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Development and Human Factors Tests of Car Phones

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16. Abstract

This report describes three experiments to develop an easy to use car phone interface. In the first experiment,19 people at two local secretary of state driver licensing offices gave their preferences for button labels and abbreviations. The second experiment with seven participants concerned label abbreviations. The following labels (and abbreviations) are recommended: power (Pwr), Call, End, delete (Del), memory (Mem), and recall (Rcl). Twelve drivers (six under 35 years, six over 60 years) participated in the third experiment, a laboratory study, in which they operated a simple driving simulator and used a car phone. The phone was either manually dialed or voice-operated, and the associated display was either mounted on the instrument panel (IP) or was a simulated head-up display (HUD). Phone numbers dialed were either local (7 digits) or long distance (11 digits), and could be familiar or unfamiliar. In addition, there were four conversational tasks, two of which were fairly ordinary (listening, talking) and two of which required some mental processing (loose ends, listing). Driving performance (voice--5.7 inches; manual--6.1 inches) and dialing times (voice--9.2 seconds; manual--10.7 seconds) were better with the voice-operated phone than the manual phone using either the IP display or HUD. In addition, younger drivers outperformed older drivers with regard to both driving (younger--5.6 inches; older--6.0 inches) and dialing performance (younger--7.4 seconds; older--12.6 seconds). Thus, voice appears to be an effective way of improving the safety and performance of car phone use, but the location of the display is not important. The benefits of voice are particularly noticeable for older drivers.

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TABLE OF CONTENTS

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 goal is 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, has undertaken a project to help develop driver information systems for cars of the future, one aspect of IVHS. This project concerns the driver interface -- the controls and displays that the driver interacts with, as well as their presentation logic and sequencing. This is one of 16 reports that documents that work.

The 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 these systems.

Although only passenger cars were considered in the study, the results apply to light trucks, minivans, and vans. Another significant constraint was that only able-bodied drivers were considered. Disabled drivers are likely to be the focus of future DOT research. A complete list of the project reports and other publications is included in the final overview report (Paul Green, 1993, Human factors of in-vehicle driver information systems: An executive summary, Technical Report UMTRI-93-18, Ann Arbor, MI: The University of Michigan Transportation Research Institute.).

To put this report in perspective, the project began with a literature review (Green, 1992) and focus groups examining driver reactions to advanced instrumentation (Brand, 1990; Green and Brand, 1992). Subsequently, the extent to which various driver information systems might reduce accidents, improve traffic operations, and satisfy driver needs and wants, was analyzed (Green, Serafin, Williams, and Paelke, 1991; Serafin, Williams, Paelke, and Green, 1991). 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, vehicle monitoring). Each system 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 probed. Interface alternatives were then compared in laboratory experiments involving response time (Green and Williams, 1992), driving simulation, and other methods. The results for each system are described in a separate report. 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.

In parallel with that work, UMTRI developed test methods and evaluation protocols, UMTRI and BBN developed design guidelines, and BBN worked on the development of the driver model.

Many of the reports from this project are dated May, 1993, the end date of the project when reports were to be delivered. However, the reports were drafted when the research was conducted, over two years earlier for the literature review and feature evaluation, and a year earlier for the laboratory research and methodological evaluations. The car phone studies reported here were completed in 1992. While some effort was made to reflect knowledge gained as part of this project, the contract plan did not call for re-writing reports to reflect recent findings.

This report concerns three experiments to develop an easy to use car phone interface.

The authors would like to thank Marie Williams, who helped with the laboratory set-up for Experiment Three.

Notice

INTRODUCTION

Using a car phone while driving has become a somewhat common occurrence. The convenience of doing so attracts many people. However, its use may distract the driver's attention from the road for a longer period of time than does traditional in-vehicle equipment (speedometer, radio, etc.). Demands may be visual (needing to look at displays) or cognitive (conversing with passengers). To safely maneuver a vehicle on a highway, it is necessary to design auxiliary systems, such as car phones, that minimize the time a driver's attention is spent away from the road.

Objectives

This report describes three experiments undertaken to develop an easy to use car phone interface. In order to test a car phone, button labels and abbreviations for functions on the phone, such as "power" and "dial," had to be identified. The first experiment was undertaken with this goal in mind. A second experiment was performed to better determine driver preferences for label abbreviations.

To determine the best design for a car phone, a third experiment examined two types of phones (manual and voice activated) and two types of displays (instrument panel (IP) and head-up display (HUD)). Results were based on performance on the phone, as well as driving performance using a simulator.

The following questions were addressed in the third study.

1. Which car phone interface is least distracting (as measured by steering error)?
2. Are there differences due to sex, age, or both?
3. Which interface do drivers prefer?

Literature Review

Few studies directly relate to the effect of using a phone on driving performance. Of the studies that do, some include secondary tasks other than using a phone (Brookhuis, de Vries, and de Ward, 1991; Brown, Tickner, and Simmonds, 1969). Others do not provide a primary tracking task. McKnight and McKnight (1990) had participants watch a videotape of roads while Hanson and Bronell (1979) simply had subjects perform various tasks on a phone. Stein, Parseghian, and Allen (1987), Alm and Nilsson (1990), and Nilsson and Alm (1991) have investigated the dual tasks of driving a simulator and using a car phone. Kames (1978) has examined on-road use.

A brief summary of these studies follows. (Note: This literature review was done in 1991.)

Brown, Tickner, and Simmonds (1969)

In this classic experiment, 24 men (ages 21-57, mean = 41) performed a grammatical reasoning task while driving. It involved driving a 1.5 mile route and making gap width judgments for 20 gaps (4 of each size: 3 inches smaller, and 0, 3, 6, and 9 inches wider than the car). The car was 5 feet wide, which led to two impossible and three possible gaps. Driving performance measures included gap judgment errors, number of successful gap clearances out of those chosen to drive through, driving time, frequency of foot control and steering wheel use, and lateral and longitudinal acceleration.

The secondary task, which the authors referred to as telephoning, involved grammatical transformations. Drivers heard a sentence (e.g., A follows B) followed 2.5 seconds later by either AB or BA. They indicated whether the pairing was correct (by saying true or false) and 2 seconds later a new stimulus appeared. Attributes of the stimuli manipulated included active or passive verb, verb precedes or follows, and so forth. Both accuracy and response time were recorded.

Their results indicated that, for the two impossible gaps and the largest gap, gap judgment errors were greater for driving while performing the secondary task than for driving alone. Driving time also increased (by 6.6%) when performing the transformation secondary task as opposed to driving alone. Speed (0.79 seconds longer) and accuracy (21.2% more errors) of the transformation task were impaired while driving. It is interesting to note that some driving performance measures (frequency of control use and latitudinal/longitudinal accelerations) were not impaired by the transformation task.

Thus, perceptual and decision-making tasks while driving may be impaired by a secondary task similar to using a phone.

Kames (1978)

Kames (1978) evaluated the effect of seven phone dials/mounting locations on driving. The configurations included: (1) rotary dial/transmission tunnel mount, (2) and (3) 2 x 6 horizontal dial/on dash or in visor area, (4) 6 x 2 vertical dial/in dash, (5) and (6) 4 x 3 dial-in-handset/handheld or on dash, and (7) 6 x 2 dial-in-handset/handheld. While driving, participants also performed a subsidiary task when making a call and at other times throughout the session. In this visual identification task drivers identified if a green or amber light on the left or right of the steering column was illuminated. Driver response time was the measure of attentional load.

Eighteen people (ages 19-65) completed the experiment. While driving, each person made 12 calls with all but one of the phone/mounting configurations. Handheld dialing was done with either the 6 x 2 or 4 x 3 dial-in-handset. The procedure with the pushbutton dial required six steps, while the rotary dial required only three steps. The six steps with the pushbutton dial were the following: (1) press CLEAR, (2) dial number, (3) press SEND, (4) lift handset to talk, (5) press END, and (6) replace handset. The rotary dial required the following three steps: (1) lift handset, (2) dial number, and (3) replace handset.

Dependent measures included reaction time to the subsidiary task, telephone dialing time, head movements (frequency and duration of the longest), and driver behavior (speed, steering reversals, brake applications, and lane position). (It is uncertain how lane position was measured.) Drivers' subjective reactions about using a phone while driving were also recorded at the end of the test session.

Dialing times on the rotary phone (16 seconds) and the 6 x 2 dial-in-handset (12.5 seconds) were significantly longer than on the other phones (11.4 seconds). The horizontal dial mounted on the dash (0.3 per second) and visor (0.17 per second) resulted in significantly fewer head movements than any other phone (0.43 per second). Lane position varied less with the 4 x 3 dial-in-handset (31.2 inches) and the horizontal dial (31.2 inches), both mounted on the dash, than with the other phone configurations (39 inches). A large majority of the participants preferred the 4 x 3 dial-in-handset mounted on the dash (42%). The 6 x 2 dial-in-handset was not preferred by any of the participants.

In the subjective responses, drivers rated the difficulty of fourteen tasks on a scale from 1 to 10 (10 being most difficult). The ratings appear in Table 1. Only dialing was rated as an activity that was more difficult than most common driving tasks.

Smith (1978)

Through a questionnaire, similar data were collected by Smith (1978) from 498 mobile phone users. Ratings (1 = not at all dangerous, 10 = extremely dangerous) of 15 activities are shown in Table 2.

The results agree with those of Kames (1978). Participants rated dialing as more difficult than only two other less common tasks.

Table 1. Ratings of task difficulty from Kames (1978)

Task	Rating
Conversing with other people in the car	1.3
Hearing the mobile telephone ring	1.3
Conversing on the mobile telephone	1.8
Answering a call on the mobile telephone	1.8
Adjusting a car heater or air conditioner	2.2
Looking for a landmark along the road	2.6
Talking into a tape recorder	2.7
Tuning a car radio	2.8
Drinking coffee or other beverage	3.5
Getting change from pocket or purse to pay tolls	4.3
Dialing the mobile phone	**4.6**
Lighting and smoking a cigarette	4.7
Writing something down	7.7
Reading a map	7.9

Table 2. Ratings of task difficulty from Smith (1978)

Task	Rating
Hearing the phone ring	1.6
Conversing on the mobile phone	2.0
Picking up the handset	2.1
Adjusting the car heater or air conditioner	2.3
Conversing with other people in the car	2.3
Tuning the car radio	2.4
Putting the handset back in the cradle	2.7
Using a dictating machine	3.8
Lighting a cigarette	4.1
Getting change from a pocket, purse to pay a toll	4.3
Drinking coffee or other beverage	4.4
Looking at street numbers to locate an address	4.6
Dialing the mobile phone	**5.2**
Writing something down	7.0
Reading a map	7.7

Hanson and Bronell (1979)

Hanson and Bronell (1979) conducted two studies to determine the best calling procedure for mobile phone systems. The first experiment compared four calling procedures summarized in Table 3.

Table 3. Four calling procedures used by Hanson and Bronell (1979)

	Procedure			
	One	Two	Three	Four
Buttons	CLEAR SEND END HANDS-FREE	CLEAR SEND END HANDS-FREE	READY SEND END HANDS-FREE	TALK END
Call Placing Method	1. Dial number 2. Press SEND or go off hook	1. Press CLEAR 2. Dial number 3. Press SEND or go off hook	1. Press READY 2. Dial number 3. Press SEND or go off hook	1. Dial number 2. Press TALK
Comments	*Last number repeat feature	Press CLEAR to unlock dialing	*Last number repeat feature Press READY to unlock dialing	

*The last number repeat feature allows the user to call the last number dialed unless a new number is entered into the display.

Although procedures one and two appear similar, in procedure two CLEAR must be activated before a call can be sent. Procedure three differs from procedure two in two ways: (1) READY is used instead of CLEAR and (2) the last number repeat feature is activated.

The 20 participants, 5 using each procedure, were administrative employees at Bell Laboratories whose business background made them similar to mobile phone customers. Twelve tasks were performed by each person (placing a call, correcting a dialing error, transferring between the handset and hands-free modes, answering and terminating calls, etc.). Participants repeated the task until they performed it correctly. Dependent measures included the total time required, the number of invalid calls made, and the number of failed attempts.

Procedure one resulted in significantly poorer performance than the other three procedures for placing a normal call. For procedure one versus the other three procedures, the time required was longer (558 versus 151 seconds), more invalid calls were made (24 versus 2.6), and more attempts were made before correctly placing the call (7.0 versus 3.1). For other tasks, there were more errors when CLEAR or READY had to be pressed before dialing. Also, a HANDS-FREE button led to more errors than simply picking up or hanging up the handset to switch between modes. The handling of incoming calls did not result in any errors.

Experiment Two tested improvements and variations on these four procedures including (1) the modification of procedure one to prevent call initiation by going off hook, (2) procedure four included the last number repeat feature, (3) some procedures were tested with and without a HANDS-FREE button, and (4) the testing of some procedures with TALK versus SEND labels.

Forty-nine Bell Laboratories administrative employees performed the same tasks as in Experiment One, but with step-by-step calling instructions on the phone. Hanson and Bronell found that 60% of the participants used the instructions and everyone using instructions placed the call correctly. The TALK and READY buttons led to some confusion when answering calls (they were pressed when they did not have to be). Finally, similar results were found as in Experiment One; having to press the CLEAR, READY, or HANDS-FREE buttons caused more errors.

Based on the results of the experiments, Hanson and Bronell recommended the following calling procedure.

1. Use a SEND button to place calls.
2. When placing a call, first dial the number then press SEND.
3. The last number dialed is saved in the display until a new number is entered.
4. It is assumed a new number is entered if SEND or END is pressed, the phone is hung up, or more than a minute has passed since the last number dialed.
5. Press END to start over when a mistake is made in dialing.
6. Press END or hang up to terminate a call.
7. Answer incoming calls by picking up the receiver or pressing SEND.

Stein, Parseghian, and Allen (1987)

Stein, Parseghian, and Allen (1987) investigated the effect of mobile phone use while driving in a simulator. (See also Billheimer, Lave, Stein, Parseghian, and Allen, 1986 for details.) The scenario of the simulator represents a rural highway at dusk. During a 15 mile drive, participants were presented with 12 curves, 20 obstacles, and approximately 50 highway signs (30 of which required a response from the driver). The obstacle was a computer-generated box that moved into the path of the vehicle and required the driver to make an emergency lane change to avoid hitting it. The highway signs included five types: (1) regulatory (e.g., speed limit), (2) warning (e.g., two way traffic ahead, (3) general information (e.g., airport), (4) motorist service (e.g., phone), and (5) interstate and highway route signs. Participants pressed the horn button when they saw warning signs, a foot switch for general information and motorist services signs, and made calls when they saw airport signs.

The 72 participants represented three age groups: under 20 years old, 25-55 years old, and over 55 years old. Half of the people in the young and middle age groups had used cellular phones.

Participants used a commercial cellular phone with a raised numeric keypad on the handset and a hands-free option. The phone was mounted either on the center console or the dash. While driving, participants made and received calls under three driving conditions (straight road, straight road with obstacles, and curves). Calls were either made manually, using the memory feature, or using voice recognition. When making calls, participants were given flight reservation information (airline, flight number, originating airport, and destination) and on the subsequent call the participants repeated the information. Using the phone while driving was compared to driving alone and tuning a radio when driving.

To motivate participants, bonuses were given for completing the driving scenario and for beating a reference time. Penalties were assessed for having an accident, going 3 mph over the speed limit, and for errors in response to signs, the memorized flight information, and radio tuning.

Dependent measures collected included traffic safety variables (accidents and speeding tickets) and driving measures (lateral position, speed, and responses to road signs).

In general, there were very few instances of speeding or accidents in this experiment, so few that there were no differences between conditions. Likewise, for straight roads, there were no differences in lateral position between conditions, though there were differences in the standard deviation of lateral position. Lateral position was significantly more variable for manual dialing (than memory or voice dialing), when the phone was on the dash (versus the console), and for older drivers. Differences were typically on the order of 6 inches. The probability of lane departure during a call was less than 1/1000 of 1% for the baseline (no phone condition), but switching to manual dialing increased the probability to 0.68% for the dash-mounted phone for the middle-aged group and 1.63% for older drivers. For the console-mounted phone, those numbers increased to 1.60% and 7.23%. For the memory and voice-activated dialing conditions, lane departure probabilities (0.1%) were considerably lower, and age differences were generally absent. Receiving a call created few problems.

For curves, drivers cut corners to minimize lateral acceleration (and discomfort) and hence lane exceedance probabilities were greater than for straight sections. Lateral deviations were almost double those of the straight sections. Again, drivers had more difficulty with manual dialing, and older drivers did much worse than the other two age groups.

Thus, calling problems are most acute for middle aged and especially for older drivers when manually dialing. The risk of hitting an obstacle for each execution of the task is comparable to manually tuning a radio, though nowadays manual radio tuning is very uncommon. Problems are far less for voice dialing and least acute for memory dialing, which requires only a single key press. Mounting the phone on the dash instead of on the console reduces risk considerably. Specifically, Stein et al. identify the following cases where the probability of going outside of the lane boundaries exceeds 0.5%, a value at which traffic safety may be a concern: dash-mounted manual phone for both middle-age drivers (0.68% probability) and older drivers (1.63% probability) and console-mounted manual phone for both middle-age drivers (1.60% probability) and older drivers (7.23% probability). These data strongly suggest manual dialing should not be used while driving. They have not, however, been verified by on-road experimentation.

Alm and Nilsson (1990)

This experiment examined the effect of phone conversation on traffic object detection, vehicle control, and driving workload, as well as whether driving task difficulty affected conversation on the phone. Forty drivers (ages 23-61, mean = 32) participated. They drove a simulator with a moving-base system and a wide field-of-view showing two-lane roads. In addition to a practice route, there were easy and difficult test routes with the difficult route having more curves.

An Ericsson phone with a hands-free capability was installed inside a Volvo 740. At various times the phone rang and the driver pressed a button to answer it. Over the phone, drivers were presented with a test for working memory span. Sentences were in the form of X does Y (e.g., "The boy brushed his teeth," "The train bought a newspaper"). The participant responded "yes" if it was sensible, "no" if it was not. After each group of five sentences, drivers recalled the last word from each sentence in the order they were presented. This task was demanding, immune to learning, and of reasonably constant duration (60 seconds/five sentences). Each driver received eight calls. Shortly after four calls, a red square appeared on the side of the road to which the driver responded by pressing on the brake.

When using the phone drivers took significantly longer to respond to the visual stimulus than when not using the phone (1.35 versus 0.95 seconds) for the easy route, but not for the difficult route (1.2 versus 1.3 seconds). It may be that the more difficult tracking task altered priorities, forcing drivers to concentrate on tracking whether using the phone or not. Also, people drove faster on the easy road, increasing the accelerator-to-brake distance, and, possibly, the response time.

In terms of lane position, the lateral position was about 1.6 m for both the experimental (phone) and control (no phone) groups for the easy road. (Lateral position was measured in relation to a zero position where the central line of the road coincides with the central line through the driver's body.) Differences between the experimental and control groups were not significant for the first 500 m (when drivers were engaging the hands-free function) but were significant for answering and performing the listening part of the task. For the difficult road, lateral position varied from 1.1 to 1.7 m (depending on where in the route the call came) when drivers were engaging the hands-free function, and from 1.4 to 1.7 m when engaging the phone and performing the listening part of the task. Lateral variance was not examined.

In terms of workload, NASA-TLX ratings changed significantly for mental demand but not for physical demand, time pressure, operator performance, operator effort, or frustration level. Driving speeds averaged roughly 90 kmh. The difficult road was driven about 19 kmh more slowly than the easy one. Adding the phone tasks decreased speeds by about 6 kmh. On the other hand, driving task difficulty had no effect on performance of the memory span task.

Thus, while drivers exhibit compensatory behavior when workload increases (they slow down), their response times were longer, increasing the risk of collision. This occurred, however, only for easy roads.

Brookhuis, de Vries, and de Ward (1991)

Every working day for three weeks 12 people (4 ages 23-35, 4 ages 35-50, and 4 ages 50-65) drove two routes and performed a paced serial addition task (PASAT), a combination of memory and addition tasks chosen to simulate the load imposed by a car phone conversation. One route was a motorway with light traffic, while the other involved heavy traffic on a four-lane ring-road (beltway). Heavy traffic was ensured by having the subjects follow a lead vehicle. A third route was driven (city traffic) during which subjects either made or received calls using the phone. Half of the subjects used a handset and half used a hands-free phone. Dependent measures included performance on the telephone task, heart rate, and driving performance measures (rear view mirror checks, steering wheel movements, car following, and lateral position).

The following results were obtained.

1. When performing the telephone task and driving, heart rate was significantly higher and heart rate variability was significantly lower than when driving alone.
2. The type of road affected the telephone task. There were fewer rearview mirror checks while performing the subsidiary task when driving alone on the motorway than on the beltway.
3. In city traffic, the standard deviation of steering wheel movement was increased before drivers were prompted to dial using the handset, but drivers who received a call using the hands-free method showed increased steering wheel movement after receiving a call.

4. Adaptation to the speed of the lead vehicle was delayed by 600 msec while performing the PASAT task.
5. Subjective workload was significantly greater for the dual task condition (driving and using the phone) than when driving alone.
6. The type of phone did not affect heart rate or subjective workload.
7. There were no age differences.

Thus, using a hands-free phone led to better control of the vehicle than did using a manual phone. Other implications for traffic safety while using a phone included decreased mirror checks on certain types of roads and delayed speed adaptation to a lead vehicle.

McKnight and McKnight (1991)

McKnight and McKnight (1991) had participants view 47 30 second driving segments, each of which contained at least 1 situation that required a change in vehicle speed or direction. Of the driving situations, 18 involved other vehicles (stopping, turning, crossing, etc.), 10 involved changes in road configurations (lane drop, narrow bridge, etc.), 4 involved pedestrians or animals, 4 involved route changes, 3 involved road sight limitations, 3 involved roadside construction conditions, 3 involved traffic control signals, and 2 involved road surface conditions. While viewing each driving situation, subjects experienced one of five levels of distraction: (1) no distraction, (2) placing a call, (3) casual conversation (social chit-chat), (4) intense conversation (problem solving), and (5) tuning a radio (a comparison distractor). The dependent measures were response occurrence (whether or not the driver responded) and response time.

One hundred fifty-one drivers participated: 45 young (25 years old and younger), fifty-seven middle-age (ages 26-49), and 49 older (50 years old and older). Fifty participants were car phone users.

Both response occurrence and response time were affected by level of distraction. Distractions increased the proportion of missed situations 0.06-0.09 times, and response times by 0.4-0.9 seconds over no distractions. Complex conversations resulted in a higher proportion of drivers failing to respond than did simple conversations (0.099 versus 0.068). Complex conversations also led to the highest response time (0.85 seconds), with casual conversations having the lowest (0.26 seconds), and placing a call (0.79 seconds) and radio tuning (0.69 seconds) falling in between.

More older drivers failed to respond to distractions when placing a call and having a casual conversation, when compared to younger and middle-age drivers. Older drivers also took longer to respond when placing phone calls than did drivers in the other two age groups. Prior experience using car phones did not affect whether drivers responded to the situations or how long they took to respond.

Thus, using a phone is somewhat distracting while driving, leading to a higher incidence of nonresponses to road situations and to increases in time to respond than when simply driving. While complex conversations are most distracting, placing calls and carrying on casual conversations also divert the driver's attention from the road.

Nilsson and Alm (1991)

This experiment extended the previous experiment (Alm and Nilsson, 1990) by examining 20 older drivers (ages 60-71, mean = 66). The equipment and tasks were identical to the previous experiment, but only the easy route was examined.

Older drivers were slower to respond than younger drivers (from the previous experiment) by approximately 0.4 seconds. Differences between control and phone conditions were about the same size. On the other hand, there were no differences in lateral position between the control and phone conditions for the older drivers (both about 1.5 m). However, there were differences in the standard deviation of lateral position (0.13 m in the control condition versus 0.19 m in the phone condition for the first 500 m, 0.17 m versus 0.19 m for the entire segment). The first 500 m was associated with activating the hands-free function. Older drivers were significantly more likely to show effects due to phone use than younger drivers.

With regard to the effects of workload (as assessed by the NASA-TLX instrument), including the phone significantly altered ratings only on the mental demand scale. Use of the phone also affected the speed at which older participants drove by 9 kmh, roughly the amount due to the age difference.

Finally, age altered the results of the working memory span test with older drivers having significantly briefer memory spans than younger drivers.

This work suggests that mobile phone use may be a matter of concern for older drivers. While they slow down to reduce driving workload when using a phone, they drive somewhat more erratically and take longer to respond to unexpected stimuli. Nilsson and Alm suggest that some of the problems could be avoided by monitoring traffic and delaying incoming calls until it is safe for the driver to respond.

Summary

The studies investigating car phone use indicate that performing another task while driving degrades driving performance (less rear mirror checking, slower adaptation to changes in traffic speed, greater lateral position, longer response time to unexpected stimuli, and longer driving time). In contrast, driving task difficulty was not found to affect performance on a memory task. Using a phone and carrying on a complex conversation leads to less attention directed toward the road, and this effect seems to be more dramatic as age increases. The Nilsson and Alm research also concludes that mobile phone use for older drivers is a concern.

With regard to the design of phones, one study concludes that using a hands-free phone rather than a manual phone results in better driving performance (Brookhuis et al., 1991), and another recommends a horizontal pushbutton dial or a 4 x 3 dial-in-handset located on the dash or the visor (Kames, 1978). Finally, drivers subjectively find that performing another task while driving is more difficult than driving alone.

Both dialing and conversing (or secondary tasks) while driving have been shown to degrade driving performance. Only a few studies, however, have examined and compared both aspects of car phone use while driving (Alm and Nilsson, 1990; McKnight and McKnight, 1990; Nilsson and Alm, 1991). For young drivers a working memory span task was found to affect lateral position, but activating the hands-free function did not, while older drivers exhibited a greater standard deviation of lateral position when activating the hands-free function on the phone, but not when performing the task. Other results indicate that the response time to driving situations was longest for complex conversations and shortest for casual conversations, with placing a call falling in between.

The reviewed studies provide researchers with initial data on driving performance and car phone use. However, important issues, which have not been examined, include performance with IP displays versus HUDs and manual versus voice phones. These issues were addressed in the present study.

EXPERIMENT ONE: CAR PHONE LABEL STUDY

Purpose

The purpose of this study was to determine driver preferences for labels and abbreviations of the function buttons on the phone such as "power" and "dial."

Test Plan

Test Participants

Nineteen drivers (14 men and 5 women) at two local Michigan secretary of state offices (Carpenter Road and Stadium Boulevard, Ann Arbor) participated. The participants were people waiting in line for driver's license tests or related matters. A criterion for participation in the experiment was that they did not have prior experience using a car phone. The drivers ranged in age from 20 to 71 years, with all but three under the age of 55. Nine drivers had a college degree or postgraduate education. Most of the drivers were native English speakers, though native Korean and Arabic speakers were in the sample. One participant had driven a car with a HUD, but no one owned a HUD-equipped car.

Test Materials and Equipment

A Macintosh SE computer (with a 9 inch monochrome display), and the associated mouse and keyboard, was used to present a prototype of a car phone. The prototype was designed using the HyperCard version 2.0 software and written in the HyperTalk programming language. The prototype filled the screen and consisted of a display, number pad, and buttons used for functions such as dialing or storing a number. (See Figure 1.) To the right of the display, a listing of numbers in memory locations one through five was shown (locations six and seven were empty). In addition to the car phone, answer boxes appeared on the screen next to the function buttons to show the subject's responses.

The following seven functions were tested on the phone: power, delete, dial, end, answer, memory, and recall. The first five are functions necessary for typical car phone use, while memory and recall are common functions found on car phones.

Materials included biographical and data collection forms.

At one testing site, a folding table and two folding chairs were used. At the other, the computer was placed on a counter and the interviewer and subject stood for the duration of the interview.

Test Activities and Sequence

Upon arriving at the secretary of state office, the computer was set up along with the folding table and chairs, if necessary. The experimenter then timed whether or not the wait exceeded 15 minutes, the time required to complete subject interviews. Visits to the secretary of state office were planned around peak service times, usually at noon and from three to five PM.

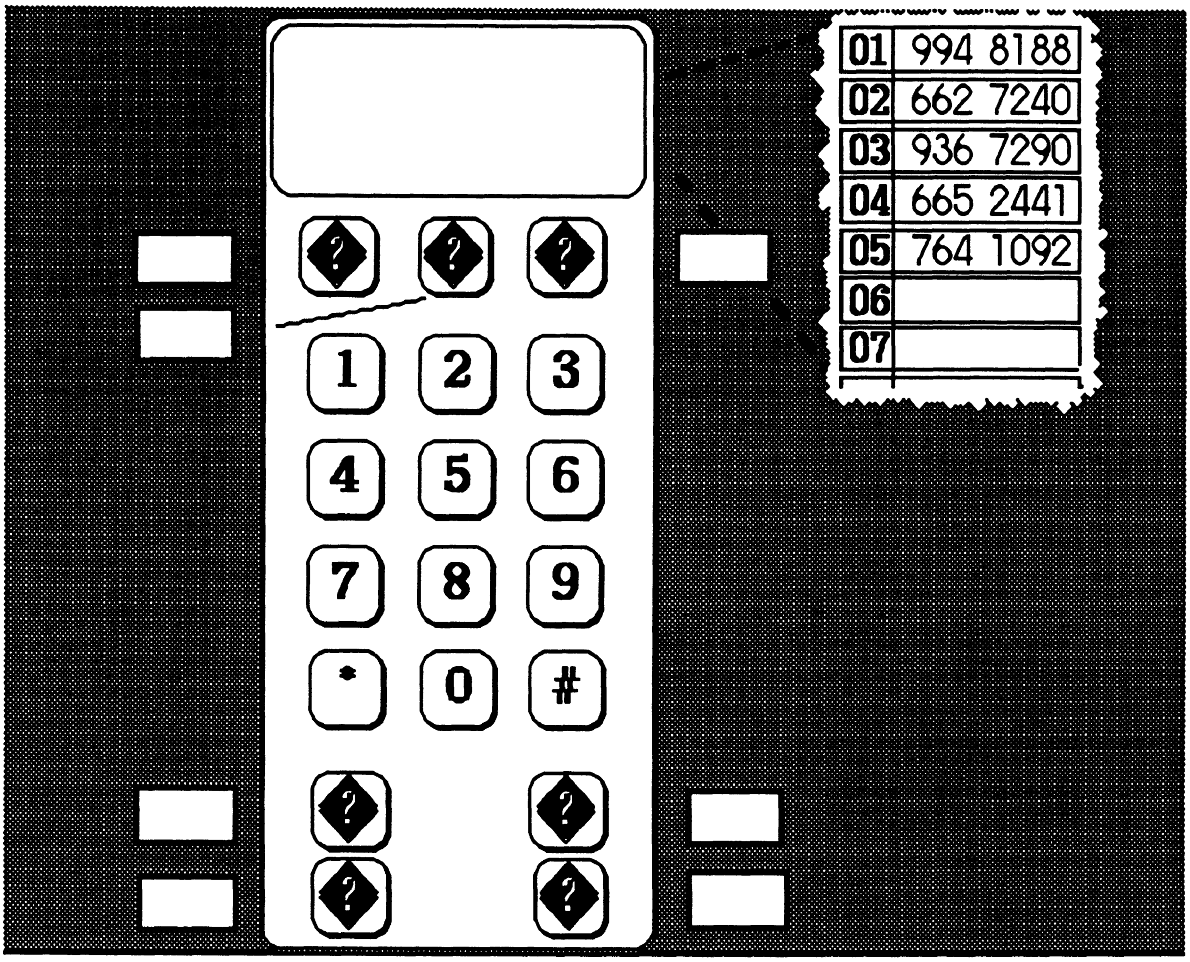


Figure 1. Car phone prototype as it appeared on the computer screen

Participants were selected based on when they arrived at the office. After a person entered the office and got settled in, the experimenter introduced herself and explained the purpose of the interview. The experimenter then asked the person if he/she would like to participate in a study while waiting. Typically, people responded positively; however, sometimes a person declined.

The experimenter asked the participant to stand (or sit) by the computer for instructions. First, the experimenter demonstrated the interface and pointed out the various parts of the phone: display, numberpad, and function buttons. Then the experimenter explained that the function buttons (the ones with question marks) needed labels and told the participant how he/she was going to help provide them. Before the button labeling proceeded, the experimenter filled out the biographical form by asking the subject questions about himself/herself and the kind of car he/she drives. Finally, the experimenter demonstrated a function and asked the subject to label the button based on what was just seen as a result of the button press. For example, pressing the unlabeled dial button would result in the tone sequence of a number being dialed. Table 4 lists the functions and the associated consequence when pressed, in the order they were tested. When the interview was completed, the experimenter thanked the participant.

Table 4. The consequences associated with the function buttons on the phone

Function	Consequence
Power	If the phone is off, a tone sounds twice when the button is pressed. A light indicator and the word "on" appear in the top right corner of the display. If the phone is on, the same tone sounds when the button is pressed. The light indicator and the word "on" are cleared from the display.
Delete	One press clears the last number entered in the display (the first digit on the right). Holding the button down clears all the numbers, starting with the first one on the right, until the button is released. A tone sounds when each number is cleared from the display.
Dial	A tone sounds when the button is pressed. One hears the tone sequence of a phone number being dialed and the phone ringing. After two rings the experimenter stops the ringing and a recorded voice says "Hello."
End	When the button is pressed a tone sounds and the recorded sound of a busy signal is stopped.
Answer	When the button is pressed a tone sounds and ringing, which signifies an incoming call, is stopped. The experimenter says, "Hello, this is ________."
Memory	After a seven digit number is entered in the display, pressing the button enters the number into the next available memory location, 06. A tone sounds when the button is pressed. The numbers 06 appear above the last two digits of the seven digit number in the display and the seven digit number is entered into memory location 06. Both the number in memory location 06 and the 06 on the phone display flash four times. Upon completion of the flashing, both 06 and the seven digit number remain on the phone display.
Recall	After the button is pressed and a tone sounds, the experimenter presses 0 and 4 on the numberpad. These numbers are entered into the top right of the display and the seven digit number in memory location 04 is put into the phone display. Both the seven digit number in memory location 04 and 04 on the phone display flash four times. Upon completion of the flashing, both 04 and the seven digit number remain on the phone display.

Results

The labels and abbreviations chosen by participants are presented in Table 5. For dial, answer, memory, and recall certain labels were named more frequently than others. It appears that participants preferred a straightforward label and simply labeled the button for the function that it performs. However, for power, delete, and end many different labels were suggested.

A majority of the suggested abbreviations used the truncation rule (using the first few letters of the word), such as POW for power, and the vowel deletion rule, such as PWR for power. Other abbreviation schemes were used, such as HG for hang-up, but with much less frequency.

Table 5. Labels and abbreviations for car phone functions

Function	Number of Subjects	Label	Abbreviation
Power	8	Power	POW, PWR
	6	On/Off	ON
	5	Other	
Delete	5	Delete	DEL,DLT
	4	Clear	CLR
	4	Erase	E,ER,ERA,RES
	6	Other	
End	3	End	END
	3	Hang-up	HU,HNU,HG
	3	Cancel	CAN
	3	Disconnect	DSC,DIS
	7	Other	
Dial	8	Dial	DIA,DL,DI,DIL,D
	3	Call	CA,CAL,CLL
	8	Other	
Answer	11	Answer	ANS
	2	Speak	SPK,SPR
	2	Pickup	PU,PKU
	4	Other	
Memory	6	Memory	MEM,M1
	3	Store	STR,STO,FIL
	2	Enter	ENT
	2	Program	PRG
	6	Other	
Recall	7	Recall	RCL,REC
	3	Redial	RED,RD
	2	Program	PRG,SPD
	2	Retrieve	RET
	5	Other	

Conclusions

Collecting data at the secretary of state office proved to be a valuable way to obtain information on how drivers label car phone functions. Notice that in several cases there was no strongly preferred choice. The abbreviations suggested by participants were put on the buttons and the following abbreviation study was undertaken to determine whether this was the optimum labeling scheme.

EXPERIMENT TWO: CAR PHONE LABEL ABBREVIATION STUDY

Purpose

After collecting data at the secretary of state office on driver preferences for car phone function labels, it was still not clear which method of abbreviation would be best understood by the user. In this case, there is space for only three legible characters on the button. Two methods of abbreviation were investigated in this study: truncation -- retaining the first few letters of a word, and vowel deletion -- retaining the first and last letters of a word, but deleting the vowels in-between.

Being consistent in the abbreviations was of concern. After figuring out the method of abbreviation, drivers expect to use the same methodology to figure out the rest of the labels. However, it was thought that some of the function labels could be ambiguous if only one abbreviation method was used. For example, when using the truncation method of abbreviation for recall, which is "Rec," some users may incorrectly interpret the abbreviation as "Receive" or "Record." Additionally, if the vowel deletion method of abbreviation is used, some users may believe the abbreviation "Dlt" stands for "Dial tone."

Previous research indicates that when the task is decoding, no abbreviation technique is consistently better than others (Ehrenreich, 1985). Therefore, if two abbreviation techniques are used on the car phone, performance in decoding the words may be better than if only one technique is used.

Test Plan

Test Participants

There were seven men and five women who participated in this experiment. The participants ranged in age from 22 to 53 years old (mean = 33 years). All were employees of the University of Michigan Transportation Research Institute (UMTRI), but were not human factors experts. None of the 12 participants owned a car phone and only 1 participant had ever used one before.

Test Equipment and Materials

Three car phones were drawn using MacDraw II (Claris Corporation, 1988). The phones were 2.5 x 7.3 inches in size and had eighteen 0.6 inch square buttons on them. The font used was 14 point Helvetica in Bold. See Figure 2 for an example of the car phone.

The following six functions on the phone handset needed abbreviations: (1) power, which turned the phone on and off, (2) call, which sent a call or retrieved an incoming call, (3) end, which hung up the phone, (4) delete, which sequentially removed numbers from the display in case one pressed the wrong number when dialing, (5) memory, which stored a phone number into a memory location, and 6) recall, which placed a number currently stored in memory into the handset display.

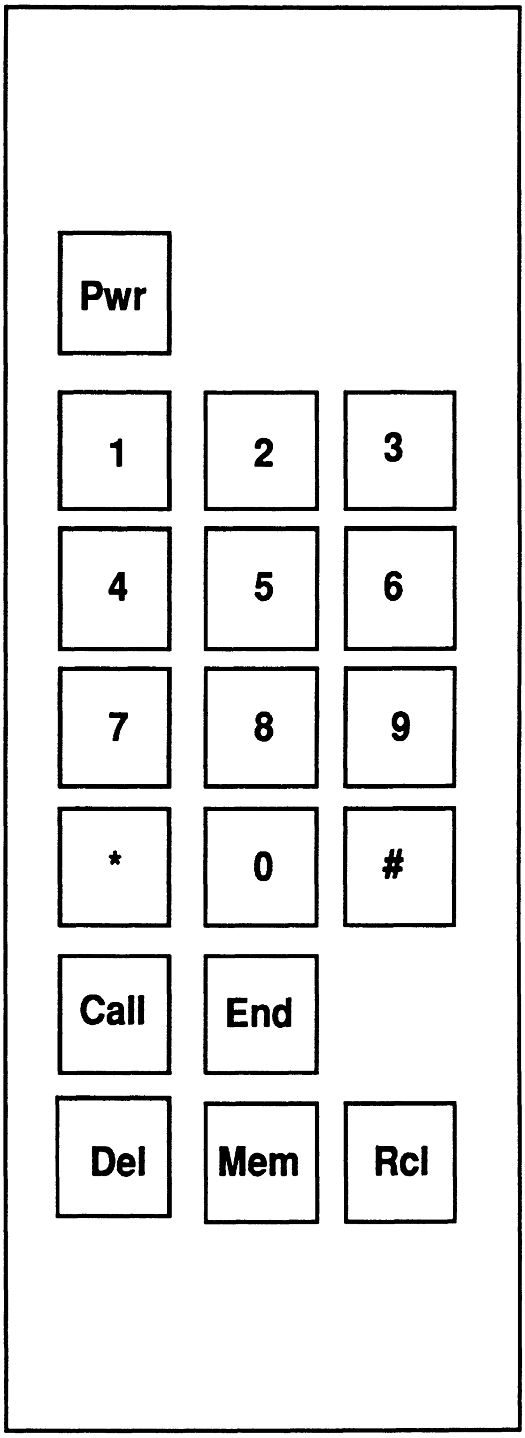


Figure 2. Car phone using a mixture of the vowel deletion and truncation methods of abbreviation

Call was the label used to send and retrieve incoming calls, as opposed to dial and answer, respectively, which were used in the study at the secretary of state office. This change was made for the following reasons.

1. To be consistent with current car phones, only one button was desired to perform the two functions of send and retrieve.
2. Call was recommended as a label by three participants in the secretary of state testing.
3. Call is a general label that refers to either making a call or answering a call, unlike the popular label, send, which refers only to making a call.

The three abbreviation methods tested are shown in Table 6. Version A of the car phone used the vowel deletion method of abbreviation, Version C used the truncation method, and Version B used a mixture of the vowel deletion and truncation methods.

Table 6. Abbreviation methods tested

	Method of Abbreviation		
Function	Version A Vowel Deletion	Version B Mix	Version C Truncation
Power	Pwr	Pwr	Pow
Call	Call	Call	Call
End	End	End	End
Delete	Dlt	Del	Del
Memory	Mry	Mem	Mem
Recall	Rcl	Rcl	Rec

Test Activities and Sequence

Subjects were tested in their offices. Four subjects began the test with Version A (vowel deletion), four subjects began with Version B (mix), and four began with Version C (truncation). First, personal data were collected and then either Version A, B, or C of the car phone was shown. The subject was asked to look at each button, tell what each button stood for, and state the function of each button. Next, the experimenter asked what the sequence of buttons would be if he/she had to make a phone call. (Three subjects were not asked this question.) The other two versions of the phone were presented individually and the same questions were asked. Finally, all three versions of the car phone were shown and the subject was asked to notice the abbreviation differences between phones and to choose the one that he/she preferred.

Results

When subjects started with the vowel deletion version of the car phone, all abbreviations and functions were named correctly except for "Dlt." Two subjects thought that it stood for dial tone. The subjects who started with the mixed version named all abbreviations and functions correctly. Of those who started with the truncation version, three believed "Rec" stood for record and one believed it stood for receive. Furthermore, "Pow" was misinterpreted by two subjects to be a button for retrieving messages from an answering machine. A summary of this information can be found in Table 7. After being presented with all three car phones, eleven out of the 12 subjects preferred the mixed abbreviation version over the truncation or vowel deletion version.

Table 7. Errors in relation to starting car phone version

Starting Version	Total Number of Errors	Error
A (Vowel Deletion)	2	Dlt
B (Mix)	0	——
C (Truncation)	5	Rec Pow

In order to make a phone call from the car phone, the power button must be pressed to turn on the power, then the phone number must be dialed. Next, the call button must be pressed to send the call, and, finally, the end button is pressed to terminate the call. Only one subject correctly named the order of the buttons to make a phone call.

There were four incorrect sequences given by subjects for making a call on the car phone. (Subjects were not told the correct abbreviation for the function buttons before answering this question.) One sequence given was to press the power button, press the call button, dial the phone number, then press the end button. Another sequence given was to press the call button, then dial the phone number. A third sequence given was to press the power button, hit the button for dial tone, dial the phone number, and then press the call button. The last sequence given was to press the power button, dial the phone number, and then press the call button.

The call button was used incorrectly in seven out of nine cases. Subjects pressed Call *before* dialing the phone number instead of pressing Call *after* dialing the phone number in order to send the number. Table 8 shows a summary of this information.

Conclusions

Although mixing two abbreviation techniques violates consistency rules, data show that people can decode the abbreviations more easily when this rule is broken. Not only did most subjects prefer the mix of abbreviation techniques, they performed better when decoding the abbreviations and naming the functions.

Table 8. Incorrect sequence of button responses for making a call

Order of Buttons	Frequency of Response
Power Call Dial phone number End	5
Call Dial phone number	2
Power Dial tone Dial phone number Call	1
Power Dial phone number Call	1

Only one of nine subjects correctly named the sequence of buttons for making a phone call. Most subjects misinterpreted the call button as a prerequisite for dialing a phone number. This suggests that perhaps a different word should be used in place of call. However, the call button has a dual function; it sends calls as well as receives incoming calls. "Call" implies both functions. If a different word was used to replace the call button functions, two buttons might be required to instruct an inexperienced car phone operator on how to use the phone. Whether or not this problem is found only in inexperienced car phone users may warrant further study. With training and practice, the function of call may be used properly.

EXPERIMENT THREE: CAR PHONE LABORATORY STUDY

Purpose

To determine the best design for a car phone, two input methods (manual and voice activated) and two types of displays (IP and HUD) were examined. Also, baseline performance data were needed for comparison with on-road data to be collected later.

Test Plan

Test Participants

Twelve people (six men and six women), ranging in age from 20 to 76 years, participated in this study. The participants were divided into two age groups, younger (20-35 years old, mean = 24 years) and older (over 60 years old, mean = 70 years). A requirement for participating in the experiment was that they had never used a car phone. In addition, none of the participants had ever used a navigation system or a HUD.

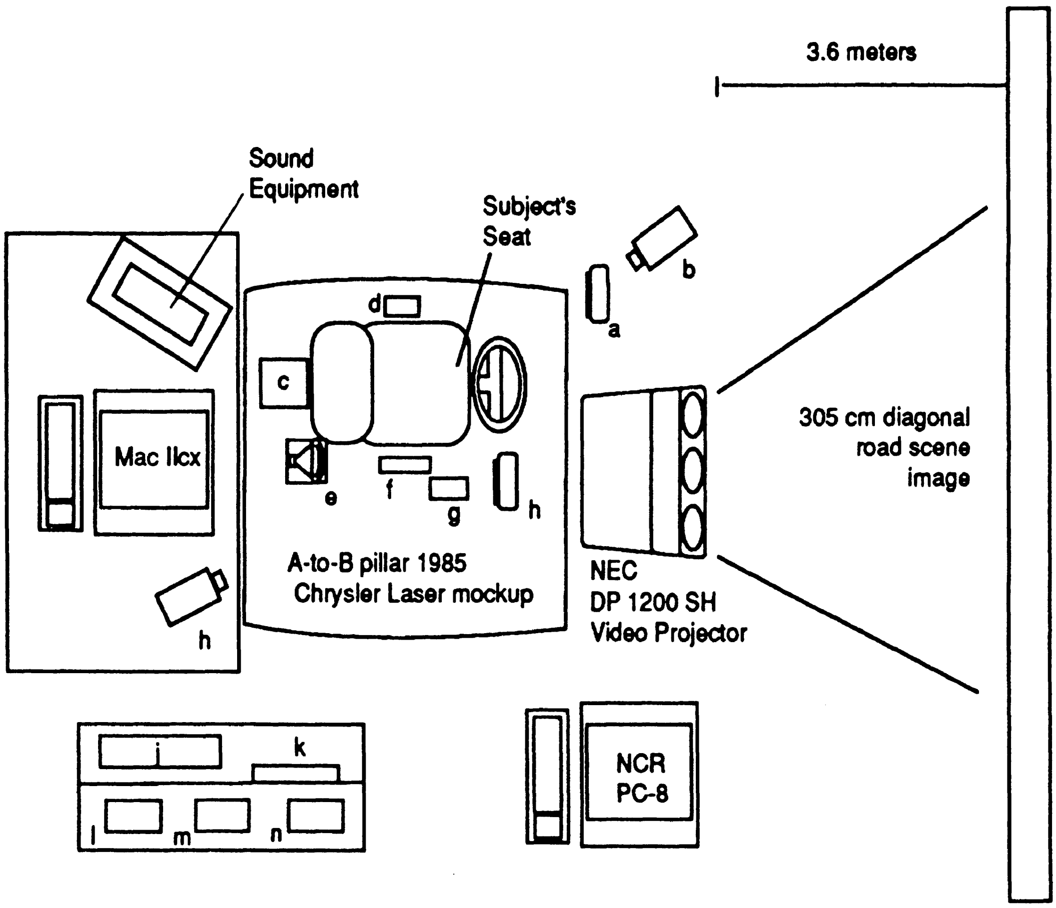
All the younger subjects used a touch-tone phone at home, whereas five out of the six older subjects used a rotary phone at home (one of the older subjects had both types of phones at home). Furthermore, all of the younger subjects had used a cordless phone, while only half of the older subjects had ever used a cordless phone. Each participant was paid $20 for the 1.5 hour session or $25 if the experiment lasted longer than 1.5 hours.

Test Materials and Equipment

A 1985 Chrysler Laser mockup was used as part of the driving simulator. Model numbers and laboratory layout are shown in Figure 3. The car phone, modified from a Motorola car phone shell, was located on a box next to the driver. A drawing of the car phone design and layout is shown in Figure 4.

The phone did not have to rest on its cradle after making a call; therefore, the driver could place the phone anywhere he/she desired within the cord constraints. Located next to the phone was a phone book and a 4 x 6 inch three ring notebook, which contained numbers to be dialed by the subject. There were four types of phone cards. Each one included a first name, last name, or a title, such as "Mom," and either a familiar local, a familiar long-distance, an unfamiliar local, or an unfamiliar long-distance number. The experimenter asked subjects to come with a familiar local and long-distance number memorized. These numbers were obtained during recruitment so a phone card could be made prior to testing.

A microphone for recording secondary task responses and a speaker to play phone sounds and experimenter commands were also in the buck. In front of the buck was a black and white video camera to record the driver's eye fixations. A JVC color video camera was located behind the buck to record the phone input on the display.



a Panasonic TR-6LC1 6" LCD display (simulated HUD)
b RCA B/W Camera TC1030/H;
Lens TC1803; Controller, TC1430; Intraspot Lens 16-160MS
c 13.5V Power Supply (for seat controls)
d Electronic seat controls
e Speaker
f Motorola phone
g Phone book
h Macintosh 13" AppleColor Display (IP display)
i JVC Color Video Camera S-100U; Canon TV Zoom Lens 16-160MM;
JVC Electronic Viewfinder VF-C511U
j JVC KM-1200 Color Special Effects Generator
k Panasonic AG-6200 Video Tape Recorder
l Sanyo VM-4209 B/W Monitor
m Sanyo VM-4509 B/W Monitor
n Panasonic BT-S700N Color Video Monitor

Figure 3. Laboratory layout and model numbers of equipment

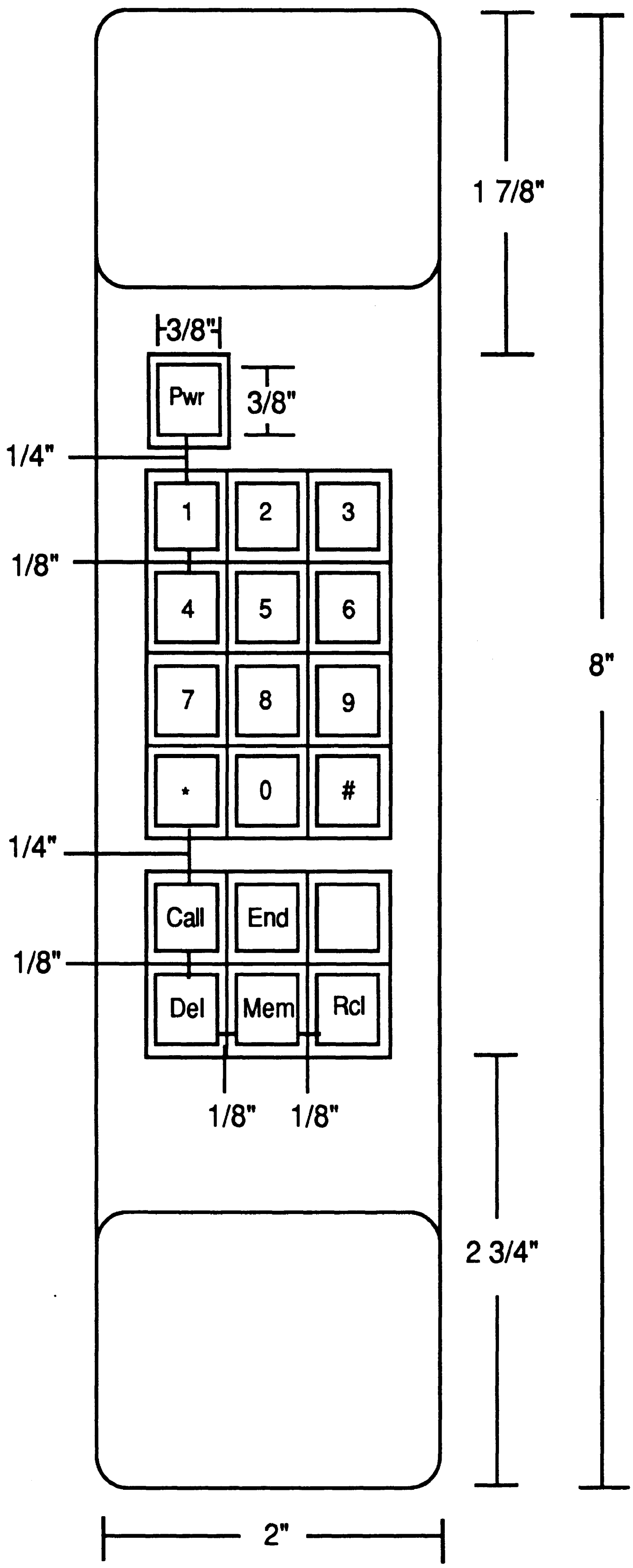


Figure 4. Manual car phone design and layout

Two types of displays were used, a simulated HUD located at the bottom left of the windshield and an IP display located in the center of the dashboard. When a driver pressed a number or function on the car phone, a tone followed by confirmation of the button press appeared on the display. Confirmation of the button press could be a number or an abbreviation of the function appearing on the screen. A sample of the display format can be seen in Figure 5.

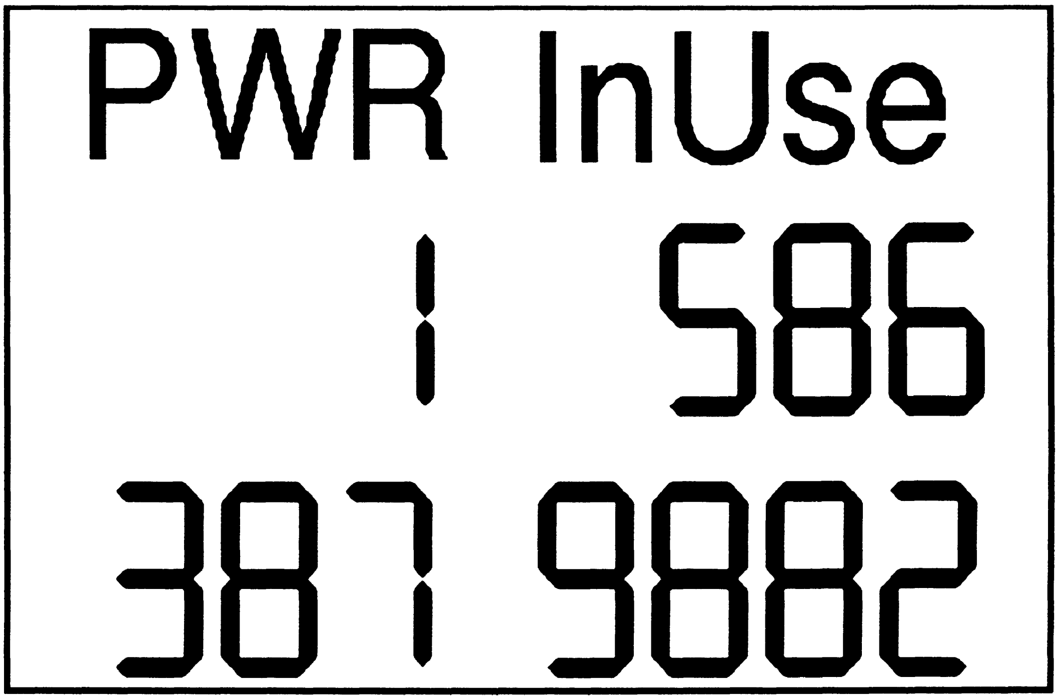


Figure 5. The HUD and IP display layout

The experimenter's station was behind the car buck. A Macintosh IIcx was used to present the phone sounds created in HyperCard. The keys in the car phone were wired in a 4 x 4 matrix. They were soldered into the usable keys on the Apple Keyboard. The matrix allowed full functionality of the phone with only eight wires. Thus, the existing Motorola phone cable could be used for connection to the Mac keyboard. Figure 6 shows the wiring of the lab setup.

A JVC color special effects generator was used to create a split screen of the image of the participant's face on the top, and an image of the display on the bottom of the recording. These images were viewed on two black and white monitors, and one color monitor. The final mixed picture was recorded on a videotape recorder.

Test participants drove on a simulated road generated from a NCR PC-8 80286 computer, and displayed by a NEC video projector onto a large screen in front of the driver. The driving scene appeared as a single-lane road at night (similar to Figure 7). The velocity of the simulator was constant during all tasks.

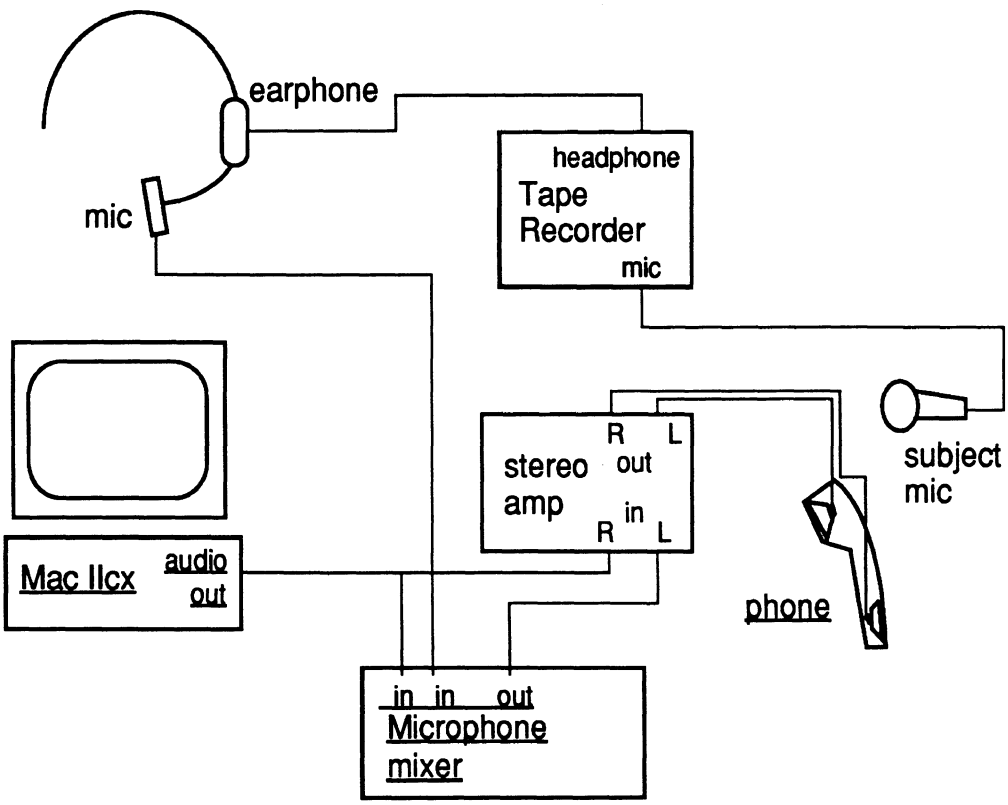


Figure 6. Laboratory setup of wires

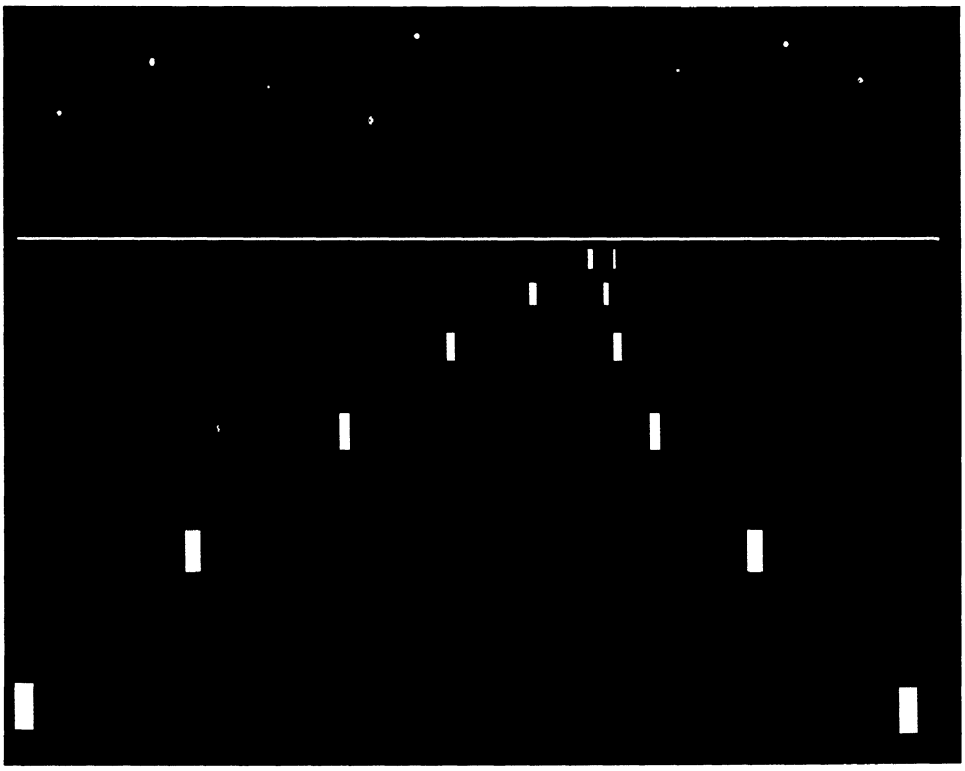


Figure 7. Sample of the nighttime driving simulator scene

The paperwork included a set of detailed instructions that identified exactly what the experimenter was to say and do (Appendix A), a consent form (Appendix B), and a biographical form (Appendix C).

Secondary Tasks

Four secondary tasks were performed by the subject to simulate what a typical driver may do while on a car phone. A task was given after the subject dialed a phone number. The secondary tasks were: listing, talking, listening, and loose ends. Each task lasted 30 seconds and all subjects were given the same questions for each task. See Appendix D for a complete listing of the questions asked in the secondary tasks.

The listing task required the subject to name as many items as he/she could in a category. Examples of the categories were a kind of fruit, a type of currency, or a type of furniture. The task simulated how a person may retrieve information from memory that would typically be necessary during a phone conversation.

The talking task required the subject to do most of the talking. The experimenter would ask a question and the driver would continue talking until time ran out. Some questions asked were "What did you do last weekend?," "Describe your favorite recreational activity," or "What is your favorite movie? Describe it." The task is similar to a conversation a person may have over the car phone in which he/she does most of the talking.

The listening task required the subject to listen to a description of a hypothetical situation. At the end of the description the experimenter would ask the subject to choose one of three options. This task is similar to a conversation a person may have in which he/she does most of the listening.

The loose ends task required the subject to determine how many loose ends there were in a capital letter. For example, if the letter A was presented, the subject would respond two because there are two loose ends at the bottom. This task was performed three times in the 30 second time period; a new letter was presented every ten seconds. This task simulated how a person may recall the spatial arrangements of streets in his/her mind while talking on the car phone and driving.

Test Activities and Sequence

When the subject arrived at UMTRI, he/she was greeted and taken to the laboratory to begin the test session. The experimenter explained the purpose of the study and gave the subject a consent form and biographical form. Next, a vision test was administered using a Titmus Vision Tester. Subsequently, the subject was taken to the car mockup where he/she practiced driving the simulator for at least 2 minutes or until feeling comfortable.

After the driving practice, the phones (manual and voice), phone book, and displays (IP and HUD) were explained. The subject was shown the format of the numbers that he/she would be dialing (familiar local, familiar long distance, unfamiliar local, and unfamiliar long distance) and reminded of the two phone numbers that he/she had memorized before coming to the study. The experimenter then demonstrated the process of dialing a phone number and correcting mistakes from misdialing. Finally, the subject was given practice using the phone-display interfaces. The subject dialed after being prompted to make a call by a recorded voice that said, "Call now, please." The subject dialed each type of phone number once and was then asked if he/she felt comfortable using the phone. If he/she wanted more practice, or if the experimenter thought it was necessary, the subject dialed a few more numbers.

After using each phone-display combination alone, the subject practiced driving and using the phones at the same time. It was stressed that he/she should concentrate on driving and should dial the phone numbers when comfortable doing so.

After the phone practice, secondary tasks to perform during phone conversations were explained one by one in the following order: loose ends, listing, talking, and listening. Practice on each of the tasks was given following each explanation. If the subject wanted more practice, or if the experimenter thought that his/her performance was not up to par, then more practice was given until both the experimenter and subject were comfortable. Before each task, subjects heard a recorded voice that announced the type of task that would be performed, such as "loose ends task" or "talking task."

Finally, formal testing began. Appendix E shows the test sequence for a subject. Each subject participated in three test blocks: pretesting, testing, and posttesting. Pretesting consisted of performing the secondary tasks alone and dialing the phone numbers alone. (There were 5 seconds between the end of a call and the prompt to initiate another call.)

In the test blocks, the subject drove, used the phone, and performed the secondary tasks together. The order in which the subjects used the phone-display combinations was counterbalanced across subjects. The phone numbers and secondary tasks were performed in the same order for all subjects. (There were 15 seconds between the end of each call and the prompt to initiate another call.)

During posttesting, the subject again performed the secondary tasks alone and used the voice and manual phones alone just as in pretesting. To compare performance before and after testing, the same numbers were dialed in posttesting as in pretesting.

Finally, participants were asked to rank order the phone-display combinations (1 = best, 4 = worst). This preference survey is in Appendix F.

Each session lasted approximately 1.5 hours.

Results

Performance measures were recorded for the four phone conditions, which included manual and voice input displayed on both the IP display and HUD.

Lane Position

Driving performance was determined from the recorded lane position on the simulator. The standard deviation of the lane position variance was converted to a measurement in inches, assuming an average lane width of 11 feet. Driving data were classified into three tasks throughout the study: dialing the phone, talking (or listening) with the phone, and base driving (no phone use). For each of these tasks, a 5 second interval of driving data was analyzed for each participant.

An analysis of variance was conducted to examine the effects of the independent variables. There were significant main effects of input method ($F [1, 493] = 8.34$, $p = 0.004$), task ($F [2, 493] = 11.18$, $p < 0.001$), and age ($F [1, 493] = 9.07$, $p = 0.003$). Figure 8 shows standard deviation of lane position as a function of these main effects.

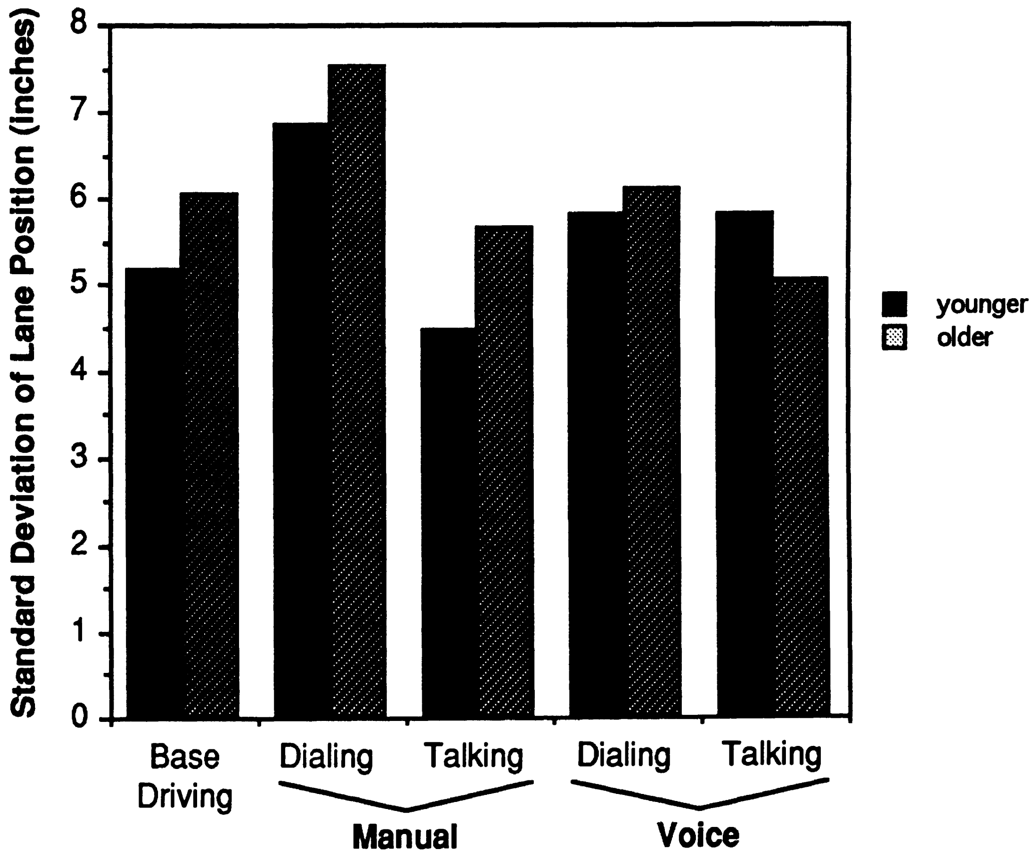


Figure 8. Age differences in driving behavior for all input and activities

The main disturbance in driving performance resulted during periods of dialing (6.6 inches versus 5.2 inches for talking and 5.6 inches for base driving), and was most noticeable with the manual phone. As indicated in Figure 8, there were no significant differences in lane position deviation between base driving and talking activities.

As shown in Figure 8, voice input greatly reduced the lane position deviation during phone dialing (voice--5.7 inches versus manual--6.1 inches). Overall, the steering performance of older drivers (6.0 inches) was worse than younger drivers (5.6 inches).

Interestingly, the type of call (local or long distance) did not have a significant effect on driving performance, despite the greater length of time that was needed to dial a long-distance number.

Dialing Times

The mean dialing time was computed as the time for entering the digits of the phone number (but did not include pressing the "call" button). A paired t-test was performed on the dialing times from the pretest and posttest sessions in order to determine if there was a learning effect. (The same numbers were dialed in these sessions.) A significant difference in dialing times was found between the pretest and posttest sessions (t [76] = 2.553, $p = 0.006$). The dialing time was lower in the posttest session (7.7 seconds) than in the pretest session (8.1 seconds).

During the test sessions, dialing time was significantly affected by all independent variables except display location. Figure 9 shows the effect of age on dialing time for familiar and unfamiliar numbers dialed using the two input methods examined.

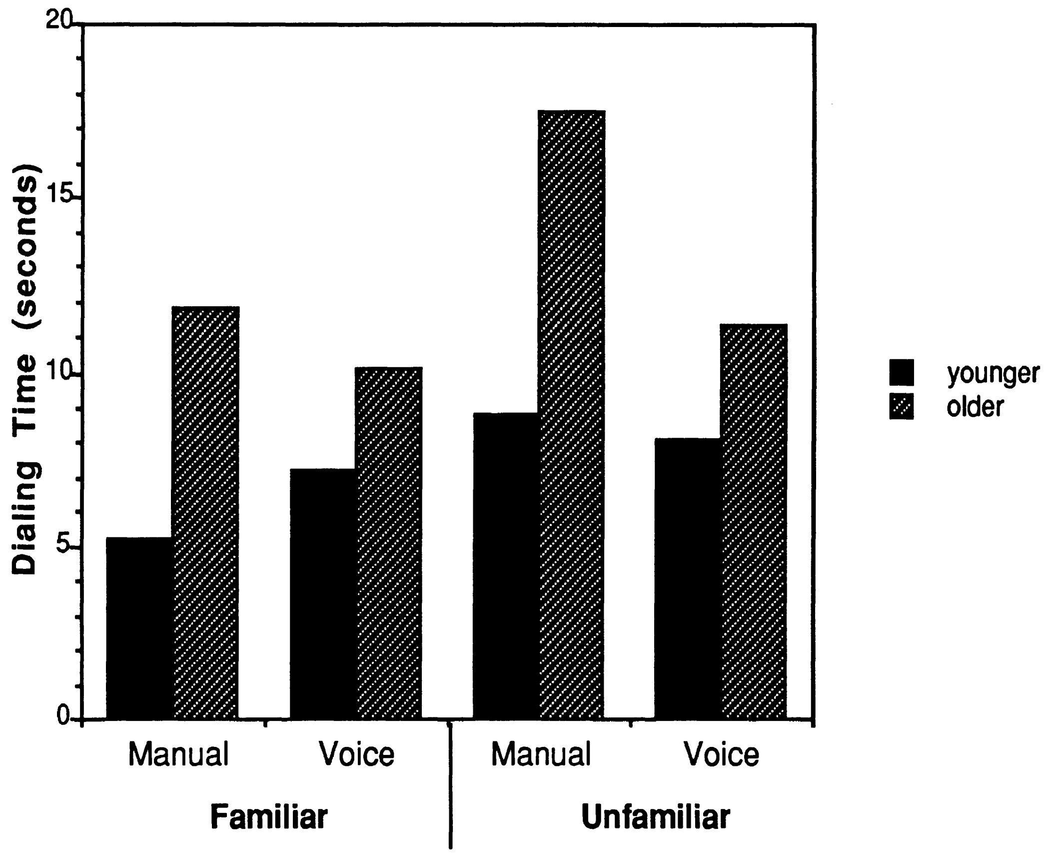


Figure 9. Dialing times based on the driver's age, familiarity with the number, and method of input

The input method was significant (F [1, 164] = 9.27, p = 0.003) with voice resulting in faster overall input times (9.2 seconds) than the manual handset (10.7 seconds). The benefit of using voice input was most noticeable for dialing unfamiliar numbers, as shown in Figure 9. For dialing familiar numbers, there was no statistically significant difference between using manual or voice methods.

Input time was also affected by whether the caller was familiar with the number or not (F [1,164] = 17.89, p < 0.001). In general, it took less time to dial a familiar number (8.6 seconds) than one that was not familiar (11.2 seconds).

The age of a driver was highly significant (F [1,164] = 88.91, p < 0.001), with younger drivers taking an average of 7.4 seconds to enter a number, and older drivers taking an average of 12.6 seconds.

Not surprisingly, the type of call was also significant (F [1,164] = 88.64, p < 0.001). It took longer to dial a long-distance (11 digit) call (12.7 seconds) than a local (seven digit) call (7.4 seconds). This difference was interactively affected by age (F [1, 164] = 8.45, p = 0.004), as shown in Figure 10. While the dialing time for long distance calls (9.3 seconds) was not significantly longer than local calls (5.7 seconds) for younger participants, it was for older participants (long distance--15.9 seconds; local--9.3 seconds).

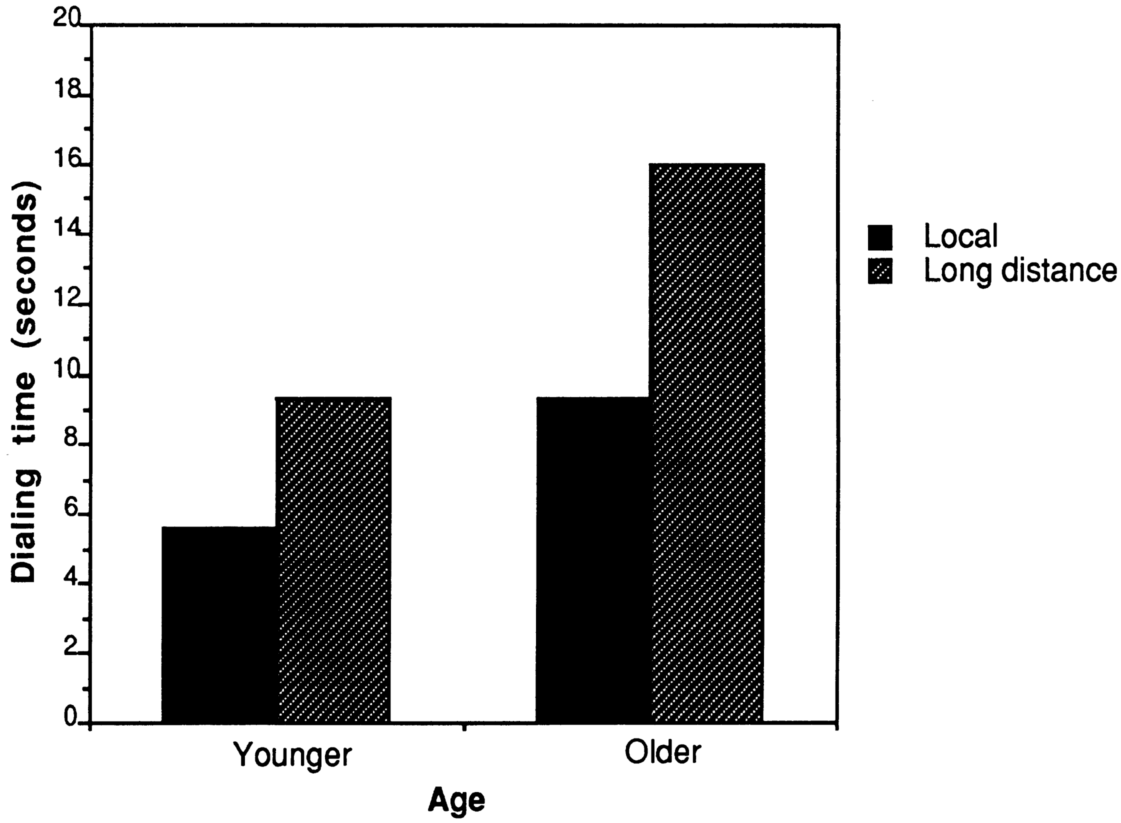


Figure 10. Age effects on dialing time for making local and long distance calls

Eye Glances

A video camera recorded where each subject looked while performing the tasks of the experiment. Since the dialing time and lane position results showed that the location of the display was not significant, only eye glances while using the IP display were analyzed. Only long distance numbers were examined. Videotapes of four subjects driving were analyzed: a younger female (YF), a younger male (YM), an older female (OF), and an older male (OM).

Eye data were grouped into one of three categories: (1) glances inside the car, which include the phone book, phone, or IP display, (2) glances to the road, or (3) blinks. For manual phone glances, a glance started when the first number appeared on the screen. It ended when the last number was displayed. However, a voice phone glance started when the subject started to *say* the phone number aloud. It ended when he/she started to *say* the last number in the phone sequence.

A summary of eye glance data is given in Table 9. It shows each subject's total time spent in each category, whether inside the car, to the road, or blinks. No entry indicates that no time was spent in that category or if any time was spent, the video was not clear enough to record the activity. Since subjects varied widely in their pattern of eye glances, each subject will be discussed separately.

On the manual phone, the younger female spent approximately an equal amount of time looking inside the car as she did at the road when dialing familiar and unfamiliar numbers. While dialing an *unfamiliar* number on the voice phone, she spent 2.60 seconds looking at objects inside the car and 9.53 seconds looking at the road. However, she spent 6.00 seconds looking at the objects inside the car and 5.00 seconds when dialing a *familiar* number. This is surprising because it is expected that the subject would spend more time looking at objects inside the car when the phone number is not familiar.

For both types of phones, the younger male spent more time looking at the road than at objects inside the car. This was especially true while using the voice phone.

The older female subject spent approximately an equal amount of time looking inside the car and at the road while using a manual phone. However, while using the voice phone, she did not look at objects inside the car at all while dialing a familiar number. Furthermore, she spent only 1.75 seconds looking inside the car while dialing an unfamiliar number.

Similarly, the older male subject spent about an equal amount of time looking at objects inside the car and at the road while using a manual phone. On the voice phone, however, he looked at objects inside the car for only 0.43 seconds with a familiar number and 3.97 seconds with an unfamiliar number.

Table 9. Eye glance total times for four subjects

	Total time for inside the car (seconds)	Total time for road (seconds)	Total time for blinks (seconds)	Age/sex	Long distance number type
Manual phone	2.47	2.40	—	YF	Familiar
	3.30	4.73	0.07	YM	Familiar
	5.33	3.23	0.07	YF	Unfamiliar
	7.77	11.63	—	YM	Unfamiliar
	7.37	10.67	0.13	OF	Familiar
	7.47	5.67	—	OM	Familiar
	9.63	12.13	0.13	OF	Unfamiliar
	9.47	16.51	—	OM	Unfamiliar
Voice phone	6.00	5.00	0.37	YF	Familiar
	3.40	7.07	0.17	YM	Familiar
	2.60	9.53	0.07	YF	Unfamiliar
	4.37	12.20	0.07	YM	Unfamiliar
	—	12.30	2.33	OF	Familiar
	0.43	13.63	0.07	OM	Familiar
	1.75	11.87	0.83	OF	Unfamiliar
	3.97	11.80	0.50	OM	Unfamiliar

For younger subjects, using a manual phone or voice phone did not make a big difference in terms of total time spent looking at the road or inside the car. The older subjects showed an increase in time spent looking at the road while dialing a number using the voice phone. The duration of time older subjects spent looking at the road was 55.2% while dialing numbers on a manual phone and 84.5% while dialing with a voice phone.

Table 10 shows the mean time for four subjects over all glances in the given condition. As can be seen from the data, older subjects glanced more often and had a longer mean duration period for each glance than the younger subjects. Both older subjects and younger subjects blinked more while using the voice phone than when using the manual phone.

Table 10. Eye glance mean times and number of glances for four subjects

	Mean time for inside the car (seconds)	Number glances to inside the car	Mean time for road (seconds)	Number glances at road	Mean time for blinks (seconds)	Number blinks	Age/ sex	Long distance number type
Manual Phone	0.62	4	0.80	3	—	—	YF	Familiar
	0.66	5	0.95	5	0.07	1	YM	Familiar
	1.07	5	0.65	5	0.03	2	YF	Unfamiliar
	0.97	8	1.29	9	—	—	YM	Unfamiliar
	0.82	9	1.07	10	0.07	2	OF	Familiar
	1.24	6	0.94	6	—	—	OM	Familiar
	1.07	9	1.10	11	0.07	2	OF	Unfamiliar
	1.05	9	1.65	10	—	—	OM	Unfamiliar
Voice phone	1.00	6	0.83	6	0.09	4	YF	Familiar
	0.85	4	1.18	6	0.08	2	YM	Familiar
	0.87	3	3.18	3	0.07	1	YF	Unfamiliar
	0.87	5	1.74	7	0.03	2	YM	Unfamiliar
	—	—	0.68	18	0.14	17	OF	Familiar
	0.43	1	6.82	2	0.07	1	OM	Familiar
	0.88	2	1.19	10	0.10	8	OF	Unfamiliar
	1.32	3	1.97	6	0.17	3	OM	Unfamiliar

Patterns of Dialing

Using the videotapes from four subjects, the pattern used to dial phone numbers while driving was analyzed. This was coded by listening for pauses while the subject used the car phone. The conditions included dialing a familiar or unfamiliar phone number, dialing a local or long-distance number, or using the HUD or IP display.
Only numbers dialed with the manual phone were analyzed. Since the experimenter entered the phone number as the subject said it aloud, the pattern of voice dialing often times depended on how soon the experimenter pressed the number key to simulate the car phone dialing. For a seven digit number, the subject could say the first three numbers quickly, pause, then say the last four digits quickly. The experimenter could either input the numbers in the same pattern as the number was stated, or he/she could input the seven digits in a steady, evenly spaced manner. This influenced the way the subject dialed subsequent numbers.

When analyzing the data, the letter *p* was used when the subject paused between numbers. A sample long distance phone number, 1-313-741-9612, could look like the following:

1 *p* 313 *p* 741 *p* 9612

The data showed that when dialing unfamiliar numbers, whether local or long distance or using the HUD or IP display, the subjects paused more than when dialing familiar numbers. Older subjects had more pauses than younger subjects. Furthermore, younger subjects tended to dial the number in chunks of three, four, or five numbers. The data were not analyzed further due to the small number of subjects.

Secondary Tasks

An ANOVA on responses times for the loose ends task indicated a significant effect of letters ($F[11,93] = 5.417$, $p = 0.0001$) and an interaction between gender and age ($F[1, 93] = 9.417$, $p = 0.0028$). The response time for letter "G" was higher than for every letter except "K." While older women had longer response times than younger women (1.9 seconds versus 1.6 seconds), older and younger men did not differ (1.6 seconds for older versus 1.7 seconds for younger).

For the list task, an ANOVA indicated no significant differences for the independent variables of interest (category, gender, age, and input method).

Performance on the talking and listening tasks was not examined.

Errors

A total of 16 errors were committed when using the phone while driving: 7 with the manual handset-IP display, 4 with the voice-HUD, 3 with the manual handset-HUD, and 2 with the voice-IP display. A majority of errors (13) resulted when an incorrect number was entered into the display; only 3 were made as a result of not entering a number. Most of the errors were corrected right away (12), while others (4) were dialed first and resulted in a wrong number auditory message.

The most frequently misdialed number was an unfamiliar long-distance number (7 errors). A familiar local number was never misdialed.

Driver Preferences

A survey of driver preferences revealed that the voice-HUD combination was ranked "best" by 10 out of 12 drivers; the other 2 preferred the voice-IP display combination. The least preferred combination was the manual IP display, with 8 of the 12 participants ranking it "worst."

Conclusions

Voice input with a HUD or IP display resulted in less lane position deviation and faster dialing times than the manual handset. Drivers also preferred the voice phone over the manual phone. The type of call (local or long distance) and familiarity affected dialing times but not driving performance. Age influenced both driving performance and dialing times, indicating that the older driver should be taken into account in the design of car phones.

While the display location was not shown to have an effect in this study, there may actually be location effects between a HUD and handset display location. The study of this location was restricted by hardware limitations.

SUMMARY AND RECOMMENDATIONS

The results of Experiments One and Two indicate that function buttons on car phones should be labeled using a mix of two abbreviation methods--truncation and vowel deletion. The recommended labels (and abbreviations) on the buttons are power (Pwr), Call, End, delete (Del), memory (Mem), and recall (Rcl). This scheme led to the most accurate decoding of the abbreviations and was preferred by subjects.

In Experiment Three, voice input with a HUD or IP display led to better driving and dialing performance than a manual handset. The voice phone was also preferred by subjects. Because driver age influenced performance on both the driving and dialing tasks, the needs of the older driver should be considered in car phone design.

Thus, voice appears to be an effective way to improve the safety and performance of car phone use. The benefits of voice are particularly noticeable for older drivers. These results suggest that car phones should be voice-operated, but the location of the display is of secondary importance. This agrees with the results of the focus groups conducted earlier in the project where several drivers argued for mandate voice-operated phones (Brand, 1990; Green and Brand, 1992). Finally, these results show that laboratory tasks using simple driving simulators can be used to assess design differences in driver interfaces for IVHS.

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APPENDIX A
EXPERIMENTAL PROCEDURE

This appendix contains the experimental procedure for collection of the laboratory phone and driving data. Instructions to the experimenter are shown in plain text and suggested dialogue is shown in **bold**.

EXPERIMENTAL PROCEDURE

Prior to arrival of participant:

Make sure there are blank consent forms, bio forms, support vouchers, and money for payment.

- •Switch on power strip behind car
- •Turn on both computers.
- •Get driving simulator ready for practice. Load road-_______.
- •Turn on florescent light by Mac.
- •Check which condition subject does first.
  Tape phone down for VOICE block if first.
- •Put phone numbers in 3 stacks on in-vehicle computer, HUD, and practice.
- •Make sure name stickers are on phone cards.
- •Get tapes ready (audio and video)

Complete as much of the bio form as possible.

When participant arrives:

Are you ____? Hello, my name is ______ and I am one of the experimenters working on the car phone study. Go into lab. Flip "Experiment in Progress" sign over. **Before we get going I would like to note this experiment takes approximately one and a half hours and you will be paid 20 dollars for your time. If you would like to visit the rest room, now would be a good time to do so. Also smoking is prohibited in this building, so please refrain from doing so.**

The purpose of this experiment is to determine a good design for a car phone. Since people will be driving while using the car phone, the phone must be easy-to-use so it won't distract the driver. The results of this study will be used for designing phones for use in future vehicles. Since you may wish to have a car phone in your vehicle in the future, your opinion is important.

Before we start, there is some paperwork to complete. First, you need to sign this official consent form the university requires us to give you, which basically repeats in writing what I just said.
Have participant sign consent form.

Also, we need to know a little more about you. Fill out bio form with subject.

Now I am going to check your vision.
Test subject's vision. Make sure both eye switches are on.

General explanation of the study:

Now we'll get ready for the study. Have participant sit in buck. **You will be driving the simulator throughout most of the study. A projection system will simulate driving a car as you sit here in the driver's seat. Position yourself as if you were driving. Are you comfortable? Would you like the seat moved at all?** Show the subject how to adjust the seat if necessary.

Every so often you will be prompted to make a call or the phone will ring and you will answer it. The prompt to make a call will be a voice saying, "Call now, please." After making a call, you may be asked to perform a task for 30 seconds.

For this study, sometimes you will be driving the simulator while using the car phone and performing memory or conversational tasks and at other times you may just be using the car phone and performing tasks without driving.

Let's get you more acquainted with each of these tasks.

Practice driving:

Let's start with the driving simulator. When driving, try to stay in the middle of the road at all times. The driving scene is similar to nighttime where you'll see road markers on the edge of the lanes. The road scene looks like this (turn on simulator). **Please try driving on it for a couple minutes to get used to it. I am going to turn off the lights now.** Turn out lights. **Are you ready to drive?**

----------------------The subject practices on the driving simulator. -------------------

Run Driving Simulator for at least 2 minutes or until subject feels comfortable.

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Phone description/practice:

Now let me explain how to use the car phone.

Manual Phone

Just a minute while I turn it on. Show subject the handset on the console. **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 buttons are down here** (point to them). **You can see the number you are dialing on the display here** (enter some numbers to demonstrate), **as well as whether or not the phone is on** (press power button a few times to demonstrate) **or inuse** (press call button to show subject inuse on display).

Explain what each of the buttons does:
As you just saw, the power button turns the phone on and off. Power is indicated on the phone by PWR on the display.

To place a call, you must first enter the number you are dialing which appears 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 end 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 pressing end at the end of a call is really important.

Another button that you may need to use on the phone is delete. When you press the button the last number on the display is deleted. If you hold down the button, the numbers are deleted sequentially. When you are using the phone during the experiment, if you dial the wrong number and you don't catch it, you will get a message that says to check the number. You should dial the number again.

To answer an incoming call, press the call button. This will connect you to the incoming party. When finished talking, just press end.

The memory and recall buttons will not be used on the phone.

We have two displays for the phone, the one you just saw and also one up here. This is called a HUD which stands for Head-Up Display. Sometimes when you use the phone you will be using this display. It shows the same information as the other one does.

This is what you hear when you dial the same number twice in a row. Experimenter dials a number twice so that the subject hears the beeps that indicate this.

Voice Phone

We also have another version of the phone which will allow you to use voice commands to operate it. There is a speaker in the car which transmits your commands to the phone. Instead of pressing buttons on the handset, simply say the command you want, such as *Power*, and power will be turned on. There are specific voice commands you must use. Let's go over them now.

Explain the voice commands:
To enter a number, simply say *the number of the person* you are calling. To place the call to that person, simply say *call*.

When the call is over, say *end* and the connection will be broken.

Saying *delete* will delete the last number on the display.
Saying *delete all* will delete all the numbers.

Again memory and recall will not be in operation.

Phone Book of Numbers

When calling, you will be dialing both familiar and unfamiliar phone numbers, as well as local (7 digit) and long distance (11 digit) numbers. The book here tells you numbers to dial that you are unfamiliar with. Show subject the book of phone numbers. **Here is a card that shows you to dial a number.** Point out that the name is irrelevant but is added to simulate a personal telephone directory. **The familiar numbers are numbers you have memorized.** Point the cards out to the person and show them what local and long distance numbers look like. Remind them of the numbers they have memorized.

Before you practice using the phone, let's set the volume level so that you can hear the phone adequately. Play something to subject over phone and adjust the sound (in background script) if the subject needs it higher.

Now you can have some practice using the phone. Use these numbers to make calls (point to the notebook and show them which numbers to use). **I will lead you through the practice and prompt you to dial or the phone will ring and you should answer it.**

When you are using the manual phone, hold it up to your ear for the task or conversation.

This is the sequence for dialing: you hear the prompt to dial, flip the card over in the book, dial the number, have a conversation or do a task, press end when finished.

Let's practice using the various types of phones in the following order:

Manual-Invehicle
Voice-Invehicle

Manual-HUD
Voice-HUD

---------------------The subject practices using the phone.--------------------------------

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Practice using the phone and driving:

Now that you know how to use the phone, why don't you practice using the phone and driving. When doing this, concentrate on driving and use the phone when you feel comfortable doing so. Remember, driving is your top priority. Run the driving simulator for 5 minutes.

---------------------The subject practices using the phone and driving.---------------

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Description/practice on tasks

Like I told you before, when you dial a number, you may be asked to perform a task or have a conversation. I'll explain the tasks and conversations now.

There are four different tasks in all. I will briefly describe them with an example and then you will be able to practice them.

> **One task is the loose ends task in which you are given a capital letter and asked to determine how many loose ends are in the letter. Here is a list of capital letters. For example, if presented with the letter A you would respond 2, for the two loose ends at the bottom. Since this task is relatively short, you will perform it three times within a 30 second period. This sheet will not be available during testing.**
>
> **This task is similar to how you might recall the spatial arrangement of streets in your mind.**

---------------------The subject practices the loose ends task. -------------------

> **Do you have any questions about the loose ends task?**

There is a listing task in which you are given a category and asked to list items that belong in that category. If given the category "girl's names" you would list as may girl's names as you could think such as Jane, Mary, Lucille, etc. We'll call this the listing task since you list items.

This task is similar to how you might reminisce about the past with an old friend. The past is already stored in your memory just as the things you list are coming from what is in your memory.

----------------------The subject practices the listing task. --------------------

Do you have any questions about the listing task?

There are also two types of conversational tasks. One is called a "talking" task because it involves you doing most of the talking. I will ask you a question or ask you to describe something , such as "Where did you grow up?", and I want you to try to talk as much as possible to answer the question. If you run out of things to say, I will prompt you to tell me more.

This task is similar to a conversation in which you do most of the talking.

----------------------The subject practices the "talking" task. --------------------

Do you have any questions about the talking task?

The other type of conversational task is a "listening" task. For this task I will present you with a situation that you need to make a decision about. For example, you have the choice of going to a movie, rock concert, or the ballet on Saturday night. I will ask you to choose one after I give you a short description of each.

This task is similar to a conversation in which you do most of the listening.

----------------------The subject practices the "listening" task. --------------------

Do you have any questions about the listening task?

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Pre-testing session:

Now I'd like you to perform each of the memory tasks again and I'll collect some data. Please concentrate on the task and do your best.

---------------------The subject performs the loose ends task. --------------------

---------------------The subject performs the listing task.------- --------------------

---------------------The subject performs the "talking" task. -----------------------

---------------------The subject performs the "listening" task. --------------------

Next you'll dial some phone numbers using the HUD. First you'll use the voice phone. Turn to the blue card in the phone book. When you hear the prompt to call, flip the card and dial the number. You'll dial four numbers in all.

---------------------The subject dials four numbers using the voice phone. -----

Now you'll dial four more numbers using the manual phone with the HUD. When you hear the prompt to dial continue in the book where you left off.

---------------------The subject dials four numbers using the manual phone. --

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Testing session:

Now you're going to do everything together. You'll drive, dial phone numbers, and perform memory or conversational tasks. Go through test blocks in appropriate order.

---------------------The subject drives the simulator, uses the phone, and performs memory or conversational tasks.--

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Post-testing session:

Now I'd like you to perform each of the memory tasks again and I'll collect some data. Please concentrate on the task and do your best.

---------------------The subject performs the loose ends task. --------------------

---------------------The subject performs the listing task.------- --------------------

---------------------The subject performs the "talking" task. -----------------------

----------------------The subject performs the "listening" task. ----------------------

Next you'll dial some phone numbers using the HUD. First you'll use the voice phone. Turn to the blue card in the phone book. When you hear the prompt to call, flip the card and dial the number. You'll dial four numbers in all.

----------------------The subject dials four numbers using the voice phone. -----

Now you'll dial four more numbers using the manual phone with the HUD. When you hear the prompt to dial continue in the book where you left off.

----------------------The subject dials four numbers using the manual phone. --

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Preferences for phone/display combinations:

Now, I'd like you to indicate your preferences for the different types of phones. Please rank order the phone/display combinations in order from best to worst. Use 1 for the best, 2 for the second best, etc., and 4 for the worst.

Give subject the form.

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Payment:

After the subject has completed the form, **Thank you for participating in our study. Here is your payment for the experiment.** Have the subject fill out the appropriate form depending on whether he/she is a UM employee. If he/she is on the UM payroll, **you should receive a check through the mail shortly.** If they get paid cash, **Here is your money.**

Thanks again for your participation. You really helped us out.

Turn off all of the equipment.

APPENDIX B
PARTICIPANT CONSENT FORM

This appendix contains the consent form which the participants signed giving their permission to participate in the laboratory study. It is normally printed on UMTRI letterhead paper.

Car Phone Study

Participant Consent Form

We are working on new designs for car phones that will make them easier to use. A well designed car phone can be used at a glance, so people can concentrate on driving. Responses from typical drivers such as you, will help identify the best car phone design.

While steering a vehicle along a simulated road, you will use a car phone to make calls. You will also have conversations with the experimenter or perform brief memory tasks.

The study takes about 2 hours for which you will be paid $20 dollars. There will be short breaks in between sessions, with one longer break midway through the 2 hours. If you have any problems completing this study, you can withdraw at any time. You will be paid a pro-rated rate for the time you did complete.

We will videotape the session with your permission. We will not release any identifying information, so your responses will remain confidential.

I have read and understand the information above.

Print your name	Date
Sign your name	Witness (experimenter)

It is okay to videotape me: yes no (circle one)

- Appendix B-Participant Consent Form -

APPENDIX C
PARTICIPANT BIOGRAPHICAL FORM

This appendix contains the participant biographical form that was used for the laboratory experiment.

University of Michigan Transportation Research Institute
Human Factors Division

Biographical Form Date:

Name: ____

Male Female (circle one) Age: __________

What is your native language? (circle one)

English Chinese Japanese Korean Spanish
Other: ____________________

Occupation: ____
(If retired or student, note it and 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: ____________

Annual mileage: ____________

Have you ever driven a car with a navigation system? yes no

Does your car have a Head-Up Display (HUD)?
(If you don't know what it is you probably don't have one.)

yes no -----> Have you ever driven a car with a HUD? yes no

Do you have a car phone?

yes no -----> Have you ever used a car phone? yes no

Do you have a touch tone or rotary phone at home?

rotary touch tone both

Do you have a cordless phone at home?

yes no -----> Have you ever used a cordless phone? yes no

TITMUS VISION: (Landolt Rings)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
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

APPENDIX D
SECONDARY TASK QUESTIONS

This appendix contains the questions asked in the secondary tasks during the laboratory study.

SECONDARY TASK QUESTIONS

Task		Questions
Loose Ends	Practice	L X I D B
	Pretest	Y N W
	Test	1. M C F 2. E S U 3. O J H 4. K Z G
	Posttest	T Q P
Listing	Practice	1. a four-footed animal 2. a unit of time
	Pretest	a city
	Test	1. a kind of money 2. a part of a building 3. an article of furniture 4. a fruit
	Posttest	a bird
Talking	Practice	1. What was the last movie you saw? Describe it. 2. Describe the layout of the house you grew up in, in detail.
	Pretest	What did you do last weekend?
	Test	1. Describe your favorite recreational activity. 2. What was the last book you read? Describe the plot. 3. Describe the last trip you took. 4. Who has influenced you the most in your life?
	Posttest	If you could travel anywhere in the world where would you go and why? Tell me what you think it will be like.
Listening	Practice	1. You are the leading sales person for a large pharmaceutical firm in the midwest. To improve sales 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? 2. Before you move to your new location, you need to find a place to live. The company has arranged for a real estate agent to show you around in a week. You just talked to her on the phone and she needs to know what type of area you want to live in so that she can schedule some houses to show you. Would you prefer to live in a house in the city, a suburban neighborhood, or the country?

Task		**Questions**
Listening	Pretest	You love to relax at home after a long, hard day at work and you've been thinking of putting in an in-the-ground pool. Your friend at work has one and says it takes a lot of work to maintain and, therefore, isn't very relaxing. Although you still like the idea of a pool, you've also been thinking of a hot tub or a sauna. Which one would you choose: a hot tub, pool, or sauna?
	Test	1. When you arrive at the office tomorrow morning you will need to make a decision about the company car that you want to drive. All of the cars come with the same options: cassette players, air conditioning, and cruise control. You have the choice of a Ford Taurus, a Pontiac Grand Am, or a Buick Skylark. Which car would you choose? 2. You are a golf and tennis enthusiast and your kids love to swim. To meet more people, you have decided to join a country club. There are three in town and you have to choose one. Are you going to join Rolling Hills Country Club which has a sprawling golf course, the Larchmont Club for their excellent tennis facilities, or the Westwood Club which has an Olympic size swimming pool? 3. Tonight you're planning a big night out on the town. You weren't sure where to go so you asked your coworkers and they recommended three restaurants, each in different parts of town. From their descriptions, it sounds like there is a lot of after dinner entertainment no matter where you go, so 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? 4. You've just finished dinner at a lovely restaurant. Now you have to decide what you want to do next. You were told that the jazz club just around the corner is excellent. There's a night club a few blocks away that is supposed to be the in place. There's also a great foreign film that you've been dying to see showing nearby. Where do you decide to go: the jazz club, night club, or movie?

Task		**Questions**
Listening	Posttest	You promised your kids you would take them out to do something fun today. There's an amusement park an hour away that has more roller coasters than any other park in the country. The local aquarium sounds like fun, there are lots of penguins and other marine life. The zoo is another option if you want to see a lot of animals. Where do you decide to go: the amusement park, aquarium, or zoo?

APPENDIX E
TEST SEQUENCE

This appendix contains the test sequence used for the laboratory experiment. Every subject dialed the phone numbers and performed the memory tasks in the same order. The display type (HUD or IP) and type of phone (manual--MAN or voice--VC) were counterbalanced across participants.

Note: In the 'phone #' column, the fictitious names and numbers appeared on the subject's phone book in the car buck.

BLOCK	DISPLAY	PHONE	PHONE TASK	phone #	MEM TASK
PRE					loose ends
					list
					talk
					listen
PRE	HUD	VC	F11		
			U7	cleary 892-8471	
			F7		
			U11	kerber 315-482-7931	
		MAN	F7		
			F11		
			U7	guincy 463-1069	
			U11	flores 517-669-9055	
TEST 1	HUD	VOICE	F11		list
			F7		loose ends
			U7	eckles 663-1572	talk
			U11	nugent 714-697-0248	listen
TEST 2	HUD	MAN	U7	laskie 676-4367	loose ends
			U11	adkins 410-774-9051	list
			F11		talk
			F7		listen
TEST 3	IP	VOICE	F11		list
			F7		talk
			U11	belden 902-725-0207	loose ends
			U7	godden 814-6171	listen
TEST 4	IP	MAN	F7		loose ends
			U11	reding 416-769-2466	listen
			F11		list
			U7	olsson 472-2466	talk
POST					loose ends
					list
					talk
					listen
POST	HUD	VC	F11		
			U7	cleary 892-8471	
			F7		
			U11	kerber 315-482-7931	
		MAN	F7		
			F11		
			U7	guincy 463-1069	
			U11	flores 517-669-9055	

APPENDIX F
PREFERENCES SURVEY

This appendix contains the preferences survey used in the laboratory experiment.

Subject No. __________

Date ________________

PREFERENCES SURVEY

<u>Instructions</u>

Please rate the four types of phones from best to worst using the following system:

1 = best
2 = second best
3 = third best
4 = worst

Phone	Display	Ranking
Manual Handset	Head-Up Display	______
Manual Handset	Instrument Panel	______
Voice	Head-Up Display	______
Voice	Instrument Panel	______