>Accelerator/Throttle sensor</u> - An analog signal representing the percent declination of the accelerator pedal was obtained from the vehicle's throttle angle sensor. This signal was also monitored by an 80486 computer and recorded at 30 Hz.

Road scene - Mounted in front of the inside mirror and facing forward was a thumb-sized color video camera. The video signal was mixed with the video signal from another camera via a signal splitter and recorded on a VCR.

Driver scene - Mounted on the left A pillar and facing the driver was a second thumb-sized color video camera. This camera captured the driver's head and upper torso (to show eye and head movements, as well as some manual operations). This video signal was mixed with video signal from the road scene camera.

Audio - A microphone was mounted on top of the IP to record comments from the driver, front seat passenger (when present), and the experimenter, as well as sounds from the information systems.

All of the vehicle and driver data was either collected and stored by an 80486 computer or stored on videotape. The data collection software provided for real-time display of all data streams so they could be checked for accuracy by an experimenter in the back seat. In addition, the software allowed for the entry of time-stamped comments via the keyboard at any time. In this configuration, data could be collected for about an hour before it needed to be saved to disk.

The arrangement and model numbers of the instrumentation are shown in figure 1.

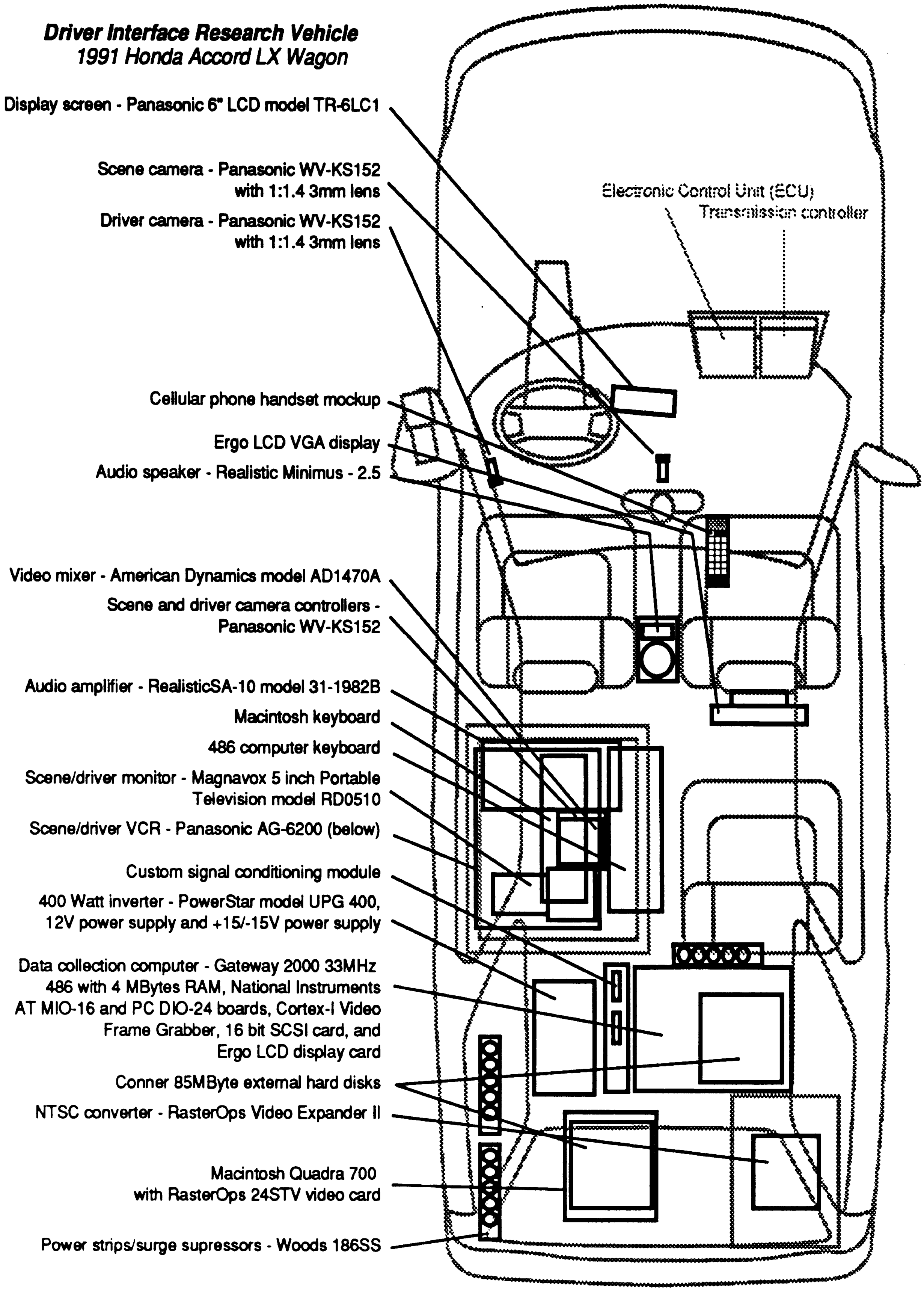
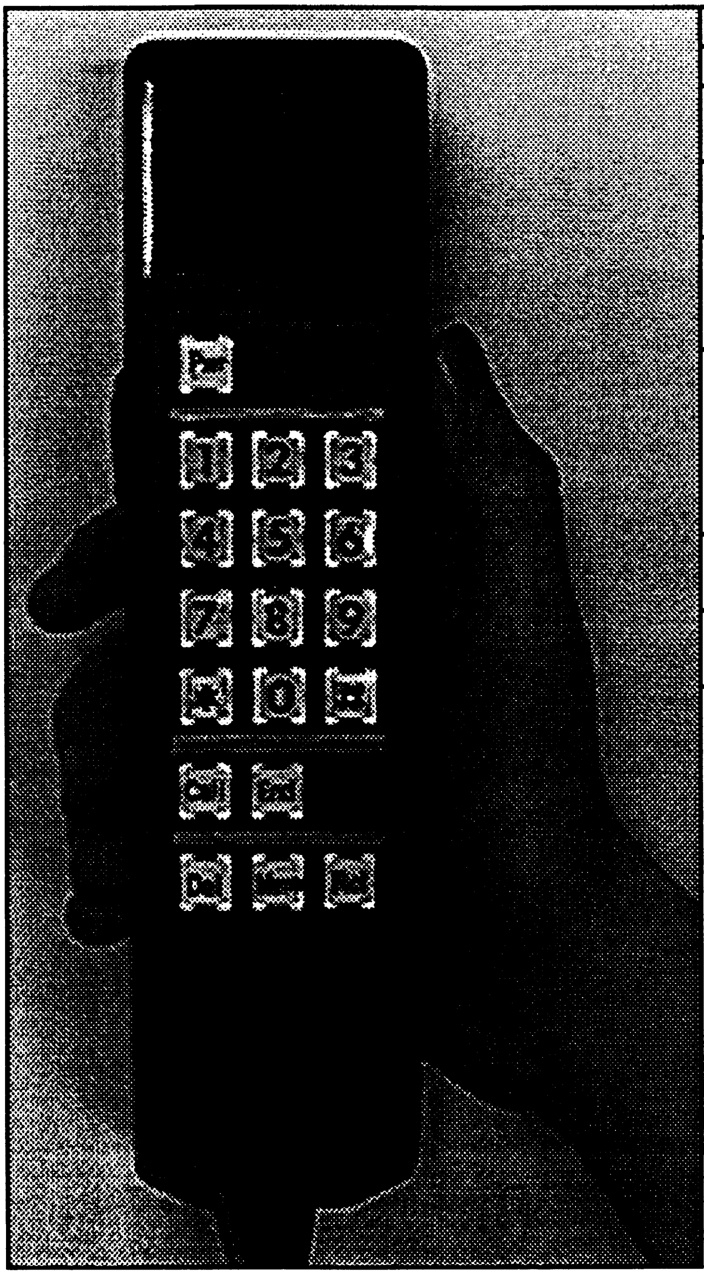


Figure 1. Instrumented test vehicle and equipment arrangement.

Car Phone

The car phone used in this on-road experiment, a modified Motorola cellular phone handset (model type SCN2085A), was the same one used in the laboratory experiment described in Serafin, Wen, Paelke and Green.[12] (See figure 2.)



	Dimension(s)	
Parameter	(mm)	(in)
overall size (height x width)	20.5 x 5.1	8-1/4 x 2
keys (height x width)	9 x 9	3/8 x 3/8
key separation (horizontal x vertical)	3 x 3	1/8 x 1/8
vertical sep. of key groups (pwr, number pad, call/end, del/mem/rcl)	6	1/4
number pad character height	5.5	7/32
function key character height	3	1/8

Figure 2. Car phone.

A Macintosh Quadra 700 computer controlled the phone display and sounds, and recorded the exact time each button was pressed and the button pressed. The buttons in the car phone were wired in a 4 by 4 matrix. They were soldered onto a 4 by 4 matrix of keys on the Apple keyboard. The matrix allowed full functionality of the phone with only eight wires, allowing use of the existing Motorola handset cable for connection to the Macintosh keyboard. Because there was little difference in performance associated with display location (IP versus HUD), the more readily implemented IP display version was used.[16,22] The phone display is shown full size in figure 3. When the phone was used, this information appeared on the screen later used for navigation.

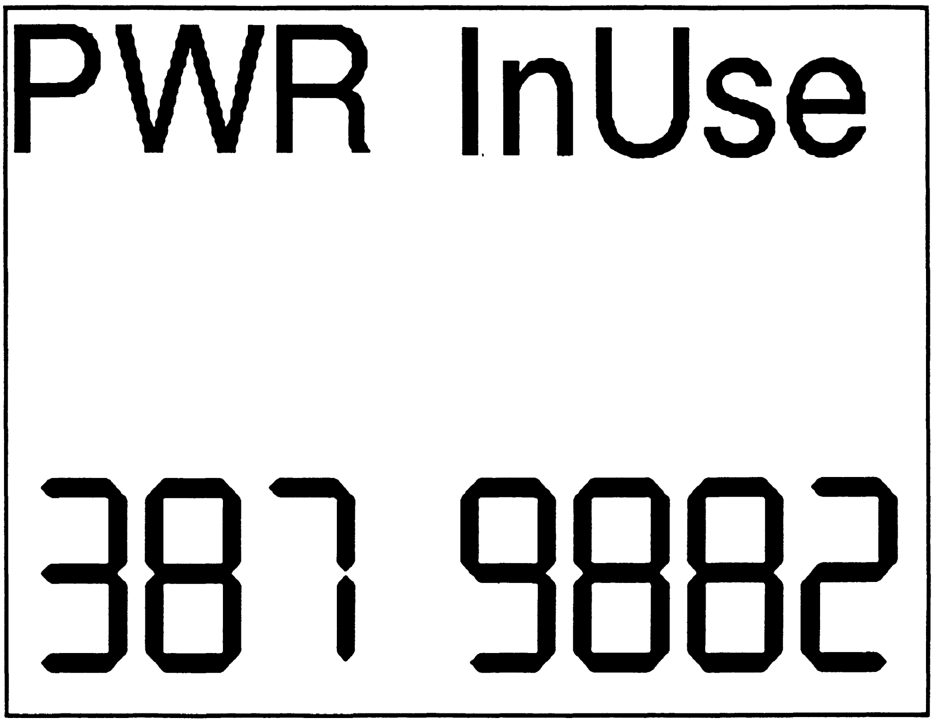


Figure 3. The car phone display.

The procedure for dialing the phone was explained to participants before using the phone in the car. When a request was made to make a phone call, drivers picked the phone up from the passenger's seat. To dial the phone number, first the caller turned on the phone's power by pressing the power button ("PWR"), then entered the 7-digit number, and finally placed the call by pressing the "CALL" button. Through the ear speaker in the handset the subject would hear a single ring and a click at which time the task would begin. When the phone task was finished a beep sounded, the subject pressed the power button again to shut off the phone, and set the phone on the seat.

Car Phone Tasks

Participants performed three types of phone conversation and question tasks: listening, talking, and listing. In the listening task drivers listened to a 30-second description of a scenario and then were prompted (over the phone) to make a decision based on the information they heard. (For example, drivers heard a description of three options for dining out: Italian, French, or seafood.) In the talking tasks the drivers were asked to describe something for 30 seconds (for example, what they did last weekend). For the listing tasks, a category was named (for example, "fruits") and drivers listed as many items in that category ("grape," "orange," etc.) as possible in 30 seconds. All practice and test session questions are listed in the appendix.

The phone questions (presented by a digitized female voice) were played back by the Macintosh through the phone handset. Participants' responses were recorded using a microphone on the dashboard.

Drivers made a total of 12 phone calls, including 3 practice calls while in a parked car, 3 practice calls while driving, and 6 calls during the test session while driving. Each call included dialing a number and completing one of the three conversation tasks (listening, talking, listing). Hence, each conversation task was completed twice by each driver on the test route. All phone numbers were familiar 7-digit numbers the participant had provided to the experimenter when scheduling the test session. Phone call durations were fixed for each task, and ranged from 38 to 41 seconds (from when the driver pressed the "call" button, initiating the call, to the beep indicating the end of the task). Drivers made each of the three types of phone calls first while driving on a 50 mi/h road, and then on a 65 mi/h expressway. The 12 calls were made in a fixed order by all drivers at the same locations along the test route, as shown in figure 4.

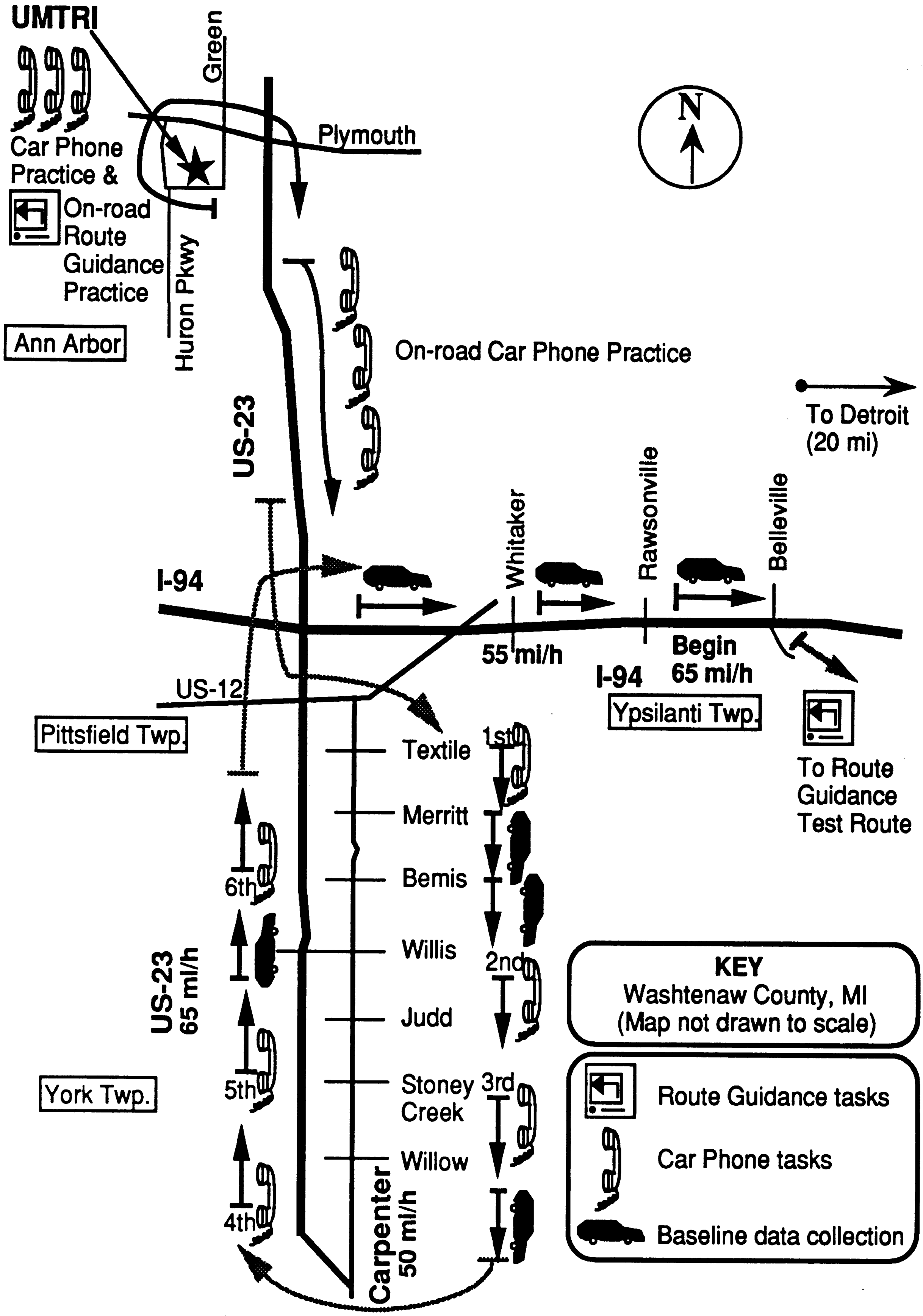
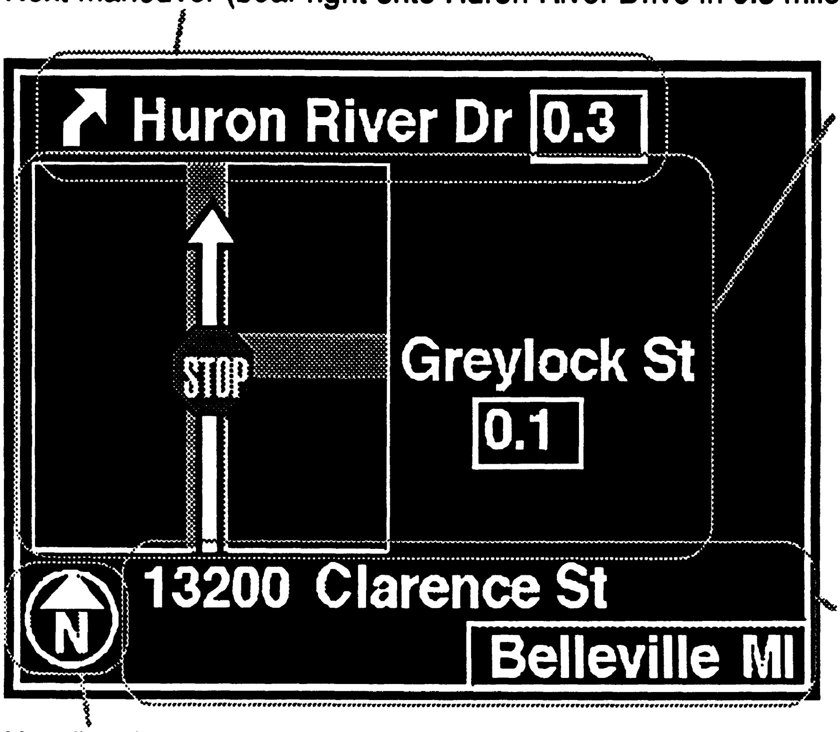


Figure 4. Routes for route guidance practice session, and car phone practice and car phone sessions.

Route Guidance System Interface

The route guidance system provided turn-by-turn navigation information to drivers. The information was presented on an IP-mounted display. This navigation system was the same one used in the previous on-road experiment, though the bars that counted down the time to the next turn were removed.[15] A sample visual route guidance system is shown full size in figure 5. A paper reproduction, in color, of this screen was also used to describe the system to drivers prior to driving.



Note: The roads, "Greylock St", and "0.1" are green, and the stop sign is red.

Figure 5. Example visual route guidance system screen.

Distances to turns and current location were updated each tenth of a mile. (Screens did not scroll.) When a decision point was passed, a new screen appeared.

Before driving the route, drivers completed a 6-minute practice session that involved driving in an area near UMTRI in Ann Arbor. The computer-generated screen sequence for that practice is shown in figure 6.

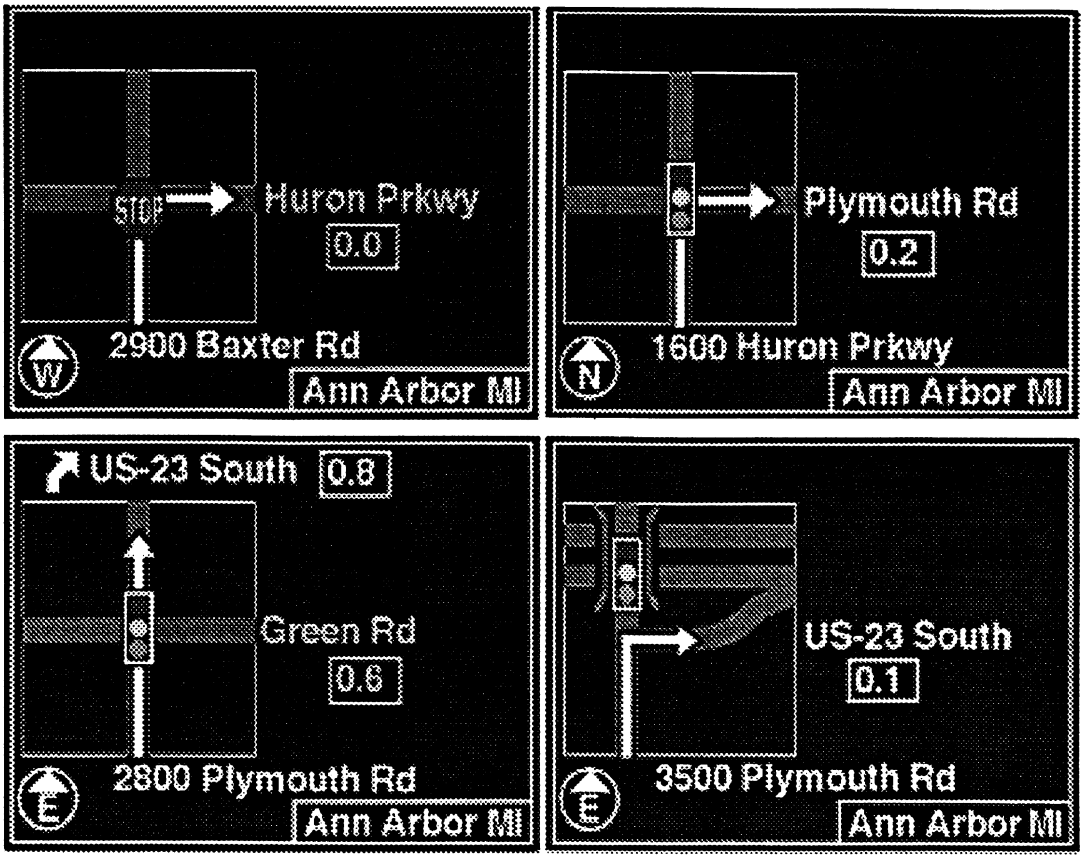


Figure 6. Practice session screen sequence.

During the test session, drivers saw a total of 30 screens, containing 19 turns, to get to the destination. The sequence of visual route guidance screens for the entire route is shown in figure 7.

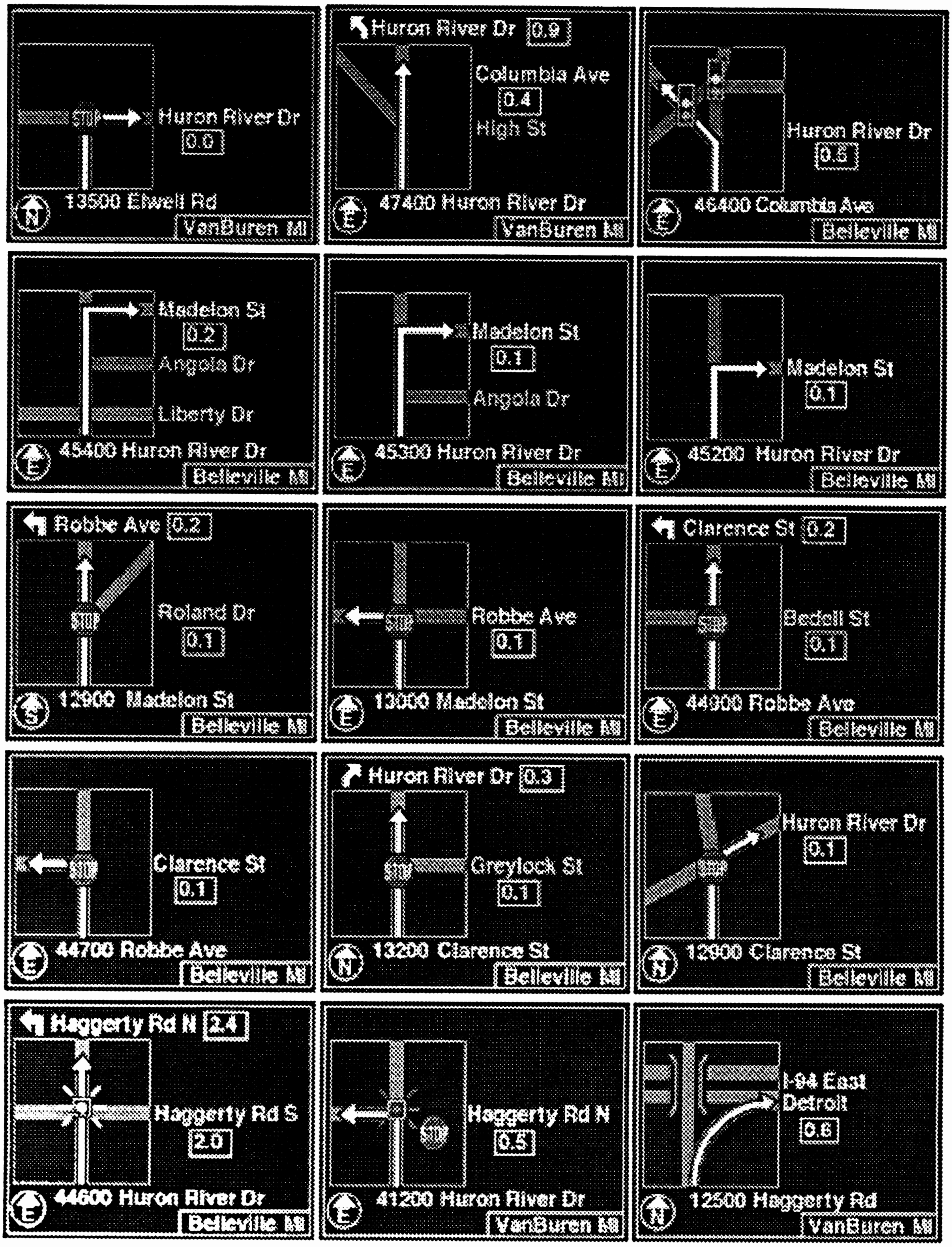


Figure 7. Route guidance screens for test route (in order from left to right).

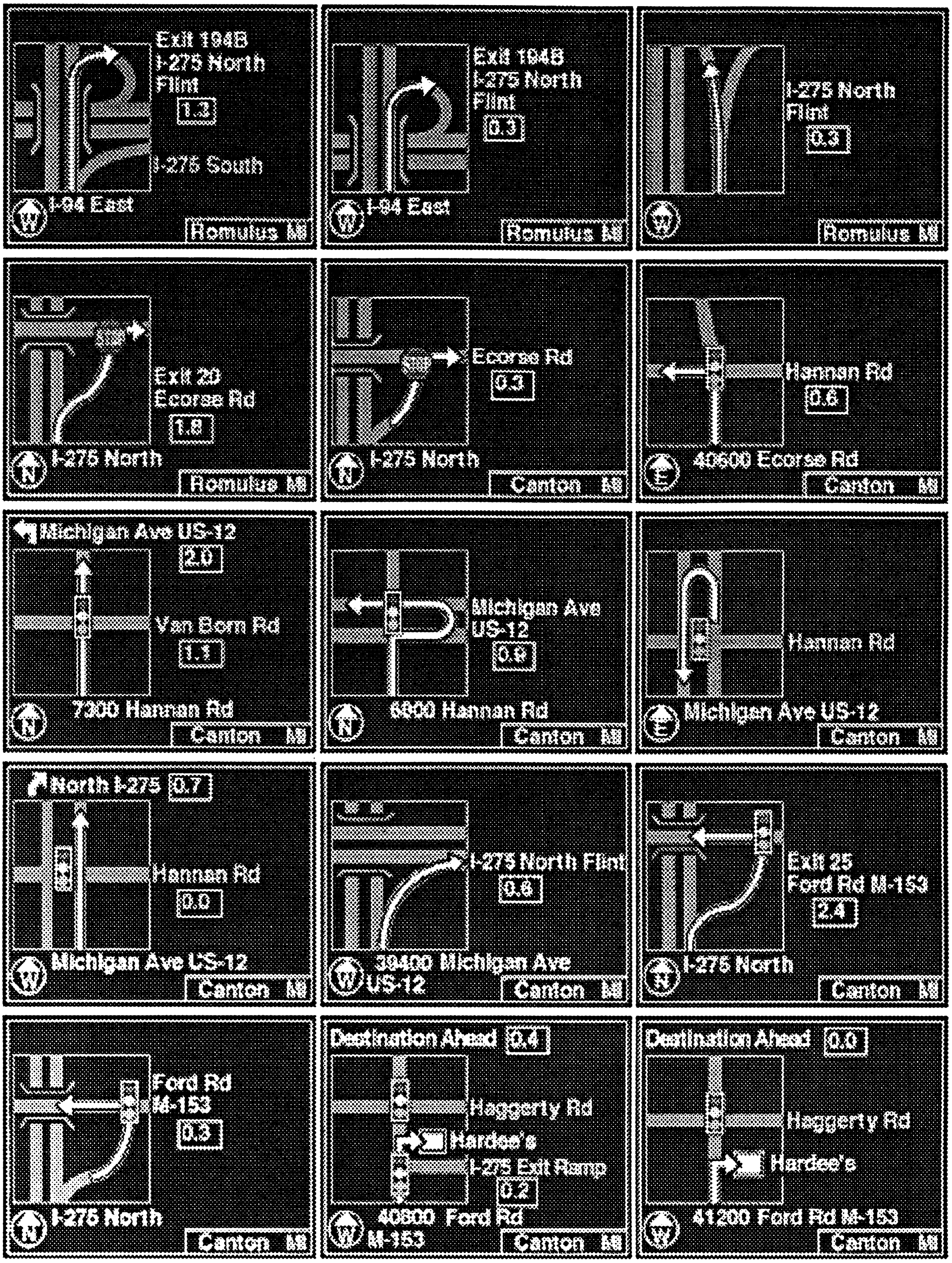


Figure 7. Route guidance screens for test route (in order from left to right) (continued).

The screen for an upcoming intersection was displayed until the driver had completely executed the previous maneuver. For example, the first screen would continue being displayed until the car turned right at the intersection of Elwell and Huron River Drive and then straightened out on Huron River Drive.

Route Guidance Test Route

The route used for the route guidance test session is shown in figure 8. This same route was also used in the previous on-road experiment with the route guidance system and other in-car information systems. This course, from the parking lot of the St. Paul's Lutheran Evangelical Church in Belleville, Michigan to the Hardees restaurant in Canton, Michigan, contained various road types: residential, suburban, city/business, and expressway. Drivers were required to make 19 turns during the 35-minute trip to reach the destination.

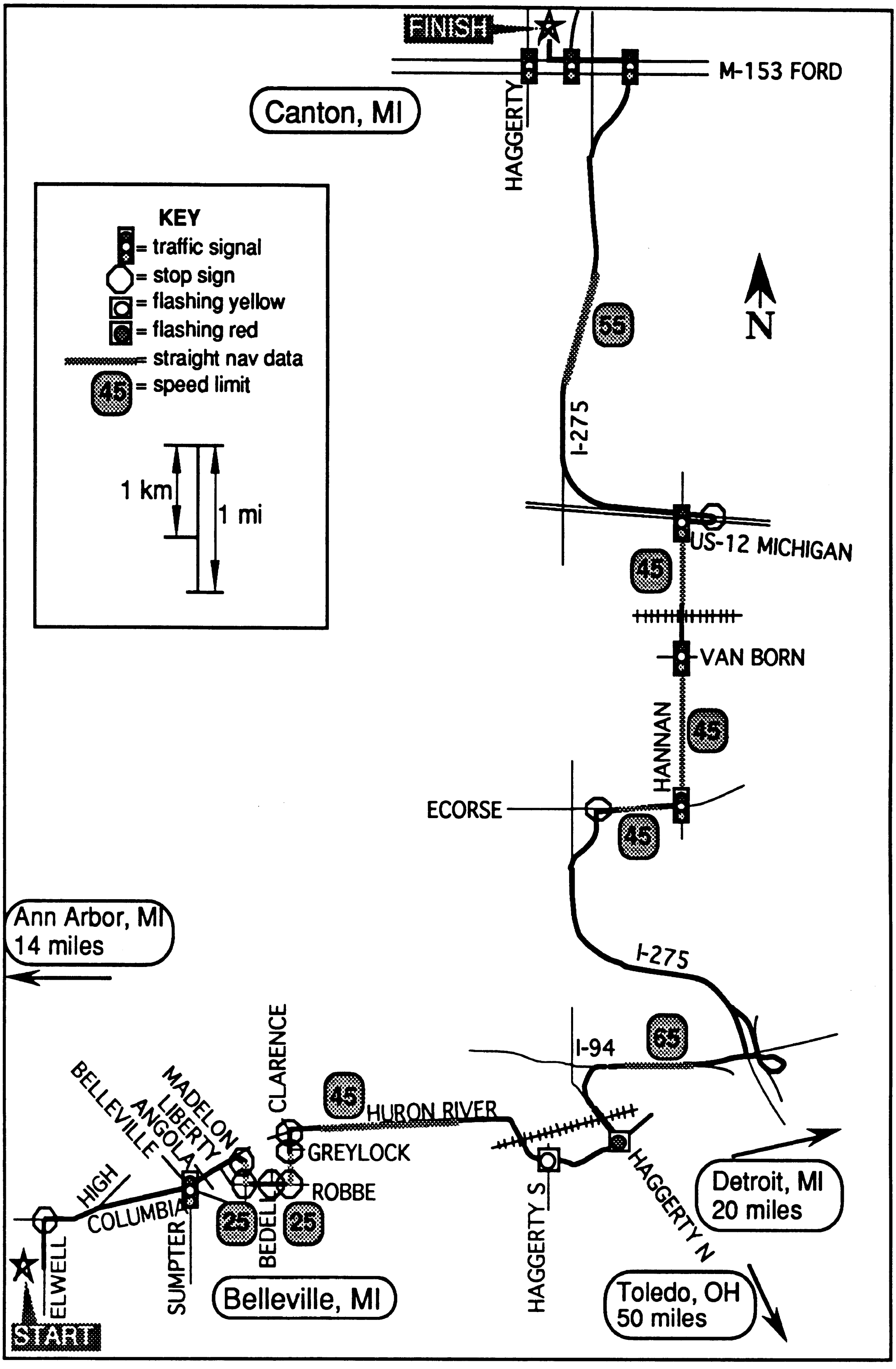


Figure 8. Test route.

Forms and Questionnaires

Forms used during the experiment included a consent form, biographical form, and a post-study questionnaire. In addition, instructions to subjects were used by the experimenter. Copies of these are in the appendices.

Test Activities And Their Sequence

When participants were recruited by phone for the study, they were asked to provide six seven-digit phone numbers that were familiar and memorized (for example, friends, or their workplace).

Upon arrival at UMTRI, participants read and completed a consent form and biographical form, followed by a vision test. They confirmed that the six familiar phone numbers they had provided were correctly recorded on the biographical form. A brief explanation of the route guidance system interface was provided by showing a color, paper reproduction of a route guidance screen. A description of the car phone followed, including an explanation of the three conversational tasks (listening, talking, and listing) and specifics about dialing the phone.

While parked at UMTRI, participants adjusted the seat, steering wheel height, and mirrors while being briefed about the test vehicle. The navigation/phone display (on the IP), cameras, and microphone were pointed out. Phone information status elements that could be displayed included "power," the digits as they are dialed, and "in use".

Drivers were told that while driving they would be asked to make phone calls to people or places on their familiar phone number list. (Drivers were not told the phone number since they knew it.) When a request was made, drivers picked up the phone from the passenger's seat to dial that person's phone number. To make the call, the driver pressed the power button ("PWR") to turn the phone on, then entered the seven-digit number, and finally pressed the "CALL" button to send the digit sequence. When these operations were complete, the subject would hear over the handset speaker a single ring and click, at which point the task would begin. (For a complete list of the three practice and six on-road test session phone tasks, see the appendices.) When the phone task was finished, the subject heard a beep, pressed the power button again to shut off the phone, and placed the phone on the passenger seat.

Participants completed three practice phone calls while parked at UMTRI to become accustomed to dialing the phone and participating in the conversation tasks. The order of the tasks were fixed for all subjects. (A map identifying where the practice and test calls were made appears in figure 4.)

Participants then began practicing use of the route guidance interface, being sure to obey all traffic laws and speed limits. This practice consisted of four screens, including instructions for 2 right turns, 1 "continue" through an intersection, and 1 expressway entrance. The final instruction of the practice session directed drivers onto US-23 south (an expressway) where they repeated the same three practice phone tasks (as done in the stationary practice session). These three calls were not strictly scheduled to occur at specific segments of the road, but rather were done when drivers felt safe and comfortable.

Verbally guided by the experimenter, drivers exited the expressway at Carpenter Road (south). Carpenter Road is a two-lane rural street with stop signs or flashing red or yellow lights at intersections approximately every mile. As soon as drivers reached a steady speed (the speed limit was 50 mi/h), the first phone call was requested. Two subsequent phone calls were requested at designated locations along Carpenter Road. These locations were selected because a call could be completed along a straight and continuous section of road (e.g., no curves, stop signs, etc.). Driving performance baseline data (steering wheel angle, throttle position, lateral position, speed) was also collected between phone calls, along specific straight sections of road. The same procedure was repeated for the other three phone calls, at specific locations along US-23 North (65 mi/h speed limit). Additional baseline driving data were collected over straight sections of I-94 East, while driving out to the start of the route guidance test route in Belleville.

Upon arrival at the route guidance interface test route, drivers were reminded about the route guidance instructions. Drivers were not assisted by the experimenter during the test session, however. If a wrong turn was made, an "off route" message appeared on the screen after which the experimenter verbally directed the driver back to the test route to continue. At the destination, drivers were interviewed about the ease of use of the route guidance system and car phone. These questions were the same as those of Green, Hoekstra, Williams, Wen, and George.[15] A more thorough paper questionnaire was administered upon returning at UMTRI. (All interview questions and post-study questionnaires are in the appendices.) Participants finally completed a payment form and were paid $30 for the 2-1/2 hour session.

RESULTS

Four measures of driving performance were of primary interest: mean lateral (lane) position, standard deviation of lateral position, mean vehicle speed, and standard deviation of vehicle speed. Four other measures of driving behavior were the mean and standard deviation of steering wheel angle, as well as the mean and standard deviation of throttle position.

Lateral position is the distance from the left front tire to the left lane line, as measured by the lane tracker. This measure indicates whether the driver is headed down the middle of the lane or off to one side. The standard deviation of lateral position indicates if the driver is maintaining a steady course in the lane or is weaving (possibly as the result of a distracting in-vehicle display), and may be a measure of attentional demand. Steering wheel angle, as measured from a string potentiometer connected to the steering column, is a very sensitive measure of whether the vehicle is going straight or turning. The steering wheel angle reading at the data collection computer was not calibrated exactly to zero as straight. The precise steering wheel angle required to drive the car straight is dependent upon the road crown and cross wind speed. As a result, the mean steering wheel angle for each straight segment was defined as "straight." The standard deviation of steering wheel angle is a measure of the effort required by the driver to steer the car. The vehicle speed was used to verify obedience to speed limits. The standard deviation of vehicle speed is another measure of attentional demand. When attentional demands are high, the vehicle speed may not be steady. Throttle angle, as measured by an engine sensor, is another indicator of speed. Because of vehicle inertia, the standard deviation of throttle angle may be more sensitive to attentional demand than vehicle speed; it more accurately reflects driver inputs than does the resulting vehicle speed.

For these four driving parameters, both means and standard deviations are considered. In the results section, first the baseline driving data are examined followed by the driving data while the navigation system was used, and then driving data while the phone was used. Finally, a comparison of the three conditions is discussed. With each section the effects of driver age, speed limit, and road section are considered as well as overall means for the eight driver sample. Because the data are partitioned in this manner, it is felt this comparison of the baseline, navigation, and phone data is appropriate, even though the data are for different road segments.

Also provided are distributions for the measures of interest. These data are required to support the selection of best expected, planned/desired, and worst case performance levels in the safety certification protocol.[17] The certification protocol describes how driver information systems should be tested to assess safety and ease of use. Descriptions of driver performance at the level of detail provided in this report are uncommon in the literature but are required for safety assessments.

Straight Road (Baseline) Driving Data

For the 7 baseline segments along the route, 3 had speed limits of 50 mi/h, 2 were 55 mi/h, and 3 were 65 mi/h. (See figure 4 given previously.) No phone or navigation tasks were administered during those baseline segments. For each of the seven baseline segments, means and standard deviations were computed. Segments typically contained 500 data points, with a range of 66 to 970. Then, overall means and standard deviations were computed across the 7 segments and 8 drivers (56 data points). Some of the figures in this section show fewer than 56 data points because those figures present subsets of the baseline driving data (e.g., one age group or speed). Table 1 shows the baseline summary statistics.

Table 1. Baseline driving data summary for seven straight road segments.

Measure	**Overall Mean**	**Overall Standard Deviation**
Mean lateral position (ft)	2.8	0.6
Standard deviation of lateral position (ft)	0.5	0.2
Mean speed (mi/h)	56.0	5.4
Standard deviation of speed (mi/h)	1.1	0.5
Mean steering wheel angle (degrees)	-16.1	0.4
Standard deviation of steering wheel angle (degrees)	0.8	0.2
Mean throttle position (%)	8.7	2.1
Standard deviation of throttle position (%)	3.0	1.1

Steering Wheel Angle

The mean of the standard deviation of steering wheel angle was 0.8 degrees with a standard deviation of 0.2 degrees. An Analysis of Variance (ANOVA) of the mean wheel angle showed no effects of age (p = 0.56), but there was a marginal difference due to the road segment ($F(6,42) = 2.00$), p = 0.08). The interaction was not significant (p = 0.96). Figure 9 shows the mean steering wheel angle for the seven baseline segments. When the experiment was planned, these segments were thought to be straight. It is unclear how the occasional need to slightly turn the steering wheel influenced other measures of driver behavior, in particular the standard deviation of steering wheel angle. If a road curves, more corrections should be needed and one would expect the standard deviation of the steering wheel angle to increase. It is possible the differences in the mean angle may be due to road crown or crosswinds, factors which are likely to have effects similar to curvature.

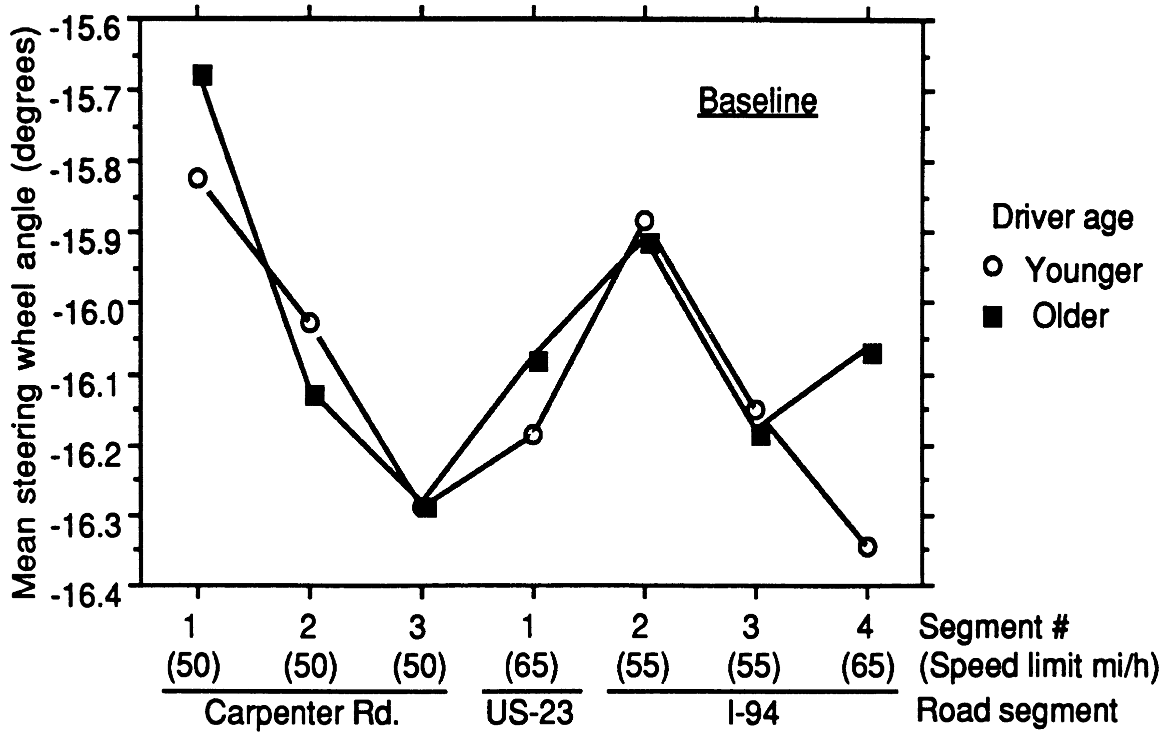


Figure 9. Mean steering wheel angle for the baseline segments.

An ANOVA of the steering wheel standard deviation showed significant effects of road segment ($F(6,42) = 6.00$, $p = 0.0001$). Age was also significant ($F(1,50) = 9.21$), $p = 0.0041$), but not their interaction ($p = 0.18$). Older drivers had larger standard deviations. Figure 10 shows the effects of road segment and age. Notice the differences between segment are primarily due to the type of road: Carpenter Road is a rural street whereas US-23 and I-94 are limited-access expressways. There do not seem to be differences in standard deviation of steering wheel angle due to the expressway speed limit (65 mi/h for the first and last sections, 55 for the second and third). Figures 11, 12, 13, 14, and 15 show histograms for the effects of age and speed limit.

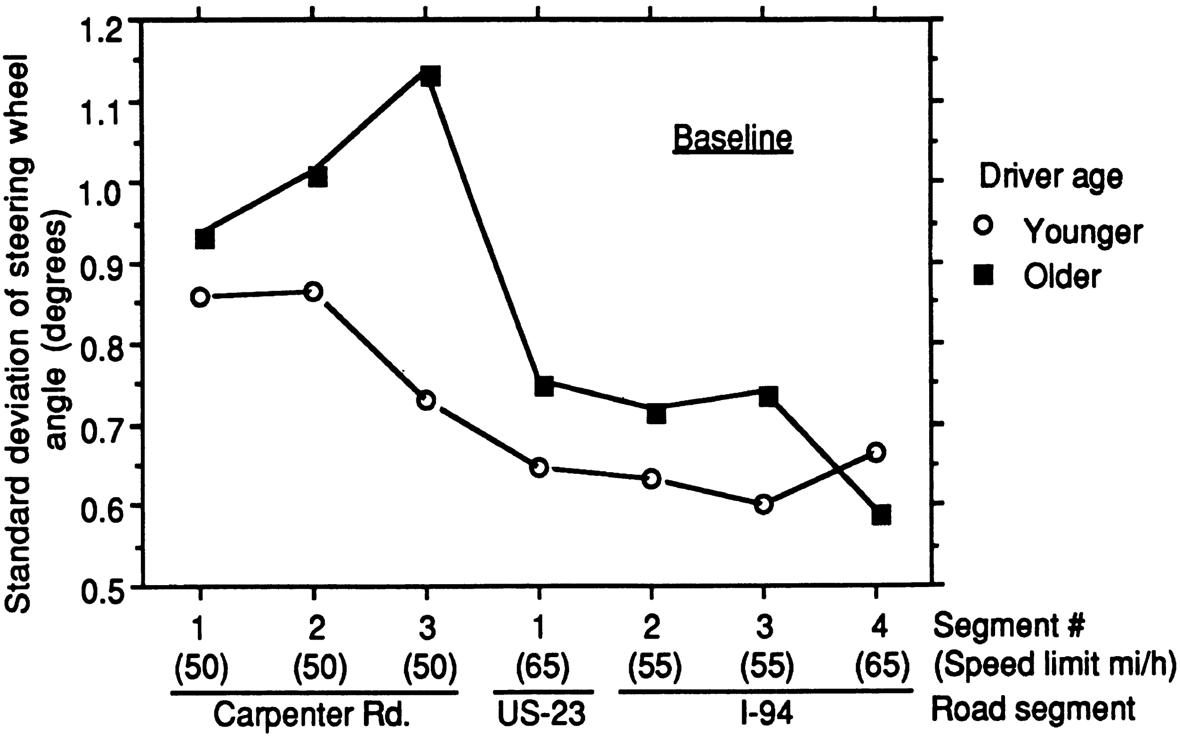


Figure 10. Effect of age and road segment on the standard deviation of steering wheel angle.

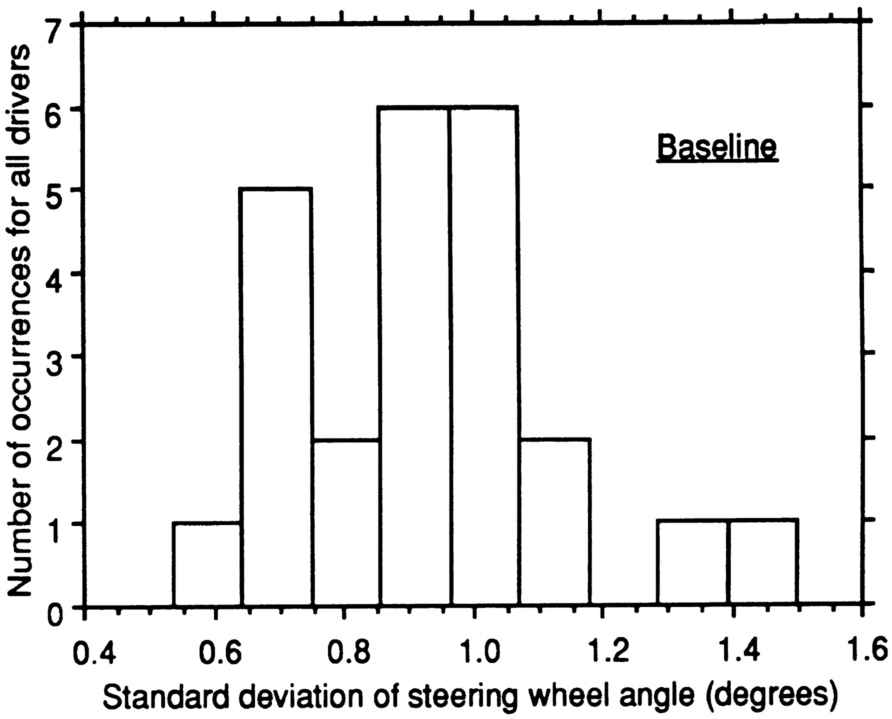


Figure 11. Distribution of standard deviation of steering wheel angle for 50 mi/h limit.

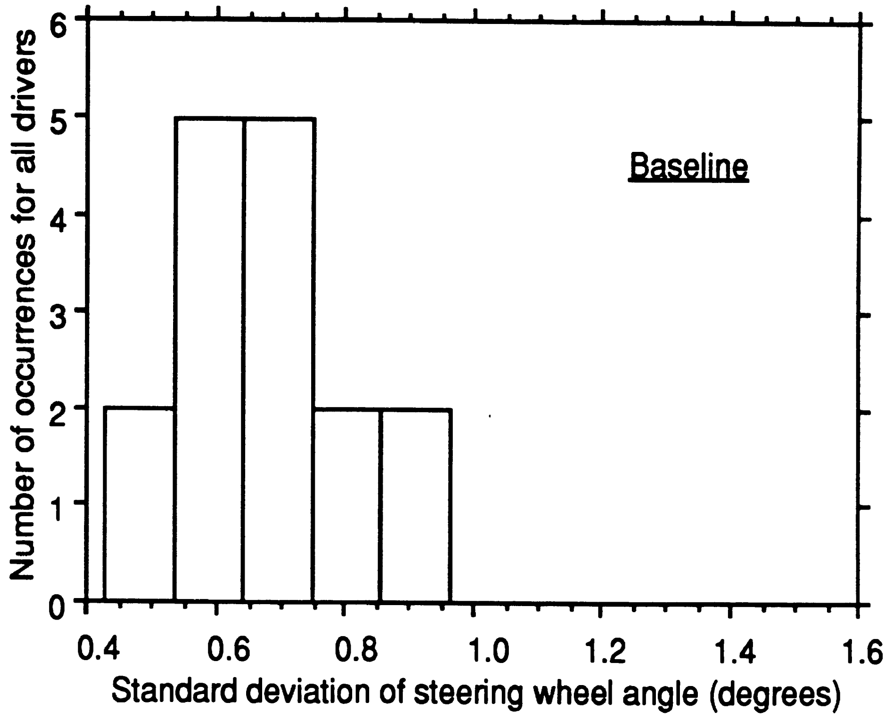


Figure 12. Distribution of standard deviation of steering wheel angle for 55 mi/h speed limit.

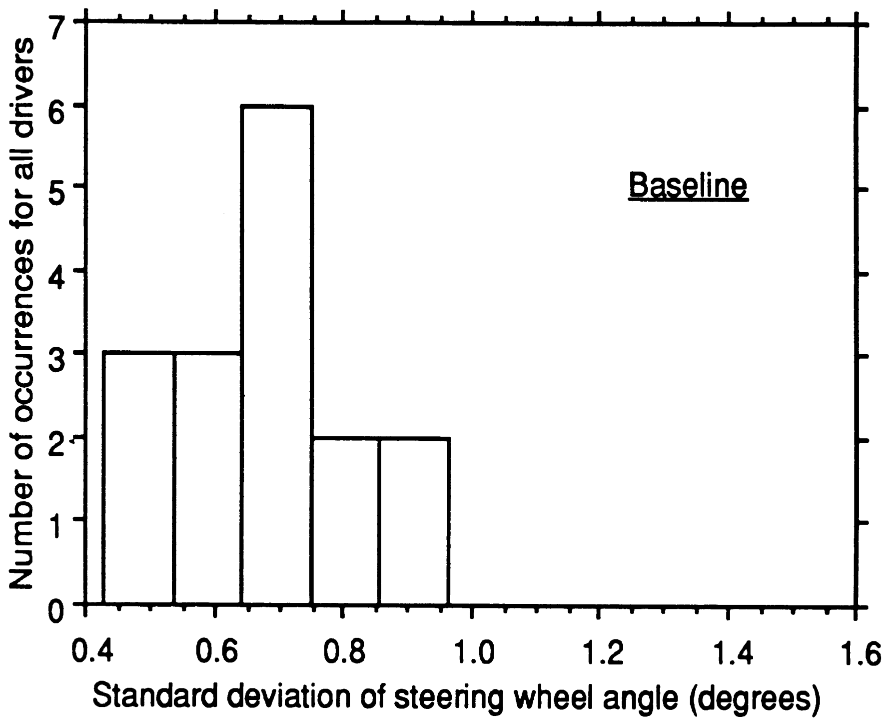


Figure 13. Distribution of standard deviation of steering wheel angle for 65 mi/h limit.

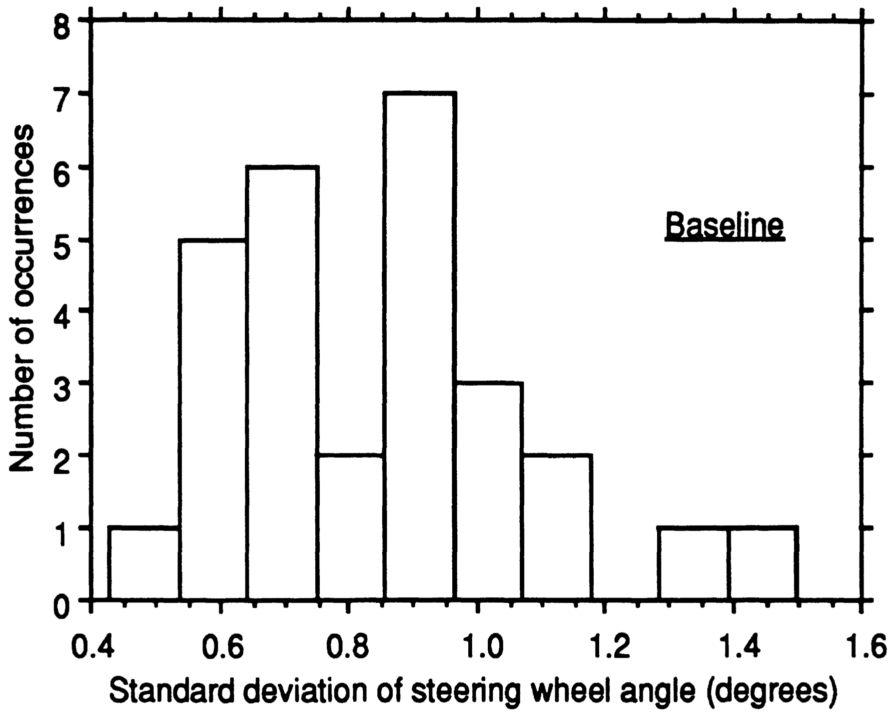


Figure 14. Distribution of standard deviation of steering wheel angle for older drivers.

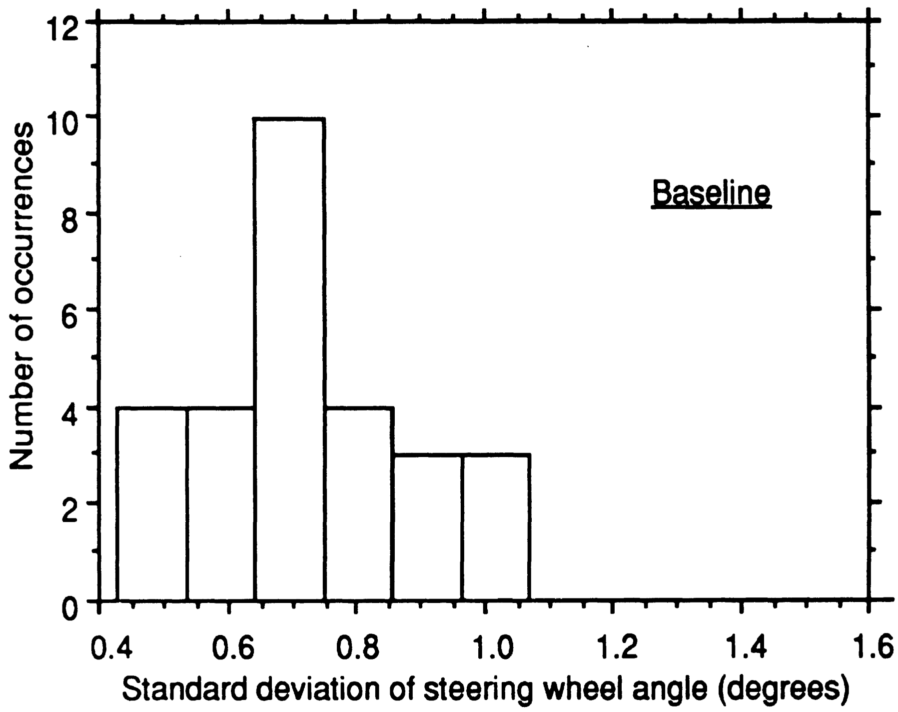


Figure 15. Distribution of standard deviation of steering wheel angle for younger drivers.

Throttle Position

The mean throttle position was 8.70 with a standard deviation of 2.07. The overall mean of the standard deviation of throttle position was 3.00 with a standard deviation of 1.08, over all baseline segments. In an ANOVA of the standard deviation, neither age (p = 0.64), speed limit (p = 0.66), nor their interaction (p = 0.55) were significant. (See figure 16.) However, there was a tendency for older drivers to have a wider range of standard deviations, as shown in figures 15 and 16.

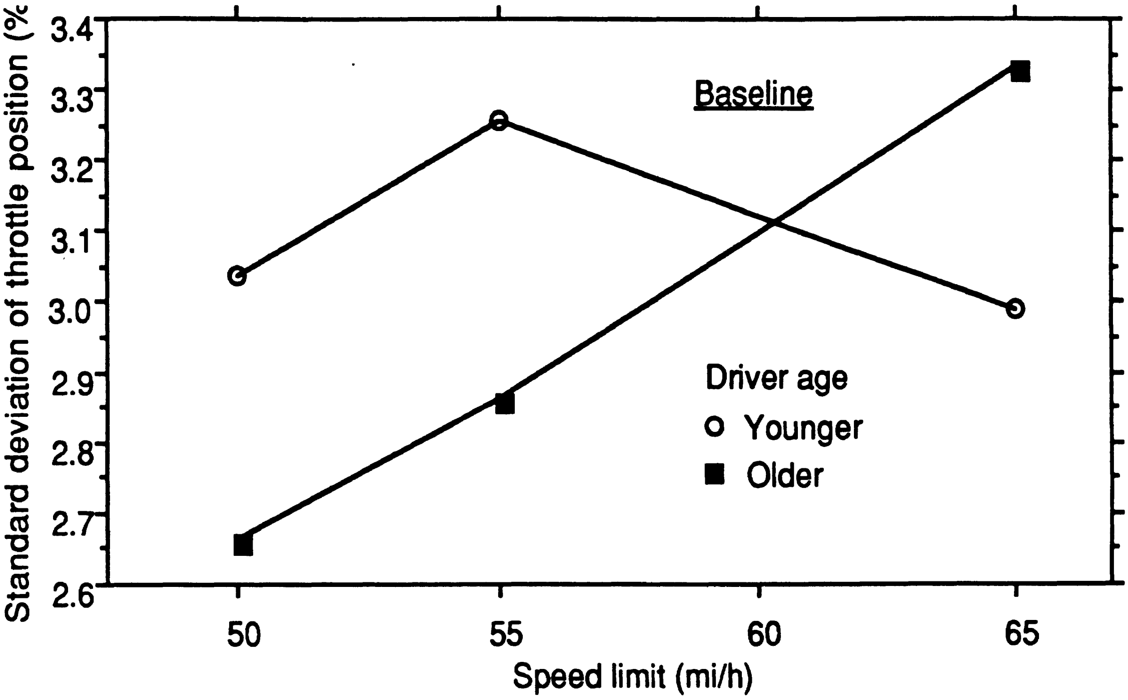


Figure 16. Standard deviation of throttle position as a function of speed limit and driver age.

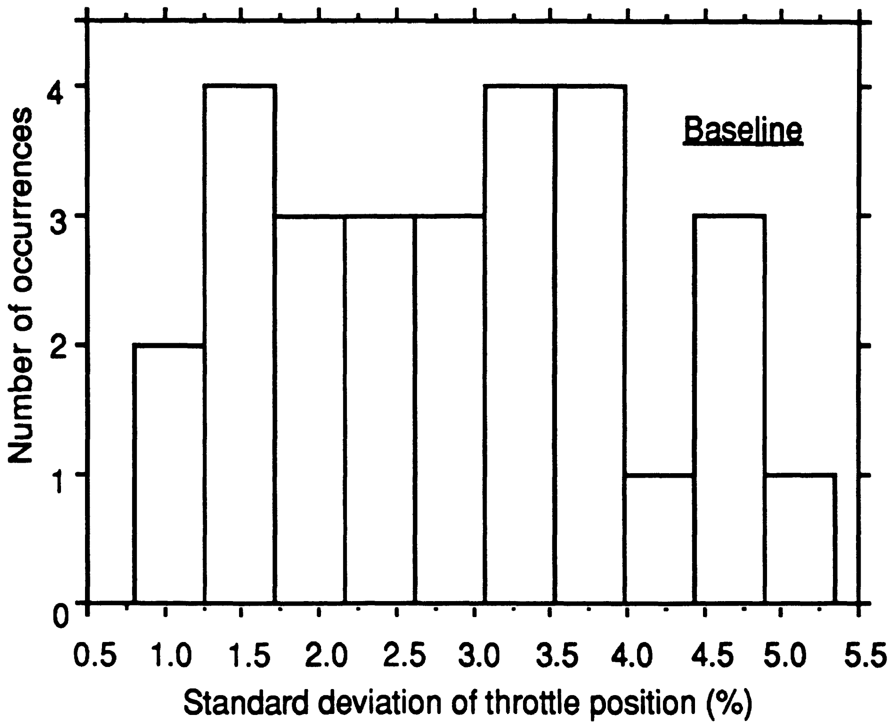


Figure 17. Distribution of standard deviation of throttle position for older drivers.

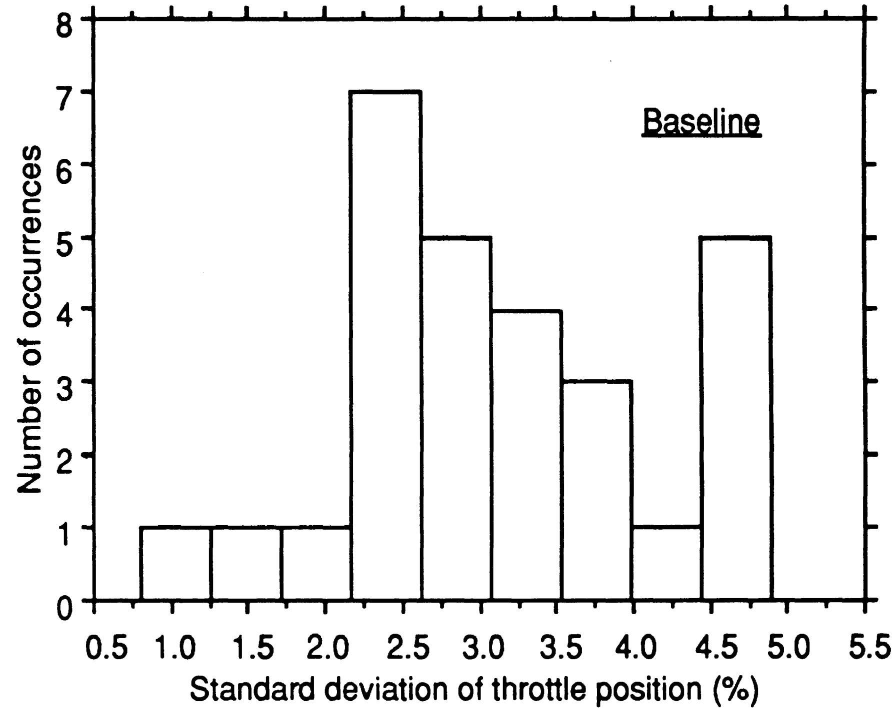


Figure 18. Distribution of standard deviation of throttle position for younger drivers.

Lateral Position

Figure 19 shows the distribution of lateral positions. Note that the distribution is not normal, with larger values being less common than smaller values. For 55 and 65 mi/h segments, mean lateral positions were symmetrically distributed around 3 ft. For 50 mi/h segments, there were some situations where participants drove closer to the left side of the lane. (See figure 20). It is difficult to determine if this difference is due to driver behavior or road widths.

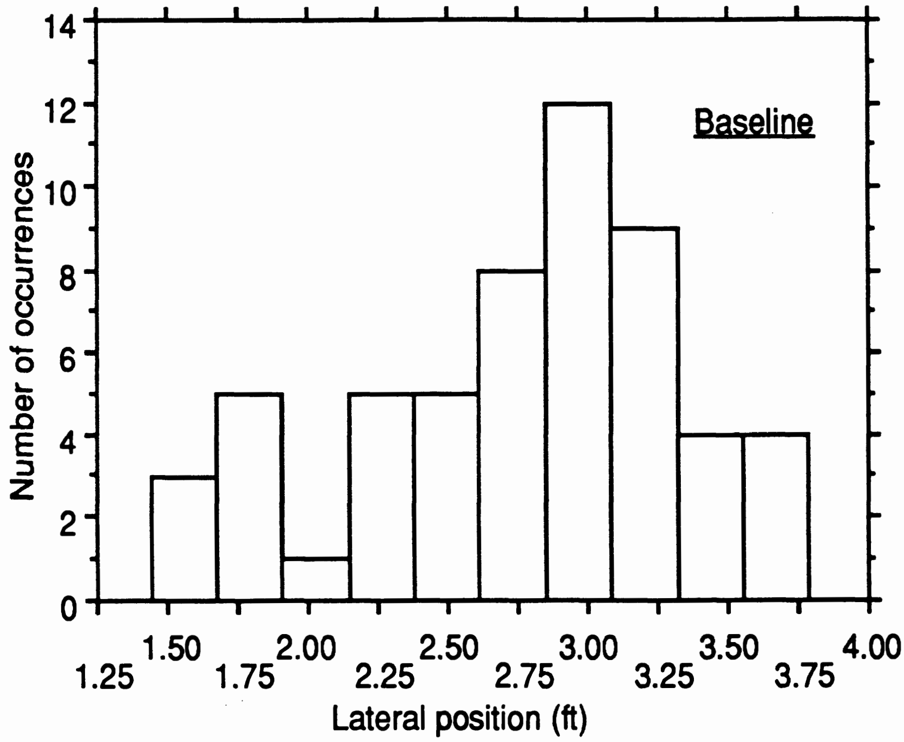


Figure 19. Distribution of mean lateral position for all baseline road segments.

An ANOVA of these data show significant effects of age ($F(1,50) = 23.25$, $p = 0.0001$), and of speed limit ($F(2,50) = 7.77$, $p = 0.0012$), but there was no age by speed limit interaction ($p = 0.48$). Younger drivers positioned the test vehicle farther to the left (2.4 feet (ft) from the left edge for younger drivers, and 3.1 ft for older drivers). It is not apparent why they did so. Figure 21 shows the means for lateral position for the 2 age groups and 3 speed limits.

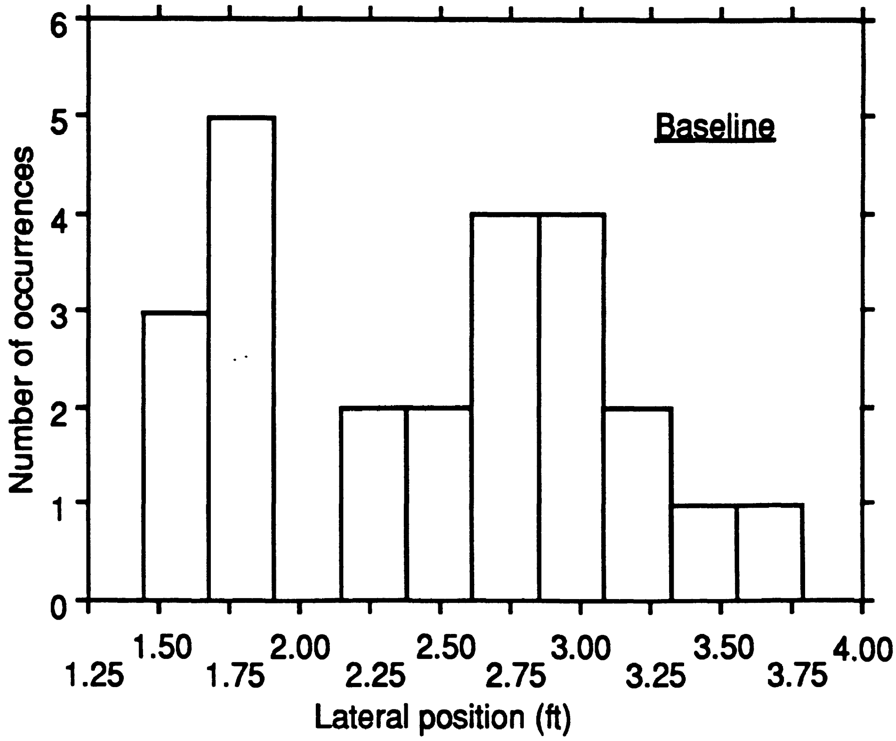


Figure 20. Distribution of mean lateral position for 50 mi/h limit.

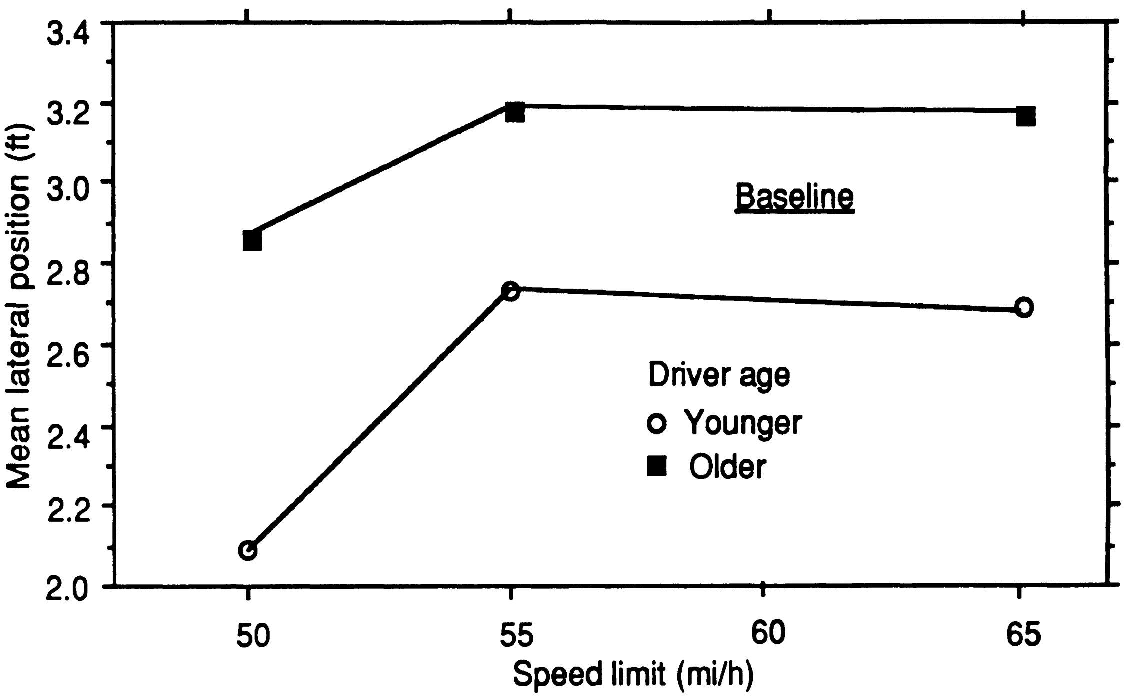


Figure 21. Lateral position as a function of speed limit and driver age.

Figure 22 shows the standard deviation of lateral position for the 7 baseline road segments collected from each of the 8 drivers. This data shows that approximately 0.5 ft is a typical value for the standard deviation of lateral position, a value that agrees with data in the literature.[18]

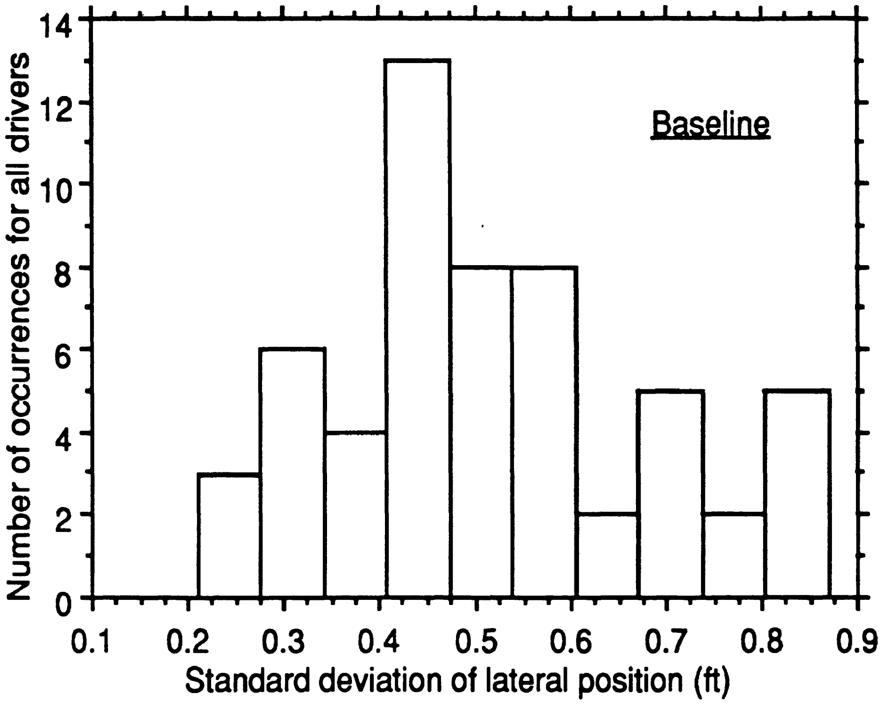


Figure 22. Distribution of standard deviation of lateral position.

An ANOVA of those data showed there was no effect of driver age (p =0.43) on the standard deviation of drivers' lateral position. There was only a slight tendency for older drivers to be more variable in their lateral position than younger drivers. In fact, the mean difference was 0.04 ft, less than the accuracy of the lane tracker (0.1 ft). The age by speed limit interaction also was not statistically significant (p = 0.99) for standard deviation of lateral position. There was an effect of speed limit ($F(2,50) = 3.98$), p = 0.03), with the standard deviation decreasing with speed. Figure 22 shows that relationship. Figures 24, 25, and 26 show the standard deviations for 50, 55, and 65 mi/h speed limit roads.

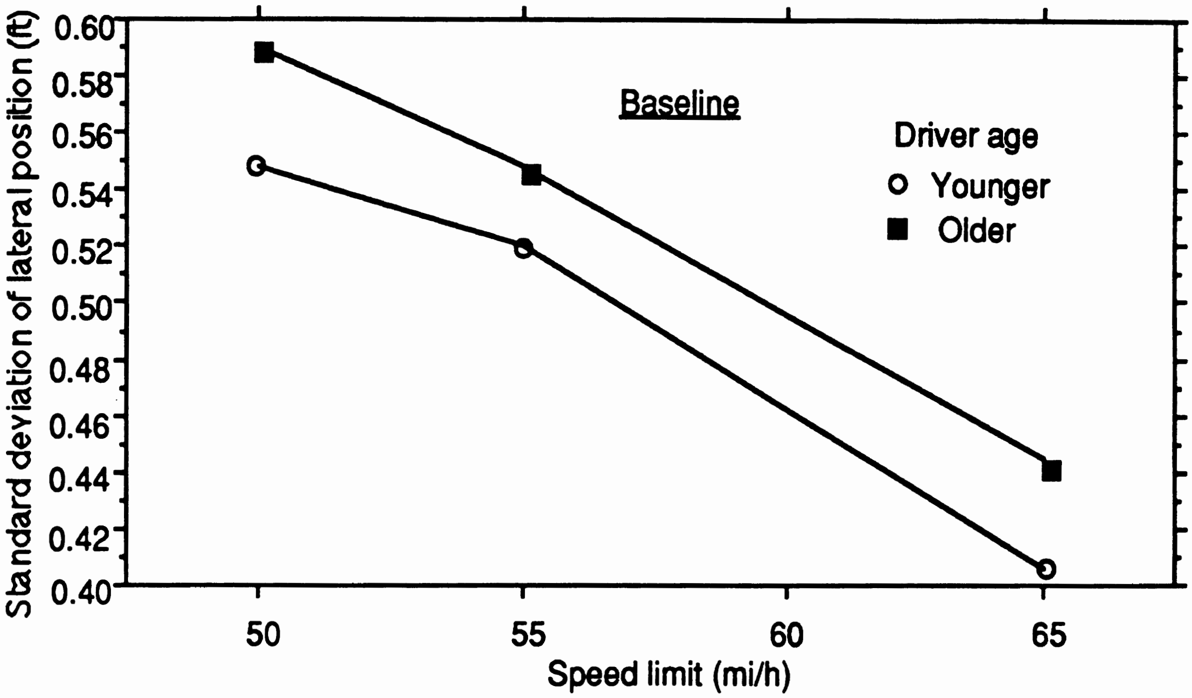


Figure 23. Standard deviation of lateral position as a function of speed limit and driver age.

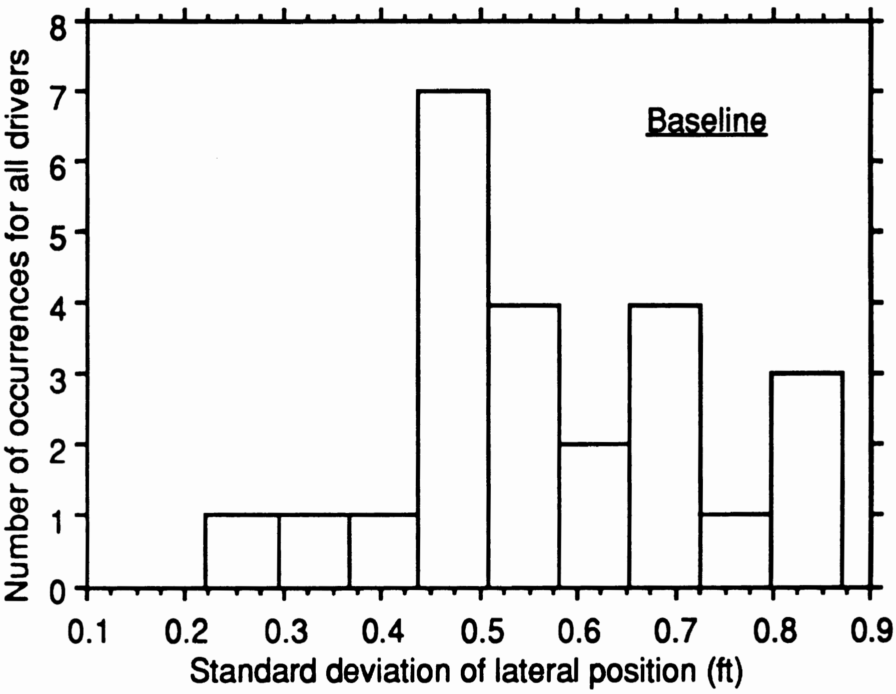


Figure 24. Distribution of standard deviation of lateral position for 50 mi/h limit.

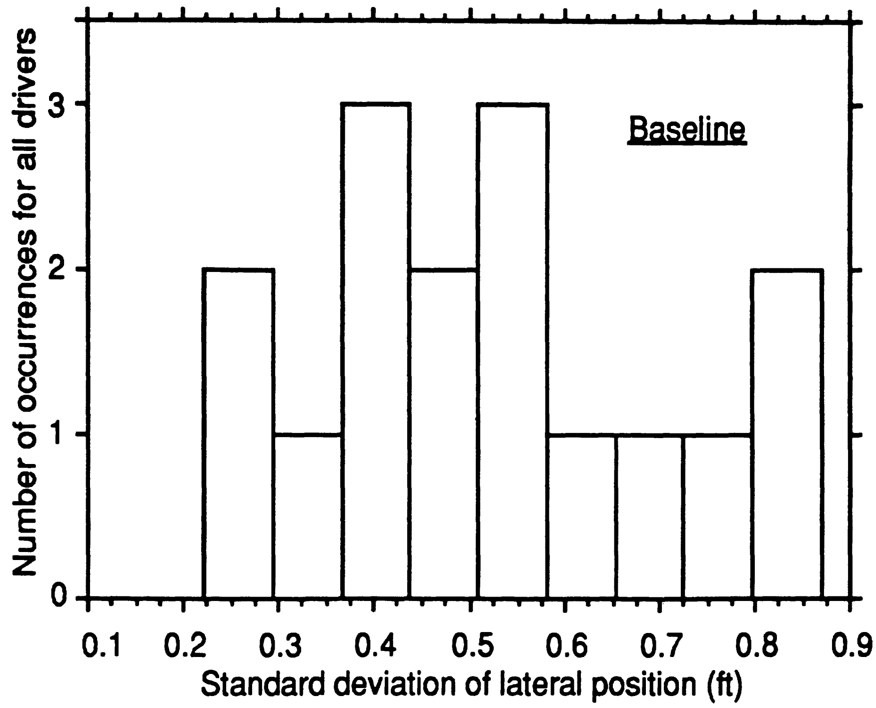


Figure 25. Distribution of standard deviation of lateral position for 55 mi/h limit.

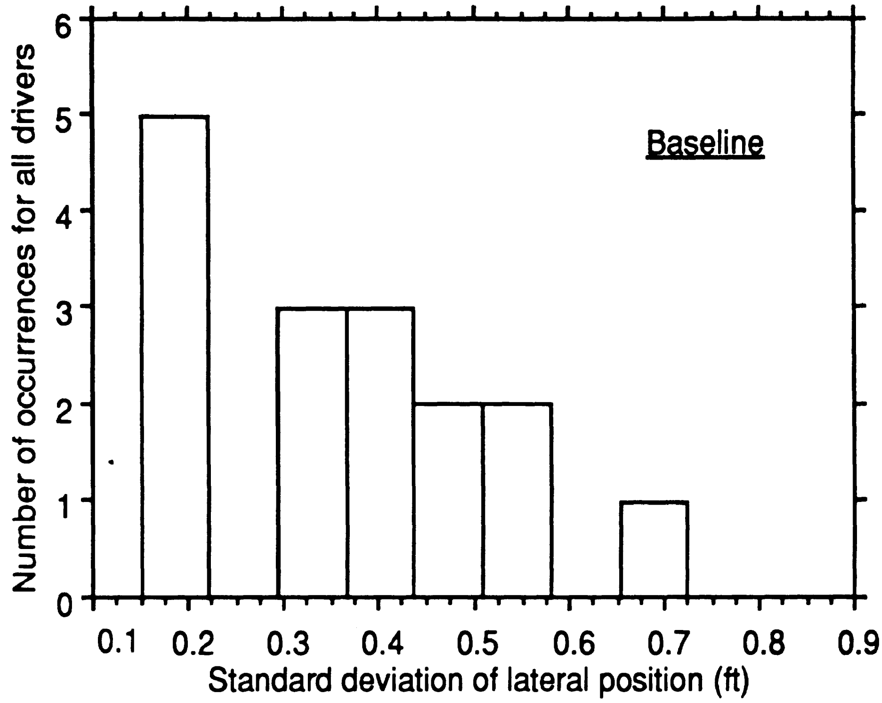


Figure 26. Distribution of standard deviation of lateral position for 65 mi/h limit.

Speed

Figures 27, 28, and 29 show the mean speeds driven for each of the three speed limits in the baseline condition. In the 50 mi/h sections, participants' mean speeds were clustered around that limit. In the 55 mi/h sections, however, they drove above the limit, while in the 65 mi/h section they drove below the limit. An ANOVA of the mean speeds showed no effect of driver age (p = 0.79). There was, however, a statistically significant difference in speeds due to speed limit ($F(2,50)$ = 102.40, p = 0.0001). The age by speed limit interaction was not significant (p = 0.11). Figure 30 shows that relationship.

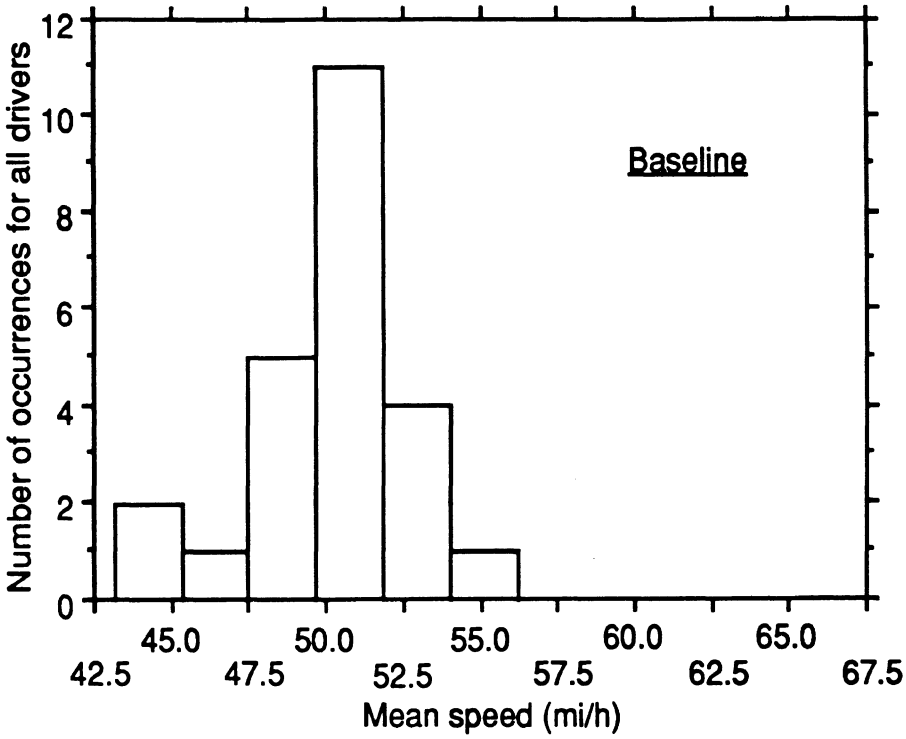


Figure 27. Distribution of speeds driven for the 50 mi/h speed limit.

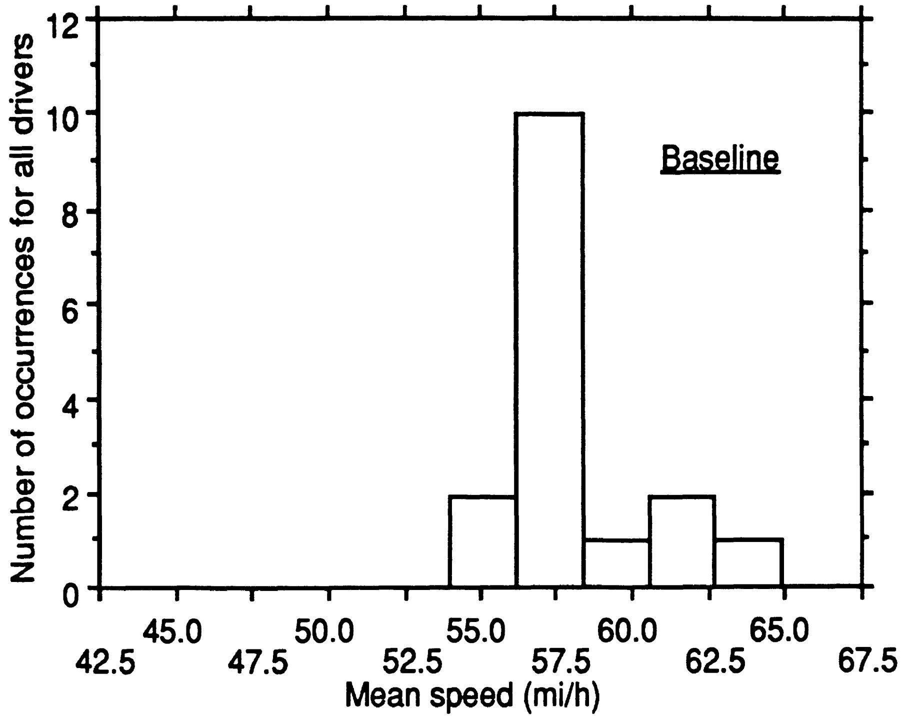


Figure 28. Distribution of speeds driven for the 55 mi/h speed limit.

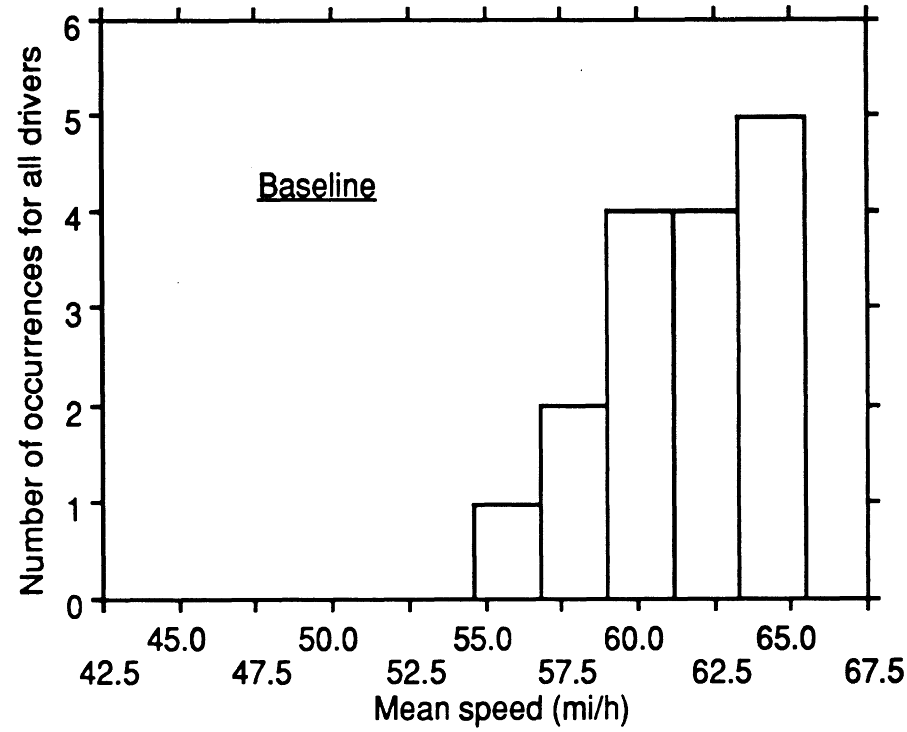


Figure 29. Distribution of speeds driven for the 65 mi/h speed limit.

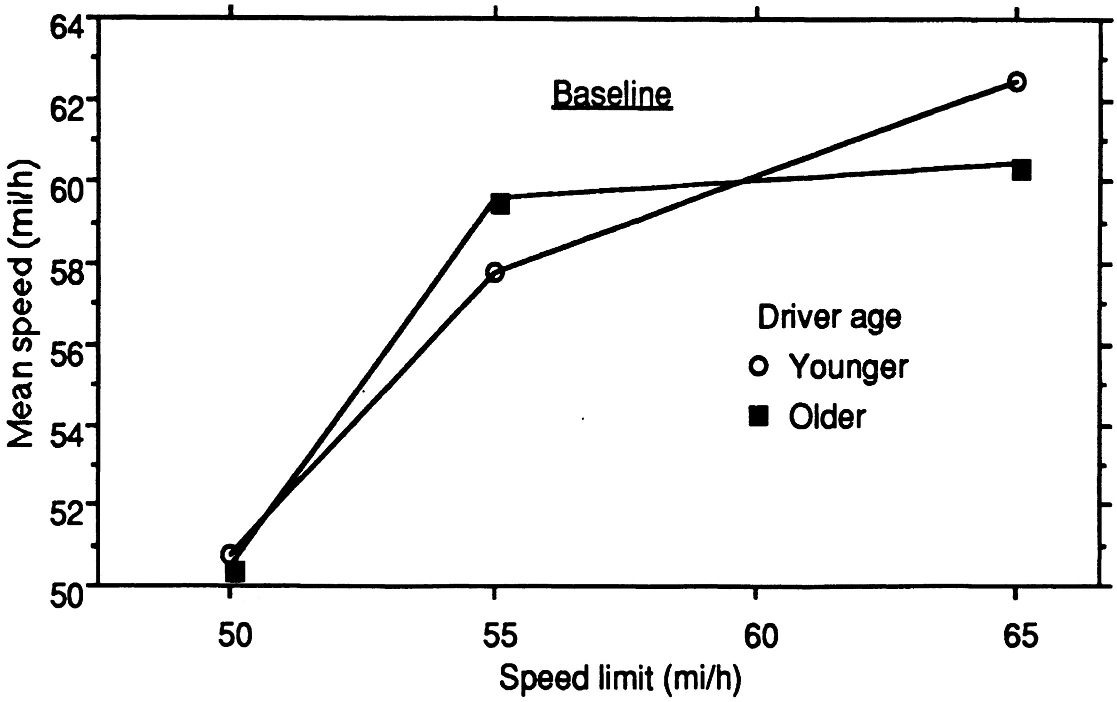


Figure 30. Mean speeds driven in the baseline sections as a function of speed limit and driver age.

Figure 31 shows the standard deviations of those mean speeds for the baseline road segments. The mean standard deviation was 1.1 mi/h. An ANOVA revealed no speed differences due to age (p = 0.64), though older drivers were very slightly more variable (1.5 versus 1.4 mi/h). Also not statistically significant was the effect of the speed limit (p = 0.56) or the speed limit by age interaction (p = 0.69) on the speeds driven by participants. Figure 32 shows the overall variations of the standard deviation of speed as a function of driver age and the speed limit.

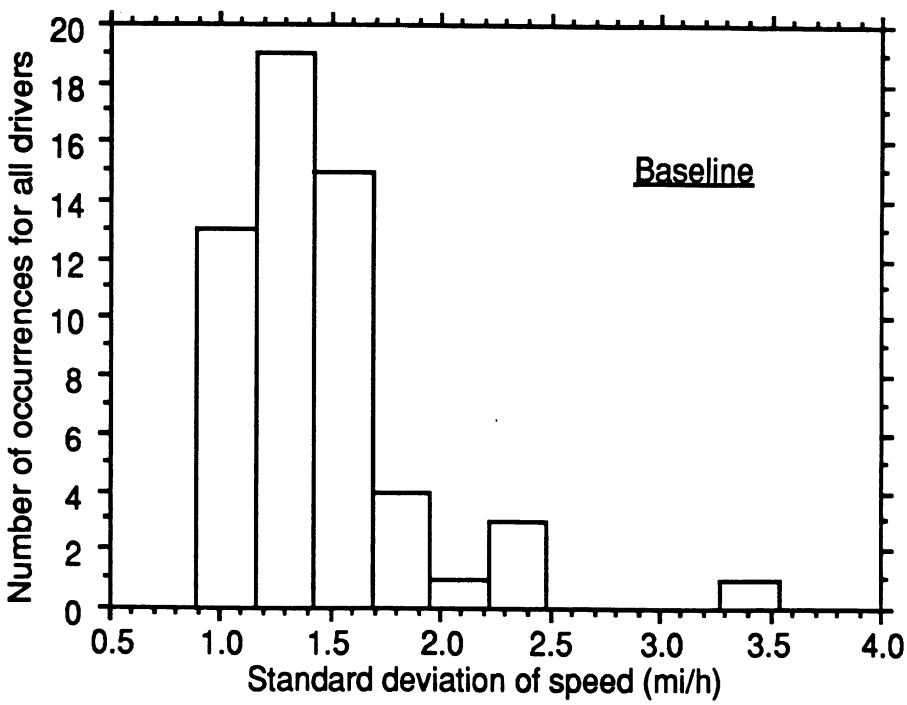


Figure 31. Distribution of the standard deviation of speeds.

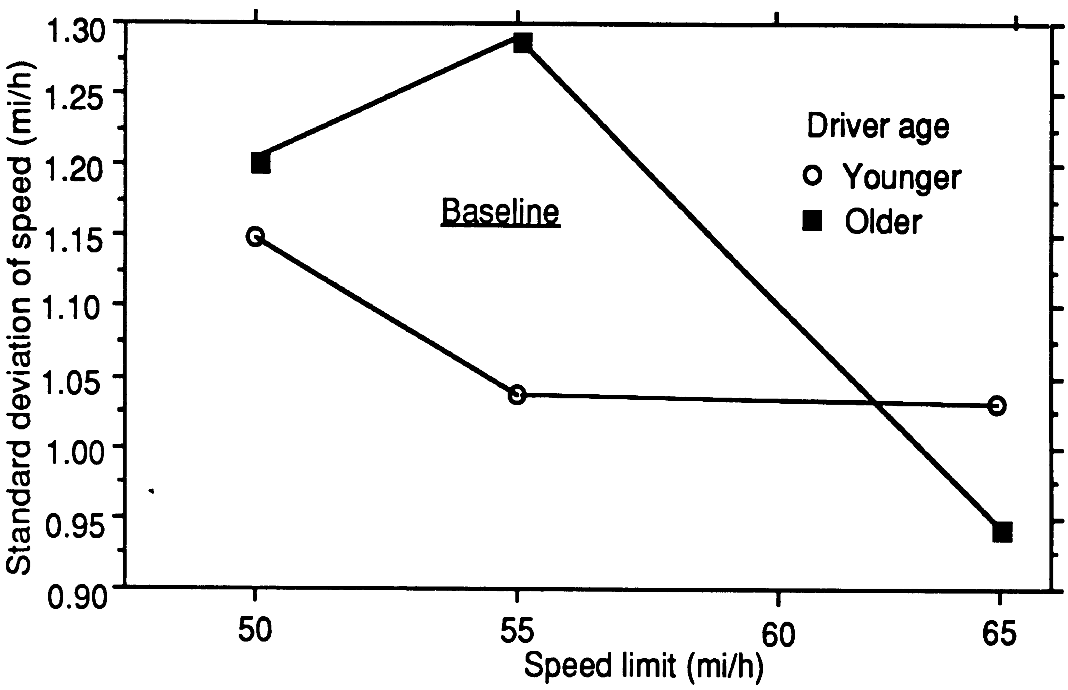


Figure 32. Standard deviation of speed as a function of speed limit and driver age.

Effects of Navigation System Use on Driving on Straight Roads

The analysis in this section is based on 48 data points (6 road segments by 8 drivers) for each dependent measure. As with the baseline data, subsets of the data (by driver age or speed limit) were also examined.

Steering Wheel Angle

Driving behavior while using the navigation system was examined for six road segments that were thought to be straight: Hannan Road to Michigan Avenue, I-275 to Ford Road, Huron River Drive, I-94 to I-275, Ecorse Road to Hannan Road, and Hannan Road to Van Born Road. These are different "straight" road segments than were used to collect baseline data. (See figure 8 above.) In fact, there were slight differences in the mean steering wheel angle due to road segment ($F(5,36) = 6.59$, $p < 0.0002$) with the Hannan Road to Michigan Avenue segment curving slightly to the left. The mean steering wheel angle was -16.4 degrees. For the Hannan Road to Michigan Avenue segment, it was -15.9 degrees, a very slight change. (See figure 33.) Differences due to age (-16.4 degrees for older drivers, -16.3 degrees for younger drivers) were not significant ($p = 0.19$) nor the interaction of age with road segment ($p = 0.96$).

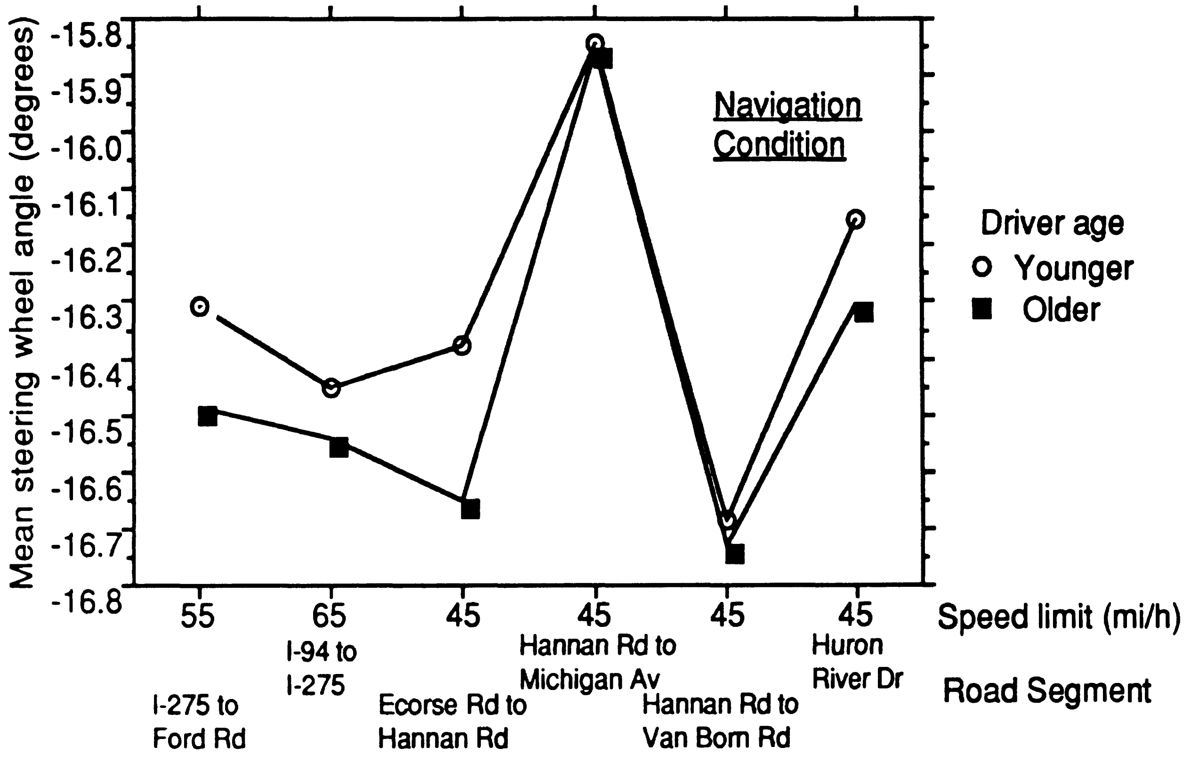


Figure 33. Mean steering wheel angle as a function of road segment and driver age.

Figure 34 shows the results for the standard deviation of steering wheel angle for various road segments; figure 35 shows the distribution. The mean was approximately 0.9 degrees. Both the effects of road segment ($F(5,36) = 2.68$, $p = 0.004$) and driver age ($F(5,36) = 2.68$, $p = 0.04$) were significant, but the interaction was not significant ($p = 0.91$). For the small changes in mean steering wheel angle shown here, there does not seem to be any relationship between the mean angle and its standard deviation, suggesting that the slight curvature of the road added little to the difficulty of driving.

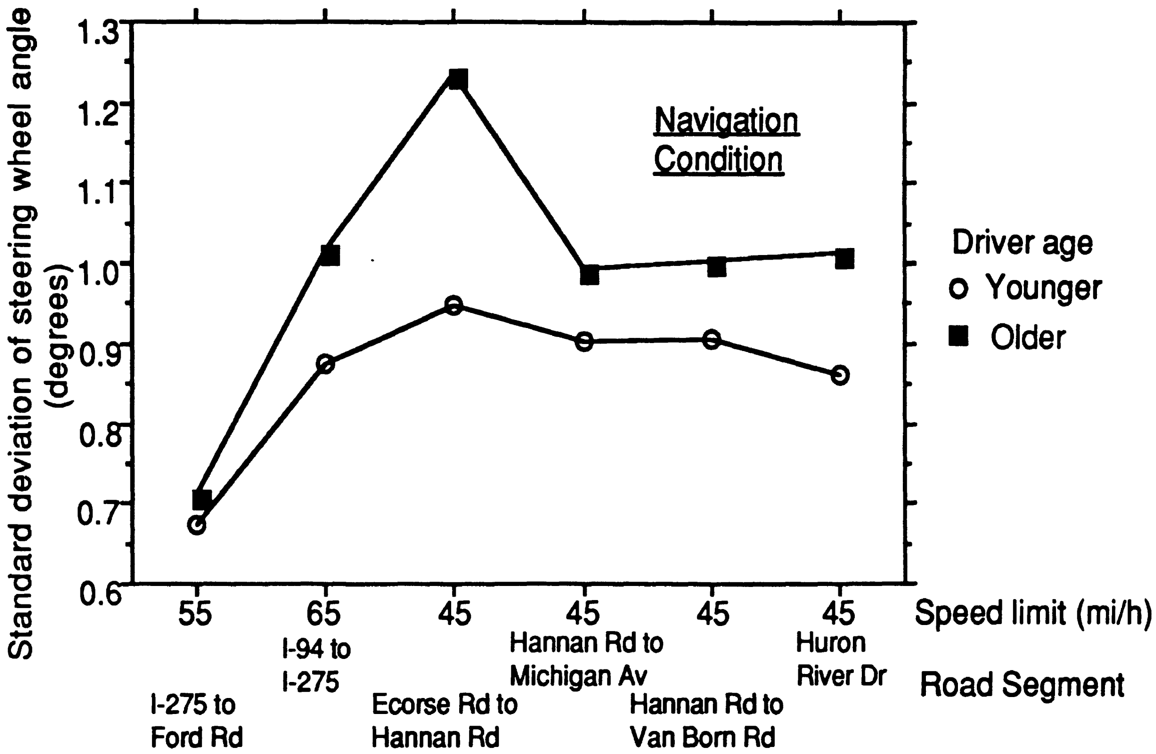


Figure 34. Standard deviation of steering wheel angle as a function of road segment and driver age.

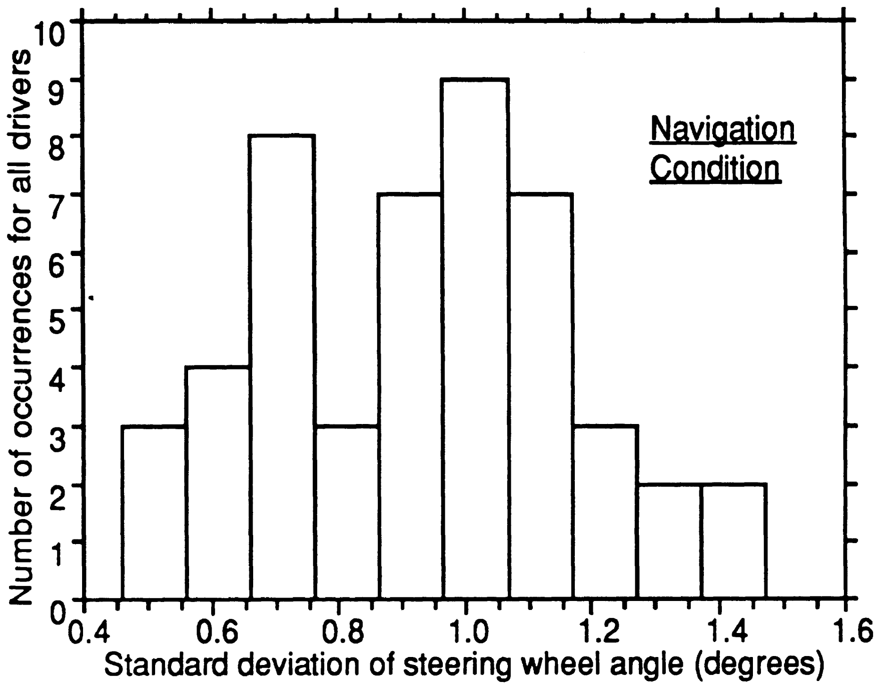


Figure 35. Distribution of standard deviation of steering wheel angle.

Throttle Position

In contrast to previous research within this project, the standard deviation of throttle position was insensitive to differences in driver age, road segments, or their interaction. (All p values were in excess of 0.5). Figure 36 shows the results, which seem random with regard to these factors.

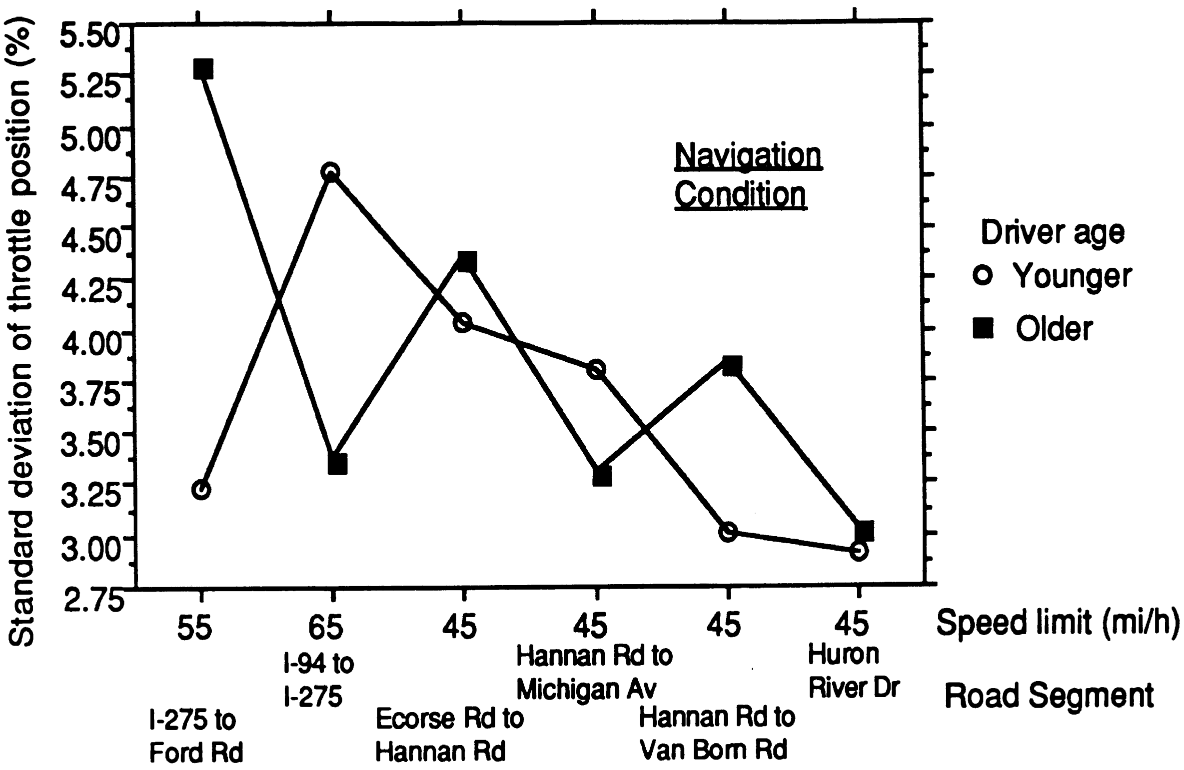


Figure 36. Standard deviation of throttle position as a function of road segment and driver age.

Lateral Position

The lateral position data showed interesting and consistent differences due to driver age ($F(1,36) = 15.84$, $p = 0.0003$) and road segment ($F(5,36) = 3.41$), $p = 0.013$). As shown in figure 37, there was no pattern to the interaction (and it was not significant).

Figures 38 and 39 show the distributions as a function of driver age. The means were 3.3 ft to the right of the left edge line for older drivers and 2.6 ft for younger drivers. This bias was also noted in the baseline condition. Lateral position for the older drivers was not normally distributed, an outcome probably due to the small sample size of drivers and differences in individual driver performance.

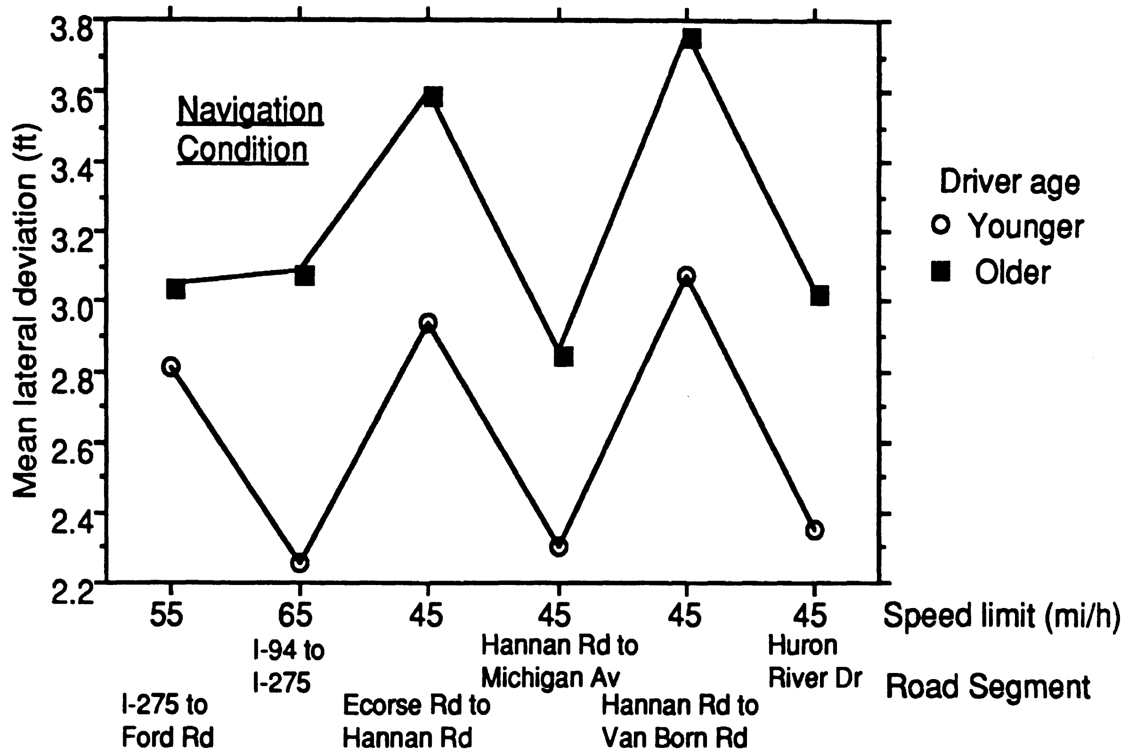


Figure 37. Mean lateral position as a function of road segment and driver age.

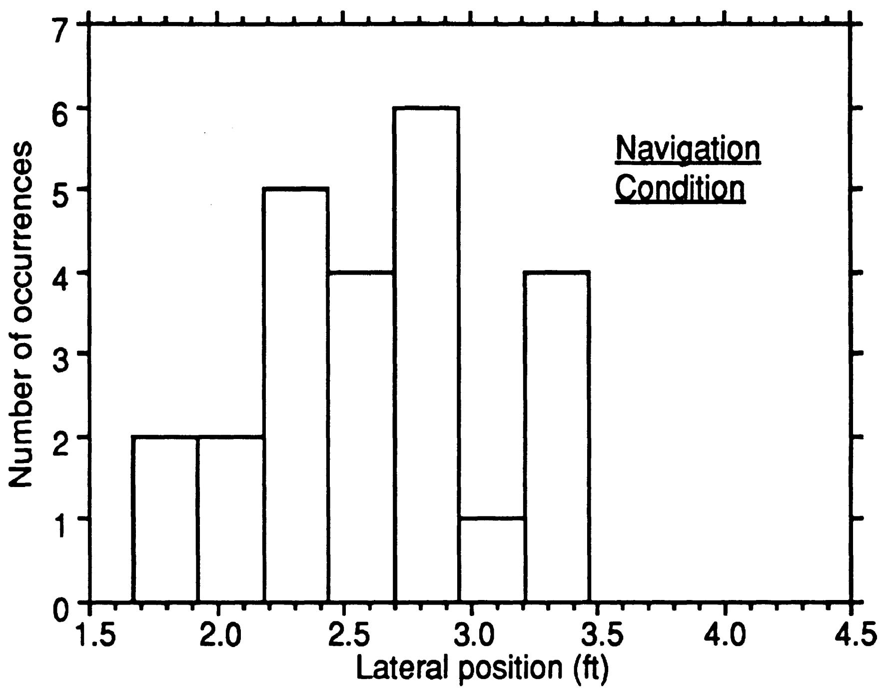


Figure 38. Distribution of lateral position for younger drivers.

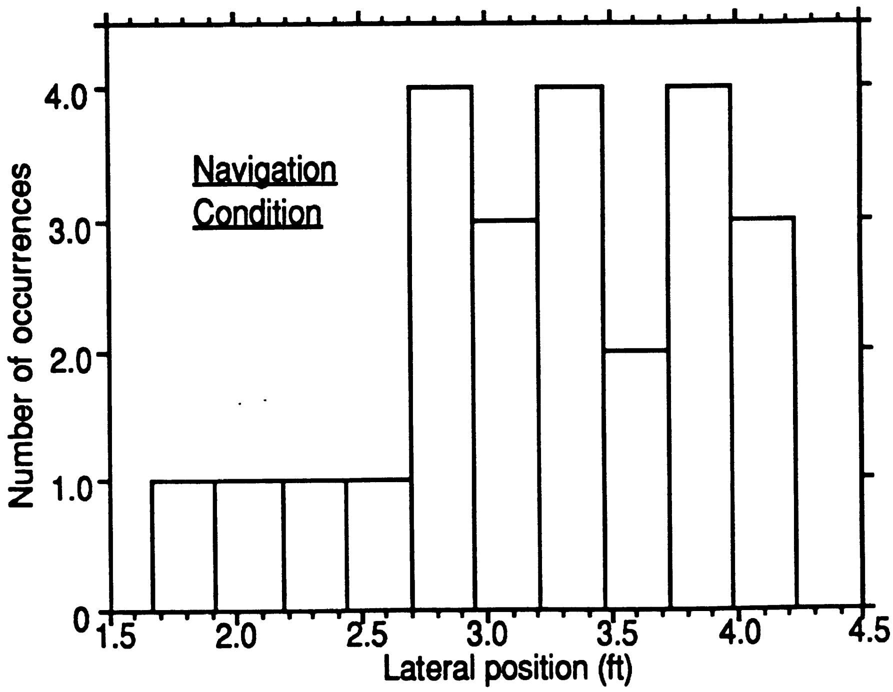


Figure 39. Distribution of lateral position for older drivers.

In contrast to previous findings, lateral standard deviations were not significantly affected by the road segment (p = 0.20) or driver age (p = 0.97). Figure 40 shows the results. The mean of the standard deviations was 0.6 ft, consistent with research reported elsewhere. Figure 41 shows the distribution of standard deviations, which is somewhat flat.

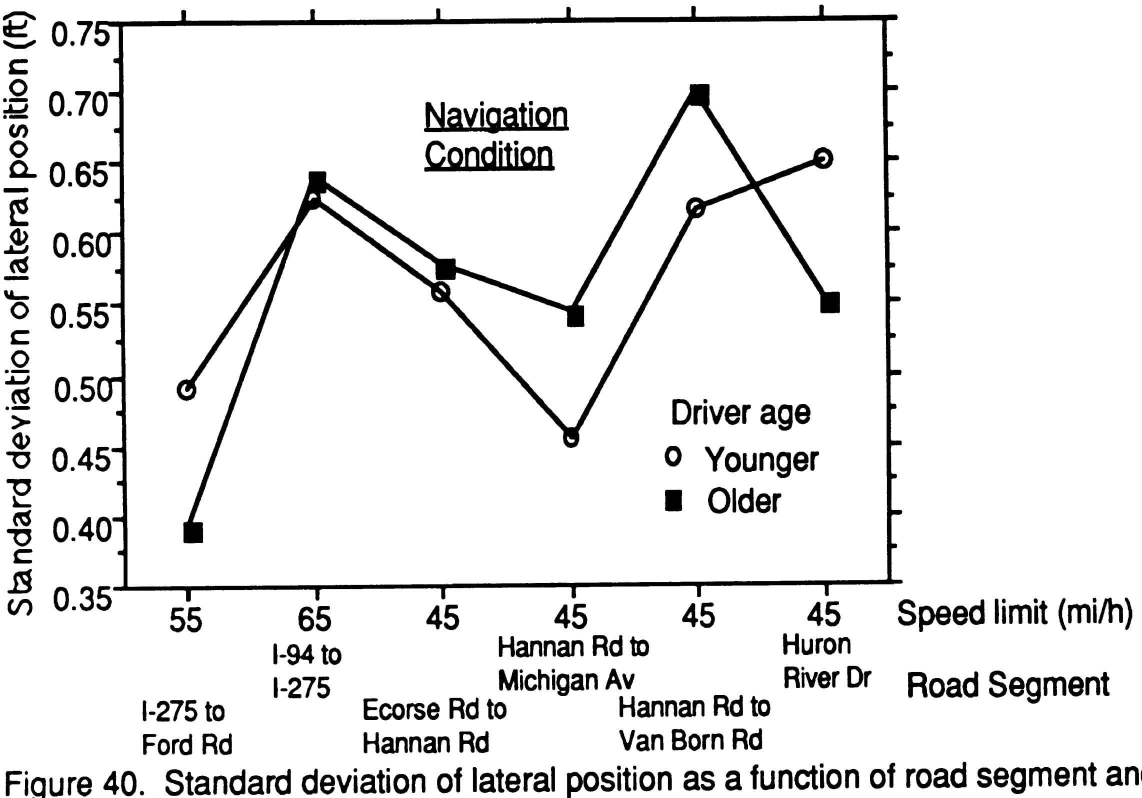


Figure 40. Standard deviation of lateral position as a function of road segment and driver age.

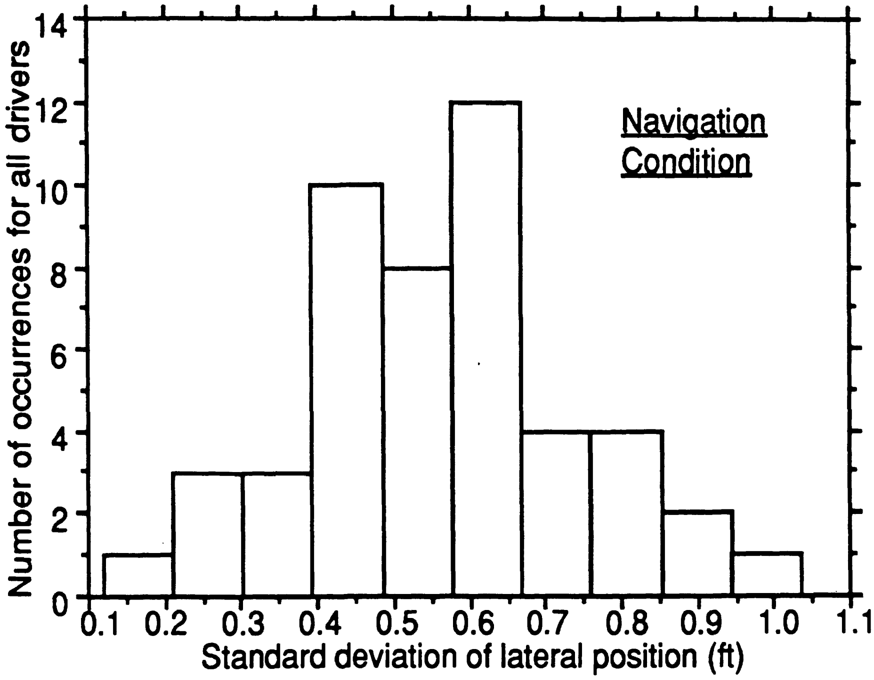


Figure 41. Distribution of standard deviation of lateral position.

Speed

Speed limits on the segments examined varied from 45 to 65 mi/h, and so too did the speeds driven ($F(1,36) = 559.87$, $p = 0.0001$). (See figure 8.) As expected, speed varied significantly with driver age ($F(1,36) = 41.47$, $p = 0.05$) with younger participants driving faster (by about 2 mi/h). There was a road segment by age interaction ($p = 0.85$). See figure 42. Also unaffected by road segment ($p = 0.74$) and age ($p = 0.84$) was the standard deviation of speed. (See figure 43.)

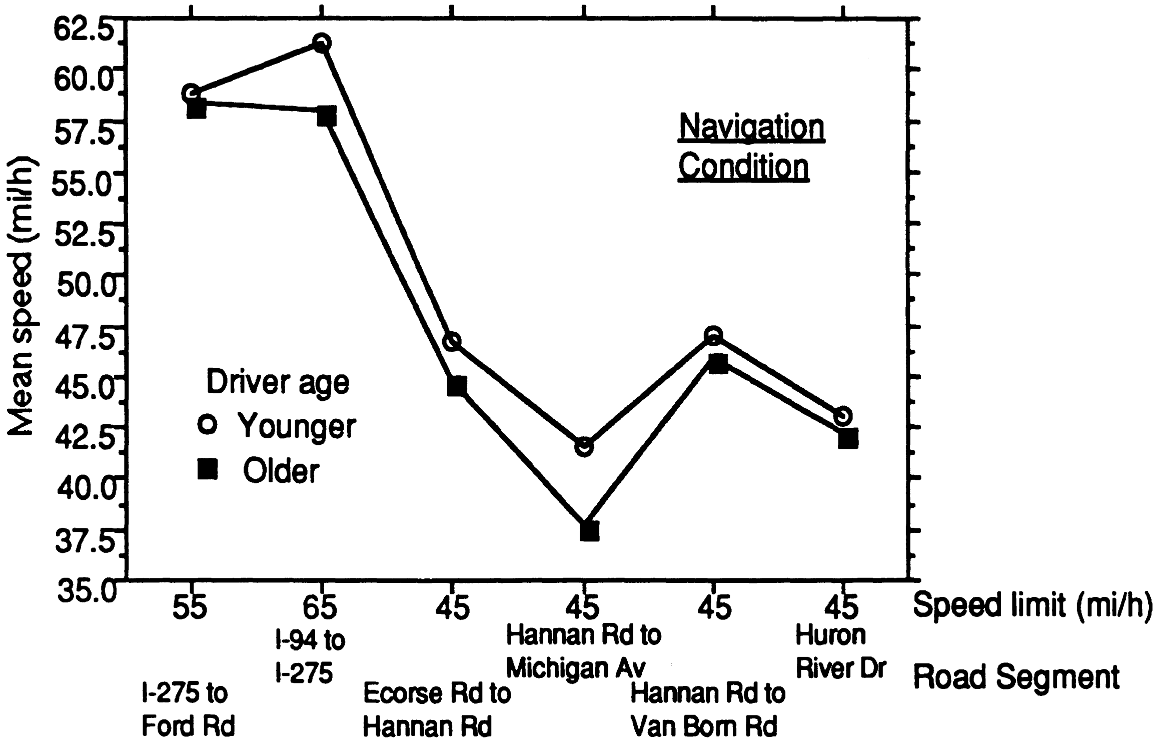


Figure 42. Mean speeds for various road segments and driver ages.

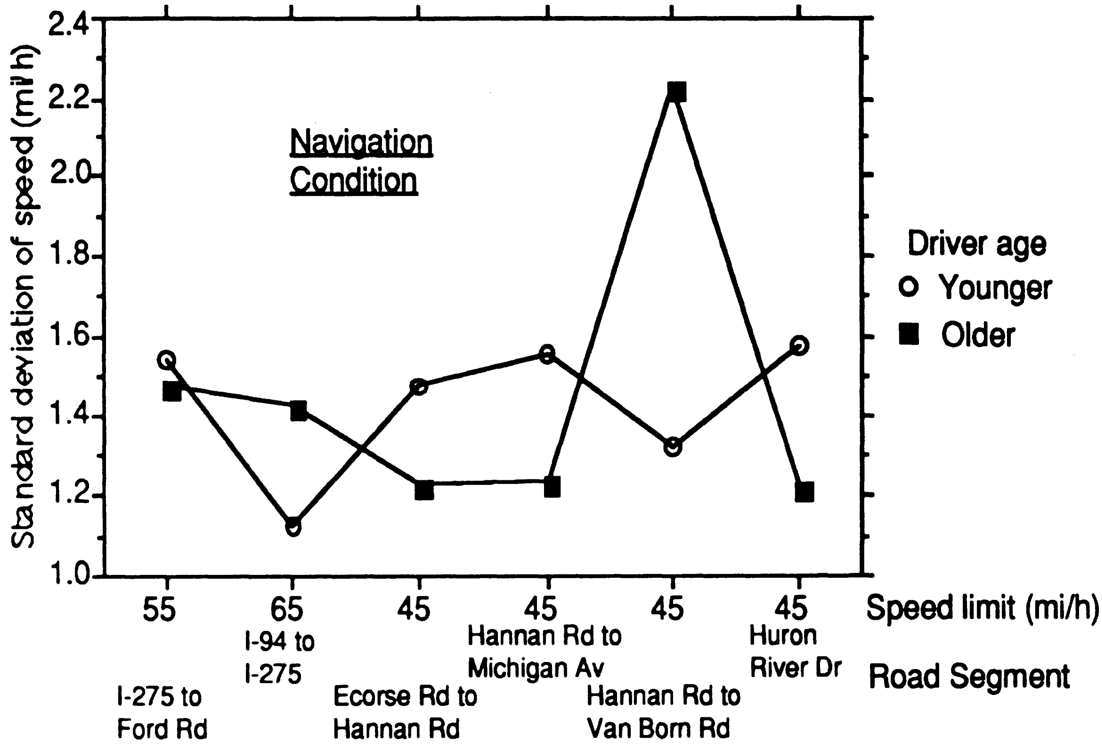


Figure 43. Standard deviation of speed for various road segments and driver ages.

Effects of Car Phone Use on Driving on Straight Roads

Dialing Times

Of particular interest are the four tasks associated with using the car phone and their effect on driving performance and behavior. As a reminder, the listening, listing, and talking tasks all had durations of approximately 30 seconds. Also, the "straight" road segments were different than those used for the baseline and navigation conditions (but the speeds were equivalent). The car phone analysis is based on as many as 192 data points (8 drivers by 6 segments by 4 tasks). For some of the measures a few data points were believed to be in error (due to sensor problems) and they were deleted from the analysis. In those cases the sample size is less than 192. For details of the test route, readers are referred to figure 8 above.

For the dialing task, the mean dialing time was 9.8 seconds (s) with a standard deviation of 4.2 s. (In the laboratory simulation, Serafin, Wen, Paelke and Green, the mean time was approximately 8.7 s, a 12 percent underestimate.)[11] This is a reasonable error given the small sample size.

Figure 44 shows the distribution of dialing times for the on-road experiment. The mean times for dialing the six calls (all for local, familiar phone numbers) were 8.5, 9.7, 9.4, 10.9, 9.2 and 11.0 s. The first 3 calls were made in a 50 mi/h road segment, and the last 3 calls in a 65 mi/h segment. For older drivers, the mean dialing time for calls was 10.7 s, and 8.8 s for younger drivers, a nonsignificant difference ($p = 0.12$). The effect of speed at which the car was driven also had no effect on dialing times ($p = 0.35$).

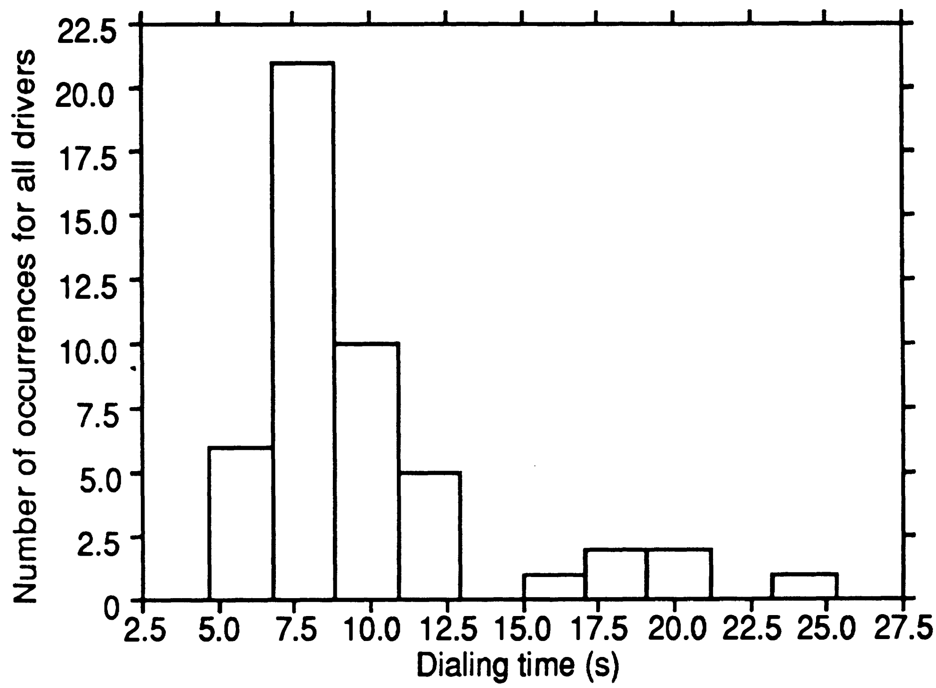


Figure 44. Distribution of phone dialing times.

Steering Wheel Angle

Six of the driver performance measures were examined separately in terms of how they were influenced by the concurrent phone tasks. In considering their effects, readers should bear in mind that the dialing episodes are very brief, less than 10 seconds. Obtaining useful comparative measures over that period is quite difficult.

An ANOVA of the mean steering wheel angles showed there were no differences due to road segment (p = 0.92), driver age (p = 0.32), or their interaction (p = 0.53). Mean steering wheel angles ranged from -16.0 to -16.4 degrees.

An ANOVA of the steering wheel standard deviation reflected a pattern that was similar to the baseline and navigation data. There was a significant effect of driver age ($F(1,84) = 9.26$), p = 0.0031). The effect of road segment was almost significant ($F(5,84) = 1.89$), p = 0.11). (See figure 45.)

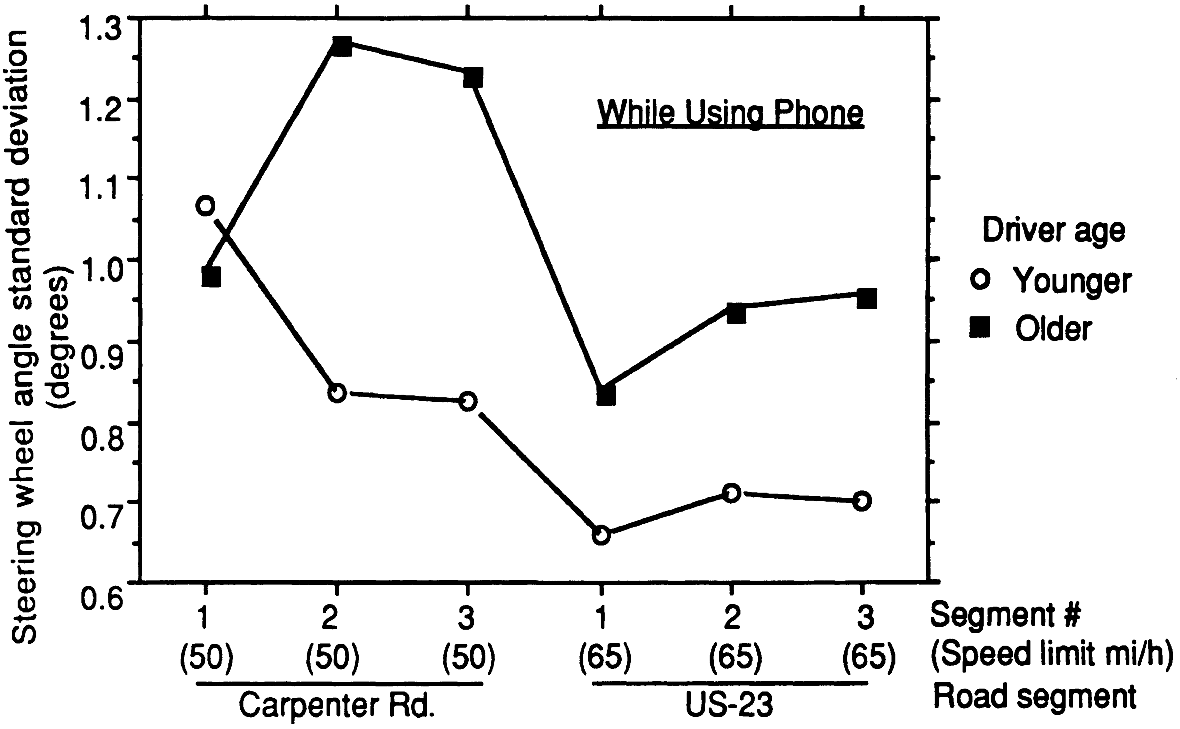


Figure 45. Standard deviation of steering wheel angle as a function of road segment and driver age.

When the data were repartitioned by task and driver age, there were significant differences due to tasks ($F(3,88) = 5.30$, p = 0.003). At face value, these data suggest that the conversation tasks were all equally difficult, and that the dialing task was more difficult (more distracting) than the conversation tasks. Again, the sampling interval for the dialing task was one-third of that for the other tasks, which may explain some of the differences. When pooled across road segments, as before, there was also a significant difference due to driver age ($F(1,88) = 6.00$, p = 0.02), but no interaction of age with task (p = 0.63). The mean of the standard deviation of steering wheel angle was 1.04

for older drivers. For younger drivers it was 0.80. Figure 46 shows the pattern of results.

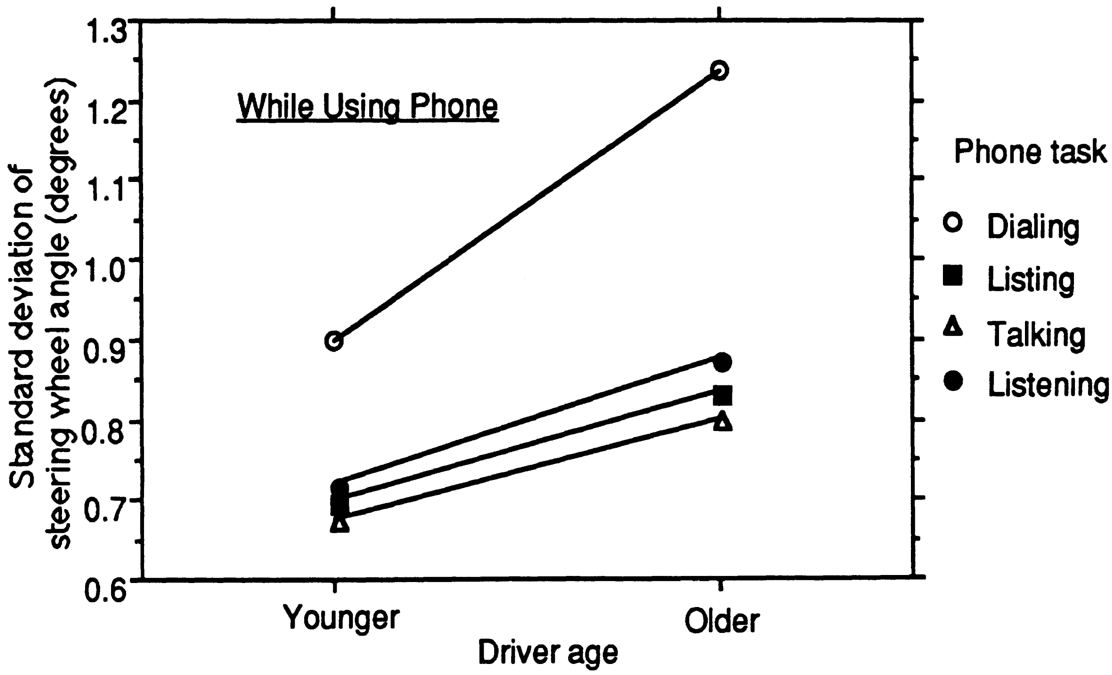


Figure 46. Standard deviation of steering wheel angle as a function of phone task and driver age.

Throttle Position

An ANOVA of the throttle standard deviations showed no effect of road segment ($p = 0.52$). The standard deviation of throttle position was significantly affected by the task ($F(3,88) = 3.57$, $p = 0.02$), but not driver age ($p = 0.12$) or the interaction with age ($p = 0.22$). Figure 47 shows these relationships. In contrast to the steering wheel standard deviations, these data suggest that the talking task was more difficult while the dialing task was relatively easier. It is not apparent why this occurred.

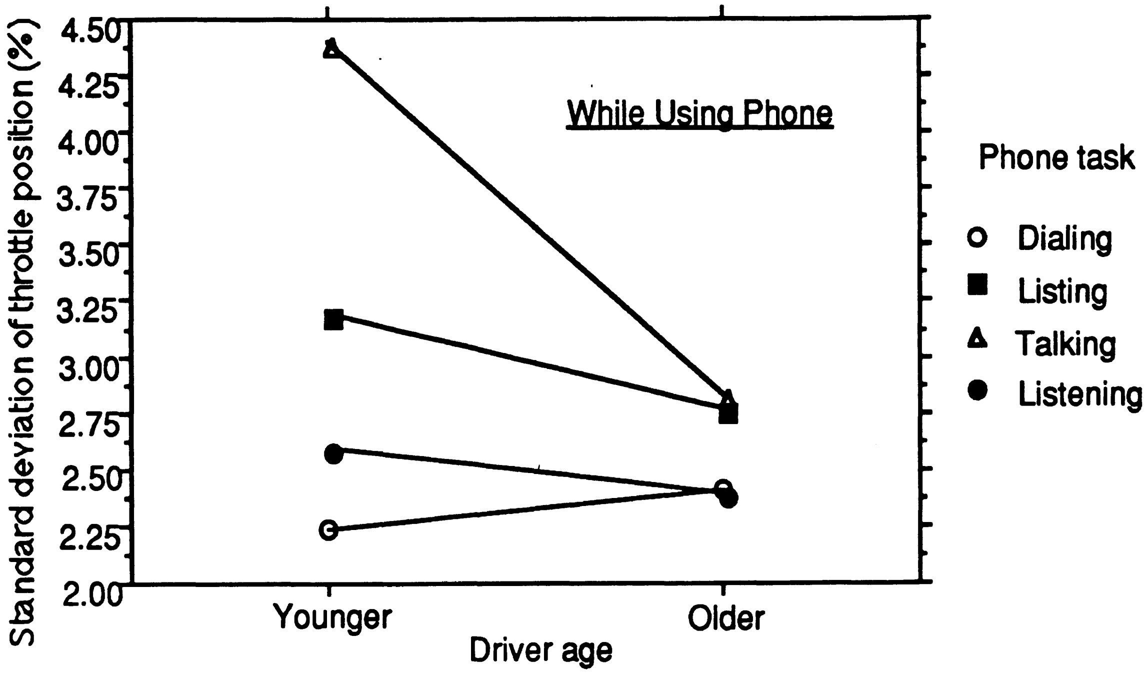


Figure 47. Standard deviation of throttle position as a function of phone task and driver age.

Lateral Position

The mean lateral position was 2.74 ft with a standard deviation of 0.71. Figure 48 shows the distribution of lateral positions. Lateral position was unaffected by the task ($p = 0.23$) but was affected by driver age ($F(1,88) = 4.64$, $p = 0.003$). There was no task by age interaction ($p = 0.85$). Figure 49 shows this relationship. Older drivers positioned the test vehicle closer to the center of the lane (3.0 ft to the right of the left edge versus 2.5 ft for younger drivers). This bias occurred for all road segments as shown in figure 50. (The differences between segments were significant, ($F(5,84) = 2.35$, $p = 0.0001$), with most of the difference occurring at one segment on Carpenter Road.)

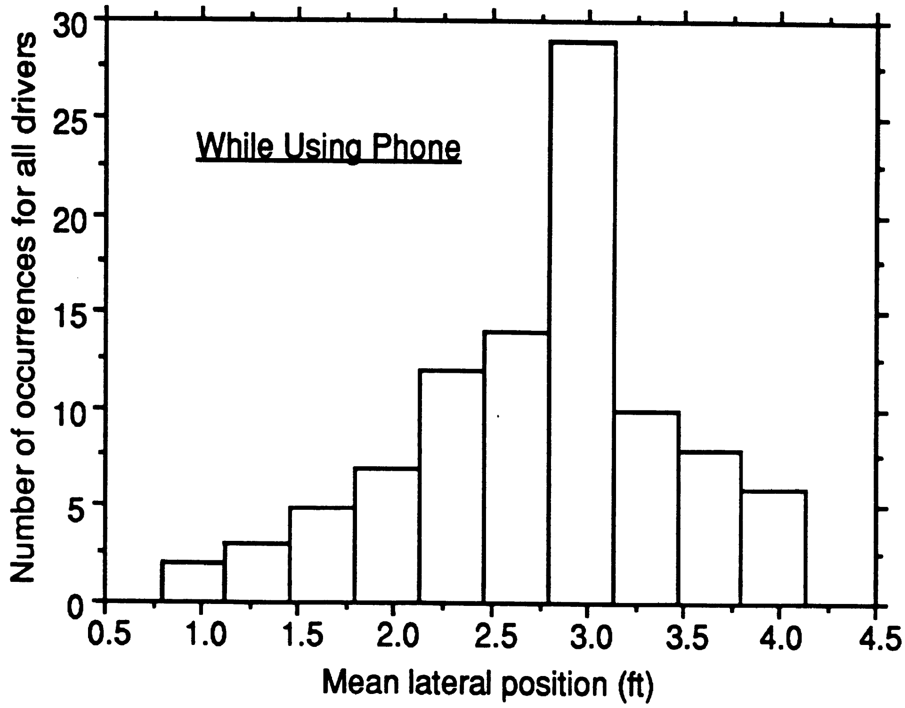


Figure 48. Distribution of lateral position for phone tasks.

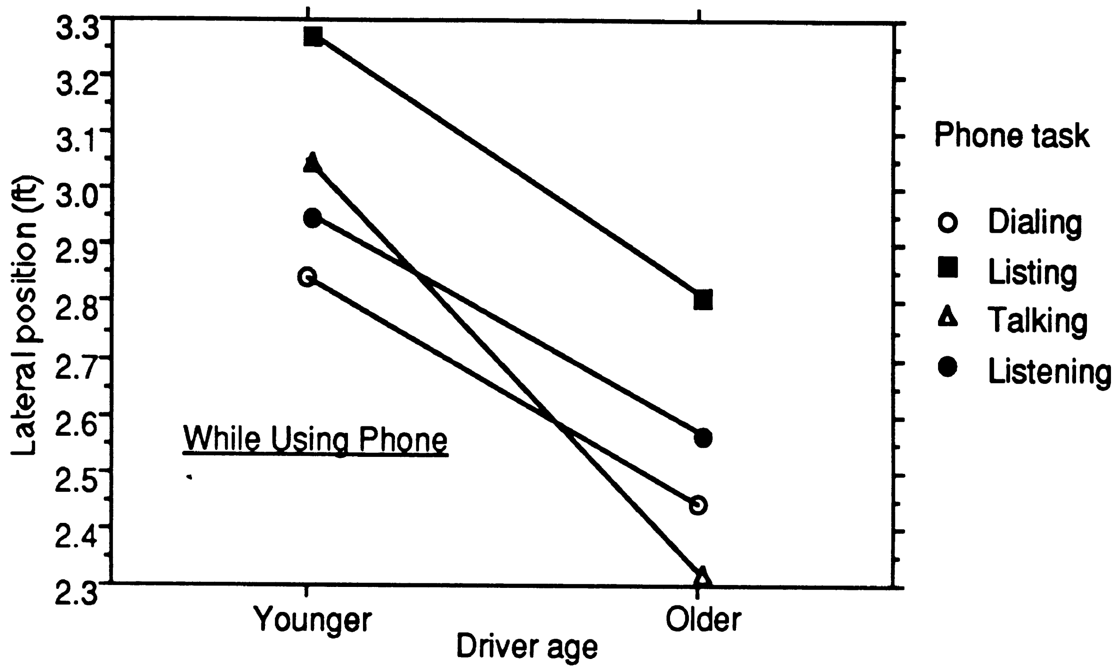


Figure 49. Lateral position as a function of phone task and driver age.

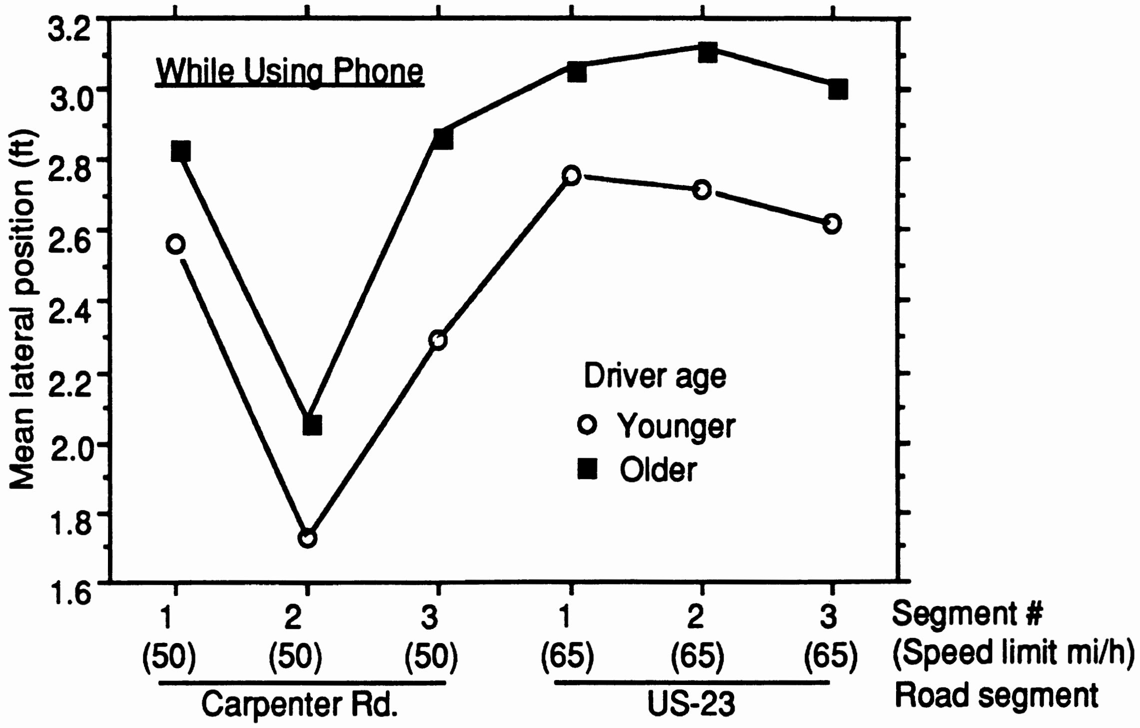


Figure 50. Lateral position as a function of road segment and driver age.

The mean lateral standard deviation was 0.43 with a standard deviation of 0.17. Figure 51 shows the distribution which is log normal. As with the other characteristics measured, there were significant differences between segments, with the primary difference being road type ($F(5,84) = 8.80$, $p = 0.0001$). Figure 52 shows the differences between road segments. None of the variables of interest (task, $p = 0.36$; driver age, $p = 0.29$; or their interaction, $p = 0.86$) had a significant effect on lateral standard deviation. Figure 53 shows the means.

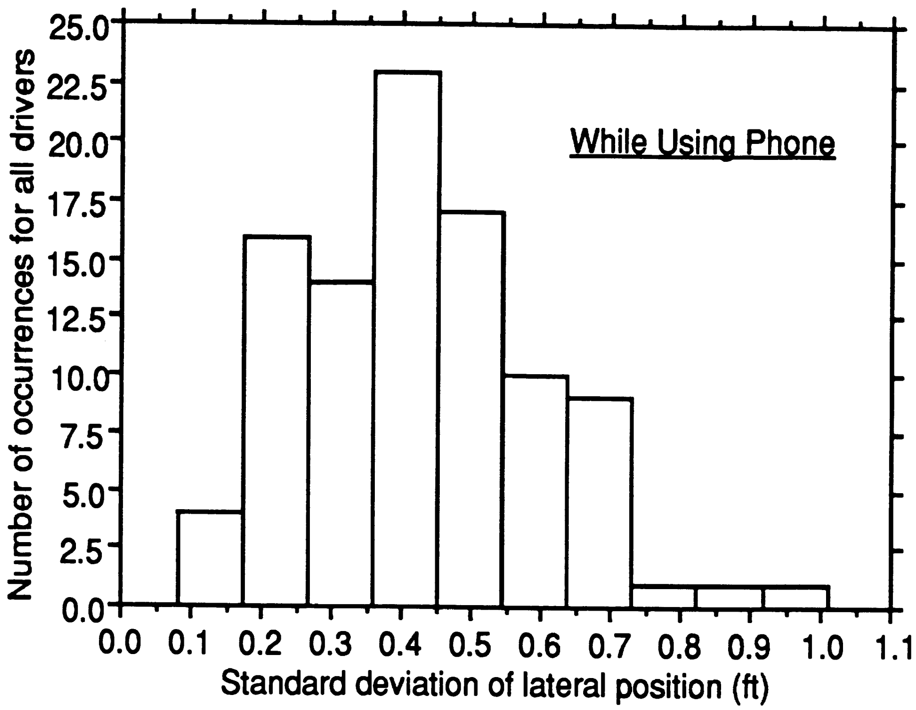


Figure 51. Distribution of standard deviation of lateral position.

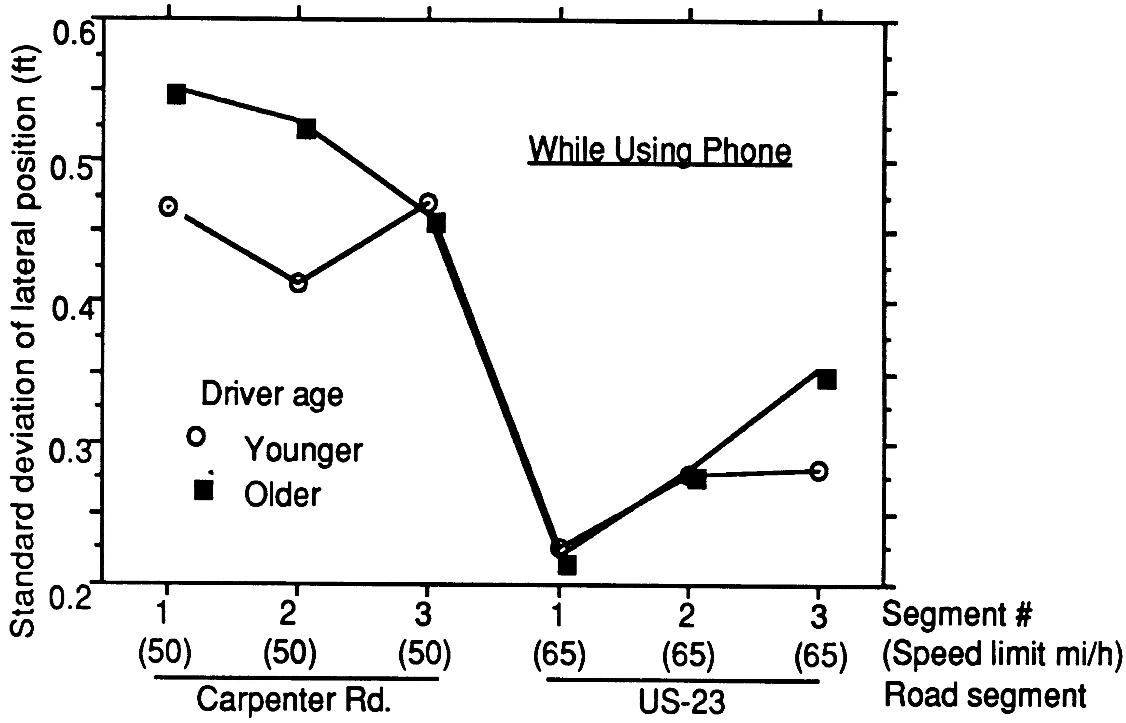


Figure 52. Standard deviation of lateral position as a function of road segment and driver age.

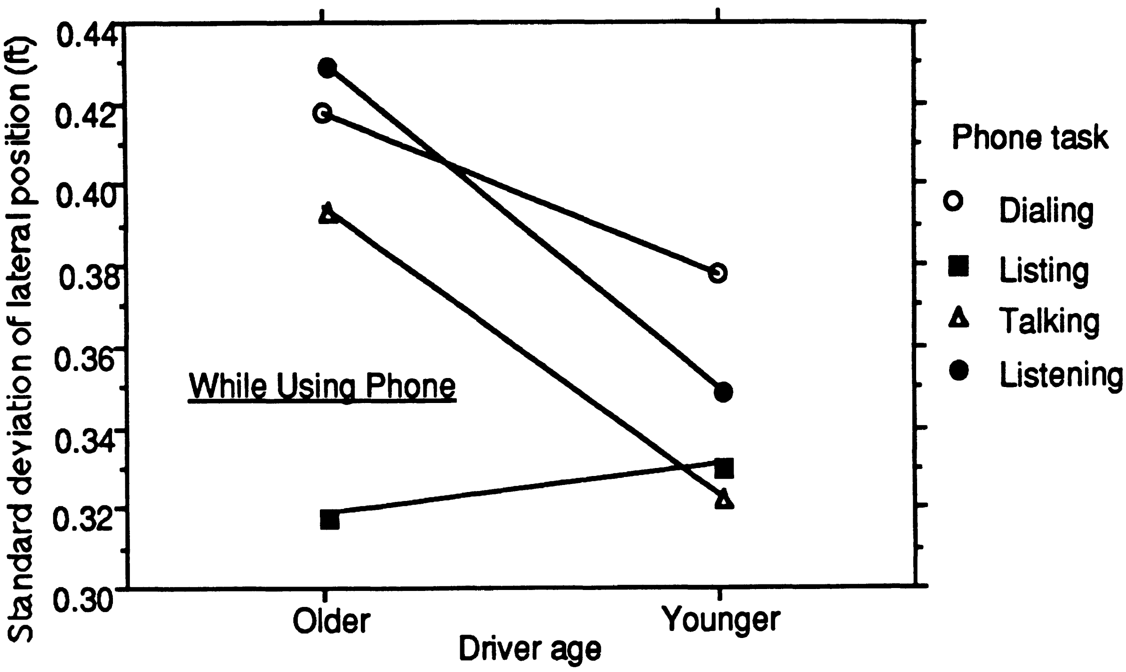


Figure 53. Standard deviation of lateral position as a function of phone task and driver age.

Speed

As shown in Figure 54, there were significant differences in the ANOVA of mean speed due to the road segment ($F(5,84) = 58.3$), $p = 0.0001$) while using the phone. (See figure 8 for the locations.) In that ANOVA there were also significant differences due to driver age ($F(1,84) = 14.28$, $p = 0.0003$) and their interaction ($F(5,84) = 2.44$, $p = 0.04$). The differences in speed between younger and older drivers was only evident on the expressway.

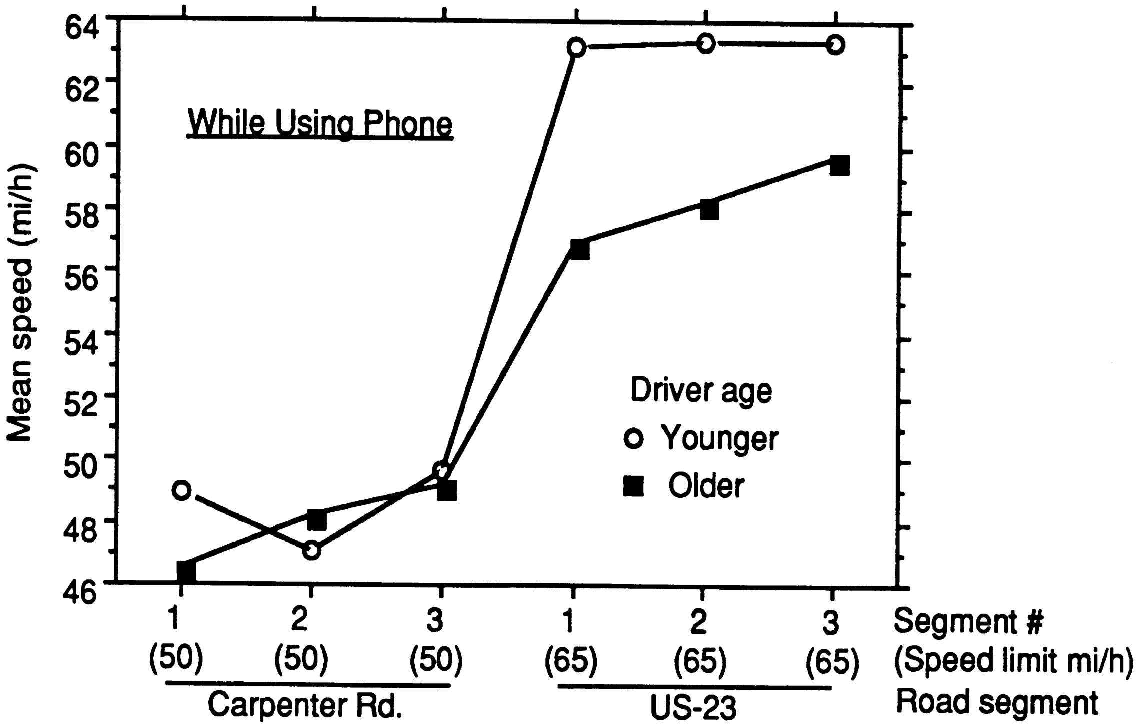


Figure 54. Mean speed as a function of road segment and driver age.

When the data are collapsed across road segments for mean speed, none of the factors (phone task, $p = 0.54$; age, $p = 0.07$, or their interaction, $p = 0.92$) were significant. Figure 55 shows the means. Thus, if there were differences in task difficulty (probably subtle), they were not reflected in how fast participants drove. As a reminder, the order of phone tasks and the locations at which they were completed were the same for all drivers.

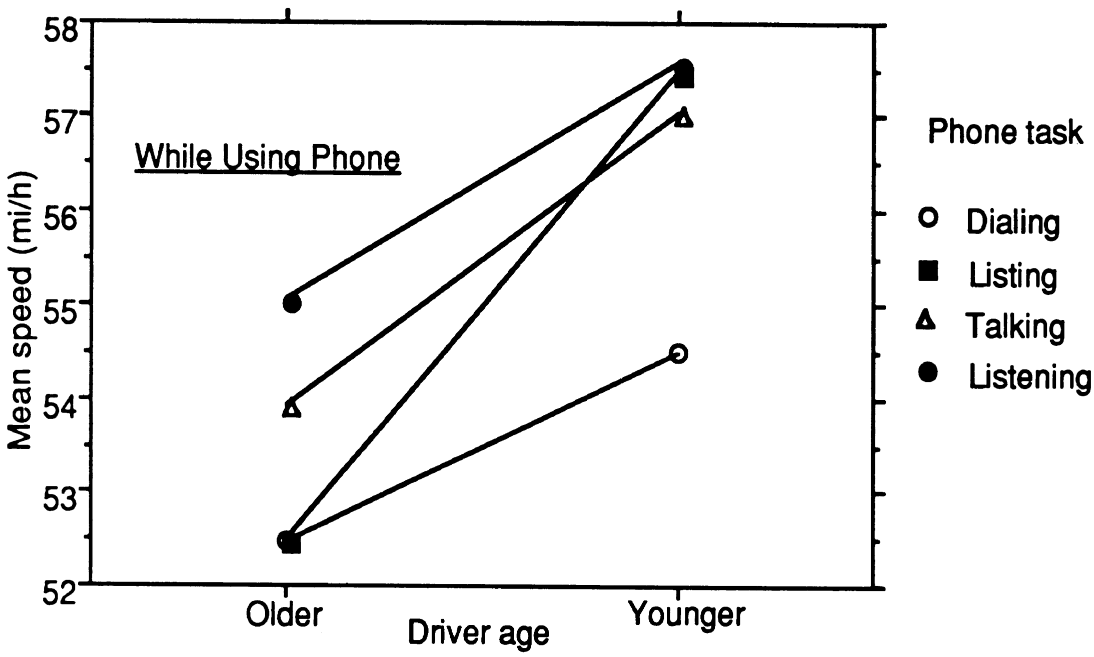


Figure 55. Mean speed as a function of phone task and driver age.

Finally for the standard deviation of speed, there were differences between road segments ($F(5,84) = 3.17$, $p = 0.01$) but these were not due to driver age ($p = 0.36$) or their interaction ($p = 0.26$). (See figure 56.)

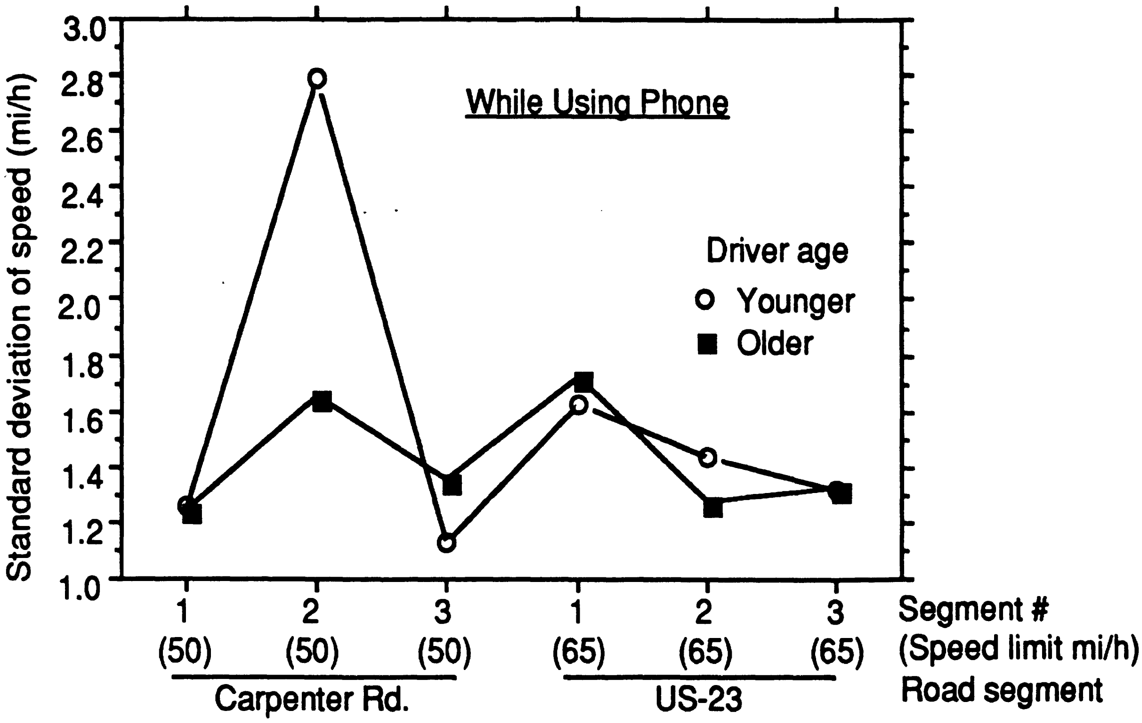


Figure 56. Standard deviation of speed as a function of phone task and driver age.

When collapsed across road segments, none of the factors (dialing task, $p = 0.37$; age, $p = 0.64$, or their interaction, $p = 0.88$) were significant. Figure 57 shows the means. For the baseline condition, the mean of the speed standard deviations was 1.44, the middle of the range for the task data shown here.

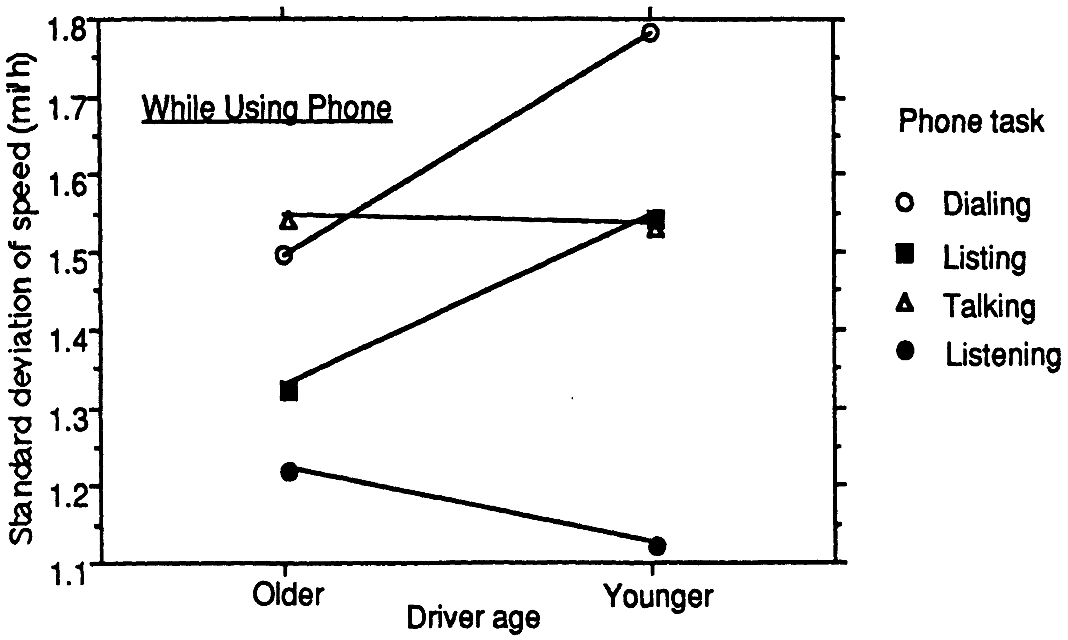


Figure 57. Standard deviation of speed as a function of phone task and driver age.

In summary, except for the standard deviation of steering wheel angle and the standard deviation of throttle position, the particular phone task conducted concurrently did not lead to differential effects in driving performance; that is there were no differences in driving characteristics. This lack of significant differences could be because of the short sampling period (10 to 30 seconds), small sample size (eight drivers), the lack of differential effects, or some combination of those explanations. This outcome makes sense in that throttle and steering wheel measures are direct driver inputs while speed and lateral position the results of these inputs as smoothed by vehicle inertia. Also, age and road segment did lead to occasional differences, with the pattern, older drivers having larger values and more stable performance on higher speed roads, fitting the pattern found for other data sets. This reduced but consistent pattern of significant effects suggests the lack of significant effects may be due to sample size limitations.

Comparison of Baseline, Navigation, and Phone Task Conditions

Each of the eight performance characteristics was examined in a separate ANOVA with conditions (baseline, navigation, phone), speed limit, and driver age as the main effects. All interactions were included in the model. The data included in the model were those examined in detail (56 plus 48 plus 192 data points) in the preceding sections. While three conditions examined were on interspersed sections of the similar roads (not the same sections), the data suggest that the main road-related factor is speed and that a comparison of conditions using these data is reasonable if speed is considered.

Speed

It should be noted that an ideal route would have had identical speed limits for all conditions. However, it was essential that the route used in previous on-the-road experiments be used again to examine the repeatability of performance across experiments. In fact, that route was selected to replicate a route that was used in laboratory simulation, a route chosen because of the variety of decision points it provided and its proximity to UMTRI. This, plus the need to append the baseline conditions on to an existing route, and the requirement for straight sections, limited route choices.

In terms of the mean speed, the differences between conditions were not significant ($p = 0.12$), but there were significant differences due to driver age ($F(1,184) = 6.37$, $p = 0.01$) and speed limit ($F(3,184) = 186.1$, $p = 0.0001$). As shown earlier, there was a tendency for participants to drive slightly slower when using the phone than in the baseline condition, an outcome that agrees with common observations. At high speed, drivers tended to drive a bit more slowly when using a route guidance system than in the baseline condition. This may result from drivers compensating for the added attention demands by driving more slowly.

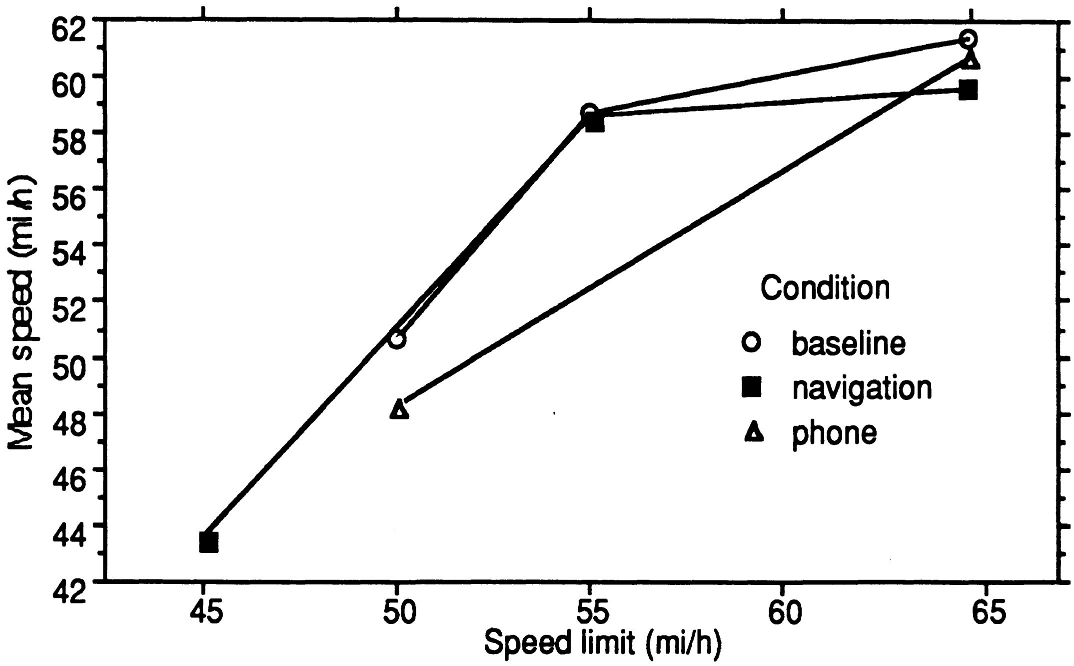


Figure 58. Effect of concurrent task on mean speed.

For the standard deviation of speed, there were significant differences due to conditions ($F(2,184) = 4.61$, $p = 0.01$). Age and speed limit effects were not significant ($p = 0.96$ and $p = 0.66$, respectively). As shown in figure 59, participants drove much more steadily in the baseline condition than when concurrently using the phone or the route guidance system.

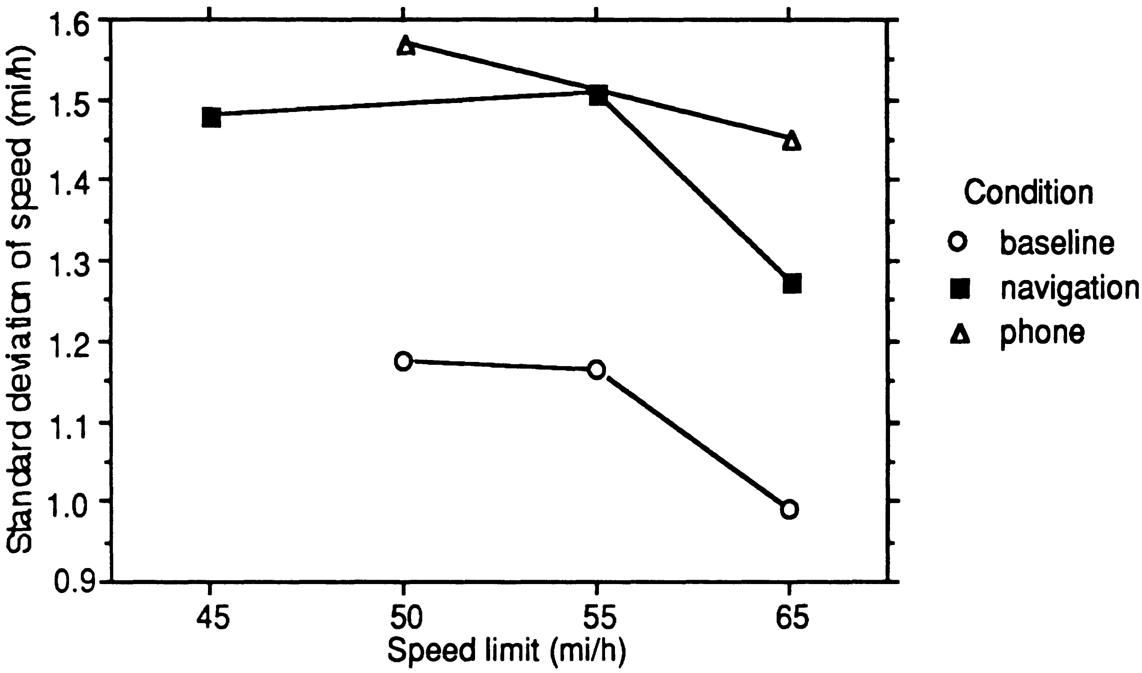


Figure 59. Effect of concurrent task on standard deviation of speed.

Lateral Position

For mean lateral position, there were no differences between the baseline, navigation, and phone conditions ($p = 0.86$). (See figure 60.) There were significant differences, due to driver age ($F(1,184) = 38.92$, $p = 0.0001$) and speed limit ($F(3,184) = 9.04$), $p = 0.0001$), however, as one would expect from the data. Younger drivers drove 0.6 ft farther to the left in the lane, on average, than older drivers. (See figure 61.)

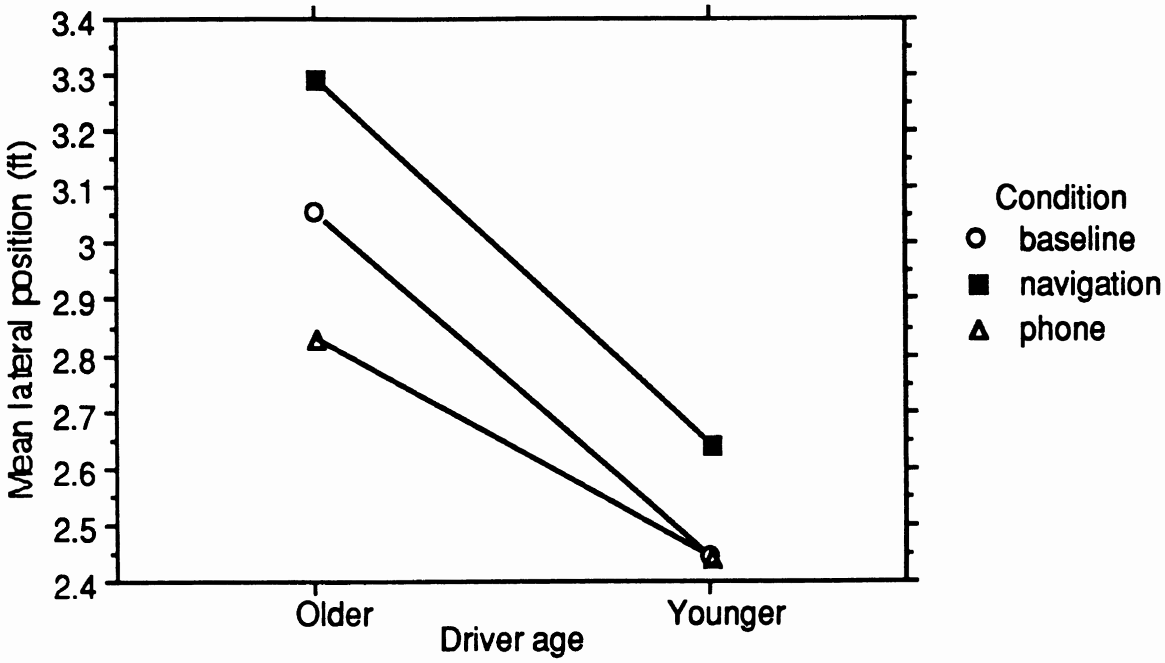


Figure 60. Effect of concurrent task on lateral position.

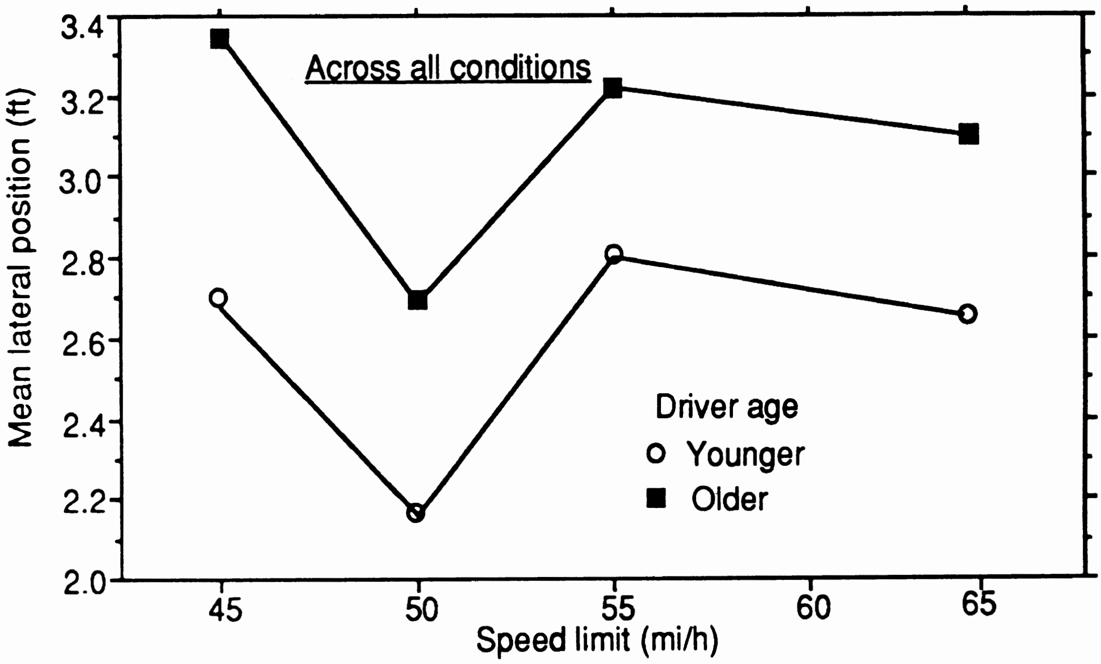


Figure 61. Effect of driver age on lateral position for various speeds.

The standard deviation of lateral position varied considerably and significantly with the concurrent task ($F(2,184) = 18.32$, $p = 0.0001$). (See figure 62.) These data do not make sense as they suggest drivers perform better (with less lateral variability) when using the phone (dialing or conversing) than when driving alone, a finding seemingly in conflict with common experience. There were no age differences ($p = 0.0001$), but there were significant differences due to speed limit ($F(3,184) = 8.00$, $p = 0.0001$). The poor performance in the navigation condition at 65 mi/h primarily is the result of one person whose driving deteriorated in the navigation condition at 65 mi/h.

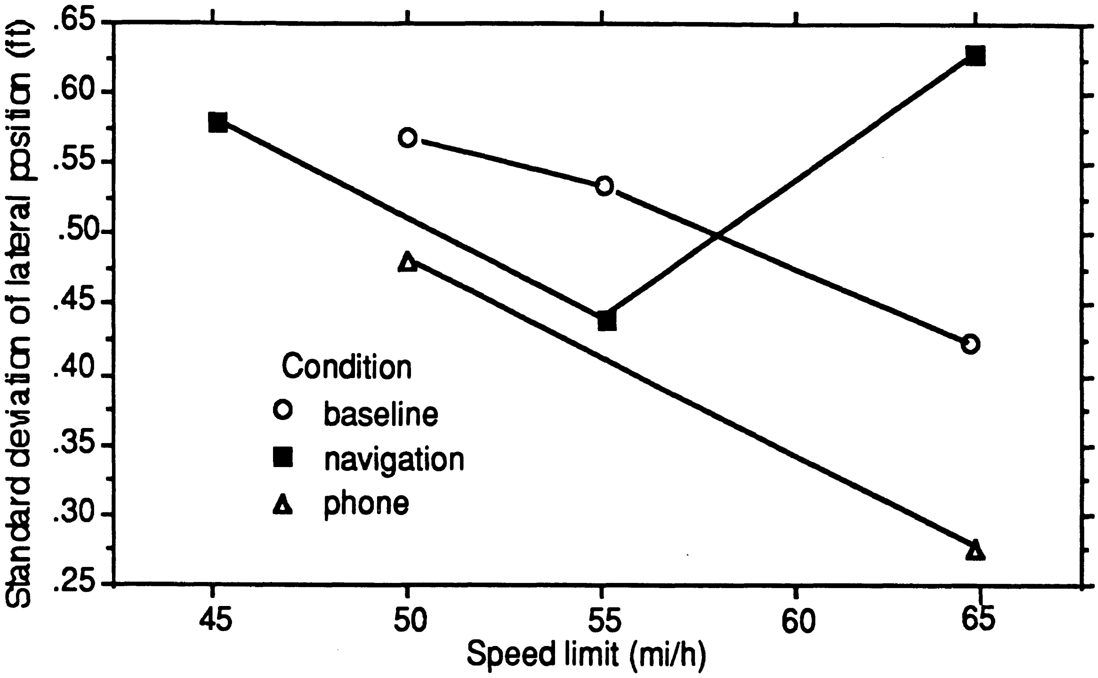


Figure 62. Standard deviation of lateral position for various conditions and speeds.

Steering Wheel Angle

There were no significant differences due to driver age ($p = 0.65$) or speed limit ($p = 0.68$) but there were differences between conditions in terms of mean steering wheel angle. (See figure 63.) This may suggest that the roads were not equally straight in all three conditions (baseline, navigation, phone), and potentially, the driving tasks were not equally difficult. The differences, however, were very small with means of -16.0 degrees in the baseline condition, -16.4 in the navigation condition, and -16.1 in the phone condition.

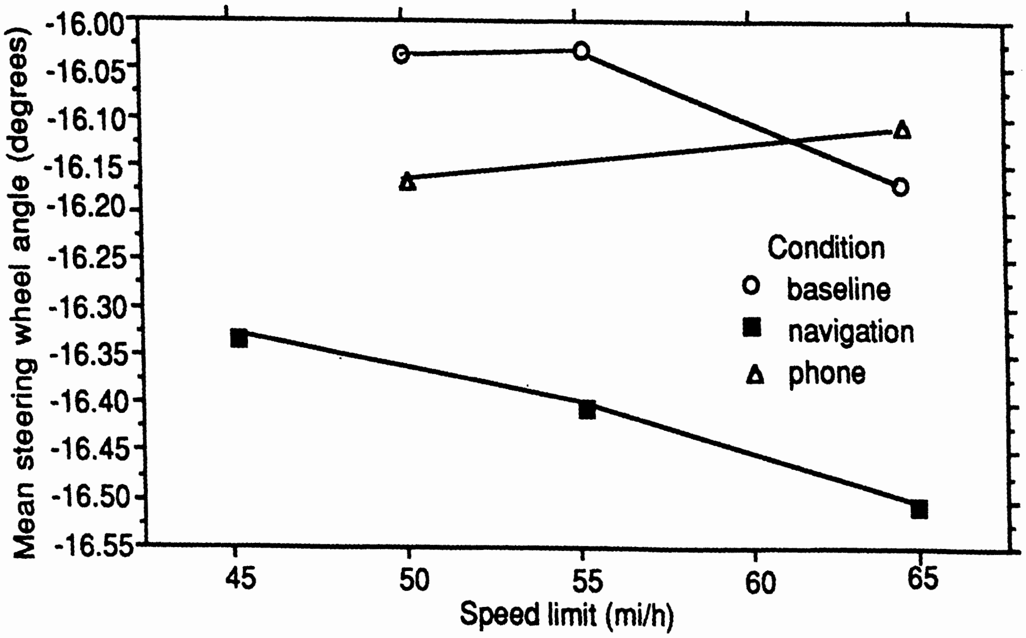


Figure 63. Mean steering wheel angle for various conditions and speeds.

Unlike the individual data sets, the standard deviation of steering wheel angle data are difficult to explain, in particular the navigation data for 65 mi/h. (See figure 64.) For that data point there was only one section of road involving navigation for which the speed was 65 mi/h, and hence that data point represents the mean of eight samples (one per subject). One of the drivers had particularly poor steering performance in the navigation condition. Overall, these data suggest that using the phone was a more demanding task. Differences between conditions were marginally significant ($F(2,184) = 2.26$, $p = 0.10$), while the effects of driver age ($F(1,184) = 10.62$, $p = 0.0013$) and speed limit ($F(3,184) = 9.70$), $p = 0.0001$) were highly significant.

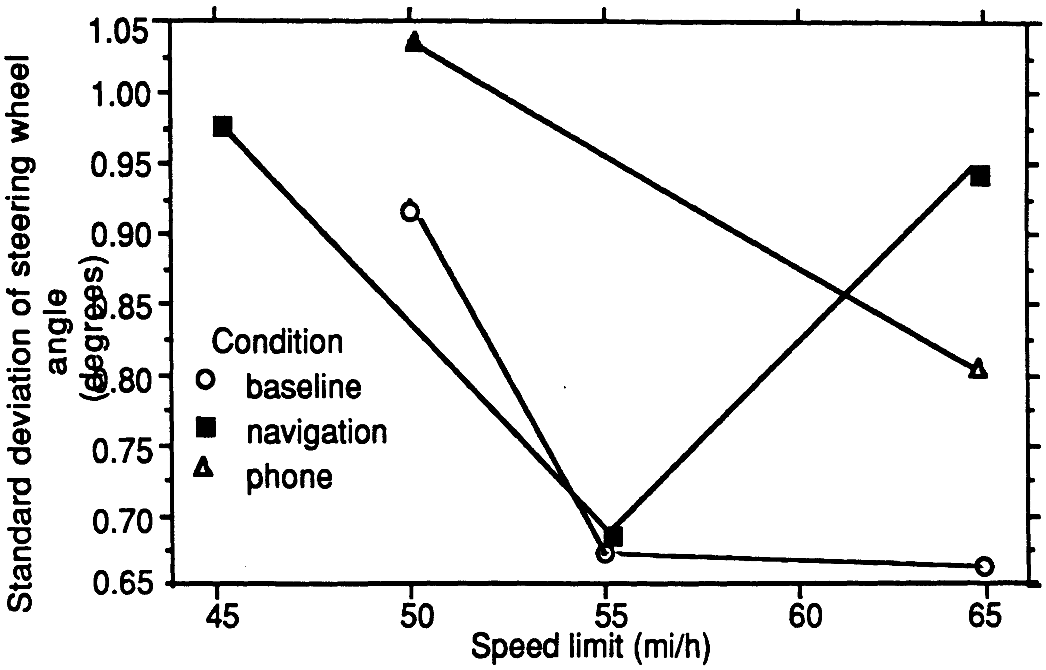


Figure 64. Standard deviation of steering wheel angle for various conditions and speeds.

Throttle

In the ANOVA of the mean throttle position, there were differences due to condition (F2,184) = 4.12), p = 0.02), and speed limit (F(3,184) = 28.70, p = 0.0001) but not driver age (p = 0.55). These results mirror those for mean speed except that driver age was significant for mean speed. Figure 65 shows the effects of speed limit and condition.

For throttle standard deviation, there was a significant difference due to test condition (F(2,184) = 4.14, p = 0.017) , but not due to driver age (p = 0.92) or speed limit (p = 0.61). As shown in figure 66, the major difference was between the navigation and other conditions. The reader is reminded that these data were collected when the test vehicle was being driven at a fairly steady speed.

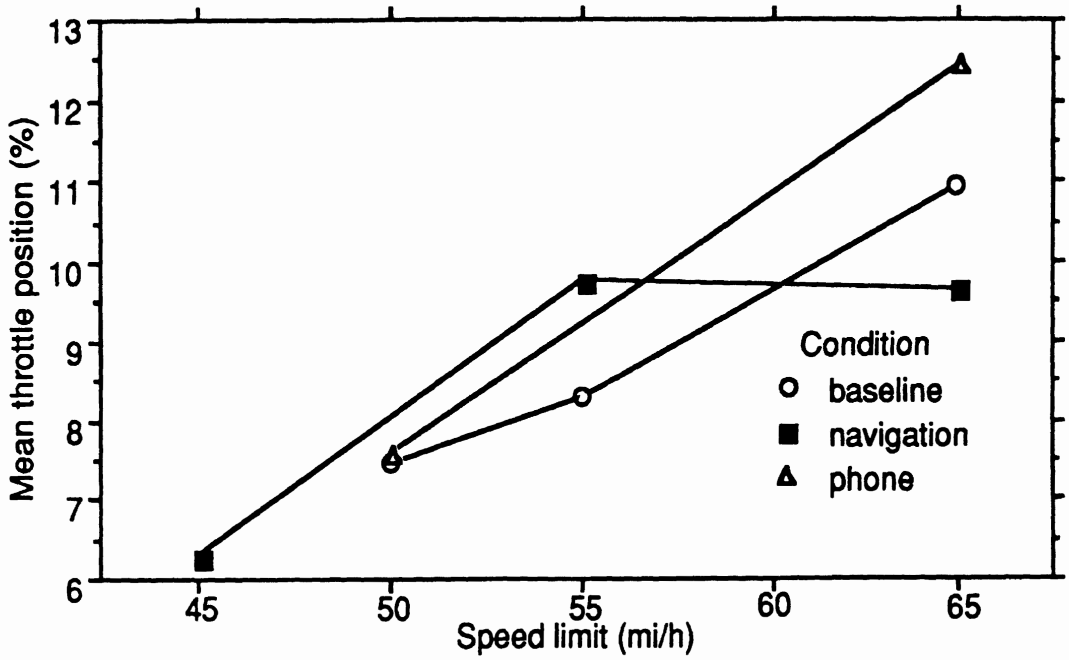


Figure 65. Mean throttle position for various conditions and speeds.

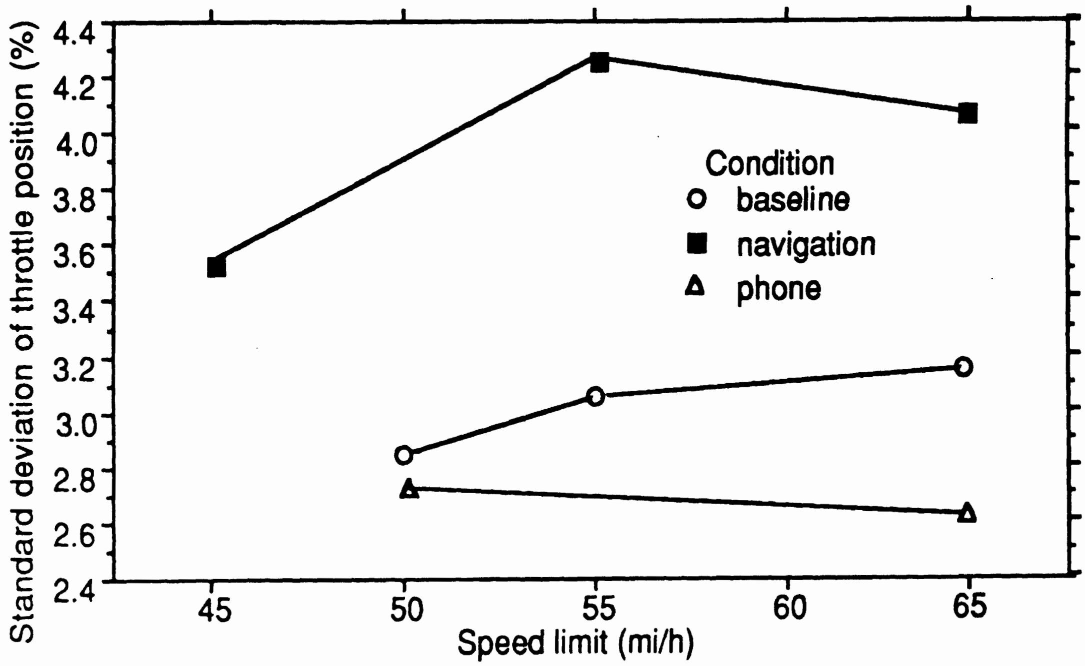


Figure 66. Standard deviation of throttle position for various conditions and speeds.

Thus, while not always going in the expected direction, these data suggest that some differences between drivers were measurable in some cases even with as few as eight drivers and very few repetitions of tasks. Participants drove slower (but not significantly) while using the phone and the speed was less variable in the baseline condition. There were significant differences in lateral position due to age, with younger drivers positioning their vehicles just over a half foot farther to the left than older drivers. The standard deviation of lateral position does not seem to make sense, with lower standard deviations occurring while the phone was used. (This could reflect a tradeoff with speed.) The steering wheel angle data suggest there may have been slight differences in road curvature between the navigation and other conditions, though the effect of these slight differences on other measures is unknown. The standard deviation of steering wheel angle was greater for when the phone was used than for other conditions, and the standard deviations decreased with speed. For the throttle, the results for the mean mirrored the mean speed data, while the standard deviation was more variable when the navigation system was being used. It is important to note that differences between systems were confounded with speed and road segments, confounding which was necessary in order to preserve continuity with previous research.

Use of the Car Phone

Car Phone Dialing Errors

Drivers each made a total of 6 phone calls during the test session: 3 calls on a 50 mi/h speed limit rural road, and 3 calls on a 65 mi/h speed limit expressway. Participants were told that if they made an error when dialing, they did not need to correct it, but rather should continue dialing. All calls were 7-digit (local) phone numbers that were familiar to the participant.

Based on a computer record of the button presses, there were 17 errors made in dialing the 48 calls, resulting in a 35 percent error rate. This is a fairly large value. Readers are reminded that while the phone was simulated, the shell was from a real phone and the switch sizes, spacing, travel, and feedback were typical of real products. Errors were categorized into 5 types, as described in table 2. "Double presses" occurred when the same digit was dialed twice; "reversed digits" were cases where two digits in the requested phone number were switched; "memory errors" resulted when participants seemed to "combine" two phone numbers, where either the exchange or the extension was incorrect for the phone call that was requested (but was still a feasible local phone number); "misdial" errors were made when the caller typed an incorrect digit, and continued to dial but finishing with a 7-digit phone number; "extra digit inserted" errors were instances were a "misdial" error occurred, yet the participant did not realize the error, and instead continued dialing the full number, for a total of 8 or more digits.

Table 2. Types of car phone dialing errors and examples.

Error type	**Example error (if trying to dial 123-4567)**
Doublepress	1223-4567
Reversed digits	132-4567
Memory error	123-7654
Extra digit inserted	1023-4567
Misdial	103-4567

The dialed phone numbers were compared with the requested phone numbers, for the test session only. A tally of these dialing errors appears in table 3. Only two drivers, the young males, made no dialing errors. One older female accounted for almost half the errors, making a total of 7 errors, with at least 1 error in each of her 6 calls. (Callers were not given feedback on dialing errors from the experimenter.) Of the 17 total errors, 10 occurred on the 50 mi/h speed limit road, and 7 occurred on the 65 mi/h speed limit road. Comparable on-road data are not available for drivers more experienced than the novices in this experiment. In the laboratory experiment of Serafin, Wen, Paelke and Green there were only 7 errors in 48 calls, calls that included both 7- and 11-digit numbers to familiar and unfamiliar phone numbers.[11]

Table 3. Car phone dialing errors.

Error type	Count
Doublepresses	7
Reversed digits	3
Memory error	4
Extra digit inserted	2
Misdial	1
TOTAL	**17**

List Task

Within both the 50 and 65 mi/h speed limit road segments, each driver performed one list task on the car phone. Drivers were required to list items within the category of "fruits," and then "cities." Table 4 summarizes the results. Comparison data from Serafin, Wen, Paelke, and Green are not available at this time.[11]

Table 4. Summary of items named for car phone list task.

		Mean # Items Named		
Category	**Speed limit**	**Younger**	**Older**	**Overall**
Fruits	50 mi/h	14.3	13.3	13.8
Cities	65 mi/h	20.8	21	20.9

Route Guidance Turn Errors

All drivers used an IP-display route guidance system. A total of 8 errors were made by the 8 drivers, including 5 near miss (NM) errors, and 3 execution (E) errors. (See table 5.) In Green, Hoekstra, Williams, Wen, and George the error rates were 10 execution errors and 15 near errors from 30 drivers using all three types of interfaces (HUD, IP, and auditory).[15] For the IP navigation interface there were 4 execution and 4 near miss errors from 10 drivers, values quite similar to those reported here. Also, considering there were 19 turns on the test route, performance with the route guidance system seemed remarkably good for a prototype.

Table 5. Turn errors for test route.

Intersection: Driving on:	At:	Error Description	Type Error
Huron River Dr	High St	Driver was unsure about turning or continuing	NM
		Driver was unsure about turning or continuing	NM
Columbia Ave	Huron River Dr	Driver was confused	NM
		Driver was confused	NM
		Driver went straight through intersection	E
Huron River Dr	Madelon Dr	Driver missed right turn	E
		Driver missed right turn	E
Madelon St	Roland Av	Driver wanted to turn right	NM
Haggerty Rd N	I-94 service road	Driver thought service road was entrance ramp to expressway	NM

Driver Preferences

Responses from the post-study questionnaire were categorized and analyzed by ANOVA, using a full factorial model with sex, age, and question. The questions were analyzed by groups, (relating to route guidance, car phone, etc.) over all participants. (A copy of the questionnaire is in the appendix.)

Responses to 11 route guidance safety and usability statements were given for a 5point scale from "strongly agree" to "strongly disagree," later coded 1 to 5, respectively. The effects of age ($F(1,40) = 5.83$, $p = 0.02$), question ($F(9,40) = 4.76$, $p = 0.0002$), and the age by question interaction ($F(9,40) = 3.84$, $p = 0.0015$) were all significant. On average, younger participants were less favorable (mean = 1.8) to the safety and usability issues relating to the route guidance system than the older participants (mean = 1.4). These questions are listed in table 6, from most to least favorable. The three least useful items were the current address, current town, and the compass.

Table 6. Ratings of the route guidance interface safety and usability.

Route guidance statements Strongly agree 1 ———>5 Strongly disagree	**Mean**
The information about upcoming (distant) intersections was useful.	1.1
The landmarks (traffic lights, bridges, etc.) were useful.	1.1
It was easy for me to figure out how the route guidance worked.	1.3
It was safe for me to use the route guidance while driving.	1.3
The mini-intersection map was easy to use.	1.4
I would rather use a route guidance system similar to this one than use a standard paper road map to find my way.	1.5
I would rather use a route guidance system similar to this one than use written instructions to find my way.	1.6
The current block address information was useful.	2.0
The current town information was useful.	2.3
The compass was useful.	2.4

(n=8)

Questions about the ease of use of the car phone were analyzed for all participants, using a full factorial model with the same three factors. (Only question was significantly different, $p = 0.0077$.) Responses to each statement were given on the same 5-point scale from "strongly agree" to "strongly disagree." Due to an editing error, a question regarding the safety of using the car phone while driving was not included. The mean response to both statements is shown in table 7.

Table 7. Ratings of the car phone interface safety and usability.

Car phone statement Strongly agree 1 ———>5 Strongly disagree	**Mean**
It was easy for me to figure out how the car phone worked.	1.1
It is easy for me to use the car phone while driving.	2.4

(n=8)

Participants also rated the difficulty of performing various tasks while driving, such as common driving tasks, using the route guidance system, and using the car phone. Participants rated the difficulty of these tasks using a 10-point scale, from "not difficult" (1) to "extremely difficult" (10). A full factorial ANOVA for sex, age, and question was done over all participants' responses to the questions relating to use of the route guidance system. The only statistically significant factor was the interaction of sex and age ($p = 0.0282$). The mean difficulty ratings for the route guidance tasks ranged from 1.4 to 2.0. These ratings are listed in table 8, from least difficult to most difficult.

Table 8. Ratings of the difficulty of route guidance tasks.

Route guidance tasks difficulty statements Strongly agree 1 ———>5 Strongly disagree	**Mean**
Looking, outside the car, for the next turn indicated by the route guidance system.	1.4
Determining the next maneuver you should make from the route guidance system.	1.5
Reading the information on the route guidance system.	1.9
Looking at the next route guidance screen to see it update.	2.0

(n=8)

The same type of analysis was done for the three car phone task difficulty questions (with the same 10-point difficulty scale). A full factorial ANOVA was done including all three factors (sex, age, and question). Only gender was statistically significant, $p = 0.0281$. Overall, men rated the car phone tasks easier (mean = 1.8) than women (mean = 4.1). Phone tasks received mean difficulty ratings ranging from 2.0 to 4.4. The tasks' mean ratings are listed in order of mean difficulty in table 9.

Table 9. Ratings of the difficulty of car phone tasks.

Car phone task difficulty statement Not difficult 1———>10 Extremely difficult	**Mean**
Listening on the phone.	2.0
Talking on the phone.	2.5
Dialing the phone.	4.4

(n=8)

Participants also rated the difficulty of 9 common driving tasks, on the same 10-point scale. The factors of sex, and question were statistically significant ($p = 0.021$ and $p = 0.0065$, respectively), from a full factorial ANOVA with age, sex, and question. Overall, female drivers rated the tasks more difficult (mean = 3.3) than male drivers (mean = 2.1). The mean task difficulty, over all participants, ranged from 1.1 to 4.5. The tasks, and their ratings, are listed from least to most difficult in table 10.

Table 10. Ratings of the difficulty of driving tasks.

Common driving activities Not difficult 1———>10 Extremely difficult	Mean
Turning on and off the car radio.	1.1
Adjusting the fan speed on the car heater or air conditioner.	1.1
Talking with other people in the car.	1.5
Changing stations on the car radio using presets.	2.1
Changing a tape cassette in a car stereo.	3.1
Looking at street numbers to locate an address.	4.0
Drinking a beverage.	4.3
Reading a map.	4.5

(n=8)

Participants also were asked to compare the ease of use and the safety of the route guidance system to the car phone. The route guidance system was overwhelmingly preferred, receiving all but one favorable response, as shown in table 11.

Table 11. Comparison of the route guidance system and the phone.

	Count	
Preference	Route guidance	Car phone
Which system was easiest to use?	8	0
Which system was safest to use?	7	1

(n=8)

In addition, participants were asked how much they would be willing to pay for each of the two systems (the route guidance, and the car phone). The mean responses are listed in table 12. The $944 amount for the route guidance system seems high.

Table 12. Prices drivers would pay for the systems examined.

System	Mean Price ($)	Range ($)
Route guidance	944	0 - 2000
Car phone	107	0 - 250

(n=8)

Thus, participants rated using the navigation system as fairly easy to use with ratings comparable to that of talking to a passenger in the car. Talking on the phone was rated as somewhat more difficult, comparable to changing the car radio using preset buttons. Dialing the phone was rated as even more difficult and was comparable to drinking a beverage or reading a map, values approaching the midpoint of the difficulty scale (ranging from not difficult to extremely difficult).

CONCLUSIONS

While this experiment satisfied its goal, it did have limitations. The sample size was small (eight drivers), but the sampling did consider the two main factors that influence driving performance, age and sex. The number of repetitions of tasks was small, for example only two each for the listing, listening, and talking phone tasks, a limitation due to schedule and funding. All drivers in the sample had identical levels of prior experience with the navigation system (none) and similar experience with car phones (minimal). The roads used for the various conditions were always examined at the same time of day, but they were not identical. Effort was made to collect data on the same types of roads with the same speed limits, and this was accomplished in most cases. Extension of the route in future experiments may allow for closer matching of the baseline and test conditions. Also desired is analysis of the data from those studies for driving on curved sections of road.

In spite of those limitations, this experiment achieved its intended purpose--to validate the acceptance and test protocol described in Green, 1993 by collecting additional data on use of a navigation system and to collected driver performance data for another system, a car phone.[18] As is described in this report the driver performance data of the test protocol were able to identify differences in driver performance between the baseline and the two test conditions (using the phone, and using an in-vehicle route guidance system). For a comparison with previously collected driver performance and other data, readers should see Green, Hoekstra, Williams, Wen, and George, 1993. [16] In brief, the two driver performance data sets are reasonably similar as were the number of turn errors, and the ratings of safety and ease of use. While the sample size was small, this experiment established that the results from the test protocol are repeatable. The value of this experiment is to demonstrate that driving behavior and performance can be characterized to allow comparison on different, but possibly similar, straight road segments with the same speed limit and similar traffic conditions. This is extremely important in assessing the effect of new technologies (car phones, navigation systems) to see if driving performance is enhanced or degraded by those systems as measured objectively (by control actions, vehicle trajectory, and vehicle route) and subjectively (by ratings of safety and ease of use).

APPENDIX A - CONSENT FORM

Subject ________

Date ___________

ADVANCED DRIVER INFORMATION AND CAR PHONE PARTICIPANT CONSENT FORM

The purpose of this experiment is to determine if new advanced driver information systems and car phones are easy to use. In this experiment you will make short phone calls while driving. You will then use a route guidance system to drive from Belleville to Canton.

After practice with the route guidance system, and then the phone, we will begin the experiment. First you will be prompted to dial familiar phone numbers and to engage in conversation over the phone. (Although you will be dialing, listening, and speaking using a phone handset, you will not be making actual phone calls.) Later, you will use an in-vehicle route guidance system that will tell you how to get to Canton from Belleville. Finally, you will be asked some questions about using the phone and route guidance system. We will videotape part of the study for experimental purposes.

This experiment will take about 3 hours for which you will be paid $30.00.

****

This experiment is a test of the route guidance system and car phone design, not of your driving skills. Remember, your priority is always to drive **safely.** You are expected to **obey all traffic and speed laws**. If you are not driving safely, you will be given one warning, after which the experiment can be stopped. Please tell the experimenter at any time if you feel you are unable to complete the study.

****

I HAVE READ AND UNDERSTAND THIS DOCUMENT.

______________________	______________________
Print your name	Date
______________________	______________________
Sign your name	Witness (experimenter)

APPENDIX B - BIOGRAPHICAL FORM

University of Michigan Transportation Research Institute
Human Factors Division
Biographical Form

Subject: [ ]

Date: [ ]

Name: ______________________________

Male   Female (circle one)   Age:________

Occupation: ______________________________

Retired or student: Note your former occupation or major________________

Education (circle highest level completed):

some high school	high school degree
some trade/tech school	trade/tech school degree
some college	college degree
some graduate school	graduate school degree

What kind of car do you drive the most?

Year:________   Make:______________   Model:______________

Approximate annual mileage: ______________

Have you ever driven a vehicle with an in-vehicle navigation system?

No   Yes, in an experiment   Yes, elsewhere

How many times have you ever used a car phone?

0   1-2   3-5   6-10   11 or more

In the last 6 months, how many times have you used a map?

0   1-2   3-4   5-6   7-8   9 or more

How often do you use a computer?

Daily   A few times a week   A few times a month   Once in awhile   Never

TITMUS VISION: (Landolt Rings)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	Vision correctors? Y / N
T	R	R	L	T	B	L	R	L	B	R	B	T	R	
20/200	20/100	20/70	20/50	20/40	20/35	20/30	20/25	20/22	20/20	20/18	20/17	20/15	20/13	______ which?

	Name	Phone #
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

APPENDIX C - SUBJECT INSTRUCTIONS

Have ready the bio forms, consent form, both post-test questionnaires, vision tester, labeled videotapes, payment forms and cash, pens, clipboards, directions to Belleville, map and phone.

Hi, are you ______(participant name)? **I'm** _______(experimenter). **Thank you for coming today. Let's go down to the conference room and get started.**

Overview

This study will take about 2 1/2 hours for which you will be paid $25.00.

Today we will be studying the use of a route guidance system and a car phone. For this study, first you will be driving while using the car phone and then you will use the route guidance system. After I tell you a little bit more about what you'll be doing, you'll get practice and then we'll start the study.

Consent and Bio Forms

First, please read and sign this consent form, and then turn the page and fill out the biographical form. If you have any questions at any time, feel free to ask.

Provide consent and biographical forms (with space on bottom for their memorized phone numbers and names).

Memorized Phone Numbers

I asked you to bring with you six seven-digit phone numbers you know well. These numbers will be kept confidential. Please check these phone numbers you told me before, to see if I wrote them down accurately. I will be asking you to "call" these people one at a time, so I need to know their first name (or however you address them), also.

Record the familiar names and phone numbers on bio form.

Vision Test

Next we need to test your vision. Can you see in the first diamond that the top circle is complete but that the other three are broke? Continue until two in a row wrong.

Driving Rules and Cautions

Let me reiterate a few important points from the consent form. First of all, we will be videotaping the session. Second, if <u>you</u> are uncomfortable or wish to stop at any time, please let me know right away. You are expected to obey all speed limits and driving laws (–do not tailgate). If you are not driving safely, you will get one warning and then the experiment can be stopped if I still feel it is unsafe.

Now, I'll explain the Route Guidance system.

<u>Route Guidance Explanation</u>

Route guidance information tells you how to get to a certain destination. Today, it will tell you how to get from Belleville to Canton. An ACTUAL system would figure out the best way to get you there, and as you drive, tell you when to turn. (Since this is an experiment, however, you will not be provided with the most direct route, because we're using it to test a variety of driving situations.) You just need to follow its instructions. They will be shown on a 4 by 5 inch display on the instrument panel to the right of the steering wheel.

This is an example of a Route Guidance screen you will see. Throughout the trip, the route guidance system will tell you where to go at intersections and expressway exits. I'll explain the screen:

1. Compass
2. Current town
3. Current block address
4. Next intersection (in green) and distance in miles to it
5. Within map, white arrows tell you what to do at next main intersection (and landmarks)
6. White arrow above map tells you the next turn (after the other) and distance

As you continue along, this information will change. You'll see other cross streets, addresses and directions along the route because the route guidance system is continually updating the roads you cross or turn onto as you're driving. You will use the route guidance system to drive from Belleville to a restaurant in Canton (about 40 minutes away).

***** YOU WILL NOT BE MAKING ANY PHONE CALLS WHILE USING THE ROUTE GUIDANCE SYSTEM. Do you have any questions?**

<u>Phone Overview</u>

There are 3 types of phone calls you will make. They involve LISTENING tasks, LIST tasks, and TALKING tasks. You will make 9 phone calls, where you will dial the familiar phone numbers I wrote down before.

I will ask you to dial the phone number of one of the people you named, by saying, "Call JOE now, please." At that time you will pick up the phone and dial the number. *In a minute I will tell you how to dial the phone.* Over the phone handset, you will be told which of the 3 types of tasks you will be doing. YOU HAVE TO LISTEN CAREFULLY BECAUSE YOU WILL ONLY HEAR EACH QUESTION OR DESCRIPTION ONCE; IT WILL NOT BE REPEATED.

Listing Task

After you dial the number, on the phone you will be told that this is a "listing task." For the listing task you are given a category and asked to list items that belong in that category. If given the category "tree names" you would list as many trees as you could think such as Maple, Oak, etc. We'll call this the list task since you list items.

Listening Task

For the listening task, after you place a call, you would be told that it is a "listening task." For this task you will be told about a situation that you need to make a decision about. For example, you might be given the choice of going to a movie, concert, or bowling on Saturday night. You will be asked to choose one after listening to a short description. This task is similar to a conversation in which you do most of the listening.

Talking Task

After you make a phone call, you will be told that this is a "talking task" by the person on the phone. This is a "talking" task because it involves you doing most of the talking. You will be asked a question, or be asked to describe something, such as "Where did you grow up?" I want you to try to talk as much as possible in the 30 seconds you have to answer the question. If you run out of things to say, I will prompt you to tell me more. This is similar to a conversation in which you do most of the talking.

YOU WILL ONLY HEAR THE QUESTION ONCE, SO LISTEN CAREFULLY. Do you have any questions?

Dialing the phone

Let me show you how to use and dial the car phone.

Show subject the drawing of the handset. **As you can see, there is a number pad** (point to it) **and various buttons for operations. The "power" button is up here** (point to it)**, while other digit buttons are down here** (point to them). **You will see the number you are dialing on the display on the instrument panel to the right of the steering wheel. You will also see whether or not the phone power is on, or if the phone is in use.**

Button Sequence for Dialing

The power button turns the phone on and off. Power is indicated on the phone by PWR on the display. This is not like a household phone; you must first turn the power on to get a dial tone.

To place a call, (after pressing PWR), you must then enter the 7 digits you are dialing, which then appear on the display. Then to make a connection you press "CALL" which dials the number and connects you to the person you want to talk to. After you have finished talking, pressing the "PWR" again button will disconnect you from the network. (It is at this point that you would stop paying for the call if this was a phone in your car.)

So, the sequence is:

- **PWR** (turns the power on the phone)
- **dial phone number** (for phone number of person I identify)
- **CALL** (calls the phone number you just entered)
- **PWR** (shuts off the power)

If you happen to misdial a phone number, don't worry about it. Just finish dialing the rest of the number, your "phone call" will still go through as long as there are 7 digits in the number. The phone will be on the passenger seat when not in use.

Now you can have some practice using the Phone, and the Route Guidance system. I will lead you through the practice and prompt you to dial.

---------------------Go down to car for phone, and then RG practice-----------------------------

<u>At the car</u>

- Adjust car seat, steering wheel height, and side view mirrors.
- Point out microphone, cameras, RG screen, and phone.
- Point out climate controls, air bag light, no cruise control.
- Remind about following speed limit, not tailgating, and slow over RR tracks.
- Please stay in right lane while using phone.

<u>Practice dialing phone - try all 3 tasks</u>

------(Click on first stack on top left of desktop)------(Remind subject of sequence)----------

- **PWR** (turns the power on the phone)
- **dial phone number** (for phone number of person I identify)
- **CALL** (calls the phone number you just entered)
- **PWR** (ends the call; it hangs up the phone)

-----(make sure they press power to end the call)-------

<u>Practice with route guidance</u>

For the first part of the trip out to Belleville, you will go through a short practice to get used to the systems I showed you before. The end of the practice route will send us on our way to the test route. This practice will stop when we get on the expressway. Then we will stay on 23, where you will make 3 phone calls. After

the phone calls I will tell you how to get to our starting point in Belleville. Then you will use the Route Guidance system from there.

Do you have any questions?

---start RG practice---

Go South on 23. Start saving data just before 94 interchange. Request phone call #1 after 94 merges into 23. Request phone call #2 just after they finish #1. Turn around at Willis Rd. Request phone call #3 after road straightens out (past closed exit).

Take 94 East. Mark the straight road sections with A, B, C, and D with comments. Take Belleville Rd exit, and get to Elwell.

<u>At Belleville / Start of Test Route</u>

Remind about speed limit, not tailgating, and slow over RR tracks!!

<u>At Destination: Hardees</u>

1. **Before I ask you a few questions, do you have any comments at this point?**
2. **Overall, how easy was it to use the Route Guidance system?**
3. **How easy was it when you first started using it?**
   What was easy? What did you like about it? Why?
   What was difficult? What didn't you like? Why?
3. **How easy was it to drive while reading from the screens?**
4. **In terms of how the information was presented, how easy was the Route Guidance system?**
5. **Is there anything you would change, add, or get rid of?**
6. **How easy or difficult was it for you to drive while using the phone?**

**Place more phone calls on Ford Rd., then save and mark baseline straight roads.

<u>When back at UMTRI -- Questionnaires</u>

Shut down car.

Return to Conference room.

Provide subject with questionnaires, and pen. Make sure all questions are answered. Ask participant to fill out payment form, pay them, and thank them. Walk them to the front door.

APPENDIX D - CAR PHONE TASK QUESTIONS

Participants were given a timed period of 30 seconds (after the question was asked) to respond to the list and talking task questions. Similarly, the questions for the listening tasks were announced over a period of 30 seconds.

List tasks

Practice session question:

1. "Name all the 4-legged animals you can in the next 30 seconds."

Test session questions:

1. "Name all the fruits you can in the next 30 seconds."
2. "Name all the cities you can in the next 30 seconds."

Talking tasks

Practice session question:

1. "What did you do last weekend?"

Test session question:

1. "Describe your favorite recreational activity."
2. "If you could travel anywhere in the world, where would you go, and why?"

Listening tasks

Practice session question:

1. "You are the leading salesperson for a large pharmaceutical firm in the midwest. Sales have been steadily increasing in your area, however, sales have been dropping in other areas of the United States. To improve market share in other geographical areas, your company wants to relocate you. You have the option of moving to one of the following three cities: Miami, Boston, or San Francisco. Which one would you choose?"

Test session questions:

1. "Since you'll be doing a lot of driving at your new job, your company has decided to give you a car. You will need to make a decision about the company car that you want to drive when you arrive at the office tomorrow morning. All of the cars are fully equipped and come with the same options: cassette player, air

conditioning, and cruise control. You have the choice of three cars: a Ford Taurus, a Pontiac Grand Am, or a Buick Skylark. Which car would you choose?"

2. "You just completed a major project, so you're planning a big night on the town to celebrate. You weren't sure where to go, so you asked your co-workers and they recommended three restaurants each in different parts of town. From their descriptions it sounds like there's a lot of after-dinner entertainment no matter where you go. Since they are all about the same distance from where you live, you just have to decide what kind of food you want to eat. Are you in the mood for French cuisine, Italian, or fresh seafood?"

APPENDIX E - POST-STUDY QUESTIONNAIRE

Using all of your driving experience (not just what you did today), please rate the difficulty of performing each of these tasks <u>while driving</u>, using the scale below.

```
   Not                                                    Extremely
Difficult                                         Difficult
  |----|----|----|----|----|----|----|----|----|----|
  1    2    3    4    5    6    7    8    9    10
```

CIRCLE YOUR RESPONSE:

Changing stations on the car radio using presets
1 2 3 4 5 6 7 8 9 10

Turning on & off the car radio
1 2 3 4 5 6 7 8 9 10

Adjusting the fan speed on the car heater or air conditioner
1 2 3 4 5 6 7 8 9 10

Looking at street numbers to locate an address
1 2 3 4 5 6 7 8 9 10

Reading a map
1 2 3 4 5 6 7 8 9 10

Talking with other people in the car
1 2 3 4 5 6 7 8 9 10

Reading the speed on the speedometer
1 2 3 4 5 6 7 8 9 10

Drinking a beverage
1 2 3 4 5 6 7 8 9 10

Changing a tape cassette in a car stereo
1 2 3 4 5 6 7 8 9 10

Advanced Driver Information **Post-Study Questions**

ROUTE GUIDANCE ONLY ***Please circle your response:***

It was easy for me to figure out how the route guidance worked.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

It was safe for me to use the route guidance while driving.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

I would rather use a route guidance system similar to this one than use a standard paper road map to find my way.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

I would rather use a route guidance system similar to this than use written instructions to find my way.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The compass was useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The current town information was useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The current block address information was useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The distance to the next maneuver was useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The information about upcoming (distant) intersections was useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The landmarks (traffic lights, bridges, etc.) were useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The mini-intersection map was easy to use.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

CAR PHONE ONLY ***Please circle your response:***

It was easy for me to figure out how the car phone worked.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

It is safe for me to use the route guidance while driving. **This question was supposed to read, "It is safe for me to use the car phone while driving," but was not corrected until the sixth subject. As a result it was not analyzed.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

It is easy for me to use the car phone while driving.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

---

Please rate the difficulty of performing each of these tasks <u>while driving</u>.

Not Difficult **Extremely Difficult**

```
|----|----|----|----|----|----|----|----|----|
1    2    3    4    5    6    7    8    9    10
```

Dialing the phone

1 2 3 4 5 6 7 8 9 10

Talking on the phone

1 2 3 4 5 6 7 8 9 10

Listening on the phone

1 2 3 4 5 6 7 8 9 10

Reading the information on the route guidance system

1 2 3 4 5 6 7 8 9 10

Determining the next maneuver you should make from the route guidance system

1 2 3 4 5 6 7 8 9 10

Looking, outside the car, for the next turn indicated by the route guidance system

1 2 3 4 5 6 7 8 9 10

Looking at the next route guidance screen to see it update

1 2 3 4 5 6 7 8 9 10

Which of the systems do you think was easiest for you to use?

Route Guidance Car Phone

Which of the systems do you think was safest for you to use?

Route Guidance Car Phone

ADDITIONAL QUESTIONS

When do you plan on buying your next (new or used) car ?

Within 5 months 6-11 months 1-2 years 3-5 years 6+ years

How much do you plan on spending? $________

How much would you pay for a route guidance system (like the one you used)? $________

How much would you pay for a car phone (like the one you used)?________

Additional Comments (optional)

____

____

____

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